An analysis of volcano inflation prior to an eruption at Stromboli volcano based on slug flow and rising gas bubble models

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Stromboli volcano is a small volcanic island located in the south of Italy, and its eruption is characterized by repeated Strombolian type which is considered to be generated by a sudden release of a large gas slug at the crater bottom. In this study, we examine the mechanism of magma flow in the conduit by comparing the tilt record reported in Genco and Ripepe (2010) with two models: slug model and rising gas bubble model.

The tilt records associated with eruptions at Stromboli are observed at five stations located at about 300 -1100 m distances from the vent. The observed tilt change prior to each eruption show volcano inflations with accelerated rate from about 200 s before eruption and same temporal changes at the five stations.

We use slug flow model presented by James et al. (2008). Rising gas bubble model assume that plural gas bubbles rise in melt without interaction of surrounding gas bubbles. Each bubble rise according to Stokes' law. Model parameters of the slug flow are the initial depth and size of slug, viscosity of melt. Model parameters of rising gas bubbles are the initial radius and depth of gas bubbles. Number of the gas bubbles is also a model parameter. Length and radius of the conduit and initial magma head depth are model parameters for both of the two models. We compare spatio-temporal changes of tilt caused by two models with the observed data. We use a 3-D boundary element method that can take into account the effects of topography of Stromboli volcano to calculate volcano deformation.

First, we compare the changes of magma pressure in the conduit from the initial condition to just before an eruption for the two models with the tilt changes observed at five stations. We estimate the model parameters that can fit the observed tilt by using grid search methods. Subsequently, we compare temporal changes of tilt at each station using the estimated model parameters with the observations. The results show that both models can explain the spatial changes of tilt at five stations with a variance reduction more than 98%. The pressure sources for the both models are located at a shallow part (about a few hundred meter depths). Slug flow model, which are often used to explain Strombolian eruptions, cannot explain the volcano inflation at a station located at 1000 m far from the vent. This is because the tilt changes at such stations show down lift toward the vent due to depressurization of magma where a slug locates at. On the other hand, the gas bubbles rise model can produce uplift toward the vent even at stations far from the vent. We obtain model parameters of the rising gas bubble model: conduit length of 550 m and radius of 5 m, initial gas bubbles radius of 0.6 m, the number of gas bubbles of 100, and initial magma head depth of 170 m.