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Formation of late-stage mineral veins in the footwall of an oceanic detachment fault (ODP Leg 304/305)

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Atlantis Massif is an oceanic core complex situated at the Mid-Atlantic Ridge at ca. 30°N. IODP Leg 304/305 Hole U1309D drilled into the footwall of a detachment fault that is related to exhumation of the core complex. The 1416 m long drilled section is mainly composed of gabbros and troctolites, with minor amounts of basaltic and ultramafic rocks. An intense retrograde overprint is recorded by granulite- to zeolite-facies mineral assemblages and late-stage mineral veins (e. g., consisting of anhydrite, calcite, prehnite, quartz, zeolite, ...). The chemical and isotopic composition of these veins was studied in order to further our understanding of the fluid regime and temperature conditions in the detachment fault system.

Syn- to postkinematic calcite veins having low concentrations of incompatible elements (e.g., U, Li, Sr) and flat chondrite-normalized REE+Y patterns with positive Eu anomalies are common. The fluids from which calcite precipitated were likely similar to basalt-hosted hight-T vents and no affinity to the nearby serpentinization-derived Lost City vent field is observed. The deep origin of the fluids is highlighted by low $^{87}Sr/^{86}Sr$ (0.704 to 0.708), mantle-like δ^7Li_{LSVEC} (+0.8 to +9.4 ‰) and $\delta^{13}C_{PDB}$ (-6 to -2 ‰). The $\delta^{18}O_{VSMOW}$ values point to calcite precipitation temperatures of 150–220°C.

Anhydrite and anhydrite + zeolite veins have $^{87}Sr/^{86}Sr$ values consistent with anhydrite formation from downflowing seawater which had leached only minor amounts of Sr from the basement. The REE pattern of anhydrite veins indicate that admixed hydrothermal fluids at depth played a minor role. The deepest section of Hole 1309D is dominated by veins consisting of silicate minerals (prehnite, quartz, plagioclase). These veins indicate precipitation temperatures ranging from 270 to 145°C (estimated from $\delta^{18}O$ values). They are comparatively unradiogenic in $^{87}Sr/^{86}Sr$ (0.7033-0.7046) and demonstrate (in contrast to anhydrite) enhanced intensity of reactions between infiltration seawater and basement with increasing depth. Geochemical reaction path models indicate that the hydrous alteration of olivine-bearing lithologies (Ol-gabbros, troctolites, ...) is of major importance not only for the formation of rodingite-type veins, but also for providing suitable fluid conditions for carbonate precipitation.

Insights into the fluid regime and temperature conditions within the detachment fault footwall during formation of the Atlantis Massif oceanic core complex are provided by late-stage mineral veins. The lack of systematic isotopic downhole trends does not allow for estimation of a geothermal gradient, but indicates that already conductively cooled basement fluids are responsible for precipitation of vein minerals. Additionally, although rocks below the detachment fault surface are strongly tectonized, the seawater influence on the fluids is insignificant and thus dominantly mantle carbon is sequestered within the examined calcite veins.