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Abstract

Oceanic crust covers more than two thirds of the Earth's surface and mid-ocean ridges, where it is formed, are the most important zones for mass and energy exchange between litho-, bio-, and hydrosphere on our planet. Nonetheless, mid-ocean ridges are still widely mysterious and our knowledge on magmatic processes taking place beneath them is very limited. A detailed knowledge on those processes is essential to understand the formation of lower oceanic crust and, thereby, its role in the System Earth. Two end-member models of crustal accretion are competing: (1) the gabbro glacier model explains crustal accretion from a subsiding crystal mush of the cumulates from the axial melt lens and (2) the sheeted sill model suggests that the lower crust is accreted by in-situ crystallizing melt sills within the lower crust. The Samail ophiolite in the Sultanate of Oman is regarded as ancient oceanic lithosphere formed at a fast-spreading ridge. With its coherent stratigraphy covering the upper mantle, the layered, foliated, and varitextured gabbros, as well as the sheeted dykes and the pillow basalts (from base to top), Wadi Gideah in the Samail ophiolite provides an ideal field laboratory for investigating ancient oceanic crust.

A profile crossing the entire gabbroic section from the axial melt lens at 5000 m above the base of the Moho transition zone (maM) down to the crust/mantle transition in Wadi Gideah was analyzed with a focus on the microstructural features of the lower crust. The variations in grain size and in fabric strength and symmetry with depth were interpreted as indicators for a hybrid accretion model, where the upper third of the gabbroic crust accretes by vertical magmatic flow either from the axial melt lens down- or from the underlying crystal mush upward and the lower two thirds of the crust crystallized in-situ. Vertical flow is indicated by steep foliations observed in the field and accompanied by a significant lineation component that disappears at 3500 maM. Beneath this horizon, the fabric strength and the degree of lineation gradually increase down section indicating magmatic deformation of previously emplaced crystal mush by the underlying convecting mantle.

Two approximately 400 m long drill cores were obtained in the lower crust of Wadi Gideah: GT1A covering an interval from 1173 down to 815 maM and GT2A covering the transition from the foliated to the layered gabbros at 2695 down to 2300 maM. GT1A was sampled with a high spatial resolution of about 2 m on average (16 m maximum) and petrological, geochemical, and microstructural tools were applied for detailed investigations. Indicators of fractional crystallization and melt evolution at depth were documented, indicating that in-situ crystallization has formed the layered gabbro section as proposed from the surface profile. Parallel variations in the phase compositions and their fabric symmetry

were observed in both drill cores which could result from changes in physical properties (e.g., viscosity) of a melt with chemical evolution, thereby, also affecting deformation mechanisms. Local core/rim zonation in clinopyroxene and an increased lineation of plagioclase and clinopyroxene crystals indicate porous melt flow in a narrow horizon of drill core GT1A.

Igneous layering is a ubiquitous feature of the lower oceanic crust at fast-spreading mid-ocean ridges and two types were investigated: decimeter scale gradual modal layering from Wadi Somerah and modal layering pronounced by millimeter scale bands being enriched in olivine from WadiWariyah. The formation of the former can be explained by crystal-laden density currents slumping from the inclined wall of a melt sill leading to density-controlled phase segregation. The latter is mostconsistent with the formation by Liesegang banding where the diffusion of elements from the melt toward a crystallization front is not able to keep pace with the cooling of the magma, thus, these elements are supersaturated at a certain distance from the crystallization front leading to the formation of a new crystal band. The preferred growth of larger grains on the expense of smaller onesand shearing of the lower crust by mantle convection might emphasize initial heterogeneities to well-developed modal layering.