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Supplemental material:

Differentiation of an upper crustal magma reservoir via crystal-melt separation recorded in the San Gabriel pluton (central Chile)

Payacán, I.; Gutiérrez, F.; Bachmann, O.; Parada, M. Á.

DESCRIPTION OF MAFIC ENCLAVES

Mafic enclaves have sharp to rounded borders, containing plagioclase, mostly as phenocrysts, and hornblende + biotite as mafic minerals (Fig. 5B, 5C and 5D). The mafic enclaves are generally up to ~10 cm in diameter, with medium to coarse grain size. The similarity between the mafic enclaves' plagioclase phenocrysts and the intermediate-silicic host rock suggests the phenocrysts were transferred to the enclaves from the host magma, evoking magma mingling between contrasting magmas (Fig. 5D). A group composed of aphanitic to fine-porphyritic blocks of mafic xenoliths is distinguished, though, containing plagioclase and biotite and Fe-Ti oxides, and exhibiting a reddish color (Fig. 5F). They vary in size from ~10 cm up to a few meters and thin veins of leucocratic material are included within the enclaves.

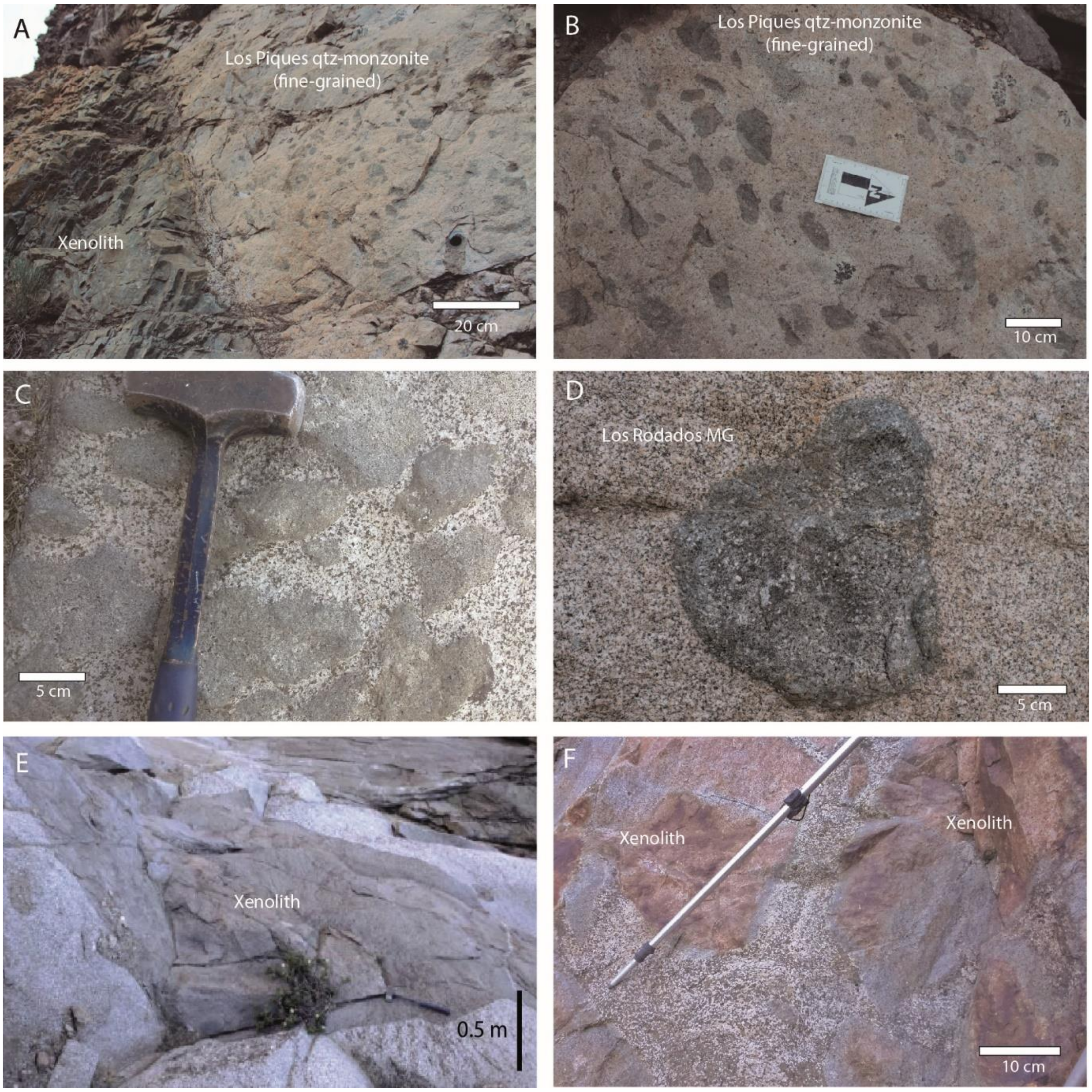

Figure S1: Photos of mafic enclaves and xenoliths preserved in the San Gabriel pluton. (A) Mafic xenolith characterized by aphanitic texture with oxidation zones, surrounded by microcrystalline mafic enclaves of centimetric scale, which are observed in the western pluton border. (B) Close-up view of the mafic enclaves shown in (A), which exhibit an elongated shape and preferrednortheasterly orientation, parallel to the border of the San Gabriel pluton (the scale indicates the north direction). (C) Mafic enclaves concentrated in the Los Espolones quartz-monzodiorite in the middle levels of the pluton. (D) Rounded-shape mafic enclave located in the Los Rodados monzogranite, containing numerous plagioclase phenocrysts (probably coming from the host intrusive rock), suggesting magma mingling. (E-F) Xenoliths observed in the middle levels of the San Gabriel pluton.

