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Simulations of melt ascent and magmatic differentiation in a monogenetic magmatic event

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The problem of magma ascent and differentiation from an asthenospheric melt source through lithosphere and crust towards its emplacement or eruption poses many challenges. A wide range of physically and chemically coupled mechanisms contributes to this process. Even for a relatively simple monogenetic magmatic system, with a single melt source and plumbing system and a single cycle of activity, the complexity of coupled processes is significant. Thus, the properties that control the time and length scale of melt ascent, as well as the factors influencing the degree of compositional differentiation a magma batch undergoes between source and emplacement have remained enigmatic. Here, we use a novel numerical method to simulate a thermally and compositionally coupled two-phase flow problem. The method is applied to the ascent, compositional differentiation and emplacement of a single monogenetic magmatic event in a realistically deforming lithosphere and crust under extensional tectonics. Magma of mafic composition is introduced in a source region of variable geometry and degree of melting, from where it ascends fully self-consistently until it reaches some final emplacement level or erupts at the surface. The results offer insight into the complex mechanics of this relatively simple example of a magmatic plumbing system. Both time and length scales of melt ascent features are closely controlled by the rheology and permeability of the host rock, as well as the buoyancy contrast and viscosity of the melt. Fractionation of the ascending magma batch is an ongoing process, the efficiency of which is linked to the mechanics of melt ascent. Additionally, the magnitude of tectonic extension has a significant influence on the style and efficiency of melt extraction. The modelling approach is based on equations for the conservation of mass, momentum, energy and composition. Constitutive laws for visco-elasto-plastic shear and compaction stresses and a simplified yet thermodynamically consistent melting model depending on temperature, pressure and composition complete the governing equations.