

Melt inclusions in olivine from New Caledonia boninites: initial melts and post-entrapment oxidation effects

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Boninites are Mg-rich high-Si volcanics enriched in water and strongly depleted in other incompatible components. Their magmas are believed to be derived by melting of depleted mantle rocks under the influence of water fluids produced by dehydration of subducted materials.

Melt inclusions were investigated in olivine phenocrysts ($mg = 0.89 - 0.92$, NiO up to 0.4 mass% and CaO < 0.2 mass%) from boninite dikes in New Caledonia (samples were provided by D. Ohnenstetter). The main distinctive features of these rocks are low CaO and very high Na₂O contents.

The inclusions contain glass, gas, and daughter orthopyroxene (Fig. 1) with high CaO (up to 2.7 mass%) and Al₂O₃ (up to 3.7 mass%). Daughter olivine always occurs on the inclusion walls, which is indicated by up to 17% increase in inclusion volume during heating up to 1250–1370 °C.

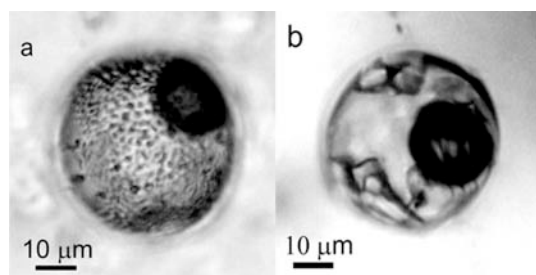


Fig. 1. Photomicrographs of melt inclusions.

In order to eliminate effects related to olivine-groundmass interaction, monomineralic olivine grains were separated for heating experiments. Crystalline phases within the inclusions were dissolved at 1200–1250 °C. Complete homogenization was never attained, because the vapour bubble remained undissolved up to 1370 °C. Two (vapour and liquid) phases were observed in the fluid phase of some melt inclusions. The liquid was frozen at –52 °C, and the beginning of melting was detected between

–22.2 and –20.3 °C, i.e. near the eutectic of the H₂O–NaCl system. The ice melting temperature was close to 0°C, indicating low solute content.

The major and trace element compositions of reheated melt inclusions were determined using electron and ion microprobe analysis. The melts contain 56–63 mass% SiO₂, up to 16 mass% MgO, and 2.6–5.0 mass% Na₂O + K₂O at a molar Na₂O/K₂O of up to 11. The melts show low Nb, Ti, and Th contents and are enriched in Sr, Zr, Hf, and LREE relative to HREE (La_N/Sm_N 2–3 and Sm_N/Yb_N 1.4–2.0). SIMS analysis indicated no more than 1.4 mass% H₂O in heated melt inclusions. Residual glasses from unheated melt inclusions contain up to 3.5 mass% H₂O. The H₂O content of fresh groundmass glasses is much higher and may reach 8.7 mass%.

Electron microprobe analysis revealed an increase in the *Mg* of olivine directly near the glass–host olivine interface (Fig. 2). Such variations in olivine composition are in apparent conflict with the observed olivine crystallization on the walls of inclusions, which usually results in a gradual increase in the fayalite mole fraction of olivine in contact with the residual melt. We believe that this peculiar effect is related to the diffusion migration of H₂ outside the inclusions, which results in Fe oxidation in the melt via the reaction $2\text{FeO} + \text{H}_2\text{O} = \text{Fe}_2\text{O}_3 + \text{H}_2$. The loss of only 0.1 mass% H₂O will result in the oxidation of 0.8 mass% FeO to Fe₂O₃ and, correspondingly, an increase in the *Mg* of equilibrium olivine. Assuming that $K_d = (\text{Fe}/\text{Mg})^{\text{Ol}} : (\text{Fe}^{2+}/\text{Mg})^{\text{Gl}}$ remains constant, the effect of oxidation of 0.8 mass% FeO in boninite melt can be counterbalanced by the fractionation of 7 mass% olivine (i.e. the composition of crystallizing olivine will remain constant). At higher rates of H₂ escape and melt oxidation, the *Mg* of olivine will increase during crystallization.

The composition of melt trapped during olivine crystallization was estimated by modelling simultaneous fractional crystallization and FeO oxidation providing the observed variations in olivine composition at $K_d = 0.3$. These exercises showed that the initial trapped melts contained 0.5–1.0 mass% less MgO compared with estimates based on the fractionation model ignoring the effect of Fe oxidation.

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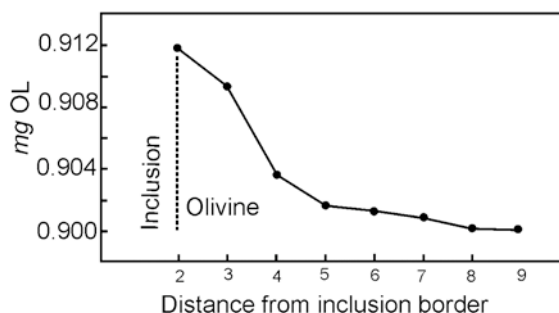


Fig. 2. Increase in the mg of olivine directly near the glass–host olivine interface. Distance from point 2 to point 9 is 20 μm .

Most of the estimated melt compositions show moderate MgO contents of 8–12 mass%. One melt inclusion showed MgO ~ 16 mass% and the highest FeO content of 10.2 mass%. This inclusion falls on the same trends as the other compositions with significantly lower MgO contents. Intriguingly, there is no correlation between MgO content in melt and the *mg* of host olivine, which suggests that MgO and FeO variations in the melts are not controlled by olivine fractionation and could be related to different degrees and depths of melting. This is supported by the analysis of correlations between other elements. The major- and trace-element characteristics of the boninite melts are similar to those of low-Ca boninites from the slope of the Marianna trench. Noteworthy is the relatively high Na_2O content in the New Caledonia magmas, which is not typical of low-Ca boninites from other regions (usually <2 mass%). The obtained melt inclusion evidence indicates that the enrichment in Na_2O is a specific feature of primary melts rather than the result of secondary alterations.

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