Seismological study on precursors of the small phreatic eruptions at Meakan-dake volcano in 2006 and 2008

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Meakan-dake volcano is an andesitic stratovolcano at an elevation of 1,498 meters; it stands on the southwestern rim of Akan Caldera in eastern Hokkaido. The documented eruptions since 1957 have all been phreatic explosions that occurred at the Pon-machineshiri summit crater (Figure 1). In the past quarter century, the volcano has produced five phreatic explosions in 1988, 1996, 1998, 2006 and 2008. Although it's not always true that volcanic earthquake swarms are accompanied by eruptive activities, the 2006 and 2008 eruptions had several evident seismic swarms and tremors months in advance. The eruption in 2006 was the first one that was observed by a broadband seismometer in Meakan-dake volcano.

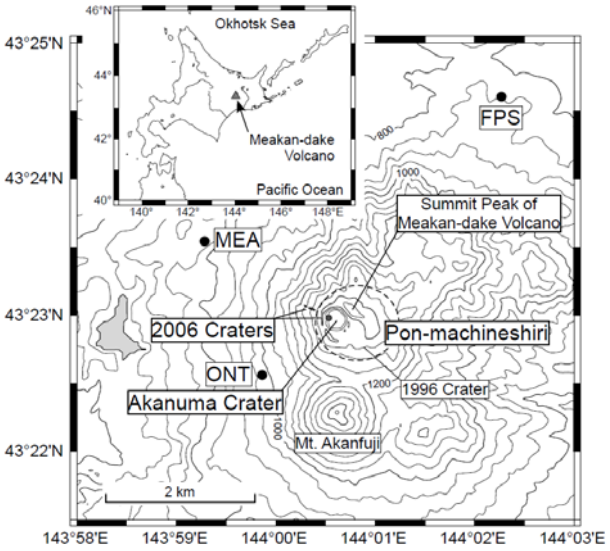

Figure 1. Contour map of Meakan-dake volcano showing location of seismic station (black circle). Contours represent 50-m elevation intervals. Dark and light gray spots are crater areas made by the 2006 and 1996 explosions, respectively. Inset shows location of Meakan-dake volcano.

The eruption on March 21, 2006 was associated with two precursory seismic swarms, the first one continued for about five days from February 18 to 22, comprising more than 1250 earthquakes. About 20 days later, on March 11, the second swarm began. Then, the seismicity increased once again one day prior to the phreatic explosion on March 21. The first swarm comprised small earthquakes and two volcanic tremors. The volcanic tremors occurred at around 0552, February 19, and at 0550, February 20. The

largest earthquake during this swarm overlapped with the first tremor, and soon after the first tremor, the number of earthquakes began to decrease.

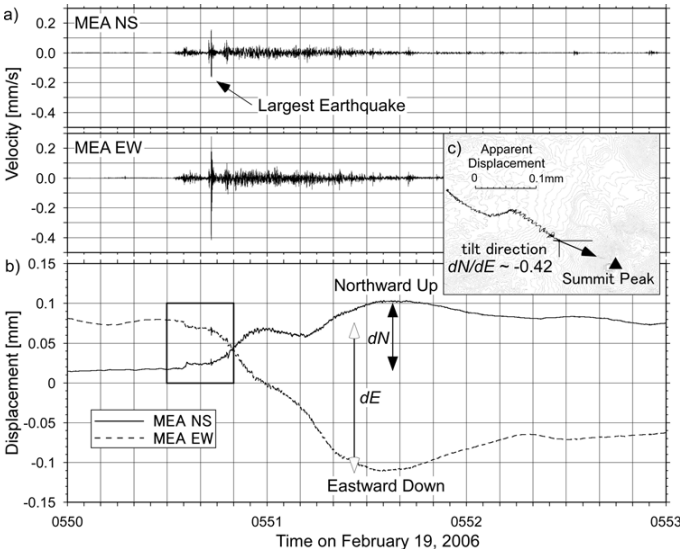

Figure 2. (a) Horizontal ground velocity at MEA. (b) Displacement traces obtained by simple integration. (c) Maximum downward tilt direction estimated from displacement traces.

An anomalous very-long period signal (VLP signal) was found in the seismic trace of the first tremor recorded at station MEA. The signal was masked by a short-period motion in the original velocity waveform, but a considerable DC step of about 0.21 mm appeared in displacement trace, especially prominent in the horizontal components (Figure 2). Such step in the displacement trace of the horizontal components can be attributed to an inclination of a seismometer due to tilt change. Aoyama and Oshima [2008] theoretically obtained the conversion factor from apparent displacement to tilt change for CMG-40T seismometer as 4.48 μrad/mm and confirmed the value and tilt response of CMG-40T by a laboratory experiment. Since the observed waveform can be regarded as the sum of translational motion and rotational motion, they estimated a time function of volumetric change under the isotropic source assumption. After the 2006 eruption, ISV, Hokkaido University installed two additional CMG-40T seismometers in Meakandake volcano area.

