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Spatial patterns of fluid- and melt-rock processes and link between melt-impregnation and metamorphism of Atlantis Massif peridotites (IODP Expedition 357)

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International Ocean Discovery Program (IODP) Expedition 357 drilled 17 shallow sites spanning ~10 km in the spreading direction (from west to east) across the Atlantis Massif oceanic core complex (OCC, Mid-Atlantic Ridge, 30°N). Exposed mantle in the footwall of the Atlantis Massif OCC is predominantly nearly wholly serpentinized harzburgite and subordinate dunite. Altered peridotites are subdivided into: (I) serpentinites, (II) melt-impregnated serpentinites, and (III) metasomatized serpentinites. Type I serpentinites show no evidence of melt-impregnation or metasomatism apart from serpentinization and local oxidation. Type II serpentinites have been intruded by gabbroic melts and are distinguishable in some cases based on macroscopic and microscopic observations, e.g., mm-cm scale mafic-melt veinlets, rare plagioclase (□0.5 modal % in one sample) or by the local presence of secondary (replacive) olivine after orthopyroxene; in other cases, 'cryptic' melt-impregnation is inferred on the basis of incompatible element enrichment. Type III serpentinites are characterized by silica metasomatism manifest by alteration of orthopyroxene to talc and amphibole, anomalously high anhydrous SiO_2, and low MgO/SiO_2. Two fundamental features of the mantle serpentinites are identified: (1) A pattern of increasing melt-impregnation from west to east; and (2) a link between melt-impregnation and metamorphism. In regard to (1), whereas a dominant fluid- rock alteration (mostly serpentinization) is distinguished in the western serpentinites, a dominant mechanism of melt-impregnation is recognized in the central and eastern serpentinites. Melt-impregnation in the central and eastern sites is characterized by enrichment of incompatilble elements, Cr-spinel with anomalously high TiO_2 (up to 0.7 wt.%) and olivine forsterite (Fo) compositions that range to a minimum of $Fo_{86.5}$. With respect to (2), in contrast to unmetamorphosed Cr-spinel of western site Type I serpentinized peridotites, spinel of the melt-dominated central and eastern peridotites record metamorphism, which ranges from sub-greenschist (<500°C) to lower amphibolite (>600°C) facies. Low grade, sub-greenschist facies metamorphism resulted in Mg and Fe^{2+} exchange between Cr-spinel and olivine resulting in Cr-spinel with anomalously low Mg# (cationic Mg/(Mg+Fe^{2+})). Higher grade amphibolite facies metamorphism resulted in Al-Cr exchange and the production of Fe-chromite and Cr-magnetite. Heat associated with magma injection and subsequent melt-impregnation resulted in localized contact metamorphism. High degrees of melt extraction are evident in low whole-rock Al_2O_3/SiO_2 and low concentrations of Al_2O_3, CaO, and incompatible elements. Estimates of the degree of melt extraction based on Cr# (cationic Cr/Cr+Al, up to ~0.4) of unaltered Cr-spinel and

modeled whole rock REE patterns, suggest a maximum of ~18-20% non-modal fractional melting. As some serpentinite samples are ex-situ rubble, the magmatic histories at each site are consistent with derivation from a local source (the fault zone) rather than rafted rubble that would be expected to show more heterogeneity and no spatial pattern. In this case, the studied sites may provide a record of enhanced melt-rock interactions with time, consistent with proposed geological models for OCC formation.