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Magma reservoir evolution at fast-spreading mid-ocean ridges

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Fast-spreading mid-ocean ridge systems are amongst the most robust magmatic systems on Earth. The high melt supply results in a well-developed lower crustal magma reservoir; here, we examine fast-spreading lower crust at Hess Deep (equatorial Pacific Ocean) to investigate the magmatic processes operating within this reservoir.

The deep lower crust comprises relatively primitive layered cumulate troctolites and gabbros. These rocks preserve evidence of reactive melt flow and deformation related to mush deformation and/or compaction. In contrast, the upper part of the lower crust is comprised predominantly of evolved gabbroic rocks (oxide gabbros, (oxide) gabbronorites) preserving predominantly vertical magmatic flow fabrics. Detailed observation of gabbroic rocks immediately below the dyke-gabbro transition provide an exceptional window into the processes operating within the geophysically-imaged axial melt lens (AML). These rocks preserve a crystal framework in equilibrium with Hess Deep MORB, surrounded by the crystallisation products of evolved melts, and generally lack signs of mush deformation.

Together, these observations indicate that the deep lower crust accommodates the intrusion of primary mantle-derived melts, likely in sills. Within these sills, primary melts evolve to MORB compositions, forming a primitive crystal mush. Melts are expelled from these sills episodically through high-porosity channels to feed the AML and ultimately source eruptions. In between decadal eruptions the AML becomes highly crystalline, with an initial cumulate framework trapping increasingly evolved melts. East Pacific Rise basalts carry a bimodal phenocryst population, reflecting both their origin in and expulsion from the deep crust (primitive phenocryst compositions) as well as their transit through the AML (evolved phenocryst compositions).

The rapid, channelised melt transport through the lower crustal magma mush reservoir is supplemented by continuous (but relatively slow) porous flow, which arises as a result of buoyancy and (deformation-assisted) compaction. This melt transport is reactive, leading to distinct compositional evolution of the interstitial melts. This compositional trend, along with the upward differentiation trends seen in mineral major elements, is present on the scale of the entire lower crust. This indicates that, although the life span of the lower crustal mush spans many (thousands?) of separate intrusive episodes, it behaves as a coherent reservoir overall.