Volcano Instability and Development of Dike Swarms Controlled by Local Stress Field

Osamu Otaki[1]; Naoyuki Fujii[2]

[1] Grad. Sch. Env. Studies, Nagoya Univ.; [2] RCSV, Grad. Sch. Sci., Nagoya Univ.

Composite volcanoes (Strato-volcanoes) have the simplest cone shape of volcanic edifice, and are built from effusive products that cumulated to a sequence of flow units from a mostly radial distribution of dike swarms. Besides, hotspot volcanoes in the Hawaiian, the Canary, and the Reunion islands have two or three directions of dominant rift zones (Dike swarms oriented parallel to the rift) have not a cone, irregular shapes. Those volcanoes had large landslides generated during the past millions of years. Presumably, most of such landslides are caused by lateral failures. Destabilization of volcanic edifices resulting from internal factors (such as local stress field by dike intrusions, steep flanks, and seismic activities) should contribute to lateral fracturing and collapsing. Marle and Lenat (2003) reported that a sedimentary layer has produced a gliding horizon caused by lateral spreading of the flanks. However, they do not show the relevance between the dike swarms associated with the rift zones and lateral spreading of the flanks.

Thereby, we, in particular, focused on the stress redistribution of the volcanic edifice due to development of the rift zones and the volcano instability from geographical features of the land, and considered them through laboratory experiments using analogue materials and numerical analysis.

(1) The volcanic edifice is simulated by a cone-like gelatin layer (ductile part) covered with a starch powder layer (brittle part). We assume that a central conduit of hot magma produced a brittle-ductile transition (approx. 300 to 400 deg.C) inside the volcano . Geometrical parameters of a gelatin cone and covered a starch part are respectively 75mm, 140mm in diameter of bottom circle, and 50mm, 60mm in height. The average slope gradient of the cone was 43 percent. First, we penetrated a central crack from the bottom of the gelatin part. Second, additional crack were injected through other holes and all visible surface open cracks associated with its propagation ware observed. As this result, the more parallel the cracks in the gelatin, the more larger the sector of any visible open cracks become. This explains why the area of Piton de la Fournaise (Reunion islands, where rift zones develop) lateral failure distribution is a lot huger than that of Mt. Etna.

(2) In numerical, we assume that the volcanic land form and the depth of magma source where the density is matched to the country rocks, and calculate the stress distribution inside with the slope angle changes. Because, we must consider if the distributions of open cracks produced by intruded dike swarms cause the lateral collapse, although their parameters are greatly affected by the thickness of cumulative fragmentations and inclination of the edifice. As the result, inflational pressures of the slope surface are clearly discernible with these parameter changes, and we also found the case that the volcanic lateral failure is significantly affected by a magma reservoir.

(3) Finally, we show that the slope failure by volcanic activities occur by the stress field which is made of the interaction both the anisotropic-shaped magma reservoir and the geographical land. Moreover, by measuring the area of the sector failure, we may be able to estimates the azimuth distributions and the directions of maximum tensile stress of the dike inside.