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Rapid high-silica magma generation in basalt-dominated rift settings

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The processes that drive large-scale silicic magmatism in basalt-dominated provinces have been widely debated for decades, with Iceland being at the centre of this discussion [1-5]. Iceland hosts large accumulations of silicic rocks in a largely basaltic oceanic setting that is considered by some workers to resemble the situation documented for the Hadean [6-7]. We have investigated the time scales and processes of silicic volcanism in the largest complete pulse of Neogene rift-related silicic magmatism preserved in Iceland (>450 km3), which is a potential analogue of initial continent nucleation in early Earth.

Borgarfjörður Eystri in NE-Iceland hosts silicic rocks in excess of 20 vol.%, which exceeds the $\leq$12 vol% usual for Iceland [3,8]. New SIMS zircon ages document that the dominantly explosive silicic pulse was generated within a $\leq$2 Myr window (13.5 $\pm$ 0.2 to 12.2 $\pm$ 03 Ma), and sub-mantle zircon δ18O values (1.2 to 4.5 $\pm$ 0.2‰ n=337) indicate $\leq$33% assimilation of low-δ18O hydrothermally-altered crust (δ18O=0‰, with intense crustal melting at 12.5 Ma, followed by rapid termination of silicic magma production once crustal fertility declined [9]. This silicic outburst was likely caused by extensive rift flank volcanism due to a rift relocation and a flare of the Iceland plume [4,10] that triggered large-scale crustal melting and generated mixed-origin silicic melts. High-silica melt production from a basaltic parent was replicated in a set of new partial melting experiments of regional hydrated basalts, conducted at 800-900°C and 150 MPa, that produced silicic melt pockets up to 77 wt.% SiO_2. Moreover, Ti-in-zircon thermometry from Borgarfjörður Eystri give a zircon crystallisation temperature $\sim$713°C (Ti range from 2.4 to 22.1 ppm, average=7.7 ppm, n=142), which is lower than recorded elsewhere in Iceland [11], but closely overlaps with the zircon crystallisation temperatures documented for Hadean zircon populations [11-13], hinting at crustal recycling as a key process. Our results therefore provide a mechanism and a time-scale for rapid, voluminous silicic magma generation in modern and ancient basalt-dominated rift setting, such as Afar, Taupo, and potentially early Earth. The Neogene plume-related rift flank setting of NE-Iceland may thus constitute a plausible geodynamic and compositional analogue for generating silicic (continental) crust in the subduction–free setting of a young Earth (e.g. $\geq$3 Ga [14]).

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