How Could the Magma be Supplied to the Long-lasting Dike Intrusion Event ? - An Example of the East-Off Kozu-jima in 2000 -

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The model for the 2000 intrusive event between Kozu- and Miyake-jima volcanoes, Japan, was reinvestigated. After the sudden earthquake swarm in Miyake-jima volcano, a dike intrusion of large volume lasting for two months (from July to end of August, 2000) was detected by the nation wide GPS network (GEONET) in the area with a radius of about 200km. We extracted the step-wise displacement of the GPS data by fitting a function which includes a step, a linear trend and an annual sinusoidal variation. As displacements cannot be reproduced by the dike alone, an aseismic creep near the dike tip opposite to Miyake-jima is introduced previously. The magnitude of the creep required, however, corresponds to M7, which seems anomalously large.

We introduced a deflation point source, instead of creep source. We assumed a vertical dike extending 5 to 15km deep with the length of 20km and centered at the middle of earthquake swarm region. We obtained optimum solution of the dike being -43 degrees for the azimuth, and 10m opening that correspond to the volume of 2.0km^3, and deflation volume of 1.5km^3 at the depth of 20km. The movement of magma inferred from deflation model is, however, different from creep model. For creep model, about 1.2km^3 of magma should be supplied moving almost horizontally from a reservoir beneath Miyake-jima volcano. On the other hand, the magma must ascent from a reservoir beneath the dike in the deflation model. Volume of the dike is about 2.0 km^3 and the deflation of the magma reservoir beneath it is about 1.5km^3. The volume deficit of about 0.5 km^3 could be supplied from Miyake-jima volcano. In both models the volume budgets are well balanced for considering the simplicity of the models.

The question where the vast amount of magma came from is still controversial. Our analysis shows that the GPS data solely do not provide enough information to resolve the source location of magma. We shall investigate the conditions for the movement of magma before freezing. The direction of magma movement, the distance it travels before freezing, the form of surficial volcanism are controlled by the mechanisms of magma transport at depth. In case of elastic or brittle country rock, magma can easily flow through fractures which results in dike intrusion process, whereas the porous flow of magma are likely to occur in partially molten and deformable source rock. To answer the question how the vast amount of magma could be supplied to the dike, we assume that the geometry of the dike has a vertical wall of about 10 km x 20 km in vertical and horizontal dimensions, respectively. Its thickness grew gradually that is 10 m for 2 months so that we estimate the conditions whether the flow directions of magma inside the dike dominate vertical or horizontal.

Because the distance that magma moves before freezing is proportional to 4th power of its width and inverse of viscosity of magma (e.g. Rubin, 1995), a 2 m-thick basaltic magma can propagate 30 km. However, the viscosity of magma at Miyakejima volcano would be 10^2 or 10^3 times larger than that of the basaltic magma (Nakada et al, 2001), so that the distance should be less than a few km. If a 20 km long dike has intruded within a few days, the width of the dike would be at most one tenth of the final width of ~10 m. Then it is very difficult for magma horizontally to move so long distance. The seismicity did not decay but continued with movement of active region back and forth over the linear region of earthquake swarm of 20 km long. This fact suggests the magma which thicken the dike was supplied from beneath the dike. The depth of the magma reservoir we obtained is 20 km, which is consistent with the thickness of the crust in this region.