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Viscous fingering during replenishment of felsic magma chambers by continuous inputs of mafic magmas: field evidence and fluid-mechanics experiments

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Vegetation Island outcrops (Terra Nova Intrusive Complex, Antarctica) offer a superb example of interaction between mafic and felsic magmas. Magma interaction structures are extremely well preserved and allow to recognise a wide range of contact morphologies, from rounded to interdigitate, between mafic and felsic magmas. Morphology of the mafic/felsic interface is analysed by applying Fractal Geometry techniques with the aim to understand the origin of the varied morphologies, by measuring the fractal dimension (D_{box}) of the interfaces. Fractal dimension is a parameter that allows us to quantify the degree of irregularity of the interface between magmas and, in detail, the higher is the value of D_{box}, the higher is the irregularity of the interface. Results show that mafic-felsic contacts at Vegetation Island are characterised by extremely variable values of D_{box} indicating, hence, a large variability in the irregularity of mafic-felsic contacts.

Morphologies of interfaces observed at Vegetation Island are identical to those observed during "viscous fingering" processes induced by the displacement of a more viscous fluid by a less viscous fluid. In the viscous fingering phenomenon, the viscosity ratio V_R=η_1/η_2, defined as the ratio of the viscosity of displaced fluid (η_1) to that of driving fluid (η_2), influences the overall shape of fluid interfaces that range from regular when V_R $\sim$1 to extremely irregular for V_R $>>$1.

Fluid mechanics experiments of viscous fingering have been performed by injecting water/glycerine solutions into pure glycerine at different $V_R$using the Hale-Shaw cell. Morphologies produced by our experiments are identical to those observed on Vegetation Island outcrops supporting that the occurrence of viscous fingering processes

between felsic and mafic magmas is a suitable hypothesis for explaining the varied mafic-felsic interface morphologies. As for natural structures the fractal dimension (D_{box}) of simulated structures has been measured and a very good exponential empirical relationship between V_R and D_{box} is derived. This empirical relationship is then used to estimate V_R of natural structures by knowing D_{box}. Results indicate that at Vegetation Island magma interaction occurred between magmas with a wide range of V_R.

These results, together with previous geochemical and petrographic data, allow us to reconstruct the evolution of magma interaction processes at Vegetation island as characterised by continuous influx of the same mafic magma within a felsic magma chamber. At the beginning of the interaction process the viscosity contrast between magmas was large and this induced the development of very irregular morphologies of mafic-felsic interfaces. With the passing of time the resident felsic magma was progressively warmed up by the continuous influx of mafic magma and viscosity contrasts between magmas decreased favouring the development of progressively more regular morphologies.