Unzen Volcano : the 1900-1992 eruption

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9. Seismological Comparison in Eruptive Activity Between Mt. Unzen and Mt. Usu

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Introduction

Yokoyama et al. (1981) said in their study of the 1977-1978 eruption of Usu Volcano, "There are more than 70 active volcanoes in Japan. Among them dacitic volcanoes are very rare: There are only the Myojin-reef upthrust far south of Tokyo and Usu Volcano in Hokkaido." Unzen Volcano erupted since 17 November 1990 and is building dacitic lava domes near the top of Mt. Fugen even now in May 1992 (e.g., Geological Party, 1992). Just now, we should include Unzen Volcano among the dacitic active volcanoes. Hokkaido university and Japan Meteorological Agency (JMA) studied in detail the eruptive activity of Usu Volcano by using their seismic networks. Now, Kyushu university and JMA are making great efforts in seismology to monitor Unzen Volcano. In this paper we seismologically compare Unzen volcano with Usu Volcano to search common characteristics of dacite volcanism in island arcs, if they have, and to show unique characteristics of Unzen Volcano.

Doesn't Unzen volcano have "a root of magma" ?

Numerous authors have suggested that the magma production under the island arcs is related to the downgoing slab, since the depth of dipping seismic zone beneath a volcanic front is constant in most subduction zones. Figure 9-1 shows the distribution of active volcanoes (JMA, 1975; Kubotera, 1991) and depths of hypocenters of deep earthquakes (Utsu, 1977) in Japan. The difference in geographical position between Unzen and Usu is that the former and the latter lie on a volcanic front and the back arc side of a volcanic arc, respectively. Figure 9-1 shows some or more volcanoes on the back arc side. Back arc volcano, therefore, is not unique to Unzen. A big geophysical difference between these volcanoes, however, is whether the deep seismic zone is observed or not beneath them. We find deep seismic zones under all active volcanoes of Japan, except Unzen as shown in Fig. 9-1. Figure 9-2 compares two hypocentral distributions projected on cross-sections for Unzen and Usu volcanoes. Petrologists (e.g., Tatsumi, 1989) proposed models for the migration of H_2O and the generation of basalt magmas in the subduction zone. Mantle diapirs containing a certain amount of melt may rise from the partially molten column on the subducted lithosphere. In Tatsumi's model, a volcano in the island arc has its origin in the subducted lithosphere. The subducted lithosphere is, in this sense, "a root of

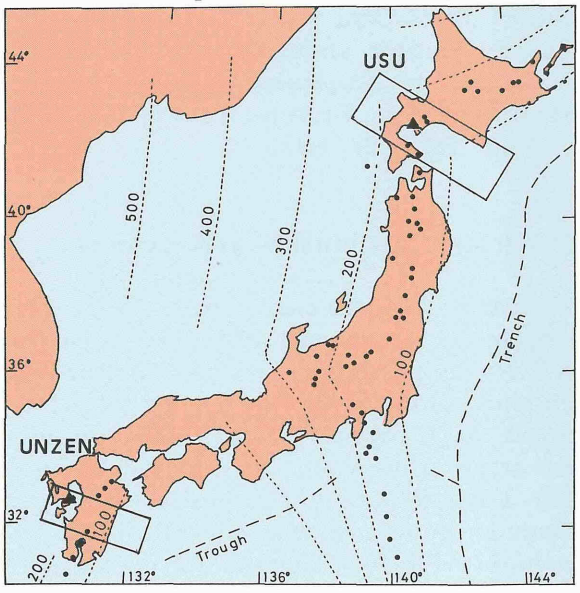

Fig. 9-1. Solid circles and triangles show active volcanoes in Japan. Two triangles indicate locations of Unzen and Usu Volcanoes. Hypocentral distributions in the rectangular areas are presented in Fig. 9-2.

