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Stress triggering of volcano-tectonic earthquakes:stress changes in the case of magma intrusions and great earthquake

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It is well known that seismicity around a volcano is one of the well-prevailing indicators of volcanic activities. The earthquakes are generated by the temporal change of stress field that is sometimes caused by magma intrusion and/or emplacement. Many evidences show that increasing seismicity leads to the volcanic eruption. For example, the seismicity around Kirishima volcano increased since 2006, and it is followed by sub-pulinian eruption on January 2011. This increase of seismicity is about 3 years prior to the remarkable inflation of volcanic edifice measured by GPS network. However, seismicity around volcano is generally treated as only an appearance of the possibility of volcanic activity and is not regarded as reliable evidence because it does not always leads to the eruption. It is partly because the stress change that generates earthquake swarms has not been considered deeply and the cause of the change has not been studied systematically. In this paper, we evaluate stress changes on known fault planes located near Izu-Oshima volcano quantitatively, and reveal the relation between the activity of the earthquake swarms and the stress change not only caused by a magma intrusion in the volcano but also induced by the great earthquake in 2011.

Several clusters of earthquake swarms occur frequently around Izu-Oshima volcano that stays in a quiescent stage since the latest eruption in 1986 but with small ground inflations in the interval of about three years in the present. The pattern of the ground deformation measured by GPS demonstrates that the magma rises and settles at the depth of about 5 km. The seismicity around the volcano increases at the several specific several regions during the ground inflation. Among them, earthquakes occurring at northward, northwestward and southwestward off the Izu-Oshima Island are located on several sub-vertical planes and their focal mechanisms support that they occur on the sub-vertical strike-slip faults. Each swarm activity begins abruptly and lasts one day to one week. It shows that the stress is accumulated on the pre-existing faults and the earthquakes occur when the stress exceeds its threshold. The cause of the stress accumulation might be the inflation source beneath the volcano.

We evaluate the Coulomb stress changes on the fault planes caused by magma intrusion. From this analysis, it becomes clear that the new earthquake swarm begins when the Coulomb stress rise 10-50 KPa from the level of the previous swarm activity. It is much affected by the geometry and location of the pre-existing faults, and the location and amount of inflation source. These parameters are well determined by intense seismic and GPS networks conducted by ourselves. We also evaluate the stress caused by the great earthquake in 2011. On a few hours after the origin time of the 2011 Taiheiyo Tohoku-Oki earthquake (M9.0), a few earthquake swarms are activated on the pre-existing faults. The Coulomb stress caused by the great earthquake is 20 and 50kPa. The value is similar with the case of magma intrusion, even the stress field acting caused by the great earthquake differs from that by magma intrusion.

From the above, we can illustrate that the accumulation of the stress can be measured quantitatively if the geometry of the pre-existing fault is known like the case of the Izu-Oshima. The seismicity around volcano reflects the stress field change, and can detect the magma intrusion and/or emplacement at the depth like Kirishima volcano. Quantitative analysis of the stress field using seismicity may become stress sensor that detects the deeper magma source if we know the features of the pre-existing faults around the volcano.

Keywords: volcano-tectonic earthquake, Coulomb stress change, magma intrusion, induced seismicity, evalueation of volcanic activity