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**SUPPLEMENTAL MATERIAL**

**Origin of alkali olivine basalts and hawaiites in the western Mexican arc: evidence of rapid phenocryst growth and magma mixing during ascent along fractures**

**by Mesa and Lange**

**INTRODUCTION**

The Supplemental Material is included to support the results and discussion in the paper. This file is divided in three parts. Part 1 is a list of all captions for Supplemental File Figures. Figures can be found in a separate PDF file without captions. Part 2 is a list of all headers for Supplemental File Tables. Tables can be found in separate Excel files containing all measured and calculated data for this study. Part 3 provides further detail to the reader on plagioclase phenocrysts analyzed in this study, and the application of the plagioclase-liquid thermometer to the hawaiites. There is a Reference section at the end this text file, with all references cited within this document, the supplemental figures and supplemental tables.

**SUPPLEMENTAL FILES**

**Part 1. Captions for Supplemental File Figures** (separate PDF file without captions)

**Figure S1.** NiO (wt%) versus Fo (mol%) is plotted for all olivine analyses in each Sangangüey sample. Data are fitted using a linear regression (red line) for the top 3 mol% Fo of each sample. Each linear regression was used to calculate the NiO (wt%) for the most Mg-rich olivine in each sample in order to minimize analytical uncertainty. Most Mg-rich olivine and calculated NiO are shown in each plot. Note the change of scale in the x-axis.

**Figure S2.** CaO (wt%) in olivine versus Fo (mol%) is plotted for all olivine crystals analyzed in each Sangangüey alkali samples. Data are fitted using a linear regression (red line) for the top 3 mol% Fo of each sample. CaO content in olivine mantle xenocrysts based on previous studies (Heinrich and Besch, 1992; Luhr and Aranda-Gómez, 1997; Housh et al., 2010) is consistently lower (dashed brown line) than CaO content in olivine from Sangangüey basalts. Only three crystals (open grey diamonds) from the Sangangüey alkali suite plot below the brown dashed line. Note the change of scale in the x-axis.

**Figure S3.** MnO (wt%) versus Fo (mol%) is plotted for all olivine analyses in each Sangangüey sample. Data are fitted using a linear regression (red line) for the top 3 mol% Fo of each sample. Each linear regression was used to calculate the MnO (wt%) for the most Mg-rich olivine in each sample in order to minimize analytical uncertainty. Most Mg-rich olivine and calculated MnO are shown in each plot. Note the change of scale in the x-axis.

**Figure S4.** CaO (wt%) versus Fo (mol%) plot of all individual analyses of Sangangüey alkali basalts, hawaiites and mugearites (grey open circles for phenocrysts, and grey open diamonds for possible inherited mantle xenocrysts). Previous analyses of olivine crystals from Mexican mantle xenoliths (brown diamonds; Heinrich and Besch, 1992; Luhr and Aranda-Gómez, 1997; Housh et al., 2010) are plotted for comparison. CaO content in olivine mantle xenocrysts (<0.12 wt% CaO) is consistently lower than CaO content in olivine from Sangangüey basalts.

**Figure S5.** Histograms of anorthite (An, mol%) content of plagioclase crystals of (A–B) two Sangangüey alkali basalts, (C–L) ten hawaiites and (M) one mugearite. Whole-rock (liq) An#, content and number of analyses (*n*) are given for each sample. Grey shading highlights plagioclase composition (~An60-75) of peak abundance (n>20; grey dashed line) in several, but not all samples. This composition may represent plagioclase growth after magma mixing (see text). Some samples additionally contain a more calcic population (>An75; A, B, E, F, H) and some contain a sparse, sodic population (≤An50; most notably J–L)

**Figure S6.** Backscattered electron (BSE) images of plagioclase crystals from five representative samples. (A–B) Weakly zoned plagioclase (~An65-70) with diffusion-limited growth textures, (C) calcic plagioclase (~An71-80) with diffusion-limited growth texture, (D-E) rounded sodic core (An41 and An46) with rapid-growth rims of ~An60-65, and (F) calcic core (An75-80) with thin, less calcic rim.

