

Online Resource 6: Melt Inclusion Post-Entrapment Modification Corrections

Olivine-Hosted Melt Inclusions

Most $K_d(\text{Fe-Mg})^{\text{ol-liq}}$ values for melt-inclusion/olivine host pairs from TAN1213-45-3 are lower than the expected equilibrium range of 0.3 ± 0.03 (Roeder and Emslie, 1970), reflecting varying degrees of post-entrapment crystallization (PEC; Fig. OR6.1). In addition, FeO^* contents are scattered with respect to K_d values (Fig. OR6.1b), implying that Fe loss has occurred (Danyushevsky et al., 2000; Rowe et al., 2011).

Measured melt inclusion compositions were corrected for PEC and Fe loss using the “Olivine MI” algorithm in Petrolog 4 (Danyushevsky and Plechov, 2011). The correction for Fe loss requires the user to enter an original melt FeO^* content, based on independent knowledge of the likely Fe contents of the melt at the time of entrapment. Given that only two mafic samples have been recovered from the vicinity of Brothers (Brothers West Ridge basalt and Brothers Northeast Ridge basaltic andesite), knowledge of the Fe contents of primitive Brothers melts and their liquid line(s) of descent is limited. Both whole-rock and matrix glass/glass embayments from these two mafic samples show relatively flat FeO^* contents with increasing SiO_2 (Fig. OR6.2). Here, we correct to the average FeO^* value of two Brothers West Ridge basalt whole-rock analyses by Brandl et al. (2023: $\text{FeO}^* = 9.29 \text{ wt\%}$), which we suggest provides a reasonable estimate for the likely initial FeO^* contents at the time of entrapment.

Calculations were performed using the olivine-melt model of Ford et al. (1983), assuming $f\text{O}_2 = \text{QFM} + 1.5 \log \text{ units}$. Olivine-melt partition coefficients from the model of Beattie et al. (1991) were applied for Ni and Co, and a value of 1.3 was assumed for Zn based on the midpoint of the range of values in the GERM partition coefficient database (<https://earthref.org/KDD-old/>). Allowing for the full range of values in the GERM database for Zn equates to a <5% relative shift in corrected Zn values relative to the case where $D = 1.3$. We also tested D values for weakly incompatible elements Sc, V and Cu from the GERM database, but found relative deviations from the case where $D = 0$ were comparable to measurement uncertainties (<5% relative). Hence, D values for these and other trace elements were set to zero.

Volatiles (H_2O , CO_2 , S, Cl and F) were adjusted via a correction factor, assuming perfectly incompatible behaviour. For the one basaltic inclusion where SIMS volatile data were collected but the major element composition was not measured by EPMA (TAN1213-45-3-B-a), the median correction factor (0.92) from all other inclusions was used to correct the volatile data for PEC.

Calculations were also performed using different $f\text{O}_2$ values and initial FeO^* contents to test the sensitivity of the results to uncertainties in these parameters. An uncertainty of $\pm 0.5 \log \text{ units}$ in $f\text{O}_2$ equates to a <6% relative difference in corrected MgO, Co and Ni contents, and <2% relative (often <1%) for all other elements including volatiles. An uncertainty of $\pm 0.5 \text{ wt\%}$ in initial FeO^* content equates to a difference of <6% relative for corrected MgO contents, <11% relative for Co, <17% relative for Ni, and <3% relative for all other elements (e.g., Fig. OR6.3).

Plagioclase-Hosted Melt Inclusions

Applying Putirka's (2008) equilibrium $K_d(\text{An-Ab})_{\text{plag-liq}}$ value of 0.1 ± 0.05 (for $T < 1050 \text{ }^\circ\text{C}$) suggests that essentially all uncorrected melt inclusion/host pairs have compositions that are plausibly in equilibrium (Fig. OR6.4a). Because K_d values are sensitive to several variables including P, T and melt H_2O content, we also compare our inclusion/host pairs with a compilation of equilibrium plagioclase and hydrous melt pairs compiled from experimental datasets by Waters and Lange (2015). Our data

neatly overlap with the plagioclase An vs melt An# field from their database (Fig. OR6.4b), again suggesting equilibrium between melt inclusion-host pairs.

