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Evidence for Crystal-mush Melt-rock Reactions in Gabbroic Plagioclase and Clinopyroxene from Atlantis Massif

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Over the last few decades, the community has recognized geophysical, chemical, and textural evidence that does not support the traditional melt-rich magma chamber model and has suggested that magmatic systems may, instead, be dominated by crystal-rich mushes [1]. An inherent consequence of the evolving crystal-mush magma storage model is that melt migration along grain boundaries should promote pervasive disequilibrium chemical reactions. In comparison to a melt-rich magma governed by pure fractional crystallization, these melt-rock reactions have been suggested to have a significant effect on the chemistry of the associated lavas and cumulates [1,2]. Here, we investigate the effect of melt-rock reactions on various major and trace elements by collecting high spatial resolution profiles across adjacent clinopyroxene and plagioclase grains in gabbroic cumulates from Atlantis Massif (30°N, Mid-Atlantic Ridge). Samples of the lower oceanic crust from Atlantis Massif are ideal for studying the effect of melt-rock reactions, as they are some of the freshest, most primitive cumulates recovered to date and were produced by small, discontinuous melt injections at a slow spreading center [3]. To distinguish melt-rock reactions from fractional crystallization trends, we calculate enrichment factors (= concentration of an element at a given point in a crystal relative to its concentration in the core) for ratios of elements with contrasted partitioning behavior [2]. Preliminary results show more variation in enrichment factors within plagioclase grains than in adjacent clinopyroxene grains, suggesting plagioclase grains record a larger variability of melts circulating through the mush. This observation is consistent with a recent clinopyroxene crystallization model [4], which suggests that while clinopyroxene cores crystallize early, most of the grain crystallizes after maturation of a plagioclase-rich mush. Further investigations will include calculating crystallization temperatures for each mineral and comparing enrichment profiles from samples with different grain sizes and reaction textures. Combined, these results will better outline the implications of open system crystal-mush storage on the geochemical diversity within mid-ocean ridge basalts.

[1] Cashman et al., 2017, https://doi.org/10.1126/science.aag3055; [2] Lissenberg & MacLeod, 2016, https://doi.org/10.1093/petrology/egw074; [3] Blackman et al., 2011, https://doi.org/10.1029/2010JB007931; [4] Ubide et al., 2025, https://doi.org/10.1016/j.epsl.2025.119423