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Hess Deep Plutonic Crust, Expedition 345

Jonathan Snow[1*], Kathryn Gillis[2], Adam Klaus[3], Shipboard Scientific Party IODP Expedition 345[4]

[1]Univ. Houston, [2]Univ. Victoria, B.C., [3]Texas A&M Univ., [4]IODP Expedition 345

Since Project MOHOLE in the 1960's, drilling studies of the oceanic crust have had the objective of understanding the processes by which the ocean crust is constructed through magmatism, deformation, metamorphism and hydrothermal cooling. Currently, much attention is focused on understanding the nature and genesis of the relatively inaccessible fast spreading lower ocean crust (Hole 1256D, Hole 894G, this study). Two major end-member models for fast-spreading lower ocean crustal accretion are recognized, the gabbro glacier model (GGM) and the sheeted sill model (SSM). The GGM predicts that most crystallization occurs within a shallow melt lens and the resulting crystal mush subsides downwards and outwards by crystal sliding, followed by largely conductive cooling. The SSM predicts magmatic injection at many levels in the crust, and requires rapid cooling of the lithosphere in order to satisfy physical constraints of heat removal from the lower crust. These two models currently cannot be definitively distinguished given the available observations. What is needed is a test of the two main model predictions against igneous, metamorphic and structural observables from near in-situ lower crust.

This undertaking has followed two main strategies: total crustal penetration (e.g. project MOHOLE) and offset drilling, which involves drilling shallow holes in tectonic windows to produce a composite section Such tectonic windows are common in crust produced at slow spreading rates but are rare at faster spreading rates. Here we report preliminary results of the ongoing Expedition 345 of the International Ocean Drilling Program to the Hess Deep Rift in the Eastern Pacific Ocean. At the Hess Deep Rift, propagation of the Cocos Nazca Ridge (CNR) into young, fast-spreading East Pacific Rise (EPR) crust exposes a dismembered, but nearly complete lower crustal section, with extensive exposures of the plutonic crust. The drilling was carried out in ~4850 m water depth under quite challenging borehole conditions. We recovered primitive (Mg-number 75-89) plutonic lithologies including gabbro, troctolitic gabbro and olivine gabbronorite. These rocks exhibit cumulate textures similar to those found in layered basic intrusions and some ophiolite complexes. Details of their mineralogic and petrologic evolution, however, are novel on the ocean floor. Additionally, they were deformed primarily under magmatic conditions at the EPR. The abundant evidence for hypersolidus plastic deformation in a crystal mush suggests that substantial amounts of the overall deformation occurred under plastic, partially molten conditions. After that, relatively little sub-solidus crystal plastic deformation took place. Metamorphism is dominated by background sub-greenschist facies alteration (including prehnite and chlorite) associated with late stage cataclastic deformation. Widespread amphibolite facies metamorphism that might be indicative of pervasive high-temperature hydrothermal cooling of the lower crust was not observed. Tremolite-chlorite coronas around olivine represent most of the high-temperature metamorphism. These observations raise the question how, exactly, the deformation associated with plate separation is accommodated in the oceanic lower crust.

Keywords: Fast spreading Ridge, Hess Deep, IODP, Oceanic Plate, Lower Crust