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SPECIAL COLLECTION: APATITE: A COMMON MINERAL, UNCOMMONLY VERSATILE

Apatite in the dike-gabbro transition zone of mid-ocean ridge: Evidence for brine assimilation by axial melt lens

Chao Zhang[1,*], Juergen Koepke[1], Moritz Albrecht[1], Ingo Horn[1], and Francois Holtz[1]

[1]Institut für Mineralogie, Leibniz Universität Hannover, 30167 Hannover, Germany

Abstract

We present textures and halogen and trace-element compositions of apatites in intrusive rocks from the dike-gabbro transition zone of a fast-spreading mid-ocean ridge, which was formed at the East Pacific Rise and recently drilled by IODP Hole 1256D. These data are used to discuss the properties of parental magmas and seawater-derived hydrothermal fluids at the roof of the axial melt lens during the formation of oceanic crust. In general, zoning of apatites from three different lithologies, tonalites, diorites, and gabbros, is common and shows a consistent evolution trend with depletion in Cl and REEs from core to rim. The cores are usually homogenous in composition and interpreted as magmatic origin, whereas zones with lower Cl and REEs are disseminated with heterogeneous concentrations, indicating exchanges with hydrothermal fluids. The apatite cores in tonalites are rich in both F and Cl, with X_{Ap}^{F} (proportion of fluorapatite end-member) up to 0.5 and X_{Ap}^{Cl} (proportion of chlorapatite end-member) up to 0.4. In contrast, the apatite cores in gabbros have high X_{Ap}^{Cl} (up to 0.85) and very low X_{Ap}^{F} (<0.05). The two contrasting types of apatite cores are both observed in diorites, implying that magma mixing processes may have controlled the formation of the dioritic intrusives. The strong depletions in Cl and REE_S in some parts of the apatite crystals (mainly rim) can be explained by removal of these components via hydrothermal fluids. Based on available F-Cl-OH exchange coefficients for apatite-melt, the very high Cl/OH and Cl/F ratios and high Cl contents calculated for tonalitic melts cannot be reconciled with a formation of these felsic melts by partial melting of amphibole-bearing metabasalts, but indicate that an assimilation of high-Cl brines must have occurred. Similarly, the low-F chlorapatites in gabbros also imply an assimilation of high-Cl brines. The source of high-Cl fluids in the axial magmatic system may result from seawater-derived fluids, which may form immiscible vapor and brine at high temperatures as a result of hydrothermal boiling.

Keywords: Apatite, mid-ocean ridge, axial melt lens, brine, chlorine, IODP