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# Geological meaning of the swarm earthquake occurrence in Hakone Volcano -Relation for Tanna and Hirayama Faults-

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1. Introduction

Tanna Fault is the active fault of N-S strike, that is located in the central part of the Izu peninsula. Kuno (1930) found that Tanna Fault was the strike-slip type having horizontal displacement of approximately 1km. This observation was innovative knowledge at that time.

On the other hand, Hakone volcano is located at the northern extension of the surface traces of the Tanna Fault. Within the caldera of Hakone volcano, there has been fumarolic activity around the Owakidani area. Takahashi et al. (1999) suggested that a pull-apart tectonic region is produced around Hakone volcano by the activity of two faults: Tanna and Hirayama Faults, and strongly related to the formation for the structure of Hakone caldera.

In this presentation, we will review previous studies about the relation between Hakone volcano and Tanna Fault, and show our recent results that suggest the relation between the occurrence of swarm earthquakes in Hakone volcano and the activities of Tanna Fault.

2. Swarm earthquake activities in Hakone volcano

Many intense periods of swarm activity have occurred in the caldera and have been reported since 1786 (Hiraga, 1987; Mannen, 2003). Strong ground motion and fumarolic activities have occasionally been accompanied by intense swarm activities (Mannen, 2003). Mannen (2003) reported that the swarm earthquakes and geothermal activities were prevalent after the occurrence of the 1930 Kita-Izu Earthquake. In recent years, the earthquake swarms were remarkably prevalent in 2001, 2006 and 2008-2009, accompanied with crustal deformation in and around Hakone volcano.

Several studies proposed that the structures developed by strike-slip fault system contributed to the formation of high permeable channel for hydrothermal water from deep-seated magma source. Sibson (1987) indicated that fracture systems develop within a pull-apart region (dilational fault jog), due to local extensional stress resulting from the interaction of the fault system. Sibson (1996) proposed a model to explain swarm activity in which earthquakes are triggered by fluid migration through the highly permeable fracture systems. Curewitz and Karson (1997) pointed out that many hot springs and geothermal activities are found in an area such as a pull-apart region where two faults meet. They also suggested that the fracture systems developing in these areas are likely to become pathways for magmatic fluid from deep regions, playing an important role for the production of hot springs.

3. Swarm earthquake occurrence based on the hypocenter distribution

To discuss the relation between the swarm activities and tectonic setting in and around Hakone volcano, we precisely determined hypocentral distribution in Hakone volcano. Yukutake et al. (2010) found that most swarm earthquakes are distributed on vertical thin plane-like zones with width/length of 100 m to 1 km, and these plane-like hypocentral distributions range from the E-W to N-S strikes. Since Hakone volcano is located in the interaction area of the active Tanna and Hirayama faults, Yukutake et al. (2010) suggested that the fracture planes revealed by the relocated hypocenter distribution have been developed by the activity of the two active faults. Moreover, Yukutake et al. (2011) determined the hypocenter and focal mechanism distribution of the swarm activity in 2009, by using the dense seismic station network data operated in and around Hakone volcano. We found that the swarm earthquakes exhibited a migration of hypocenters that appears to be represented by the diffusion equation, and concluded that the swarm earthquakes were triggered by the diffusion of highly pressured fluid within the fault damage zone.

We think that the occurrence of swarm earthquakes in Hakone volcano is strongly related to the high permeable fault network that was formed by the interaction of two active faults: Tanna and Hirayama Faults.

Keywords: Tanna Fault, Hakone volcano, Swarm earthquake, Hypocenter distribution