Most plagioclase-hosted melt inclusions from Brothers dacites plot part way along a continuous compositional trend defined by andesitic-dacitic glass embayments in olivine from the Brothers Northeast Ridge (Brandl et al., 2023) and the matrix glass and whole rock compositions from the main Brothers edifice (Fig. OR6.5), which we interpret as representing a liquid line of descent. The fact that most melt inclusions plot along this trend suggests that they have experienced little to no post-entrapment crystallisation.

Given the above evidence for equilibrium and the apparent adherence of melt inclusion compositions to an inferred representative liquid line of descent for evolved Brothers magmas, we infer that the plagioclase-hosted melt inclusions have experienced little to no PEC and opt to present the data as measured.

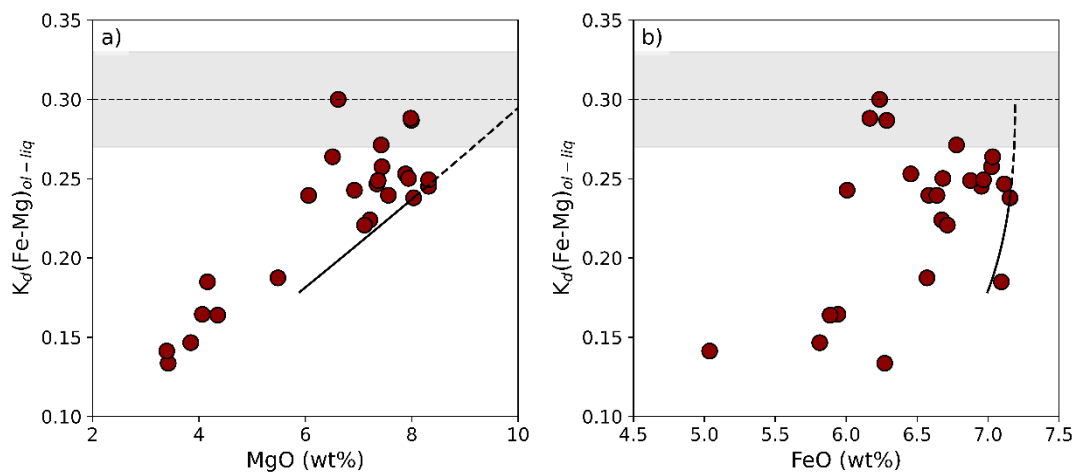


Figure OR6.1. Calculated Fe–Mg distribution coefficients (K_d) for uncorrected olivine-hosted melt inclusions and host olivine, plotted against measured melt-inclusion a) MgO and b) FeO contents (normalised volatile-free, with FeO calculated assuming $\text{Fe}^{3+}/\text{Fe}^{\text{tot}} = 0.2$). Dashed horizontal line with grey band represents the equilibrium K_d value of 0.3 ± 0.03 from Roeder and Emslie (1970). Dashed and solid lines show 5% addition and subtraction, respectively, of equilibrium olivine (assuming $K_d = 0.3$) for a representative melt inclusion (TAN1213-45-3-A-a). All calculations assumed melt $\text{Fe}^{3+}/\text{Fe}^{\text{tot}} = 0.2$. Note that FeO values are highly scattered with respect to K_d values and do not show the steep positive correlation predicted by the crystallization model, reflecting Fe loss.

