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Modeling of gas bubbles rise in low viscous magma and volcanic deformation

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Eruptions characterized by low viscous magma, such as Strombolian type eruptions, are considered to be generated by a sudden release of a large gas slug. Because ascending slug acts a deflation source, volcanic deformation due to gas slug rise shows deflation at the stations far from the vent (Kawaguchi et al., 2011, JPGU). However, tilt data observed at Stromboli volcano show inflations prior to each eruption at a station away about 1 km from the vent (Genco and Ripepe, 2010). This observation suggests that the slug flow model may not explain these observed data. In this study, we model the gas bubbles rise process in melt and examine the spatio-temporal changes of volcanic deformation due to gas bubbles rise.

We assume that gas bubbles which have a same radius concentrate at a certain depth in cylindrical conduit. According to Stokes' law, individual gas bubbles rise without interaction with surrounding gas bubbles. As gas bubbles rise, the pressure of surrounding melt decreases and gas bubbles expand. Magma head depth ascends by gas bubbles expansion. Using the mass conservation law of liquid melt, temporal changes of the depth and radius of gas bubbles and magma head depth are calculated. Magma pressure at shallow part of the conduit increases with the rise of magma head depth. The void ratio of magma where the gas bubbles exist increases with gas bubbles expansion. As a result, magma pressure at deeper part of the conduit slightly deceases. We examine the spatio-temporal changes of volcanic deformation due to the gas bubbles rise. We assume that many gas bubbles concentrate at the bottom of the conduit at the beginning, and an eruption occurs when the gas bubbles reach the magma. Because the gas bubble velocity is proportional to the square of gas bubble radius, the gas bubbles rise in melt at an accelerated rate. As a result, the magma head depth ascends at an accelerated rate in the conduit. We calculate volcanic deformation due to the gas bubbles rise, assuming an open conduit and elastic half-space. At a station at a same distance of the initial gas bubbles depth from the vent, displacement and tilt increase at an accelerated rate with magma head ascent. The amplitudes of deformation increase with increasing the initial gas bubbles radius or the number of gas bubbles. Because pressure decrease at deeper part of the conduit become smaller than that of slug flow model, volcanic deflation is not likely to appear at a station far from the vent. The tilt changes calculated by gas bubbles rise model fairly well explain with the observed tilt change prior to the eruption at Stromboli volcano which are reported in Genco and Ripepe, (2010). As a result, gas bubble rise model can explain the volcanic inflation at a station far from the vent.

Keywords: open conduit, gas bubble rise, volcanic deformation, Strombolian eruption