WHOLE-ROCK MAJOR AND TRACE ELEMENT RESULTS

Whole-rock major element concentrations, which were obtained via XRF measurements of glass-fused pills, are presented in the Table DR1 (attached as supplementary material). Whole-rock trace element concentrations are presented in the Table DR2 (attached as supplementary material), which were measured via LA-ICP-MS measurements of glass-fused pills. The mean of the three measurements is presented for each trace element. Details of the analytical method are described in the main text.

LA-ICP-MS RESULTS FOR U-Pb DATING

The mean U-Pb data on zircon for samples from the San Gabriel pluton are presented in the Table S3. The data were obtained via LA-ICP-MS measurements whose analytical parameters are detailed in the main text. The Table DR4, attached as supplementary material, presents the individual spot measurements obtained via LA-ICP-MS on zircon crystals. Both the isotope ratios, U-Pb dates and zircon composition data (concentration in ppm, 2σ error in ppm and the limit of detection in ppm for each element) are included. Detailed parameters of the analytical setup and results for sample measurements are reported following community-derived guidelines of Horstwood et al. (2016). Data were not corrected for common-Pb. Uncertainties were quoted without systematic error.

The concordia plots were constructed by using Isoplot 4.15 (Ludwig, 2008), both for the totality of the analyzed samples of the San Gabriel pluton (Figure DR2a), and the three magmatic units (Figure S2b, c and d). 2σ error was considered for ellipses calculation.