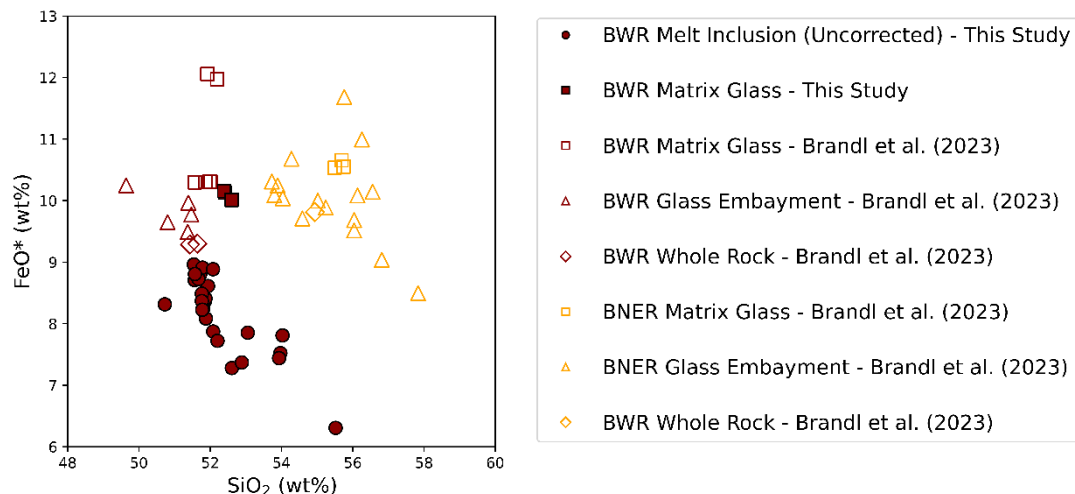


Figure OR6.2. FeO^* vs SiO_2 (all values normalised volatile-free) for Brothers West Ridge (BWR) basalt and Brothers Northeast Ridge (BNER) basaltic andesite. Uncorrected melt inclusion data and some BWR matrix glass data are from this study; all other data are from Brandl et al. (2023). Note the low FeO^* contents of the uncorrected melt inclusions and the relatively flat FeO^* contents with increasing SiO_2 for the whole rock and matrix glass/glass embayments.

