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Microstructures reveal brittle and viscous flow during exhumation of the high-temperature lower oceanic crust from Site U1473A, Atlantis Bank, Southwest Indian Ridge (IODP Expedition 360)

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Detachment faulting has been hypothesized as the main process of tectonic spreading in mid-ocean ridges. The ongoing faulting leads to exhumation of oceanic core complexes (OCC) through large-scale normal faults, exposing heterogeneous sectors of the mylonitic lower crust, locally interlayered with pristine upper-mantle rocks. However, the mechanisms involved in this process – and the interplay between magmatism, deformation and fluid-rock interaction – are still debatable. To address these issues, we performed a quantitative microstructural analysis and thermodynamic modelling on mafic shear zones that occur in the lower section (≥ 600 meters below sea-floor) of Site U1473A (Atlantis Bank OCC, SW Indian Ridge), the target of IODP Expedition 360, to constrain deformation conditions and strain localization mechanisms during detachment faulting. The gabbroic shear zones consist of large (up to 5 mm in size) porphyroclasts of clinopyroxene, orthopyroxene, plagioclase and olivine embedded in a fine-grained (≤ 30 µm), polyphase matrix composed of plagioclase, clinopyroxene, orthopyroxene, amphibole, ilmenite, magnetite and olivine. Plagioclase-rich layers (~ 80 µm) are in abrupt contact with the fine-grained mixture, which define the mylonitic foliation. The porphyroclasts have undulose extinction, subgrains and are surrounded by fine-grained recrystallized grains (core-mantle structure) showing internal lattice distortion. Microfractures are common in orthopyroxene porphyroclasts. Amphibole replaces clinopyroxene and orthopyroxene porphyroclasts at their margins and fills cleavage planes. The plagioclase-rich layers show undulose extinction and subgrain boundaries in the larger grains within the layers. Mechanical twin lamellae occur in some grains regardless of grain size. Plagioclase grains show a weak shape preferred orientation with their long axes parallel to the main planar fabric of the shear zone. The grains in the polyphase matrix are mostly strain free. EBSD data in clinopyroxene clasts indicate activation of (010)[001] slip system and twinning along (001)[100]. Plagioclase-rich layers deforms by slip along the (010)[100] system. The polyphase matrix has a very weak but non-random CPO pattern. #Mg and Al content in the recrystallized clinopyroxene and orthopyroxene grains are lower compared to the porphyroclasts. Plagioclase has similar An content in both porphyroclasts and recrystallized grains. Amphibole has low concentrations of Cl and high content of F. The content of #Mg, Al and Si is similar in amphibole grains replacing pyroxene and in the polyphase matrix. Thermodynamic modelling indicates that the gabbroic shear zones formed at 820-870 °C and 2.0-2.8 kbar. Our results suggest

that deformation in the porphyroclasts was accommodated by combined mechanical fragmentation and intracrystalline plasticity, which resulted in fractured grains of orthopyroxene, and clasts rimmed by recrystallized neoblasts. Plagioclase-rich layers formed mainly through dislocation creep. Phase mixing and weak CPO in the polyphase matrix point to oriented-growth during diffusion-assisted grain boundary sliding, mainly in the presence of melt, as evidenced by amphibole formed at the expense of pyroxene. Magmatic fluids are the possible source of reactant amphibole. Such mechanisms effectively resulted in strain localization in fine-grained, polyphase shear zones that contributed to the weakening of the ocean crust during detachment faulting and subsequent exhumation of the Atlantis Bank OCC.