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Magma storage and transport in the Eyjafjallajökull magmatic system: the message from clinopyroxene megacrysts

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The Eyjafjallajökull volcano is located in southern Iceland, within the Eastern Volcanic Zone, and has a long eruption history dating back about 800,000 years. Magma transport, storage and concomitant geochemical modification might be expected to have changed as the plumbing system evolved with time. Megacrysts entrained in the lavas provide clues about these processes by assessing the depths and temperatures of crystallization, along with their geochemical signatures. We have undertaken a study of clinopyroxene (cpx) megacrysts (1 to 4.5 cm) collected from four units around Eyjafjallajökull that range in age from 20-30 Ta on the northern flank, close to the summit, to southern flank localities near the Katla volcano having ages of 100-300 Ta and ~700 Ta (Loughlin, 1995). The samples were investigated by microprobe, LA-ICP-MS and Mössbauer spectroscopy (Fe^{3+}/Fe_{tot}).

The megacrysts are almost always quite homogeneous, but some contain inclusions of plagioclase, olivine, sulfides or magnetite. The northern flank samples exhibit a Mg# = $\sim$ 0.75 with FeO = $\sim$ 8.3 wt.%, while those from the southern flank are Mg-richer with Mg# = 0.82-0.87 (oldest unit) (FeO $\sim$ 5 wt. %) and 0.85-0.90 (younger unit) (FeO $\sim$ 4.3 wt. %). Samples with the highest Mg# numbers are from the basal horizon of an ankaramite flow. Megacrysts from this most primitive unit also have much lower Fe^{3+}/Fe_{tot} = 0.13 compared to 0.25 (south) and 0.20-0.32 (north). Al contents vary from sample to sample and between localities.

Trace element concentrations reveal the same trends. Chondrite-normalized REE patterns show the typical shape for mantle-derived basalt, with the youngest samples from the north being the most enriched. Samples from the ankaramite display the least enrichment and have flatter patterns.

Preliminary thermobarometry following Putirka (2008) indicates little difference in crystallization temperature for a given locality: northern flank = 1135 $\pm$ 30°, oldest southern flank = 1150 $\pm$ 20°C, and 1175 $\pm$ 20°C for the samples from the ankaramite. Calculated crystallization pressures are lowest for the megacrysts in the ankaramite ($<$1 to 2 kb). The oldest locality in the south exhibits more grain-to-grain variation, yielding pressures from $<$1 to 4 kb. In the north, crystallization pressures of 2-4 kb are common, with several megacrysts recording slightly higher pressures and temperatures (5-6 kb and 1170°C).

These results indicate that the ankaramite magma rose rapidly to shallow depths before crystallization began. Megacrysts from the oldest unit reveal somewhat lower crystallization temperatures, which may explain the greater depth range at which cpx formed. The more evolved lavas exposed on the northern flank are from magma batches that stalled at various depths between 18 and 6 km long enough for cpx megacrysts to crystallize. The rarity of observed near-surface crystallization pressures at this locality indicates that eruption was driven by a final rapid magma ascent from ~6 km.

(1) Loughlin, S.A. (1995) PhD. thesis Univ. Durham, pp 337.

(2) Putirka, K.D. (2008) Rev. Mineral. Geochem., 69, 61-120.