Geophysical Research Abstracts,
Vol. 10, EGU2008-A-07601, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-07601
EGU General Assembly 2008

The importance of analytical precision in deciphering magma differentiation processes: the case of Hekla volcano, Iceland

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3. Understanding magma differentiation processes is a prerequisite for better evaluation of volcano behaviour and associated risk, quantitative assessment of volcanic gas contribution to the atmosphere etc. It is, however, not always straight forward to distinguish between the different processes causing changes in magma composition, and a few conditions must be met before quantitative assessment of any single differentiation process can be undertaken. For volcanic rock, a well-defined temporal suite of eruption products with few crystals presents the optimal case. Moreover, whole-rock analysis of major- and trace elements are often too imprecise to permit a clear distinction between potential differentiation processes. Isotope ratios are excellent tracers of magma sources and crustal input but only if the crust has a different isotope composition than the incoming magma, which is rarely the case in oceanic environments.

   Hekla volcano erupts almost aphyric rocks and its volcanic history is well established by written records and tephrachronology. This volcano produces silicic to intermediate rocks in zoned Plinian eruptions every 1500 years on average, whereas intra-cyclic volcanics are of intermediate composition strongly correlated with the length of preceding repose time. Only trace element concentration measured by isotope dilution mass spectrometry, with a precision of 0.5% (2σ), and short-lived U-series nuclides allow deciphering the rather complex magma evolution beneath this volcano. Lower (^{230}Th/^{232}Th) and (^{238}U/^{232}Th) in the silicic magmas strongly argues for a crustal origin of dacitic magma that upon fractional crystallization forms the explosive high-silica rhyolites. Crustal melting is induced by the heat released by fractional

crystallisation of mantle derived basalts forming basaltic icelandites, which upon mixing with crustal derived basalts form the icelandites.

Disequilibria between ^{226}Ra and ^{230}Th is observed in all magma types from Hekla constraining the differentiation time to less than 8000 years or so, which is coherent with the volcanic record. The ^{226}Ra-excess varies from 22% in basalts down to 5% in basaltic icelandites but increases to 10% in the dacites. Assuming a negligible D_{Th}, the D_{Ra} is estimated as 0.07 for the evolution from basalts to basaltic icelandites, which can be accounted for by important (40%) fractionation of plagioclase after 62% crystal fractionation. The differentiation time is thus likely to be shorter than 200 years after which radioactive decay of ^{226}Ra becomes significant. Although ^{210}Pb is found in radioactive equilibrium with ^{226}Ra in Hekla products, fast magma differentiation at Hekla is coherent with short magma chamber residence time derived from ^{210}Pb-deficit observed elsewhere.