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Reaction-induced microcracking and fluid flow into the oceanic crust beneath an extensional detachment fault at 30 ^{o}N, IODP Site U1309

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IODP Hole U1309D was drilled north of the summit of the Atlantis inside corner high at 30 ^{o}N during Expedition 304/305. The hole was located on a corrugated surface assumed to be a low angle extensional detachment fault, and small samples of talc-tremolite-chlorite schist recovered at the top of the Hole are believed to represent the detachment fault rock. During Leg 304, 400m of diabase, gabbros, troctolites and ultramafic cumulates were penetrated with around 75% recovery. Many sections of the core show characteristic corona textures around olivine grains, produced during the reaction olivine + plagioclase + water = chlorite + tremolite. The low-T stability of plagioclase + forsterite lies at the upper limits of amphibolite facies (for P = 100 MPa, T $\sim$ 650˚C) The absence of hornblende in the coronas suggests that the reaction occurred mainly at 400-450 ^{o}C. At the time of reaction, the corona-textured rocks are assumed to have been covered by 1-2 km of crust, which has since been removed by denudation associated with detachment faulting.

The coronitic reaction involves an increase in solid volume of 15-20% depending on the involvement of mobile components. In thin section, plagioclase is invariably rimmed by chlorite, and contains abundant chlorite veins. The veins radiate away from tremolite-filled pseudomorphs of olivine, and commonly follow curved trajectories linking one corona with another, resulting in a connected microcrack network. This textural observation gives independent evidence for substantial volume increase, and indicates that stresses induced by the volume change were greater than tectonic stresses at the time.

We assume that, in most samples, initial cracking of the rock occurred due to thermally-induced stresses during cooling, although oriented cracks filled with actinolite or chlorite in some samples may reflect tectonic stresses. Once fluid entered the rock, a positive feedback between volumetric strain, cracking and permeability, combined with a large ΔG overstepping of the reaction, led to rapid influx of fluid and total alteration of either olivine or plagioclase. Only below 300 mbsf did the reaction fail to go to completion in significant numbers of samples. Below this depth a new, lower temperature reaction involving serpentinisation of olivine along oriented microcracks, accompanied by replacement of plagioclase by prehnite and hydrogarnet, becomes dominant. The stability of prehnite, hydrogrossular and chlorite fixes the temperature of this reaction at $<$350 ^{o}C.

These results demonstrate the critical role of metamorphic hydration reactions on fluid flow and the thermal evolution of the oceanic crust. In addition, volumetric strain in a laterally confined system may have reoriented stresses such that σ_1 became horizontal even in an extensional environment, explaining the occurrence of late diabase sills in the upper part of the hole.