Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SVC048-P02 Room:Convention Hall Time:May 22 14:00-16:30

Dilatational crustal deformation preceding earthquake swarm activities in Hakone volcano

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Hot springs Research Institute (HSRI) has been carrying out seismic observation in and around Hakone volcano since 1968. In early times of the observation hypocenter determination was performed using S-P times read from seismograms recorded on feeding paper. It is a bit surprising to see that most of the hypocenters were determined just beneath near Owakudani in the northern part of central cones. However, having re-examined hypocenters of swarm earthquakes in 1970s using the current method of hypocenter determination, Honda et al. (2011) found out that seismic activities actually had occurred in a wider region not much different from recent activities. The seismic activity in Hakone caldera had been quiet in 1970s. Then, after rather notable activities in mid 1980s and in mid 1990s a most remarkable activity occurred in June through October in 2001 accompanying crustal deformation. Since the greatest activity in recent several decades, it is said that the over all seismicity as well as the active areas in Hakone caldera has increased (Harada et al., 2009). Having de-clustered the earthquake catalogue of HSRI, we examine characteristics of both clustered and de-clustered activities (here we call the former swarm activity and the latter background activity), noting differences in temporal changes and in spatial distributions between those two types of activities. We especially pay attention relationship between appearance of crustal deformations in 2001, 2006 and 2008-2009 and changes in both types of the activity.

From the Gutenberg-Richter diagrams it is considered that almost all earthquakes equal to or larger than M0.1 have been detected over the whole period of the examination and number of earthquakes after 2001 is more than ten times compared to that before 2000. The increase in the occurrence rate after 2001 for both swarm and background activities is clearly seen from the curves depicting cumulative number of earthquakes. However, it should be noted that apparent changes of the occurrence rate differs significantly depending on the cut-off magnitude (Mc). Dilatational crustal deformations have been observed three times by the GEONET of the Geospatial Information Authority of Japan since 2001. Although the associated changes in the occurrence rate of earthquakes are clearly seen in the catalogue of Mc 0.8, they are hardly seen in the catalogue of Mc 0.1. A notable feature is a tendency which rise of the increasing rate in the background activity and occurrence of the clustered activity are delayed to the start of the dilatational crustal deformation. This indicates that occurrence of swarm activity could be forecasted before its occurrence by noting crustal observation. It seems that no direct relationship exists between the occurrence of swarm activity and progress in the crustal deformation. This is a notable difference from the swarm activity in the east-off Izu peninsula. The b value for swarm activities is larger than that for background activities, meaning that the former activity includes relatively more small earthquakes. It implies that swarm earthquakes occupy only a small part of the energy released by the activity of Hakone volcano. The feature is also inferred from the occurrence mechanism of swarm activities suggested by Yukutake et al. (2010). We would like to note here that there is a clear difference between the swarm and background activities in the spatial distribution, where the latter is especially high in the southern part of central cones.

Keywords: Hakone volcano, swarm activity, background activity, b value, crustal deformation, forecasting