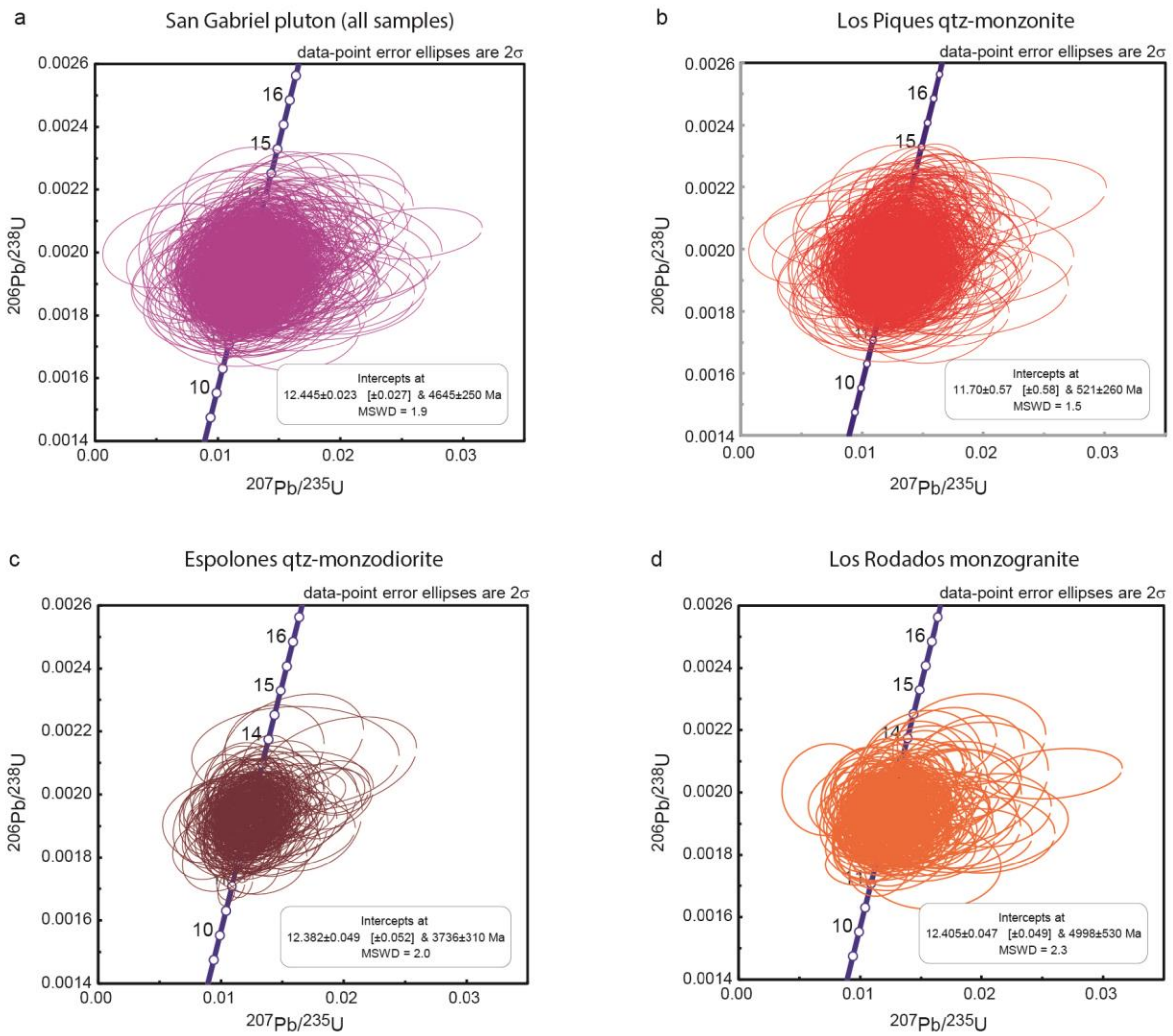

Figure S2: Concordia plots for (a) all the samples of the San Gabriel pluton, (b) the Los Piques qtz-monzonite, (c) the Espolones qtz-monzodiorite and (d) the Los Rodados monzogranite. Ellipses represent the 2σ error.

GEOCHEMICAL SIMULATIONS OF TRACE ELEMENT PARTITION

We carried out geochemical modeling of trace element partition between solid phase and residual melt, formed during the crystallization of hypothetical parental magma. In this study, the composition of the parental magma is considered as equivalent to the sample SG0702 (consistent with the inflexion point in the Rb-Sr graph; see main text). The simulations were performed by using the formulation and algorithm proposed by Gelman et al. (2014). This includes a crystal-melt segregation probability with a maximum efficiency around crystal fraction of 0.6, based on the optimal crystallinity window proposed by Dufek and Bachmann (2010).

As we exposed in the main text, the bulk partition coefficient was calculated for different crystallinities following the mineral crystallization sequence obtained in rhyolite-MELTS version 1.0.2 (Gualda et al., 2012), by using the partition coefficients for individual minerals (Table S6), which was introduced in the algorithm of Gelman et al. (2014). Based on the variation of D_i with respect to crystallinity, we use constant bulk partition coefficients for Rb ($D_{Rb} = 0.3$) and Sr ($D_{Sr} = 6.0$) because they are the expected values in the interval of optimal crystallinity window for the extraction of interstitial melts (~0.6; Fig. 11c; Dufek and Bachmann, 2010). Different total volume of extracted melt was selected, considering values of 0.1, 0.25, 0.5 and 0.8. The simulations do not consider assimilation of external contaminants of the magma.

