Relationships between mafic replenishment and eruption triggering at silicic systems: Insights from time scales of magma interactions

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In silicic systems (dacites to rhyolites), evidences of mixing/mingling with a mafic component (basalts to basaltic-andesites) are frequently observed. The time scales for mixing prior to eruption have been inferred using the presence of disequilibrium mineral assemblages and applying reaction and diffusion-based models. Interestingly, these time scales are often on the order of a few hours to months, and the usual interpretation is that the intrusion of mafic magma triggered the silicic eruption. However, given the complexity of fluid dynamic interactions between magmas of contrasting physical properties it is unclear whether these time scales accurately record the arrival of mafic magma in the system, or if there is a delay between replenishment and mixing that is not registered by the crystals and their reactions.

The efficiency with which two magmas interact and mix depends on several factors, including the mafic injection rate, the Ra number (i.e. the ability to convect), and the viscosities of both magmas. In the case of large injection rates, low magma viscosities, and the presence of a large reservoir (i.e. large Ra), silicic and mafic magmas will mix rapidly. Therefore the time scales recorded by reaction and zoning of mafic minerals will accurately report the time between mafic injection and eruption. On the other hand, if the injection rates are low and the viscosity of the ambient silicic magma is high (i.e. low Ra), the mafic magma can pond at the base of the reservoir rather than mix. In this case, the zoned mafic minerals record a time scale that can be significantly shorter than that of injection, and thus lead to erroneous interpretation of eruption triggers.

We investigate the likelihood and implications of each scenario by combining theoretical arguments and thermal modelling with petrological investigations. We consider the case of the Rabaul caldera where above background seismic and deformation signals started in 1971, and peaked between 1983 and 1985, but the onset of eruptive activity only occurred in 1994. Evidence for basaltic injection into a dacitic reservoir is preserved in the 1994-to-present eruptive products. A textural maturation from fine, acicular to large, blocky mafic crystal clots implies different relative ages of formation. Modelling the trace element zoning in plagioclase yields two contrasting time scales of mixing. One event occurred a couple of decades prior to the 2006 eruption and coincides with the peak of unrest. The other occurred a few days to weeks prior to the 2006 eruption, which could imply that mafic injections were the trigger for this eruption. We explore the range of mechanical parameters pertinent to the Rabaul system to address whether (i) all the basaltic replenishment occurred in 1983-85 and mixing occurred subsequently as a number of discrete events, or (ii) multiple replenishment events are required to produce the observed sample textures and characteristics.