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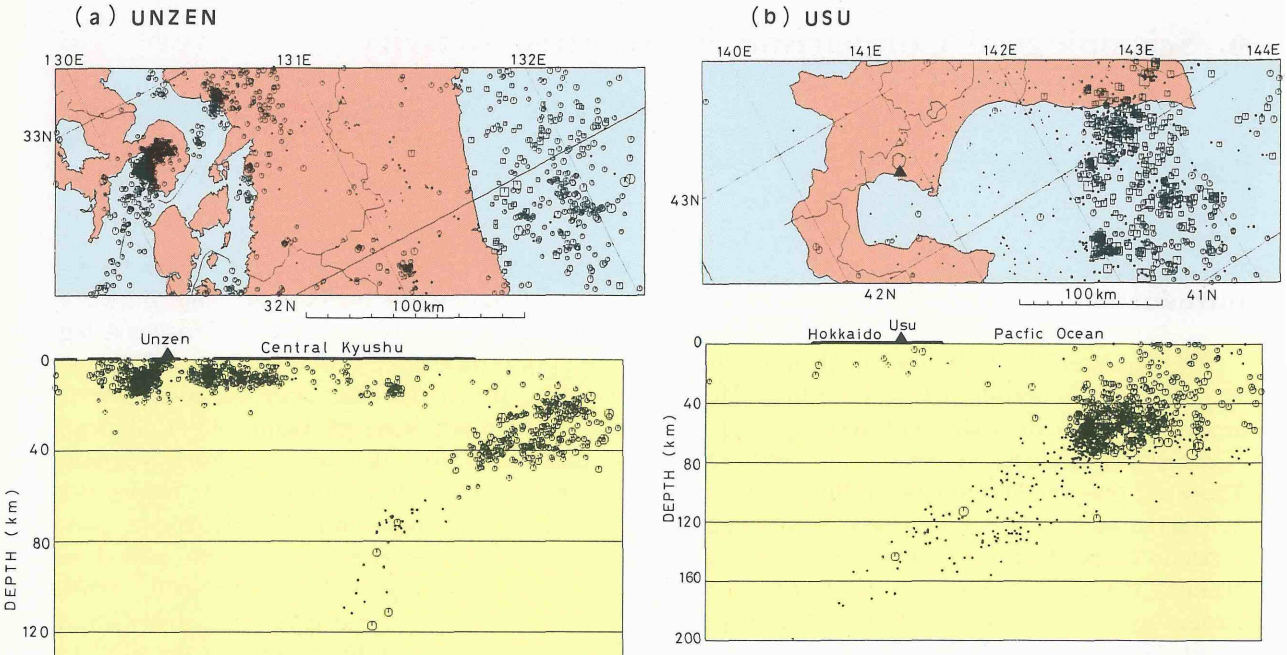


Fig. 9-2. Hypocentral distributions of earthquakes occurring in and around central Kyushu (a) and Southern Hokkaido (b) from 1989 to 1991. They were presented by Fukuoka District Meteorological Observatory (FDMA).

volcano". Unzen, therefore, has no "root of volcano ". Why not a subduction zone is there under Unzen? Ohta (1984) suggested that the lack of the deep seismic zone is one of the geological and geophysical questions of the Beppu-Shimabara Graben. We will discuss it briefly in the later section.

Precursory earthquakes and tremors

There is a big difference in precursory seismic phenomena between the 1990 Unzen and the 1977 Usu eruptions (Figs. 9-3 and 9-4). The Usu eruption started with the ejection of dacite pumice on 7 August 1977 and formed the first new crater at the southeastern foot of Ko-Usu. The eruption was preceded by a earthquake swarm under the summit area for about 32 hours as shown in Figs. 9-3b and 9-4b. JMA-A and SSU stations observed that earthquakes including felt events increased catastrophically up just before the eruption. The hypocenters of precursory events were shallower than 6 km. Especially the events shallower than 2 km predicted the exact place of the first eruption. We suppose that a part of magma and gas rose several kilometers in 32 hours. Roughly speaking, if we assume a vent length of 3 to 6 km, the ascending velocity may be estimated to be 100-200 m/hour.

On the other hand, Unzen eruption began on 17 November 1990. As for the precursory seismic phenomena, Ohta (1991b) pointed out that the earthquake swarm started under the Chijiwa Bay on November 1989 and migrated eastward to Unzen volcano in July 1990 (Figs. 9-3a and 9-4a). Volcanic tremors which were a new phenomenon in Unzen started in July 1990. And they increased since the next month and continued about four months before the eruption (Fig. 9-3a).

