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Petrochemistry of the 1998 and 2004 eruptions at Grimsvotn volcano, Iceland and its implications for magma plumbing

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Geochemical investigation of the 1998 and 2004 tephra deposits from Grimsvotn central volcano reveal significant and systematic variations in major and trace element compositions with stratigraphic height. The range in incompatible element concentrations in the 1998 and 2004 products indicate that this compositional variation can be explained by 10-20% fractional crystallisation during residence in the shallow (1-3 km depth) magma storage zone beneath the Grimsvotn volcano. As expected, the 1998 and 2004 products have similar Zr/Nb values (1998, 10.1; 2004, 9.7), indicating a common source. However, they define two distinct trends on a Fe-Ti plot, both intercepting the origin, suggesting independent evolution within the shallow (low-pressure) magma storage zone via fractional crystallization of plagioclase. This result is somewhat surprising considering the small volumes (<0.05 cubic km) of magma erupted, and the short repose interval between these two events. Previous studies of historic Grimsvotn products (e.g. 1983, 1934) give the impression of uniform magma compositions [1,2]. The largest known eruption from the Grimsvotn volcanic system is the 1783-84 AD Laki eruption (15 cubic km), which is characterized by an exceptionally uniform magma composition [3].
Our new results have implications for how we view the magma plumbing system and storage zones beneath Grimsvotn. Firstly, our results imply that the 1998 and 2004 eruptions were fed by physically separate magma pockets residing in the shallow magma storage zone beneath the Grimsvotn volcano. The existence of such a shallow-level storage zone is corroborated by previous geophysical studies [4,5]. Secondly, the observed compositional patterns of Grimsvotn products – variable in small volume eruptions at the central volcano, but uniform in large eruptions out on the fissure swarm – argues against a common magma storage zone for events on these two separate parts of the Grimsvotn volcanic system and, by deduction, refutes the notion that the Laki eruption was fed by lateral flow of magma from a shallow chamber beneath the Grimsvotn volcano.

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