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IODP Expedition 345: Primitive Layered Gabbros From Fast-Spreading Lower Oceanic Crust

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Three-quarters of the ocean crust formed at fast-spreading ridges is composed of plutonic rocks whose mineral assemblages, textures and compositions record the history of melt transport and crystallization between the mantle and the seafloor. However, owing to the nearly continuous overlying extrusive upper crust, sampling in situ the lower crust is challenging. Hence, models for understanding the formation of the lower crust are based essentially on geophysical studies and ophiolites. Integrated Ocean Drilling Program (IODP) Expedition 345 recovered the first significant sections of primitive, modally layered gabbroic rocks from the lowermost plutonic crust formed at a fast-spreading ridge, and exposed at the Hess Deep Rift (Gillis et al., Nature, 2014, doi:10.1038/nature12778). Drilling Site U1415 is located along the southern slope of the intrarift ridge. The primary science results were obtained from coring of two ∼110 m deep reentry holes and one 35-m-deep single-bit hole, all co-located within an ∼100-m-wide area.

Olivine gabbro and troctolite are the dominant plutonic rock types recovered, with minor gabbro, clinopyroxene oikocryst-bearing gabbroic rocks, and gabbronorite. All rock types are primitive to moderately evolved, with Mg# 89-76, and exhibit cumulate textures similar to ones found in layered mafic intrusions and some ophiolites. Spectacular modal and grain size layering, prevalent in >50% of the recovered core, confirm a long held paradigm that such rocks are a key constituent of the lowermost ocean crust formed at fast-spreading ridges. Magmatic foliation is largely defined by the shape-preferred orientation of plagioclase. It is moderate to strong in intervals with simple modal layering but weak to absent in troctolitic intervals and typically absent in intervals with heterogeneous textures and/or diffuse banding.

Geochemical analysis of these primitive lower plutonics, in combination with previous geochemical data for shallow-level plutonics, sheeted dikes and lavas, provides the best constrained estimate to date of the bulk composition of crust formed at a fast-spreading ridge. Simple crystallization models using this bulk crustal composition as the parental melt accurately predict the composition of both the lavas and plutonics. However, the recovered plutonic rocks show unanticipated early crystallization of orthopyroxene, challenging current models of melt extraction from the mantle and mid-ocean ridge basalt differentiation.

The core recovered at Site U1415 originated at a stratigraphic level at least 2 km beneath the sheeted dike–plutonic transition, representing intervals of the lower half to one third of the EPR plutonic crust. A more precise depth cannot be assigned as the results of Expedition 345 (e.g., magnetic inclinations) and site survey indicate that the sampled units are tilted, mass-wasted blocks. However, sampling four large blocks of relatively fresh rocks proved facilitated observations of the wide variety and complexity of rock types and textures present in fast spread primitive lowermost crust.