The main focal area of the earthquake swarm inclined to west in a depth range from 5 km to 20 km. Seismic inactivity in the shallower area beneath the volcano is one of the big characteristics in comparison with the Usu eruption. Watanabe et al. (1991) reported that the first eruption is a phreatic explosion containing no magmatic rock. Seismic inactivity in the shallow

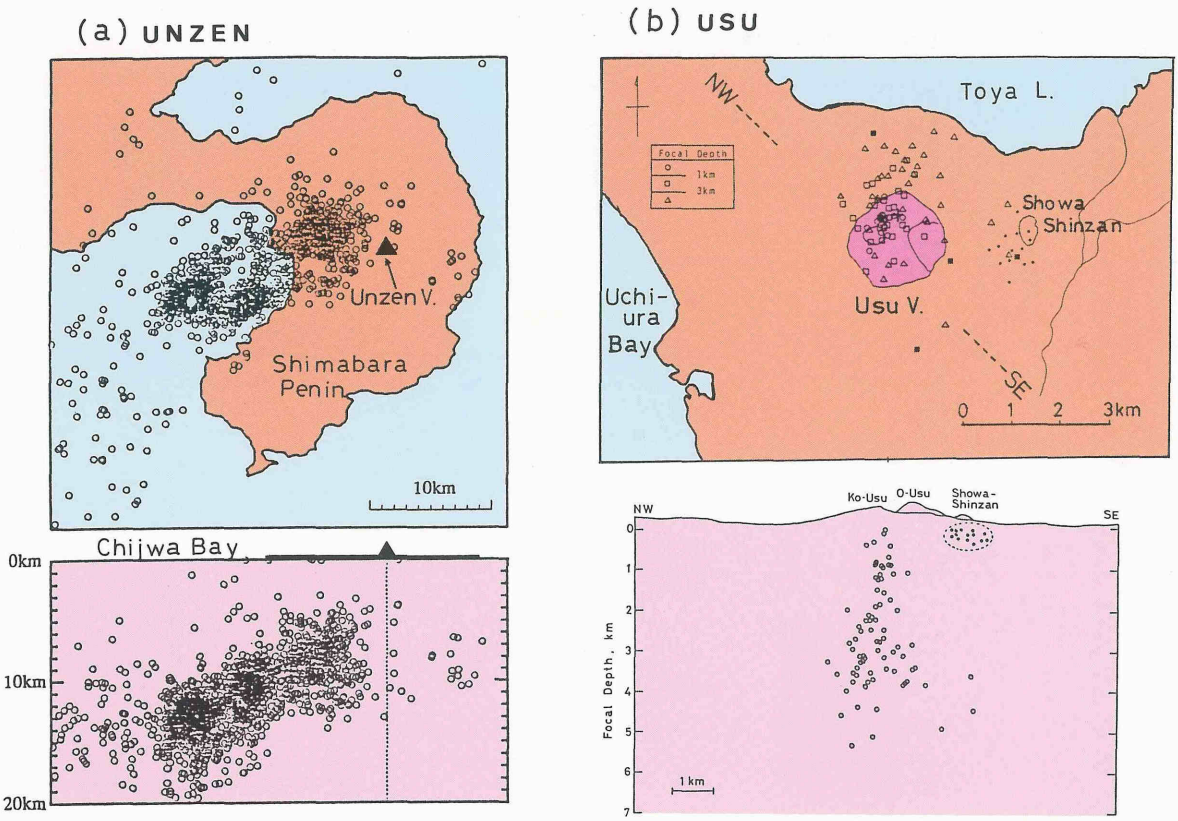


Fig. 9-3. Hypocenters of precursory earthquakes occurring in Unzen (a) and Usu (b) volcanoes. Figures (a) and (b) were from Umakoshi et al. (1991) and Suzuki et al. (1980), respectively.

area and phreatic explosion may show that the top of magma located deeper than 4 km under Unzen volcano just before the first eruption. We suppose that volcanic tremors were caused by movement of hydrothermal fluid or phreatic gas. Remember that we did not observe prominent volcanic tremors before the eruption of dacite pumice in Usu. Roughly speaking, Unzen and Usu volcanoes were wet and dry before the eruptions, respectively.

