Geophysical Research Abstracts,
Vol. 11, EGU2009-4118, 2009
EGU General Assembly 2009

Highly impregnated slow-spread lithosphere : microstructure and geochemistry of olivine-rich troctolites from IODP Hole U1309D

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IODP Expeditions 304-305 sampled the Atlantis Massif, an oceanic core complex located at 30°N in the inside corner of the intersection of the Mid-Atlantic Ridge with the Atlantis Fracture Zone. IODP Hole U1309D was drilled to 1415.5 meters below seafloor; it is the second deepest hole in slow-spreading crust, after Ocean Drilling Program (ODP) Hole 735B on the Southwest Indian Ridge. The recovered rocks are mostly gabbroic.

We present a petrostructural (EBSD) and in-situ geochemical (EPMA, LA-ICPMS and LA-HR-ICPMS) study of olivine-rich troctolites (ol > 70%; 5.5 % of recovered section) and associated gabbros. Olivine-rich troctolites from Hole U1309D display poikilitic textures, with olivine ranging from coarse-grained subhedral crystals to medium-grained rounded crystals, embedded in large, undeformed clinopyroxene and plagioclase poikiloblasts. Trace element compositions of clinopyroxene and plagioclase poikiloblasts indicate that they crystallized from the same depleted MORB melt in both olivine-rich troctolites and associated gabbros. Olivine trace element compositions appear too depleted in light REE to be in equilibrium with plagioclase and clinopyroxene. Olivine crystallographic preferred orientations are weak, and misorientations are consistent with deformation by dislocation creep with activation of the high-temperature (010) [100] slip system, commonly described in asthenospheric mantle. The fabrics also display a relatively strong uncommon [001] concentration that we interpret as resulting from abundant melt impregnation.

The joint study of geochemical processes and microstructures in these rocks suggest a complex crystallization history in an open system with percolation of large volume of MORB-type melt that postdate olivine crystal-plastic deformation. Although the mantle origin of the olivine is difficult to demonstrate unequivocally, we propose that olivine-rich troctolites represent the ultimate residue of melt-mantle reaction processes. Our results are consistent with the formation of oceanic core complexes associated with relatively strong magmatic activity, and with the crystallization of most of melt in the Atlantis Massif lithosphere without basaltic counterpart erupted on the seafloor.