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Large-scale lateral magma transport: what processes occur on a 200km journey?

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Recent geophysical observations in the active Izu-Bonin arc indicate that magma is transported long distances from the main volcanic edifices by dyke propagation (e.g., Miyakejima volcano: Geshi et al., 2002; Hachijojima volcano: Ishizuka et al., 2008). The significance of evacuating 2 to 20 km3 of magma from a volcano's plumbing during a dyking event is now recognized as one cause of catastrophic explosive eruptions (e.g., Katmai 1912: Hildreth and Fierstein, 2000). However, studying the physical and chemical properties of upper crustal fissures in active volcanic systems is difficult. Hence this study investigates the processes occurring during magma transport away from volcanic centres in the British Tertiary Volcanic Province, where erosion has exposed extensive dyke networks within the upper crust. The most extensive part of our survey has systematically taken samples, and measured the physical parameters, along dykes extending directly from the Isle of Mull volcanic centre.

Lineations within dykes formed by bubble and crystal alignment indicate that the direction of magma flow gradually changed with distance from the volcanic centre. Adjacent to the volcanic centre the dominant flow direction is near vertical to high-angle, while beyond c. 20km the flow direction is essentially horizontal. These observations indicate that the dykes extending southwest from Mull were fed by laterally-transported magma from this volcanic centre.

Geochemically, the dykes show two distinct trends: one representing magmatic differentiation and the other crustal assimilation (or mixing). Assimilation is most clearly recognized in the correlation between radiogenic isotopes and major elements (e.g., SiO_2 vs. 143Nd/144Nd), and in the relationships between trace element ratios or ΔNb. In general, these trends are found to have a relationship with the sampling distance from the volcanic centre. Most dykes sampled close to Mull following the differentiation trend, while dykes c. 60-100 km away are predominantly aligned with an assimilation (mixing) vector.

Dykes recognized as having a negligible or minor assimilation component show an additional geochemical variation reflecting a contribution from an enriched mantle component (low 143Nd/144Nd, Sm/Yb>2, Th/Ce<0.03). Some dykes within 60 km of Mull have higher Nb/Zr and Nb/Ta than other dykes at a similar distance, implying a variable contribution from the enriched component. Equivalent variation in incompatible element enrichment has been reported from the Mull lava sequence (e.g., Kerr et al., 1999). Accordingly, isolating geochemical signatures constrained by high-precision 40Ar/39Ar dating of dyke rocks enable us to isolate individual magma transport stages (dyke formation) and their correlation with known effusive events. Based on the correlation between geochemistry and distance from the magmatic centre, the effects of magmatic differentiation/crustal assimilation during long-distance magma transport will be evaluated in this presentation.