Geophysical Research Abstracts
Vol. 15, EGU2013-2251, 2013
EGU General Assembly 2013

Magma Plumbing and Emplacement Mechanisms within Sedimentary Basins

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In recent years our understanding of sub-volcanic magmatic plumbing systems has been revolutionised by the study of hydrocarbon industry 3D seismic reflection datasets from offshore sedimentary basins. In particular, 3D seismic reflection data has provided important insights into sheet intrusion geometry and emplacement mechanisms as well as linkages and magma flow between multiple intrusions within sill-complexes. However, even high-quality 3D seismic reflection datasets have a limit to what they can resolve; thus, to allow a better understanding of detailed emplacement mechanisms and to test the validity of subsurface-based interpretations, it is critical to bridge the resolution gap that exists between seismic and outcrop datasets.

Magmatic sheet (sill) intrusions contribute significantly to the upper crustal magma transport network. The emplacement mechanism of the magmatic sheets controls the final geometry of the intrusions and the characteristics of host rock deformation. Previous observations have highlighted the preponderance of brittle structures (e.g. intrusive steps and broken brides) associated with shallow-level sheet intrusions. However, recent studies have suggested that non-brittle host rock behaviour also occurs, particularly related to the formation of magma fingers during shallow-level sill intrusion. Importantly, these structures can provide insights into emplacement style and magma flow directions. Here, we examine both brittle and non-brittle intrusion mechanisms and structures using both field- and 3D seismic-based observations from a series of widespread and variable magmatic systems. Non-brittle emplacement (i.e. magma finger and lobe development) appears to be primarily associated with viscous flow of the host rock during intrusion and is therefore intimately linked to the contemporaneous host rock rheology as well as magma dynamics. Purely brittle and non-brittle emplacement processes are found to be end members with many intrusions containing evidence of both behaviours.

Deriving the host rock characteristics is therefore an important step in discerning potential diagnostic magma flow indicators and intrusion geometries within field-, seismic- and model-based studies. Incorporation of variable host material behaviours in numerical and analogue modelling, tuned using direct field observations, may consequently further our understanding of the controls on shallow-level intrusion.