**Figure S7.** Anorthite (mol% An) content in plagioclase versus whole-rock An-number of Sangangüey whole-rock samples. Hydrous (open circles) and anhydrous (solid grey diamonds) phase-equilibrium experimental results used for the calibration of the plagioclase-liquid hygrometer/thermometer of Waters and Lange (2015) are shown in this diagram. The peak population in each sample (gray shaded area in Figure S5) is shown as solid line (>5 wt% MgO, red; <5 wt% purple). The dashed line shows the sparse plagioclase population that is more calcic and/or more sodic in each sample. The compositions of the peak plagioclase population in the Sangangüey samples overlap those of the anhydrous experiments, which is consistent with relatively low melt water contents (≤ 1 wt%) in these intraplate magmas.

**Figure S8.** Histogram of MgO (wt%) content in titanomagnetite and ilmenite phases of samples (A–B) XAL 110 and (C–D) XAL126. The average of the most MgO-rich crystals that passed the Bacon and Hirschmann (1988) Mg/Mn equilibrium test were applied to determine temperatures and oxidation state at the onset of their co-crystallization using the Fe-Ti two-oxide thermometer and oxybarometer of Ghiorso and Evans (2008). Note the change of scale on the x-axis.

**Part 2. Supplemental file Tables** (separate Excel files)

**Table S1.** Trace element composition of Sangangüey intraplate alkali basalts, hawaiites and mugearites

**Table S2.** Measured FeO (wt%) from titrations following the Wilson (1960) method

**Table S3.** List of standards used for electron microprobe analyses of olivine, plagioclase and Fe-Ti oxides

**Table S4.** Trace element composition of TVF arc basalts

**Table S5**. Composition of individual analyses of olivine per sample

**Table S6.** Composition of individual spinel crystals analyzed in sample XAL 118A

**Table S7.** Composition of individual plagioclase analyses per sample

**Table S8.** Plagioclase peak population An content and calculated temperature of Sangangüey hawaiites

**Table S9.** Composition of individual Fe-Ti oxide analyses in samples XAL110 and XAL 126

**Table S10.** Calculated TNi of Sangangüey hawaiites using the olivine-melt thermometer by Pu et al. (2017)

**Part 3.** **Supplemental File on Plagioclase in Sangangüey basalts**

Individual analyses of plagioclase in each Sangangüey basalt are reported in Table S7. The results are summarized in histograms of composition (mol% An) for each sample in Fig. S5. In most samples, the most frequent plagioclase composition ranges from ~An60-75. In several samples there is an additional population that is more calcic (≥An75), and/or another that is more sodic (~An40).

In five representative SB samples, examples of the most calcic and most sodic plagioclase crystals (both sparsely present), as well as the most compositionally abundant, are shown as BSE images (Fig. S6). In all cases, sodic plagioclase occurs as a rounded core surrounded by a thin, more calcic rim (<100 microns) that matches the most abundant plagioclase composition (~An60-75). The sparse calcic plagioclase crystals (≥An75) in each sample occur either with a thin, less calcic rim (<150 microns), which again matches the most abundant plagioclase composition (~An60-75), or with no rim at all. The compositionally most abundant plagioclase crystals in most samples (~An60-75) display either euhedral, faceted edges and/or diffusion-limited textures (Fig. S6).

**Plagioclase-liquid thermometry applied to hawaiite samples**

A notable feature of most of the hawaiite samples is a common composition for the most abundant plagioclase population (Fig. S5). When the peak plagioclase composition (shaded region in Fig. S5) in each sample is plotted as a function of the respective whole-rock An#, the analyses mostly overlap the compositional range of anhydrous plagioclase-liquid equilibrium experiments from the literature (Fig. S7) used to calibrate the plagioclase-liquid hygrometer/thermometer of Waters and Lange (2015). This result is consistent with other evidence for relatively low water contents in these intraplate magmas, and also supports the hypothesis that the peak plagioclase composition grew after mixing.

A broad constraint on the temperature of peak plagioclase crystallization in the hawaiite samples can be made if an average melt water content is assumed (based on results of olivine-melt hygrometry above). Note that application of the plagioclase-liquid thermometer is most sensitive to melt water contents and that melt and mineral compositional variations have a more muted effect. The results lead to an average (±1) temperature of ~1156 and ~1121 (±20) °C for peak plagioclase growth in the hawaiite magmas with ~0.5 and ~1.0 wt% H2O, respectively (Table S8). These temperatures are slightly lower than those (~1240 and ~1190°C) calculated for the onset of olivine growth in the two high-MgO basalts, which is expected and thus internally consistent.

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