Volcanic earthquakes during the eruptive activity

Hypocentral distributions and daily frequency variations of volcanic earthquakes are shown in Figs. 9-5 and 9-6. Eruptive activity of Usu Volcano continued intermittently until October, 1978 (Fig. 9-6b). In other words, eruptive activity continued for 15 months. During the eruptive activity, the domings within the summit crater to form the cryptodomes have resulted in the land upheaval of about 160 m in height (Yokoyama et al., 1981). They showed the close agreement in temporal variations between the daily discharge of seismic energy and the daily rate of crypto-dome upheaval. The distribution of the abundant hypocenters shallower than 3 km (Fig. 9-5b) shows clearly an earthquake-free zone beneath the summit crater. Okada et al. (1981) suggested that the location of newly intruding magma body corresponded to the earthquake-free zone.

On the other hand, on 20 May 1991 magma of Unzen Volcano approached the surface and started forming lava domes (Fig. 9-6a). The occurrence of earthquakes shallower than several kilometers is strongly related with dome-building. Accurate hypocentral distribution of shallow earthquakes shows the shape of lava domes (Matsuwo et al., 1992). Figure 9-5a shows that the main focal area located in the depth range

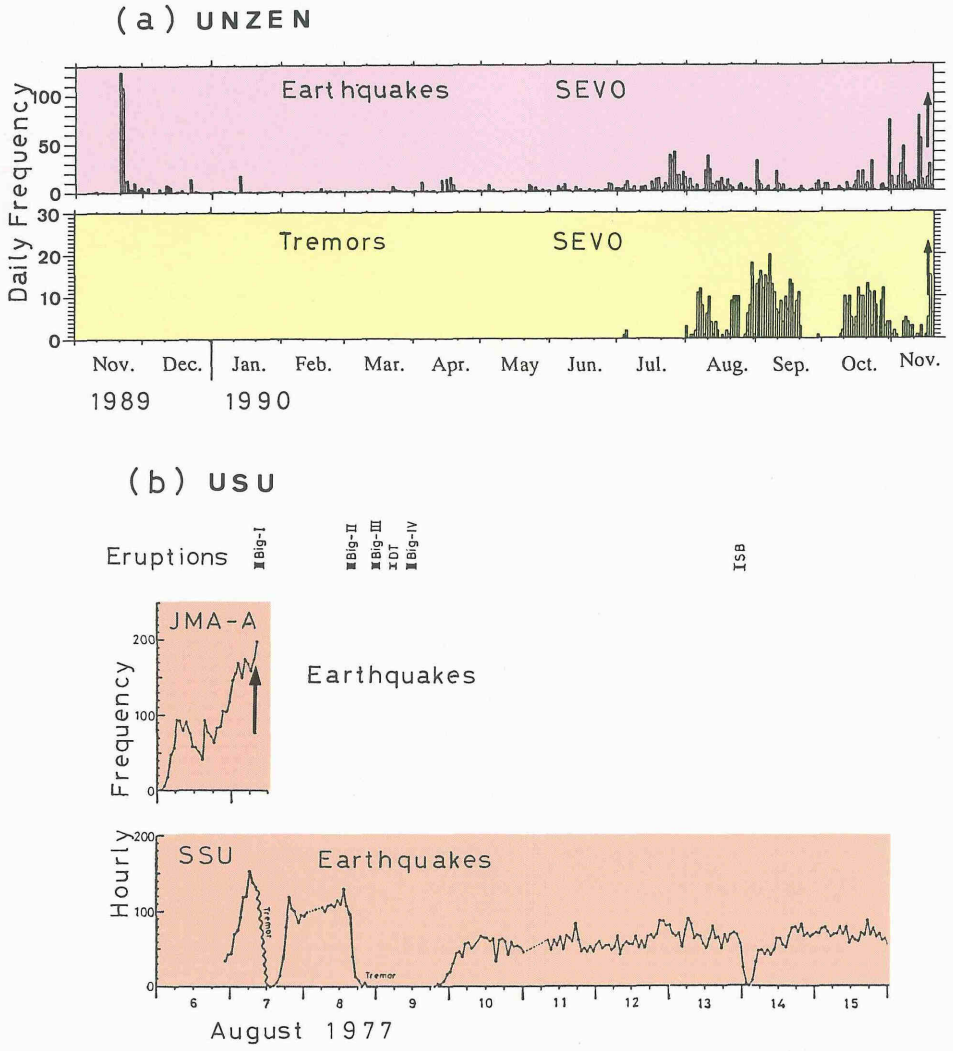


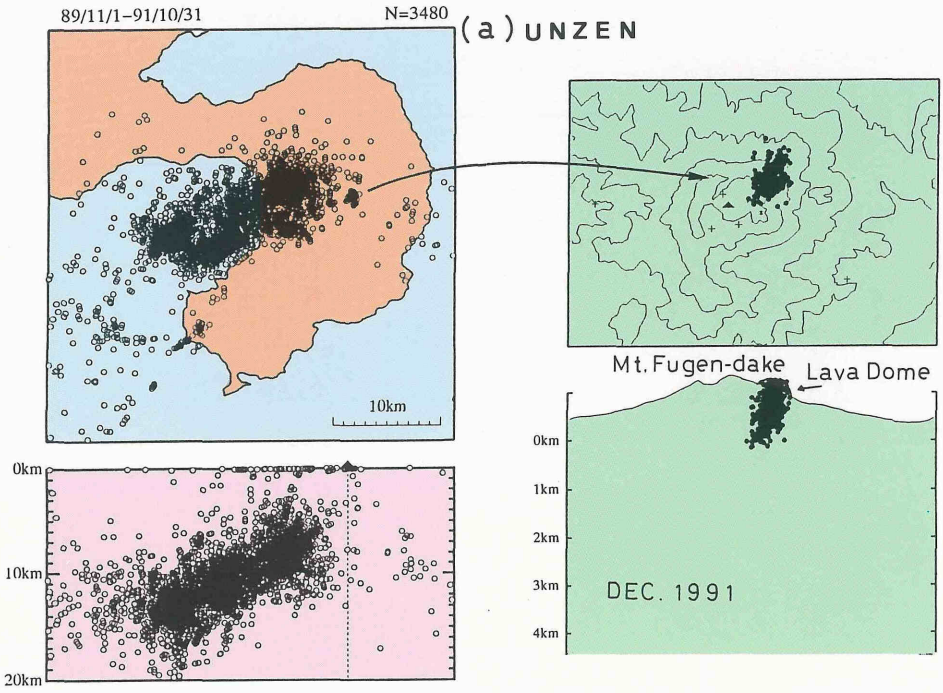
Fig. 9-4. Daily frequencies of earthquakes before and just after the first eruptions of Unzen (a) and Usu (b) volcanoes. Allows indicate the times of the first eruptions. Daily frequencies of volcanic tremors are also shown. Figures (a) and (b) are from Umakoshi et al. (1991) and Suzuki et al. (1980), respectively.

from 5 to 20 km as like as of the precursory earthquakes shown in Fig. 9-3a. The focal area inclining to west may imply a vent of magma ascending eastward from deep crust and mantle.

The eruptive activity of Unzen Volcano has continued for 18 months since the first eruption. Dome-building has continued for about one year. The long activity of eruption may be one of the common characteristics in dacite volcanism. We expect that the seismic activity of Unzen Volcano will probably continue for much longer time.

Where does magma of Unzen Volcano come from?

As mentioned above, many researchers have presented models related with the descending slab to explain "the root of volcano" in the island arcs. It may be acceptable to interpret the origin



