Transcrustal Magmatic Systems

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Traditional concepts of magmatic systems involving large, shallow, liquid-rich reservoirs (magma chambers) are inconsistent with a wealth of evidence from geophysics, numerical modelling, geochronology and petrology. Instead, the emerging view is of a vertically extensive system of partially molten rock, with a low-volume intergranular melt phase that only locally and ephemerally accumulates in sufficient volume to become eruptible. Percolative reactive flow is a key process in such systems.

Mid-crustal (2-5 kbar) plutonic xenoliths from the Lesser Antilles record a wealth of textural evidence for amphibole-forming reaction of hydrous melts percolating through crystal mushes. At Cerro Uturuncu, Bolivia, gneiss xenoliths record 4 kbar dehydration melting processes at the roof of the partially molten Altiplano-Puna Magma Body. Mixing of crustal melts and H_2O-rich andesite melt from the APMB gives rise to hybrid Uturuncu dacites. At Mount St Helens, thermobarometry of zoned plagioclase phenocrysts, coupled with Sr-diffusion chronometry, reveals that pre-eruptive mush destabilisation and magma ascent from a deeper (~14 km) storage region occurs on month/year timescales.

In partially molten, transcrustal systems, reactive porous flow is a more effective mechanism of chemical differentiation than crystal settling or boundary wall crystallisation. In long-lived systems the mineralogy of the mush buffers the chemistry of the melt phase. Liquids that emerge from the tops of transcrustal systems are typically multiply-saturated, notably with amphibole. The chemical diversity of arc magmas can be mapped onto the compositional spectrum of multiply-saturated melts using phase diagrams for arc magmas at crustal pressures.

Finally, numerical modelling of transcrustal magmatic systems shows that melt fraction varies in time and space but is normally low, falling to zero in some regions of the system at any given time; indeed, limitations on the rate of heat supply to and transport within the magmatic system mean that some long-term, cold (sub-solidus) storage of magma is inevitable. Reactive flow periodically and locally accumulates younger, evolved melt within older, cold mush to form eruptible magmas, rapidly rejuventing older mush. The resulting magmas are buoyantly unstable and only transiently present so are unlikely to be imaged in geophysical data. Rather, these data reveal the low melt fraction background state of such magmatic systems.