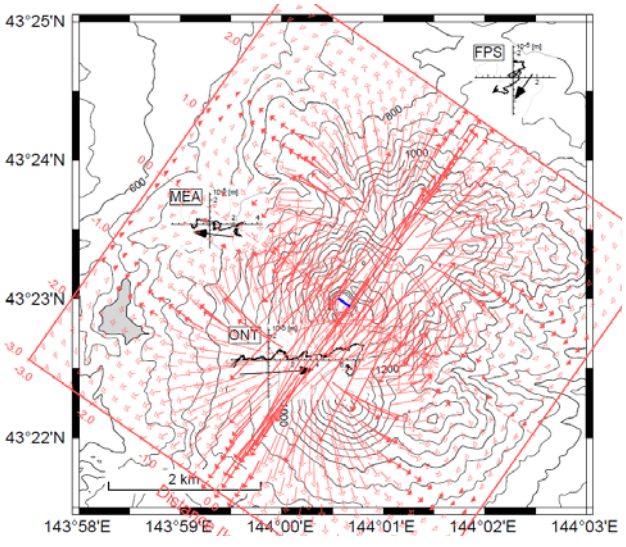

Figure 3. Down-dipping directions of the three seismic stations estimated from apparent displacement traces. Red arrows are theoretically expected spatial distribution of down dipping tilt change at the ground surface due to opening of a vertical crack beneath Akanuma crater. Amount of dike opening is arbitrary.

The eruption on November 18, 2008 was also preceded by three seismic swarms; the first one began on September 26 and continued for about 5 days and the second one observed in late October. Increase in seismicity began again since No-

vember 5 and the third swarm lasted more than 10 days till the eruption on November 18. Several volcanic tremors have also been observed during the precursory stages over about two months. The biggest tremor occurred on September 26, which only consisted of short period components, was large in amplitude but short in duration. On the other hand, a long sustaining tremor occurred at around 0053, November 16, contained strange VLP component that suggests tilt changes. The VLP signal was commonly recorded at three broad-band seismic stations; one of them, station MEA, indicates subsidence of the mountain side similar to the tilt motion of the 2006 precursor, and the remaining two conversely suggest uplift of the summit area. Such variation of the observed tilt motions may be explained by a non-isotropic source having azimuthal dependence on the surface deformation. Spatial pattern of the tilt change is modestly explained by the expansion of a vertical dike striking in the NW – SE direction located under the summit Akanuma crater. Although we still have only two examples, these two activities revealed that the broad-band seismometer is very effective for monitoring of tilt change associated with the volcanic activities.

Both tilt changes coincident with volcanic tremor in 2006 and 2008 preceded the phreatic eruption. A possible mechanism that caused the tilt change may be migration and/or phase change of volcanic fluid under the ground. For the 2008 eruption, source location of the volcanic tremor occurred on November 16 was investigated by the grid search method using high-frequency seismic signal amplitude (e.g., Battaglia and Aki, 2003; Kumagai et al., 2010). Centroid of the estimated source location is almost 1km away southward from the summit crater. This result may be inconsistent to the location of the vertical dike assumed to be a source of the tilt change that is located just beneath the summit crater. Future monitoring and researches will elucidate this inconsistency.

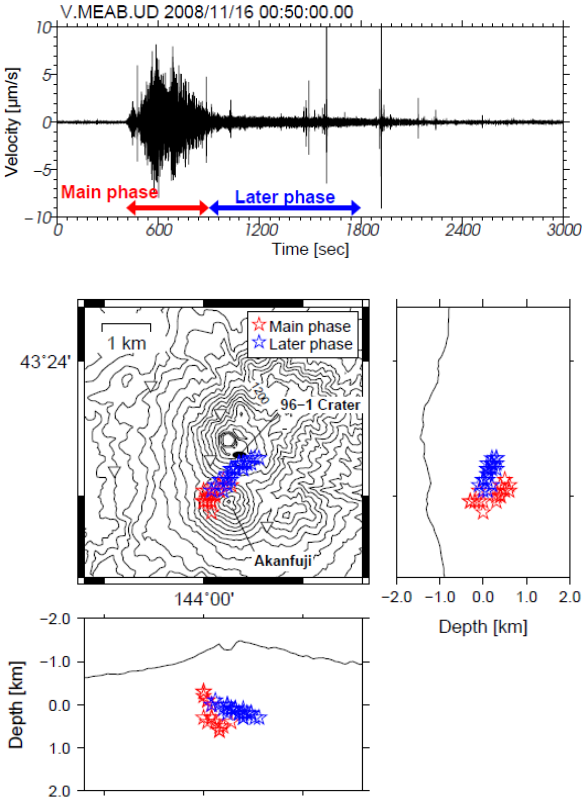

Figure 4. Velocity waveform of the volcanick tremor on Novemver 16, 2008 and its source location estimated from amplitude distribution.