Article

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Volcano-tectonic Earthquakes during the Stage of Magma Accumulation at the Aira Caldera, Southern Kyushu, Japan

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At Sakurajima volcano, activity of volcano-tectonic (VT) earthquakes has gradually increased since 2002, as the inflation of the Aira caldera progressed since 1993. In particular, VT earthquakes SW off the volcano and in the caldera swarmed during November 2003–February 2004, and then a baseline of GPS across the volcano indicated a significant extension. However, no significant increase in eruptive activity was observed. Location and focal mechanism of VT earthquakes, which occurred during 1998–2005, are determined and the relationship between the seismic activity of VT earthquakes and volcanic activity is discussed. The VT earthquakes originated in an elongated zone extending in NE-SW direction, namely from the NE part of the Aira caldera through Sakurajima volcano to SW off the volcano. This zone coincides with active tectonic zone. The focal zones of VT earthquakes are distinguished into three regions: (1) 0 to 4 km deep beneath the summit of Sakurajima, (2) 6 to 9 km deep SW off the volcano, and (3) 4 to 14 km deep in the Aira caldera. At the summit area, VT earthquakes occurred mostly south of the crater and a few located north, and very few VT earthquakes were found inside the crater. Focal mechanism of VT earthquakes beneath the summit area has variation with depth. Reverse fault type was dominantly obtained at depths from 0 to 2 km. Meanwhile at deeper portion of 2–4 km, strike-slip fault type is predominant. In contrast, most of VT earthquakes SW off Sakurajima indicated uniquely normal fault type with horizontal T-axes oriented to WNW-ESE direction. Whereas the mechanism of those in the Aira caldera is strike-slip types which one of the nodal lines oriented in NE-SW direction. These are consistent with regional stress field and direction of depression zone inferred from geological study. A hypothetical model adding a tensile fault to dual Mogi's pressure source is proposed to examine the relation of inflation of Aira caldera and the following seismicity SW off the volcano.

Key words: Sakurajima volcano, volcano-tectonic earthquake, ground deformation, magma supply system

1. Introduction

Various types of earthquakes are observed at active volcanoes. From the nature of waveform, Minakami (1974) classified volcanic earthquakes into four types: A-type, B-type, explosion earthquakes and tremors. A-type earthquakes usually originate beneath the volcanoes at the range of depth from 1 km to 20 km. Their waveform is similar to shallow tectonic earthquakes, and P- and S-phases of seismic waves are clearly recognized. On the other hand, B-type earthquakes occur at shallow depth and their S-phases are not clear. On the basis of source mechanism, Latter (1981) reclassified earthquakes observed at Ruapehu and Ngauruhoe volcanoes into two groups, "volcanic" and "tectonic" types. "Volcanic" type usually has emergent onset with poorly-defined phases and originates in partially molten material by some extended source mechanism. This category includes B-type, explosion earthquakes and tremor in the Minakami's classification. "Tectonic" type is characterized by sharp onset and well-defined phases. A term "volcano-tectonic" is proposed to distinguish between earthquakes of "tectonic" type originate on or beneath volcanoes and those which occur at some distance. "Volcano-tectonic" type takes place in competent rock as a result of some instantaneous source mechanism. This category covers Minakami's A-type. The terminology of volcano-tectonic (VT) earthquakes has been widely used instead of A-type earthquakes. In the present study, the terminology of volcano-tectonic earthquakes will be used instead of A-type earthquake, although A-type has been used at Sakurajima volcano.

An increase in VT earthquake activity is often an early sign of volcanic unrest and potentially leading to eruption. At Merapi volcano, occurrence of VT earth-

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