Quantifying the rates of magma accumulation, differentiation, and cooling

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Magmatism is a complex process that cannot be fully understood without taking into account its spatial and temporal dimensions. Before solidifying or erupting, magmas are subjected to various processes involving mass and heat transfers. The chemical evolution of magmas requires a separation of melt from crystals, i.e. a differential move of the two phases. The presence of melt, its viscosity, and its ability to move are strongly controlled by temperatures. Cooling rates are in turn controlled by geometry. For example, the cooling rate of a quasi-spherical body is significantly different from the cooling rate of a sheet-like body. Similarly, the ascent rates of magma as a diapir is dramatically different from the ascent rate of magma within a dyke.

Geochronological, geophysical, and experimental data provide the framework of new conceptual models that describe magma transport and emplacement. With numerical simulation of magma emplacement and heat transfer, those conceptual models can be put to the test. The integration of field data, experiments, and simulations suggest that the transfer and emplacement of magmas within the crust is discontinuous. In a similar way to the cycles of activity that characterize volcanic eruptions, intrusive activity appears to be cyclic. Simulations show that only during periods of the highest magma fluxes can magmas accumulate in the upper crust and form vast shallow magma chambers that are able to feed the largest eruptions. Because of higher temperatures, the deeper levels of the crust are more favourable to the accumulation of melts and are believed to be where most differentiation occurs. In deep crustal hot zones, magma injection from the mantle, magma compaction, and crust partial melting lead to the generation of a large diversity of melts that sporadically move upwards and intrude the upper crustal levels.

Magma cooling times inferred from crystals radiogenic ages are often difficult to reproduce with heat transfer computation. This suggest that the crystals crystallised before reaching their final level or that geothermal gradients are higher than previously thought. Determining magma cooling and accumulation rates is not of academic interest only; it has societal implications as it affects our models of ore deposits formation, as well as our interpretation of the possible precursors of volcanic eruption.