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Geothermobarometry of the 2010 Eyjafjallajökull eruption

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The Eyjafjallajökull volcano, Iceland, began erupting March 20 2010, following almost 200 years of quiescence. The eruption, which was preceded by 4 months of precursory activity, evolved from an initial phase of effusive activity at the pass of Fimmvörduháls through an explosive phase underneath the Eyjafjallajökull glacier, until the cessation of activity in late May. We have examined mineral and co-existing melt compositions from tephra samples to place preliminary constraints on magma storage depths and crystallization temperatures during the eruption.

An early mildly alkaline basalt with 46 wt% SiO2 was emitted during the initial flank eruption, whereas benmorite to trachyte were produced during the explosive eruption. These latter magmas show pervasive magma mingling between basalts and silicic magma. Phenocryst compositions vary greatly with olivines ranging from Fo82 to Fo46, feldspars vary from An93 to An4, and Mg-number of clinopyroxene range from 76 down to 27. Pressure-temperature (P-T) estimates were computed from the pyroxene + liquid and plagioclase + liquid thermobarometers. To avoid crystal–whole-rock pairs unlikely to yield valid P-T estimates, several data filters were employed. Temperature calculations show that the early basaltic eruptions at Fimmvörduháls have magmatic temperatures of 1170 °C (± 25°C) and a narrow temperature range (< 30°C) at any given depth. In contrast, benmoritic products crystallized at lower temperatures (1020-1060 °C) deduced from the most primitive melt-mineral compositions. Pressure estimates based on clinopyroxene geobarometry yield an average pressure of 5.6 kbar (± 1.5 kbar) for the basaltic tephra and variable but lower pressures for the trachyandesites samples ranging down to 0.6 kbar. The maximum pressure calculated here from the basaltic tephra is consistent with MELTS modelling pointing towards pressures about or lower than 4-5 kbar since olivine is not a liquidus phase at higher pressures.

We propose a model where primitive basalt of deep-origin was injected into the plumbing system of Eyjafjöll volcano during the period December 2009 to 20 March 2010 as indicated by the continuous seismic and GPS monitoring stations. After 3 months halt in migration of the magma at about 12-15 km depth, eruption of primitive basalt magma (∼1160°C) broke out further east at the Fimmvörduháls flank fissure. Three weeks later, the older and partially crystallized basalt remobilized and mingled with a rhyolitic magma body at shallower depth directly beneath the summit crater as observed in the more evolved chemical compositions and lower P-T estimates of the late-stage volcanic products.