Igneous petrology and geochemistry of basement rocks from IODP Expedition 309

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Ocean Drilling Program (ODP) Hole 1256D in the eastern equatorial Pacific is the first basement borehole prepared with the infrastructure desirable for drilling a moderately deep hole into the oceanic crust (1.5-2 km). ODP Leg 206 drilled 500 m of the uppermost oceanic crust in Hole 1256D, and IODP (Integrated Ocean Drilling Program) Expeditions 309 is the second scientific ocean drilling leg in a multicruise program to drill, for the first time, a complete section of the upper oceanic crust from extrusive lavas, through the dikes, and into the underlying gabbros.

The basement cored during Expedition 309 has been divided into three crustal sections: the sheet and massive flows (533.9-1004.1 mbsf), which continue from Leg 206, a lithologic transition zone (1004.1-1060.9 mbsf), and the sheeted intrusives (1060.9-1255.1 mbsf).

The sheet and massive flows are mainly composed of sheet flows and massive flows. Sheet flows (with individual cooling units ranging from tens of centimeters to less than 3 m thick) make up 80% of the total sheet and massive flows. The sheet flows and massive flows are generally aphyric (less than 1% phenocrysts) and nonvesicular. Where phenocrysts occur, these rocks have plagioclase, clinopyroxene, and olivine phenocrysts, in order of decreasing abundance.

The transition zone is characterized by increasing abundance of volcanic breccias interbedded within sheet flows. The top of this zone is defined by the cataclastic massive unit. This unit has a complex structure with fine- to medium-grained basalt in contact with brecciated clasts of cryptocrystalline basalt. The fine- to medium-grained basalt contains highly altered glass clasts and is disrupted by an intensive network of thin chlorite-smectite veins imparting an incipient cataclastic texture. Another type of breccia is also present in the transition zone. The breccias comprise angular to subangular aphyric cryptocrystalline basaltic clasts (0.5-4.5 cm) and subangular to elongate clasts of altered glass with rare flame-shape clasts (0.1-1.5 cm), cemented by chalcedony, saponite, calcium carbonate, albite, anhydrite, and sulfides.

The upper boundary to the sheeted intrusives is defined by a distinct change from sheet flows to massive basalts. The massive basalts are most commonly aphyric and nonvesicular. Most rocks are microcrystalline and fine-grained basalts, but rare units are cryptocrystalline to microcrystalline basalt. In contrast to shallower zone in Hole 1256D, subvertical intrusive contacts, thought to be dikes, are common, suggesting that the massive basalts of the sheeted intrusives represent the beginning of the sheeted dike complex. In general, two types of contacts can be distinguished: sharp or irregular direct contacts and brecciated contacts. Most contacts belong to the latter category, with brecciated zones one to several centimeters wide along the contact.

Whole rock compositions of the Expedition 309 basements correspond to typical values for mid-ocean ridge basalt (MORB). There are subtle variations in the basalt chemistry downhole, with a number of step changes or reversals of fractionation trends possibly indicating cycles of fractionation, replenishment, and, perhaps, assimilation (e.g., at ~600, 750, 908, and 1125 mbsf). Analyses of cryptocrystalline basalts that are unambiguously dikes are chemically indistinguishable from massive basalts into which these dikes were intruded. There do not appear to be any systematic geochemical differences between sheet flows, massive flows, and dikes.