Table S5: Whole-rock geochemistry for samples from the San Gabriel pluton (XRF data)

Unit	Los Piques qtz-monzonite
Sample	SG0702
Major elements wt.%	
SiO_2	59.74
TiO_2	0.86
Al_2O_3	17.01
Fe_2O_3	6.15
MnO	0.08
MgO	2.50
CaO	4.96
Na_2O	4.59
K_2O	2.72
P_2O_5	0.24
Cr_2O_3	0.01
NiO	0.00
LOI	0.54
Total	99.41
Trace elements ppm	
Rb	102.30
Sr	531.90

Table S6: Melt/mineral partition coefficients (Kd) used in geochemical modeling.

Phase	(Kd) Sr	(Kd) Rb
Plagioclase	12.500 [a]	0.001 [a]
K feldspar	7.400 [a]	0.700 [a]
Biotite	0.100 [a]	2.000 [a]
Clinopyroxene	0.516 [b]	0.032 [b]
Ortopyroxene	0.009 [b]	0.003 [b]
Apatite	0.000 [c]	0.000 [c]
Magnetite	0.000 [c]	0.000 [c]
Ilmenite	0.000 [c]	0.000 [c]
Quartz	0.000 [c]	0.000 [c]
Hornblende	0.400 [a]	0.000 [a]

[a] Bachmann et al. (2005).
[b] Arth et al. (1976).
[c] Elements are incompatible in these minerals, according to Gelman et al. (2014).

THERMODYNAMIC SIMULATIONS

Initial conditions

Based on the inflection point in the Sr and Rb content of samples from the San Gabriel pluton close to the 60 wt.% of SiO_2 and the absence or poor occurrence of cumulate textures in euhedral crystals of the Los Piques qtz-monzonite, the closest composition to the parental magma of the reservoir is that of sample SG0702 (Table S5). That composition was used as starting point to model the crystallization sequences and composition of the residual melts during the isobaric cooling of the magma system by using the thermodynamical software rhyolite-MELTS version 1.0.2 (Gualda et al., 2012).

Constant pressures were set at 1, 1.5 and 2 kbar. The buffer for oxygen fugacity was defined by +2QFM. Both 2 and 4 wt.% of H_2O content were imposed for the simulations, considering the presence of miarolitic cavities in the field, which indicates the water saturated character of the magma system.

Main results

The simulated crystallization sequences show similar patterns for all the considered physical conditions. In early stages, the system crystallized plagioclase and accessory phases (mainly spinel), whereas clinopyroxenes start to crystallize when the magma reaches the 15%

of crystal content (Figure S3 and Figure S4). Then, during a late stage that starts at ~55% of crystal content, biotite and quartz begin to crystallize, whereas K-feldspar crystallizes as a late phase when the magma reaches the 70% of crystal content (Figure S3 and Figure S4).

In general, the simulated composition of the residual melt and bulk solid phases reproduces the compositions of the San Gabriel pluton, showing small variation with changes in the H_2O content and pressure value of the simulation. The compositions of the San Gabriel pluton coincide with the mixing line between the solid and residual melt in equilibrium at different crystallinity values (Figure S5 and Figure S6), which supports the idea that most of the rocks were generated by unmixing during crystal-melt segregation processes.

Because of Na_2O is the only element that exhibits a curved pattern, where the mixing tie-lines between the respective compositions of the solid and residual melts in equilibrium, we chose the simulation to apply a mass balance to calculate the amount of removed residual melt or crystals. Details of those calculations are provided in the main text.

