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Depth of magma differentiation before the Holuhraun eruption, Bárdarbunga (Iceland), constraint by trace element systematics

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Basaltic fissure eruptions occurring several tens of km away from central volcanoes in Iceland are interpreted to reflect either lateral magma migration from a shallow magma chamber beneath the central volcano, or semi-vertical dyke propagation from greater depths under the associated fissure swarm. The spectacular lateral migration of seismicity from 16 to 29 August 2014 and the associated ground deformation has been interpreted to reflect a lateral dyke injection over 45 km, from a shallow magma chamber beneath the Bárdarbunga central volcano to the Holuhraun eruption site.

Basalt magmas, crystallizing at variable depth, should have different trace element composition reflecting the effect of pressure on the crystallizing mineral assemblage, with clinopyroxene (cpx) proportions decreasing with decreasing depth. The parental magma of Bárðarbunga and Holuhraun is likely to have similar composition as primitive olivine tholeiites of the nearby Kistufell table mountain, argued to be close to that of a primary mantle melt (Breddam, 2002). Over two-fold increase in highly incompatible element concentrations in Holuhraun lava relative to Kistufell suggests that approximately 50% fractional crystallization is needed to derive the Holuhraun basaltic melt from the more primitive magma. At low pressure, the crystallizing assemblage will be dominated by olivine (ol) and plagioclase (pl) in the approximate proportions 3/4:1/4 whereas at approximately 15 km depth (0.5 GPa), ol, pl and cpx will crystallize in nearly equal proportions (1/3:1/3:1/3). Shallow fractional crystallization of the primitive olivine tholeiite will generate Ni/Sr in the range 0.016-0.025, whereas deep fractionation will produce a magma with an order of magnitude higher ratio, or 0.34-0.57, due to the enhanced fractionation of cpx relative to ol. A more drastic difference is observed for the Sc/Ni, which principally reflects the change in the cpx to ol proportion in the crystallizing assemblage. At low pressure, Sc/Ni will be in the range 19-31 whereas at higher pressure the ratio of the derived magma will much lower, or in the range 0.57-0.93. The measured Ni/Sr and Sc/Ni in the new Holuhraun are 0.38 and 0.79, respectively, or within the range generated by fractional crystallization at 15 km depth. Both ratios are in sharp contrast to values produced at shallow depth and strongly suggest crystal fractionation at considerable depth with substantial amount of cpx fractionation relative to that of ol and pl. The trace element ratios thus do not concur with the proposition of a shallow magma transfer during the 2014 Bárdarbunga rifting event.

Breddam, K., Kistufell: primitive melt from the Iceland mantle plume. J.Pet. 2002