Reactive porous flow in mafic magmatic systems

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Reactive porous flow (RPF) is a melt transport mechanism characterised by reactions between migrating interstitial melt and the crystalline framework of its surrounding crystal mush. Here, we review the evidence for RPF in mafic magatic systems by examining plutonic rocks from the lower oceanic crust and their overlying extrusive rocks (MORB). Texturally, RPF manisfests itself in plutonic rocks by locally complex zoning paterns in plagioclase, as well as dissolution of cumulus phases by reactive melt. In some rocks this leads to the formation of new, hybrid rock types. However, RPF is commonly cryptic, leaving no textural evidence. Geochemically, RPF leads to the formation of minerals with major- and minor element compositions not predicted by conventional crystallization models (e.g., clinopyroxene with anomalously high Mg# and Cr_2O_3). Moreover, RPF has the potential to redistribute trace elements, with relative over-enrichment (compared to fractional crystallization) of the highly incompatible elements over moderately incompatible elements. In the lower oceanic crust, this leads to extreme trace element enrichment in the reactive melt, coupled with changes in incompatible trace element ratios.

The rock record from the lower oceanic crust demonstrates that, at least in a mid-ocean ridge setting, RPF is pervasive. It is recorded in all studied sample suites, predominantly as core-to-rim trace element enrichment. Moreover, in the only available more or less complete lower crustal section (from Hess Deep in the equatorial Pacific) trace element enrichment increases upwards over ~4 km, peaking at the top of the lower crust. The peak in enrichment occurs at the level where the seismically imaged magma chamber occurs. This is an important observation, because erupted MORB show an over-enrichment in incompatible trace elements. This over-enrichment shows striking similarities with that observed upsection in the lower oceanic crust, suggesting that MORB trace elements record the effect of RPF. Hence, RPF may affect both the plutonic and volcanic components of mafic magmatic systems.

We posit that RPF is a natural consequence of the gravitational compaction of, and melt extraction from, a crystallising magma body, at least at mid-ocean ridges. Further data are required to test whether this also holds true for continental magmatic systems.