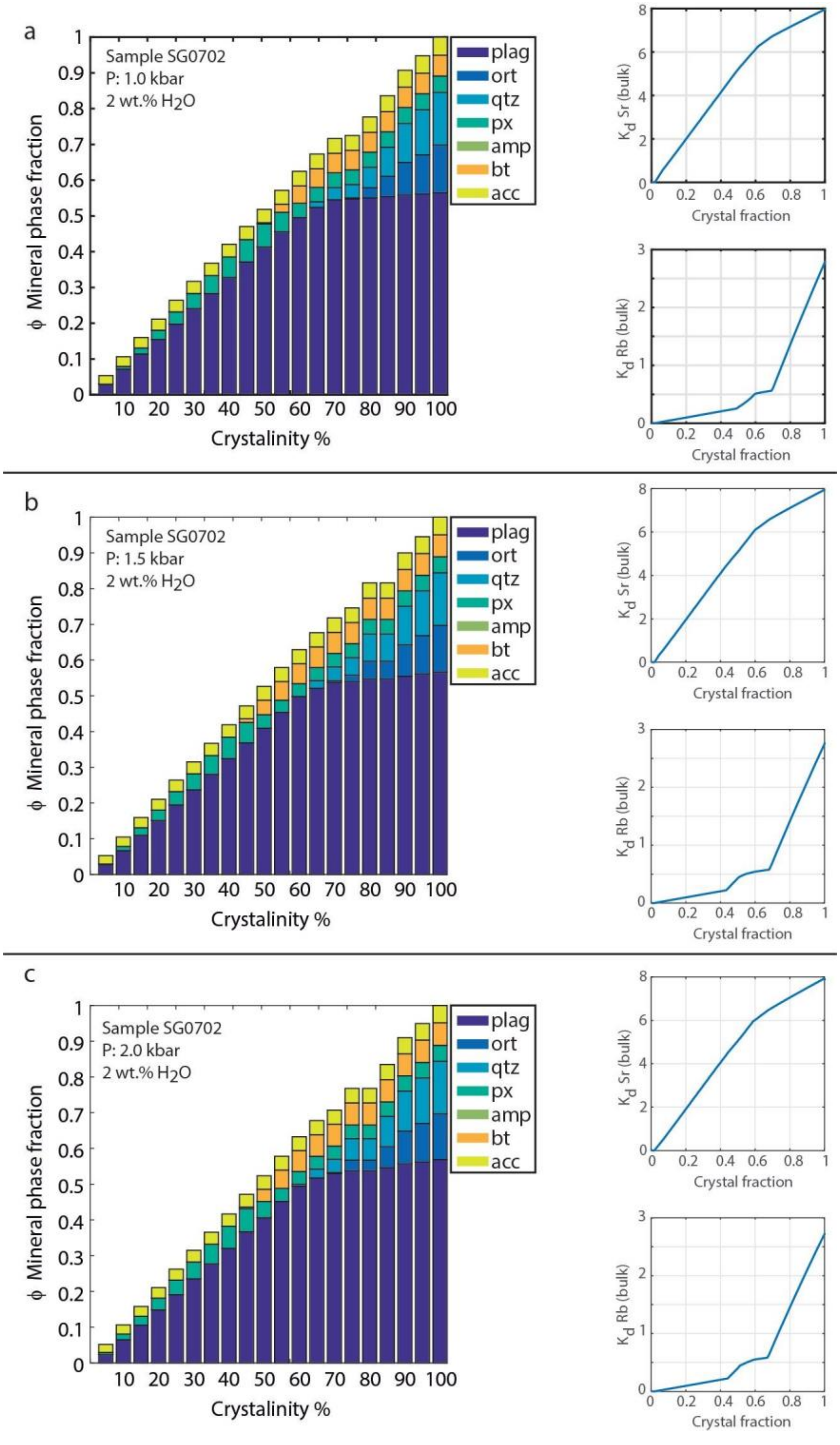

Figure S3: Simulated modal percentages of minerals obtained from rhyolite-MELTS version 1.0.2 (*histograms at left*), and calculated bulk partition coeficients for Sr and Rb depending on the magma crystalinity (*curves at right*) for a magma with composition equivalent to sample SG0702 with 2 wt.% of H_2O content. Pressure values were selected according to the emplacement conditions of San Gabriel pluton, considering: (a) 1 kbar; (b) 1.5 kbar and (c) 2 kbar.

