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Tephra leaching and trace element degassing during the 2000 eruption of Hekla volcano (Iceland)

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The Plinian phase of the 2000 Hekla eruption emitted a mixed tephra-gas plume that was condensed and scavenged by snowstorms, offering the unique opportunity to study the geochemistry of the gas phase of highly explosive eruptions. We present data on the contents of trace element and volatile species (SO_4^{2-}, Cl^- and F^-) in snow samples in order to better constrain the degassing and the enrichment of several trace elements in the plume of Hekla. Trace element volatility is quantified by means of enrichment factors (EF) relative to Be. As expected, most of the well-known volatile trace elements (e.g., Cd, Te, Bi, Pb) observed at mafic volcanoes are also enriched in the Hekla's plume and are degassed as halides or sulfates. More surprisingly, refractory elements (e.g., REE, Th) are significantly enriched in the gaseous phase of Hekla. Those enrichments are difficult to reconcile with degassing processes only. The REE patterns normalized to the 2000 lava composition are strongly fractionated and show a significant enrichment of HREE over LREE which can be explained by the presence of REE-fluoride compounds in the volcanic plume. Both thermodynamic data on REE mobility in hydrothermal fluids and modeling of silicate glass dissolution in F-rich aqueous solutions suggest that REE enrichments at Hekla could be linked to the partial dissolution of tephra grains in a F-rich environment. Leaching experiments on the tephra performed at the laboratory confirm this hypothesis. Taken together, REE enrichment and fractionation observed at Hekla are best explained by the

non-stoechiometric partial dissolution of tephra by F-rich volcanic gases. This process occurs within the eruptive plume where fluorides are easily adhered onto solid particles. Such dissolution may also explain the observed enrichments in other refractory elements (e.g., Th, Y and Ba) and could contribute to the degassing mass balance of some volatile trace elements provided that they are mobile in F-rich fluids. It thus appears that both primary magmatic degassing and secondary tephra dissolution processes govern the geochemistry of eruptive plumes released during explosive eruptions.