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Chemical profiles along olivine crystallographic axes: a record of the melt-rock interaction sequence forming Hole U1309D Olivine-rich troctolites (Atlantis Massif, MAR, 30°N)

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The gabbroic section drilled at IODP Hole U1309D (Mid-Atlantic Ridge, IODP Expeditions 304, 305) comprises a whole range of modes from primitive olivine-rich troctolites to evolved gabbros. These series occur as discrete alternating intervals of variable composition and thickness at different depths. High MgO contents and a relatively large proportion of olivine-rich lithologies (up to 90% modal olivine) characterize this gabbroic section. Contacts between olivine-rich troctolites and neighboring coarse grained olivine gabbros are sharp, with the exception of the contacts between olivine-rich intervals and cross-cutting gabbroic veins, which are diffuse and characterized by progressive variations in plagioclase content. Olivine-rich troctolites are heterogeneously distributed along the borehole and show variable modal composition: centimeter to decimeter scale dunitic (90% olivine), troctolitic (enriched in plagioclase) and wehrlitic (enriched in clinopyroxene) domains were identified. Previous in-situ trace element geochemistry and crystallographic preferred orientation measurements of olivine-rich troctolites indicated that they record extensive melt impregnation of pre-existing olivine-rich material, either mantle rocks or dunitic cumulate. We performed a detailed multi-scale petro-structural and geochemical study on selected samples of well-preserved olivine-rich troctolites with the aim to unravel the sequence of re-equilibration processes and better constrain the local conditions driving the formation of these rocks. Processed EBSD maps show variable textures at single sample scale. All identified domains are characterized by coarse grained and deformed olivines, and small rounded undeformed olivines. Coarse grained and small rounded olivines have the same major and trace element compositions. Small olivines are interpreted as relicts after dissolution of coarse grained olivines. Clinopyroxene, plagioclase, and minor orthopyroxene are present as interstitial phases. Dunitic and troctolitic domains display different microstructural and geochemical signatures. Their mineral modal percentages and compositions are not correlated along typical trends of fractional crystallization. The dunitic domain has olivines showing lower Mg# (82-83, against 85-86 in troctolitic domain), higher Ni and Mn contents. In the dunitic domain olivine, plagioclase and clinopyroxene are more enriched in trace elements compared to those in the troctolitic domain. These compositions reveal reaction and re-equilibration processes of pre-existing mantle-derived olivine-rich rock with an infiltrating olivine-undersaturated MORB-type melt. Chemical traverses along principal crystallographic axes of olivine reveal flat cpxcore-cpxrim-olrim-olcore profiles for all major and trace elements with the exception of Ca and Y, which are modified due to late subsolidus re-equilibration. Flat profiles indicate either (i) slow olivine dissolution kinetics relative to equilibration of primary olivine with incoming melts or (ii) preservation of initial chemical signature and fast olivine dissolution kinetics. These two end-member scenarii are investigated using thermodynamic models to better constrain (dis-)equilibrium relationships between mineral phases and reactive percolation modeling to determine the contribution of advective and diffusive processes to local chemical signatures.

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