Evidence of accretionary processes at mid-ocean ridges with variable spreading rates based on olivine-hosted melt inclusions

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We present volatile (CO_2, H_2O, F, S, Cl), major, and trace element data from >400 olivine-hosted, naturally glassy, melt inclusions from 5 mid-ocean ridges (East Pacific Rise, EPR; Juan de Fuca Ridge, JdFR; Lucky Strike on Mid-Atlantic Ridge, Southwest Indian Ridge, SWIR; and Gakkel Ridge). We provide geochemical constraints on compositional variations and depths of crystallization beneath ridges of variable spreading rate. We use equilibrium CO_2-H_2O concentrations to determine vapor-saturation pressures, which are converted to depths of crystallization below the seafloor. The range of crystallization depths is similar at all ridges, spanning from the uppermost mantle to the seafloor. However, these distributions vary with spreading rate and correlate with the presence or absence of a shallow melt lens. Crystallization depths indicate a peak in the distribution of crystallization at 1.5–2.5 km on the EPR, 2.5–3.5 km on the JdFR, and 3–4 km on Lucky Strike—consistent with crystallization in or near the shallow melt lenses. By contrast, the distribution of crystallization at the ultraslow-spreading SWIR and Gakkel Ridge is more uniform, extending from ~9 km depth to the seafloor. At the EPR, JdFR and Lucky Strike, >25% of the melt inclusions equilibrated below the melt lens, suggesting significant crystallization occurs in the lower crust. These results are inconsistent with the exclusively shallow depths of crystallization anticipated for purely top-down, gabbro glacier models of crustal accretion and instead, require models in which crystallization occurs throughout the oceanic crust and uppermost mantle. Combining depths of crystallization with melt compositions allows us to examine how melts evolve with depth. Trace element ratios (La/Yb) suggest that melts are homogenized in the uppermost mantle at fast- and intermediate-spreading rates and beneath the large volcanic centers on Gakkel Ridge. However, ratios are much more variable at Lucky Strike and SWIR, suggesting little to no melt homogenization. EPR and JdFR have the least primitive host-olivines (Mg# 82–86), while higher Mg# olivine are erupted at slower spreading rates (Mg# >88). Higher Mg# olivine generally host more variable trace element ratios, suggesting that olivine crystallizing from more primitive melts preserve greater melt diversity.