Experimental constraints on the evolution of alkaline magmas from Ross Island, Antarctica: A case for CO_2-dominated volcanism

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Background and Experimental

Erebus volcano on Ross Island, Antarctica is home to the only phonolite lava lake in the world and, in combination with the continuous suite of alkaline lavas found in outcrop, provides an excellent natural laboratory for studying the genesis and evolution of alkaline magmas at a rift setting. Two geochemical lineages make up the majority of lavas erupted from Erebus and the surrounding basaltic volcanic centers at Hut Point Peninsula and Mts. Bird and Terror: The Erebus Lineage (EL) lavas and the Dry Valley Drilling Project (DVDP) lavas taken from drill core [1]. The occurence of kaersutite phenocrysts in DVDP lavas, attributed to a higher f_{H2O} and lower temperatures, is the key mineralogical distinction between these two lineages. Modelling suggests that both lineages evolved through fractional crystallization from parental basanite melt [2].

High pressure and temperature experiments (2−4 kbars; 1000−1150 °C) with added H_2O and CO_2 (X_{H2O} varying between 0−1) were performed with primitive members from both EL and DVDP lavas to investigate the evolution of these magmas.

Results and Conclusions

Preliminary results show that only very CO_2-rich conditions (X_{H2O} approaching 0) reproduce the mineralogy of natural samples, even for kaersutite-bearing assemblages. This is consistent both with measurements of gas emissions and melt inclusion data. Kaersutite, which only occurs in DVDP lavas, is the liquidus phase in experiments carried out with EL samples, even when no water was added to the experimental capsule (some H_2O is present, however, even in “dry” runs from the reduction of Fe_2O_3 in the melt). This indicates that: a) DVDP and EL lavas are likely sourced from the same parent magma – that is, the differences in mineralogy and geochemistry between DVDP and EL lavas is caused by slight variations in differentiation and eruption conditions, and b) assuming that f_{H2O} controls the presence or lack of kaersutite, only a very small amount (<1 wt%) of H_2O is needed to stabilize the phase, making it a very precise threshold indicator of dissolved H_2O contents in Ross Island melts. In contrast, the occurrence of amphibole in calc-alkaline magmas is typically indicative of at least 4 wt% dissolved H_2O.

Previous work has made the case for deep CO_2-fluxing at Erebus to explain CO_2-rich gas emissions and the induction of crystallization in the magmatic system [2]. Further work aims to determine whether CO_2-fluxing is necessary to achieve the gas composition at Erebus and, ultimately, to determine the deep source of the carbon feeding the volcano.

[1] Kyle (1981) *J. Pet.* **22** 451-500 [2] Kyle *et al.* (1992) *J. Pet.* **33** 849-875. [3] Oppenheimer *et al.* (2011) *EPSL* **306** 261-271.

Late Cretaceous migmatites in the southern Mojave Desert and their contribution to gabbro genesis and magmatic diversity

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Within the tilted crustal section found at Joshua Tree National Park in the southern Mojave Desert of California, we observe a >100 km long "heterogeneous sheeted complex" composed of meter-thick, tabular, intrusive igneous sheets that were intruded into Proterozoic gneisses that were locally partially molten. The sheeted complex contains a wide range of composition and texture, but is primarily composed of tonalites and two-mica garnet granites. We are testing the hypothesis that the genesis of this sheeted complex is likely intricately connected to the partial melting by a mantle-derived heat source of a heterogeneous package of Proterozoic host rocks.

In this study, we focus on the subset of hornblende gabbros present to better trace migmatization and crystal segregation processes. We have analyzed samples for bulk rock and single mineral chemistry, Sr and Nd isotopes, and U-Pb zircon ages to complement geologic mapping and microscopy for these hornblende gabbros. Samples contain hornblende + plagioclase ± clinopyroxene or biotite ± quartz, are medium to coarse-grained, and are equigranular to porphyritic in texture (hornblendes range up to 3 cm in length in hand sample). Samples range in melt fraction and amount of host rock present, and some sheets and pods observed have a cumulate texture and predominance of hornblende suggestive of fractional crystallization. Later greenschist-facies metamorphism overprints many of the gabbros observed. Crystallization ages are 74-78 Ma (U-Pb in zircon), although all samples have inherited zircon cores of ~1700 Ma. Two diatexites have been measured at 0.707 to 0.709 Sr_I, -12.4 to -13.6 εNd.

The hornblende gabbros of Joshua Tree National Park are primarily formed by a combination of partial melting of metamafic rocks and mantle-sourced magmatism. In some cases, this is followed by a period of fractional crystallization to form hornblende cumulates. Leucosomes derived from partial melting of metamafic rocks or melt extracted from these hornblende gabbro magmas are plagioclase-dominated and leucotonalitic to leucodioritic. As leucosomes and neosomes from metamafic protoliths rise and mix with those from metafelsic/quartzofeldspathic protoliths and mantle-sourced magmas, a continuum of melt compositions between tonalite and peraluminous granite is formed. Evidence of mixing exists down to the thin section scale and may explain the formation of biotite in some samples of otherwise K-deficient hornblende gabbro diatexites. These mixing and fractionation processes occur in igneous compositions beyond the gabbros and can also explain the textural diversity of magmas observed in the heterogeneous sheeted complex.