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Melt-rock reaction at the crust-mantle boundary: Insight from Atlantis Massif peridotites (30°N, Mid-Atlantic ridge)

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Very olivine-rich plutonic lithologies (> 70% olivine), in the following referred to as olivine-rich troctolites (ORT), have been identified at several locations dominantly along slow-spreading mid-ocean ridges. Particularly well preserved ORT were recovered at Atlantis Massif, 30°N, Mid-Atlantic Ridge, an oceanic core complex drilled during IODP Legs 304/305. At Site U1309, ORT comprise around 50 m of core length that is otherwise dominantly composed of gabbroic lithologies. Several studies on ORT from Atlantis Massif concluded that they represent reactively overprinted residual mantle peridotites, transformed in several steps (dunitization, disaggregation and precipitation of plagioclase and cpx) by large melt influx at shallow levels (1,2,3,4). This in combination to the abundant gabbroic rocks is at odds with their location which is commonly thought to represent melt-limited conditions.

We performed a detailed petrologic investigation of mantle peridotites also drilled at Atlantis Massif. Mantle peridotites represent a subordinate lithology at Site U1309 (<0.5%) and occur as screens in the otherwise gabbroic core. The peridotites show textures and mineral compositions that suggest a formation through melt-rock reaction between harzburgite and residual melts from their associated gabbro intervals. Notably, impregnated peridotites commonly show orthopyroxene-clinopyroxene reaction relationships and different generations of clinopyroxene. Mineral phases produced by this process show large compositional overlap ORT from the same location but are otherwise incompatible with crystal fractionation trends shown by basaltic melts. We interpret them as proto-ORT giving insight into the early stages of ORT formation.

All evidence suggests mineral replacement by assimilation-fractional crystallization at moderate to low melt-rock ratios, in contrast to current models on ORT formation. The newly formed high Cr-cpx shows a distinctive composition that is the result of buffering by the peridotitic assemblage in which opx is an important component. This distinct mineral composition allows the recognition of further rock intervals representing former crust-mantle contacts that are masking now as inconspicuous troctolites and olivine gabbros within the gabbroic section. Using the available mineral data, we can show that up to 20% of mantle may be stored in the lower crust at Atlantis Massif. This significantly lowers the amount of melt estimated to form the crustal section of Atlantis Massif. Comparison with data from ORT worldwide shows that this is a widespread process at modern and fossil mid-ocean ridges. Hence, there may be significant amounts of mantle incorporated into the lower crust at slow-spreading ridges that are likely not easily detectable by geophysical methods.

References:
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