Formation of lowermost oceanic crust: A microstructural and geochemical study of troctolites from IODP site U1415 (Hess Deep)

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Troctolites were recovered during Integrated Ocean Drilling Program (IODP) Expedition 345 at the Hess Deep Rift, East Pacific Rise. The troctolites are divided into three groups based on textural differences; coarse-grained (1–10 mm in length) troctolite (CGT), fine-grained (~2 mm in length) troctolite (FGT), and skeletal olivine-bearing troctolite (SOBT). All troctolites exhibit magmatic fabric to certain degree. Fine olivine grains with similar orientation notably form clusters (~5 mm in length) in the FGT.

Major-element compositions of olivine, plagioclase and clinopyroxene in CGTs are intermediate between those in gabbroic rocks and peridotites recovered from the Hess Deep Rift. In contrast, FGTs and SOBTs partly overlap with gabbroic rocks in mineral chemistry. Rare-earth element (REE) compositions of olivine in the troctolites show relative enrichments in light REE (LREE) and depletion in heavy REE (HREE) in comparison with troctolites from slow-spread crusts (e.g., Atlantis Massif). LREE/HREE ratios of plagioclase are relatively higher in the FGTs and SOBTs than the CGTs. Clinopyroxene REE patterns are consistent with precipitation after variously evolved LREE depleted MORB-derived melts.

Thermodynamic calculations and numerical modelling using Rayleigh equation for mineral chemistry show that fractional crystallisation of primary MORB melt, interacted with the mantle, was the dominant process for the CGT formation. In contrast, transitional changes in mineral chemistry from the CGTs to FGTs and SOBTs, as well as olivine clusters left in the FGTs, are ascribed to variable degrees of interaction between unsolidified troctolite containing interstitial melts with migrating evolved melts to form FGTs and SOBTs during cooling. The mingled melts were undersaturated in olivine, hence pre-existing olivine grains were dissolved and segregated into fine olivine grains with skeletal habit.