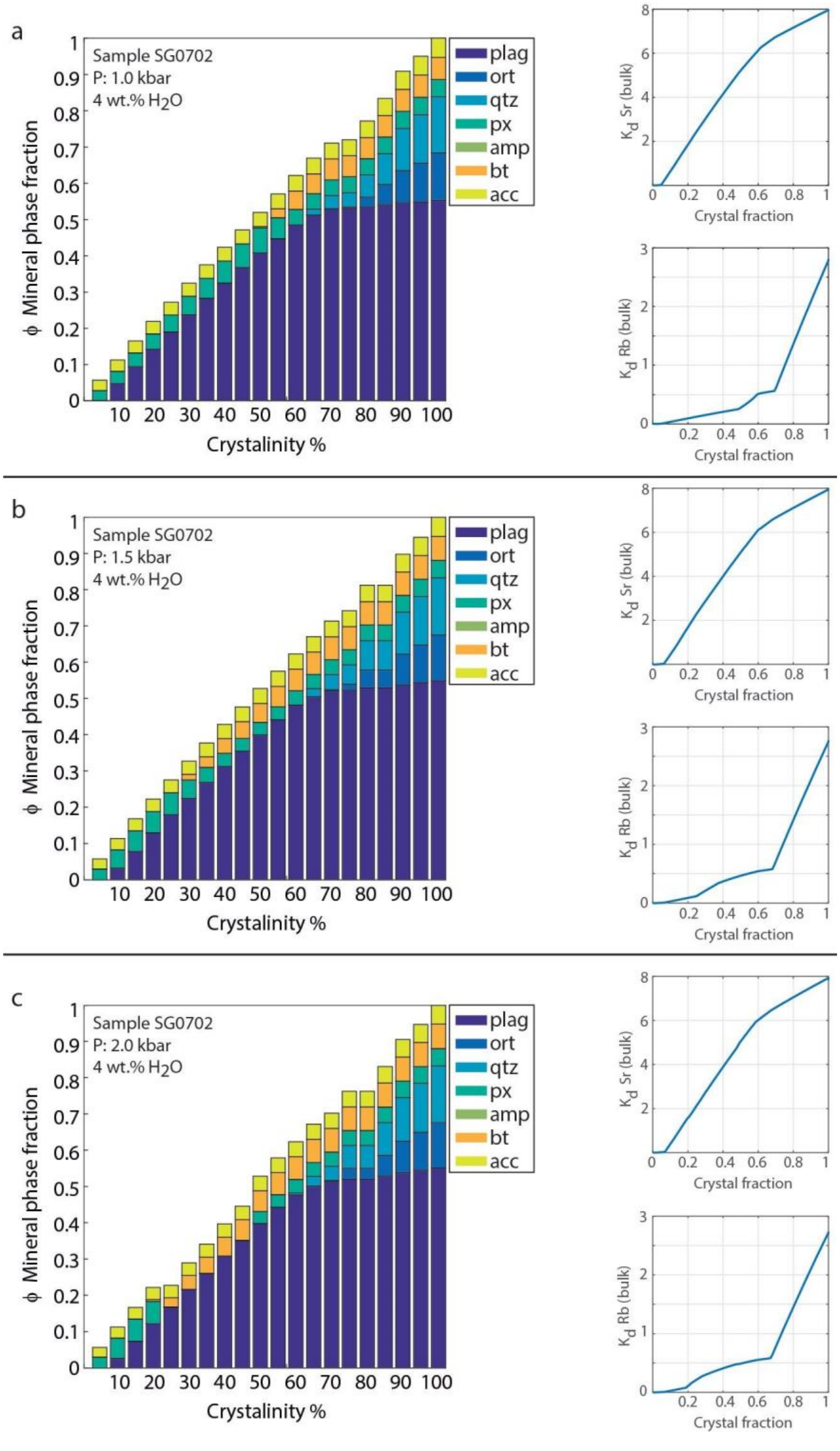

Figure S4: Simulated modal percentages of minerals obtained from rhyolite-MELTS version 1.0.2 (*histograms at left*), and calculated bulk partition coeficients for Sr and Rb depending on the magma crystalinity (*cruves at right*) for a magma with composition equivalent to sample SG0702 (Los Piques qtz-monzonite) with 4 wt.% of H_2O content. Pressure values were selected according to the emplacement conditions of San Gabriel pluton, considering: (a) 1 kbar; (b) 1.5 kbar and (c) 2 kbar.

