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A petrological and geochemical cross section of lower crust at the Wadi Gideah (Samail ophiolite):

Implications for the crustal accretion at fast-spreading mid-ocean ridges

A cross section of fast-spreading mid-ocean crust lithologies was sampled at the Wadi Gideah, which is located in the Wadi Tayin Massif in the southern part of the Oman ophiolite. A coherent data set for advancing our understanding of crustal accretion processes at fast-spreading mid-ocean ridges was created by performing different analytical and structural investigations on the same suite of samples.

Major and trace element studies from Wadi Gideah lower crust reveal an up section trend of chemical evolution. Although it is slight within the layered gabbros, it becomes more distinctive at the layered/foliated gabbro transition. In the upper foliated gabbro section it is accompanied by the first occurrences of mineral zonation and late magmatic phases. Petrological modeling in a chemical system corresponding to Wadi Gideah reveals that the overall up section trend of chemical evolution can be produced by hydrous fractional crystallization. Melt H_2O content is estimated to be ~0.8 wt% and 0.8 to 1.2 wt% by modeling for lower and upper crust, respectively. Hydrous modeling combined with a very steep bulk Zr/Hf vs. Zr gradient, a high F and Cl content for magmatic amphibole, a general Nb-Ta depletion of Wadi Gideah melts in comparison with normal mid-ocean ridge basalt (NMORB), and a Sr^{87}/Sr^{86} ratio generally higher in comparison with modern East Pacific Rise (EPR) crust indicate that the Wadi Gideah layered gabbros accreted by in situ crystallization within sills in a subduction initiation setting. Evidence for reactive porous flow is not observed. The distinctive change in the chemical trend of evolution associated with a distinctive change in average grain sizes at layered/ foliated gabbro transition is probably related to a horizon of enhanced cooling below the axial melt lens (AML), considering deep crust hydrothermal cooling. Upper foliated gabbros represent a ~500 m thick transition with evidence for both subsidence of crystals from the AML above and upward flow of melt from below. In summary, Wadi Gideah lower crust displays a formation history similar to hybrid accretion models proposed by previous studies. Hydrothermal cooling, required for heat extraction from deep crystallization, was probably facilitated by channeled hydrothermal flows, preserved today in multiple, up to 100 m wide zones of extensively altered former layered gabbro which cut host

rock layering. These metagabbros display significantly high Sr^{87}/Sr^{86} ratios, late stage phases, and evidence for high temperature partial melting.

Lower crust hybrid accretion is supported by plagioclase crystallographic preferred orientations (CPO), which show very low intra-mineral misorientation and no significant crystal-plastic deformation down to mantle/crust boundary. Furthermore, clinopyroxene fabric strength shows a lack of continuous increase down section associated with high scatter. Upper foliated gabbro plagioclase displays random or very weak CPO, similar to that in the varitextured gabbro, reflecting the transition zone character. A slight but nevertheless apparent increase of plagioclase fabric strength with depth, observed for the complete lower crust, is possibly related to increased shear flow caused by an impact of active plastic mantle flow below.

The outcrop of the frozen AML on top of lower crust, at the gabbro/dike transition, includes varitextured gabbro bearing relics of very primitive poikilitic clinopyroxene. These gabbros are intruded by masses of oceanic plagiogranites bearing relics of assimilated sheeted dikes, which in turn are cut by trondhjemite dikes. All lithologies are cut by basaltic dikes with chilled margins. Time constraints on the sequence of intrusions, modeling of AML melt fractional crystallization and comparison to previous partial melting experiments give evidence that these Wadi Gideah lithologies were formed as a consequence of episodic vertical movements of the AML, probably caused by changes in AML replenishment rates.