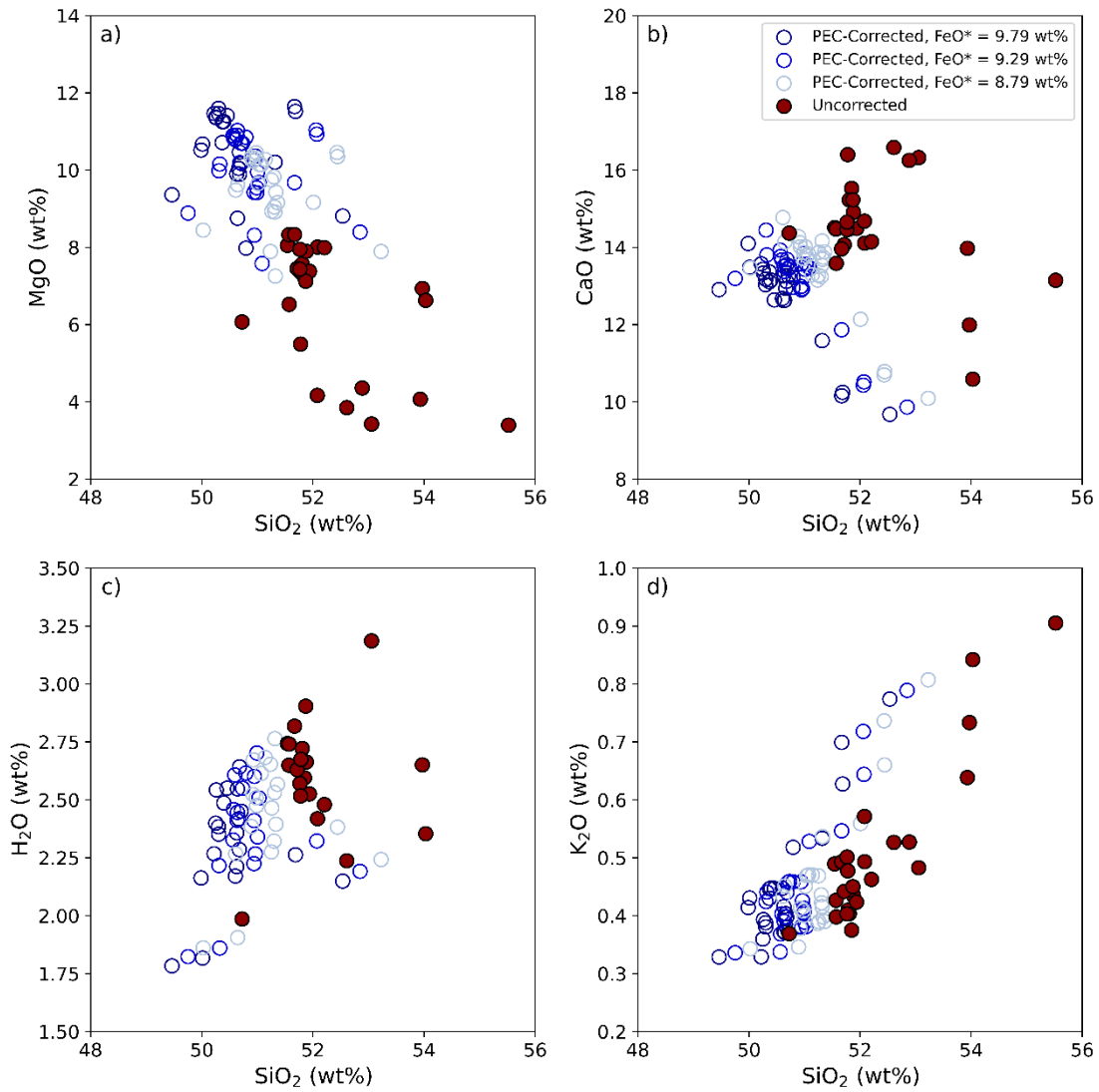


Figure OR6.3. Plots for selected elements vs SiO_2 (major elements normalised volatile-free), showing influence of assumed initial melt FeO^* contents on final PEC-corrected olivine-hosted melt inclusion compositions (corrections applied with Petrolog 4, assuming $f\text{O}_2 = \text{QFM} + 1.5$). A generous uncertainty of ± 0.5 wt% in the initial FeO^* content translates to relatively minor differences in the PEC-corrected concentrations for most elements.

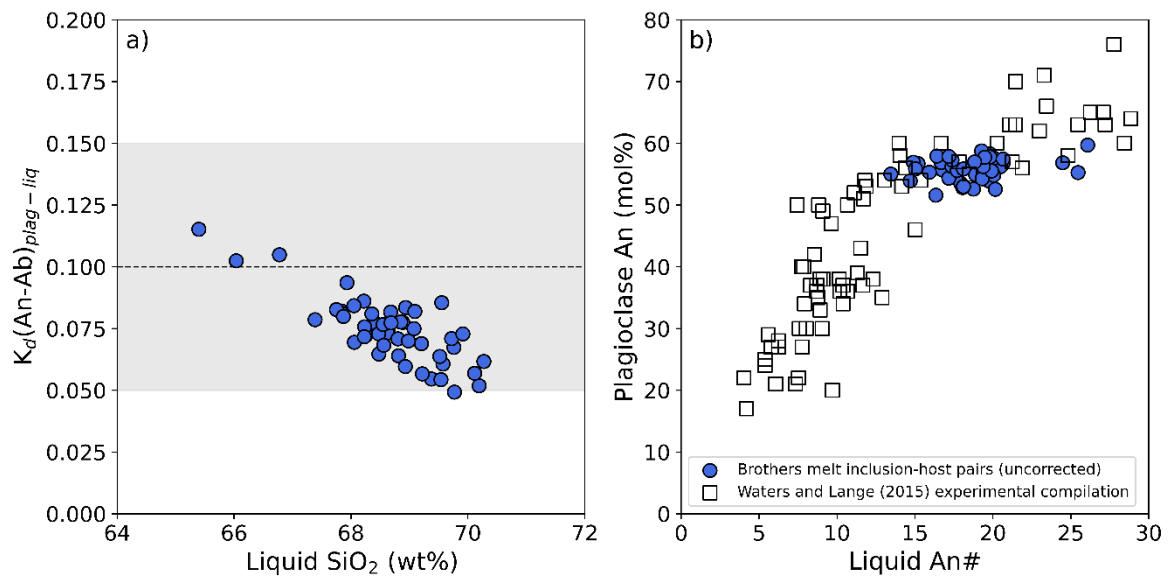


Figure OR6.4. Plots showing equilibrium tests for uncorrected melt inclusion/plagioclase host pairs. a) $K_d(\text{An-Ab})_{\text{plag-liq}}$ vs. melt inclusion SiO_2 content (normalised volatile-free). Dashed line with grey band shows suggested equilibrium K_d value of 0.1 ± 0.05 from Putirka (2008) for $T < 1050$ °C. b) Plagioclase An content vs. liquid An# (calculated after Waters and Lange, 2015). Overlap of our data with equilibrium pairs from the Waters and Lange (2015) experimental compilation for equilibrium plagioclase and hydrous melt pairs suggests equilibrium between inclusions and hosts.

