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Validating predictions made by a thermo-mechanical model of melt segregation in sub-volcanic systems

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A quantitative understanding of the spatial and temporal evolution of melt distribution in the crust is crucial in providing insights into the development of sub-volcanic crustal stratigraphy and composition. This work aims to relate numerical models that describe the base of volcanic systems with geophysical observations. Recent modelling has shown that the repetitive emplacement of mantle-derived basaltic sills, at the base of the lower crust, acts as a heat source for anatectic melt generation, buoyancy-driven melt segregation and mobilisation. These processes form the lowermost architecture of complex sub-volcanic networks as upward migrating melt produces high melt fraction layers. These 'porosity waves' are separated by zones with high compaction rates and have distinctive polybaric chemical signatures that suggest mixed crust and mantle origins. A thermo-mechanical model produced by Solano et al in 2012 has been used to predict the temperatures and melt fractions of successive high porosity layers within the crust. This model was used as it accounts for the dynamic evolution of melt during segregation and migration through the crust; a significant process that has been neglected in previous models. The results were used to input starting compositions for each of the layers into the rhyolite-MELTS thermodynamic simulation. MELTS then determined the approximate bulk composition of the layers once they had cooled and solidified. The mean seismic wave velocities of the polymineralic layers were then calculated using the relevant Voight-Reuss-Hill mixture rules, whilst accounting for the pressure and temperature dependence of seismic wave velocity. The predicted results were then compared with real examples of reflectivity for areas including the UK, where lower crustal layering is observed. A comparison between the impedance contrasts at compositional boundaries is presented as it confirms the extent to which modelling is able to make predictions that are consistent with the real data. This highlights improvements that could be made to the thermo-mechanical model, such as an extension into 3-D that would be capable of capturing the effects of convective instabilities. In addition, it describes how far numerical models are capable of reducing the uncertainty in the parameter space for poorly defined crustal properties. Most importantly however, it gives an improved understanding of the intrusion and development of melt zones in the continental crust that ultimately control the formation of volcanic systems.

[1] Solano, J. M. S., M. D. Jackson, R. S. J. Sparks, J. D. Blundy, and C. Annen (2012). Melt segregation in deep crustal hot zones: a mechanism for chemical differentiation, crustal assimilation and the formation of evolved magmas. Journal of Petrology, 53, Number 10, Pages 1999-2026. DOI: 10.1093/petrology/egs041.