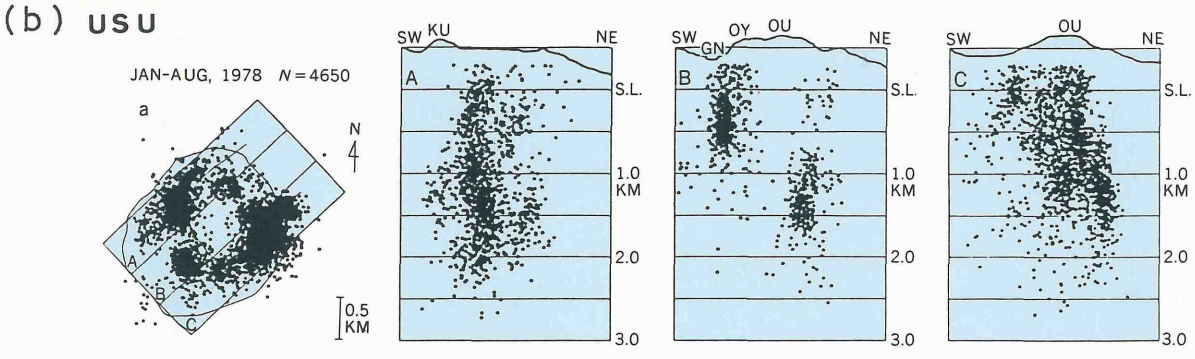


Fig. 9-5. Detailed distributions of volcanic earthquakes around Unzen (a) and Usu (b) during the eruptive activities. Figure (a) is from Umakoshi et al. (1992) and Matsuwo et al. (1992). Figure (b) is from Nishimura and Okada (1987).