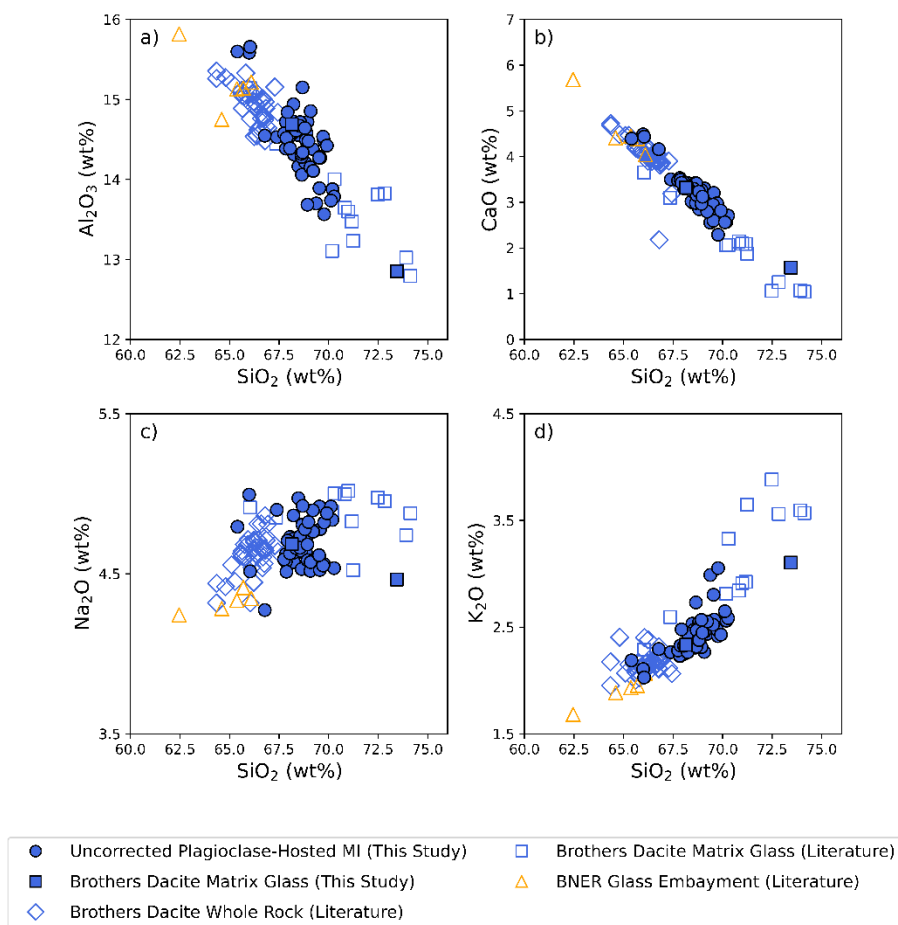


Figure OR6.5. Selected major elements vs. SiO_2 for intermediate to silicic Brothers glass and whole-rock compositions (all values normalised volatile-free with total iron expressed as FeO). Brothers Northeast Ridge (BNER) pyroxene-hosted glass embayment data are from Brandl et al. (2023). Dacite whole-rock data are from Wright and Gamble (1999), Timm et al. (2012), Brandl et al. (2023) and Georgatou et al. (2024). Literature matrix glass data are from Brandl et al. (2023), and Georgatou et al. (2024; including only analyses with totals >96 wt%). Uncorrected plagioclase-hosted melt inclusion data from this study plot along a continuous trend between andesitic glasses from BNER and rhyolitic matrix glasses in the Brothers dacites, which we infer to represent a liquid line of descent.

References

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