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The fate of melts within the slow-spreading lower oceanic crust: New insights from Atlantis Bank (SWIR)

Abstract

Oceanic crust covers about two-thirds of the Earth's surface and is built along oceanic spreading ridges, accounting for more than 60% of the Earth's yearly magma budget. Yet, processes of magma emplacement and evolution within the crust are not sufficiently constrained, and especially at slow-spreading ridges that represent more than half of the 55 000 km-long ridge system (spreading rates <40 mm/y). Since the early 80's, several drilling operations were conducted by an international consortium (the current International Ocean Discovery Project) and provide the scientific community with an invaluable opportunity to study *in situ* lower oceanic crust samples. Oceanic Core Complexes (OCCs) exhume deep mantle and gabbroic sequences thanks to the development of long-lived detachment faults at the ridge axes during asymmetric spreading. The largest OCC and one of the most thoroughly studied is Atlantis Bank on the Southwest Indian Ridge (32°S, 57°E). In total, three deep Holes were drilled in the structure: ODP Hole 735B during Leg 118 and 176 (1500 m-long), IODP Hole 1105A during Leg 179 (157 m-long) and IODP Hole U1473A during Exp. 360 (800 m-long). The results of their study regarding magmatic accretion are consistent with what has been found during the studies of other OCCs (e.g., Atlantis Massif on the Mid-Atlantis Ridge) or fossil portions of oceanic crust from ophiolites (e.g. the Ligurian and Alpine ophiolites). The heterogeneous character of the slow-spreading oceanic crust is directly related to the modes of melt emplacement and migration within the crustal reservoirs. The current vision of the magmatic systems involves a predominance of mushy magma reservoirs, with the implication of reactive porous flow processes during differentiation of the gabbroic crustal lithologies in addition to simple crystallization processes.

During my PhD thesis I conducted high-resolution petrographic, structural and geochemical studies of gabbroic cumulate sections from the two deepest drilled holes of Atlantis Bank, i.e. Hole 735B and Hole U1473A. The new resulting igneous reservoir models and associated evolution processes provide new constraints on magmatic accretion at slow-spreading ridges. The coupled experimental study of simple crystallization processes aimed at better constraining those processes in order to better characterize, in the future, the balance between crystallization and melt-rock reactions in the evolution of the studied gabbro lithologies.

The results of the study of a layered gabbro sequence from Hole U1473A indicate that layers originally formed by intrusion of a crystal-bearing magma into a solidifying coarse-grained, more evolved mush. Melt-rock reactions are widespread, occurred at all stages of formation of the layers, and contrasting melt dynamics due to variable focusing of the porous flow impacted the geochemical signatures and textures of the reacted gabbros. In addition, among the two main types of systematic grain size variations described in gabbro cumulates at Atlantis Bank, layering likely represent contacts between magma reservoirs within the crust. The geometry and the different steps of formation of a major igneous reservoir have been established thanks to the study of a 250 m-long section from Hole 735B. The section was previously described as a single intrusion due to its characteristic large-scale whole rock upward differentiation trends. In details, the lower half of the reservoir formed by sills stacking, and was impacted by successive replenishment events that assimilated the

primitive cumulates initially crystallized in the sills. In contrast, the upper half of the reservoir constitutes a homogeneous unit that evolved by progressive percolation of melts collected from the lower units, and by accumulation of evolved melts towards the top of the section. We additionally show that melt-rock reactions triggered by a global upward porous melt flow in the reservoir constitute the main processes governing magma differentiation. We infer that the principal driving force for the upward percolation of melts through the entire section is a "melt flushing" process caused by successive replenishment of the reservoir. Comparison of the geochemical and structural characteristics defining the igneous reservoir model with other sections of *in situ* lower crust from Atlantis Bank and Atlantis Massif, reveal that all or part of the model can apply to those sections. This led to the broader conclusion that the model could initiate new perspectives regarding the formation and evolution of the lower slow-spreading crust outside of the Atlantis Bank system.

Finally, the experimental study help constraining simple crystallization processes under lower crustal conditions. The results confirm that crystallization alone cannot account for the formation of the lower crust gabbroic lithologies, and paves the way for further characterization of melt-rock reactions and the quantification of their involvement in magma accretion at slow-spreading ridges.