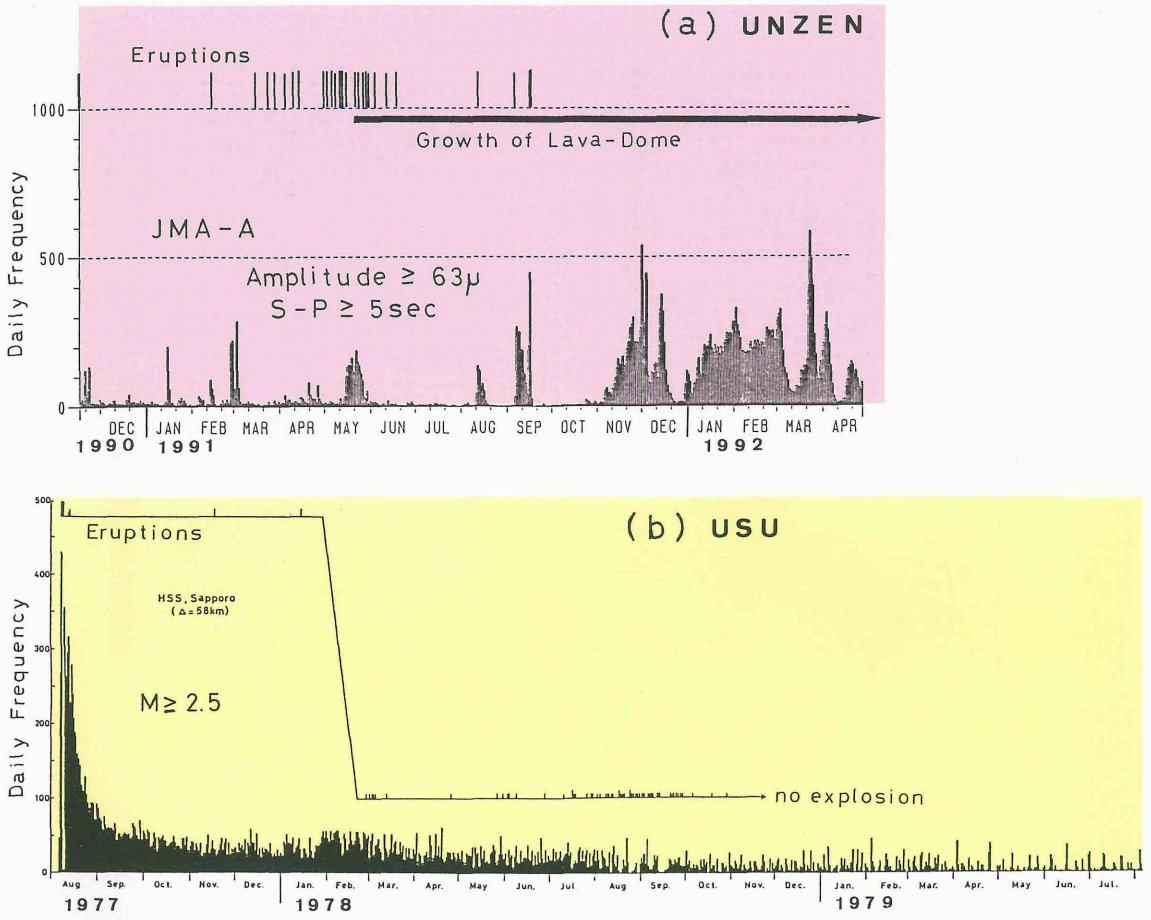


Fig. 9-6. Daily frequencies of earthquakes during the eruptive activities of Unzen (a) and Usu (b) volcanoes. Vertical bars indicate the times of eruptions. Daily frequencies for Unzen are presented by FDMA. Daily frequencies for Usu are from Suzuki and Kasahara (1979).

of magma beneath Usu Volcano by employing such models (Fig. 9-7b). Such models, however, are not acceptable to explain where magma of Unzen Volcano come from, because there is no descending slab under Unzen. We have poor knowledge of crust and mantle structures to propose a definitive model for Unzen Volcano. The hypocentral distribution as shown in Fig. 9-2a, however, is one of the useful data to consider magma generation. And we have three observational facts on magma movement as follows. The first is a focal distribution of the earthquake swarm inclining to the west in a depth range form 5 to 20 km as shown in Figs. 9-3a and 9-5a. The second is chemical observation that the hot spring in the western part of Shimabara Peninsula emanates magmatic gas (Ohta, 1984). The third is the ground deformation 2.5 km west of Mt. Fugen (Geodetic Survey Group, 1992). We, therefore, propose a schematic explanation of magma generation as shown in Fig. 9-7a. Magma generation is one of the biggest problems to understand the eruption at Unzen Volcano.

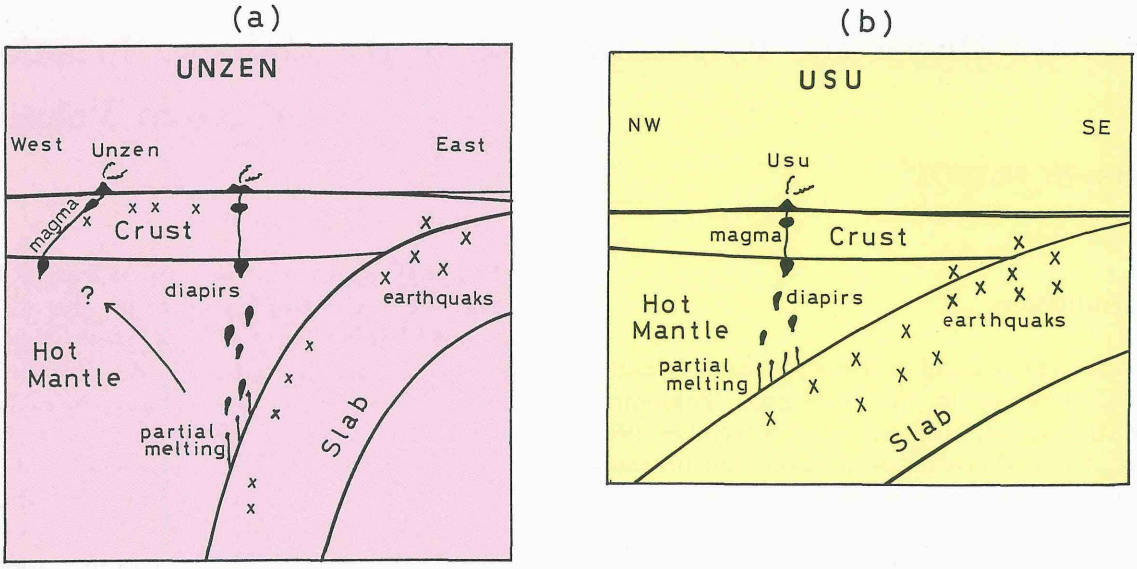


Fig. 9-7. Schematic explanations of magma generations for Unzen (a) and Usu (b) volcanoes. Structures of crust and mantle are speculated by using hypocentral distributions in Fig. 9-2.