Eruptions are more likely: A suggestion from a Miocene dike swarm in Amakusa, Japan

*Atsushi Yamaji[1], Kentaro Ushimaru[1]

1. Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University

Magma transport through a fracture to the Earth's surface gives rise to volcanic eruption, where the fracture is usually thought to be perpendicular to the local σ_3-axis in volcanology (e.g., Acocella, 2021, "Volcano-Tectonic Processes," Chapter 3). However, can fractures oblique to and sometimes even parallel to the axis be dilated by highly overpressured magma, and be chosen as conduits? If so, the prediction of volcanic eruption based on the common assumption underestimates eruption risks. The purpose of this presentation is to address the possibility of fractures with various orientations to be chosen as the conduits based on the geological mapping of a Miocene felsic dike swarm—a fossil of magma plumbing system.

We mapped ~250 planar intrusions in Amakusa, Japan, and found that they showed a radial-parallel pattern transition. The radiating pattern has the center where stocks make a cluster with a diameter of ~5 km (Ushimaru & Yamaji, 2022, J. Struct. Geol.; Ushimaru & Yamaji, a poster of this session). Intrusions were found as far as 40 km from the center. The parallel part had roughly an E-W trend. The planar intrusions of the swarm had various dips and strikes even in small spatial windows. If each one was formed perpendicular to the local σ_3-axis, the variations indicate spatially and temporarily complicated stress conditions. Was this really happened?

To answer this question, first, the theoretical stress trajectory pattern predicted using the elastic model with internally pressured cylindrical hole was fitted to the dike trends. Second, the orientations of planar intrusions in the parts of the swarm were inverted by the technique of Yamaji and Sato (2011) to determine local stress conditions at the time of magmatism. The technique assumes that a fracture can be dilated when the normal stress acting on the fracture surface is smaller than magma pressure irrespective of the attitude of the fracture. As a result, the σ_{Hmax}-orientations determined by the technique were consistent locally with the best fit stress trajectories, though the model to predict the trajectories neglected stress perturbations due to the volcanic edifice loading at the paleo-surface and to the heterogeneous physical properties of the host rocks. This coincidence indicates the validity of the assumption about the dilation of fractures by overpressured magmas. Finally, the frequency of the supply of overpressured magmas were estimated by the technique. We found the negative correlation of the frequency and the distance from the central magma chamber, suggesting the validity of the picture that overpressured magmas were supplied from the chamber. These results indicate that fractures not necessarily perpendicular to the σ_3-axis can be dilated by overpressured magmas and used as their conduits.

Keywords: magma plumbing system, magma pressure, stress, dike