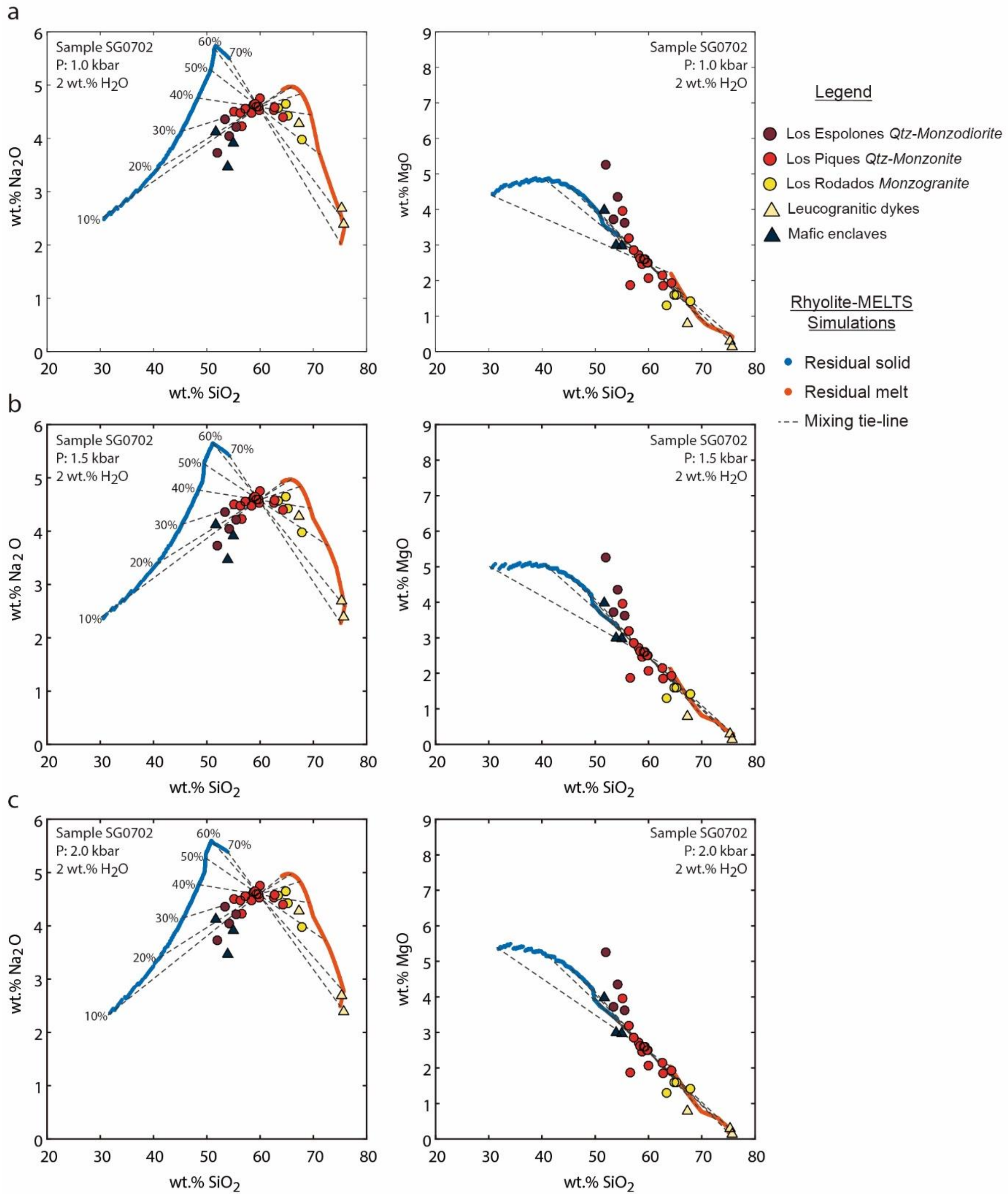

Figure S5: Simulation of Na_2O and CaO content in solid and melt counterparts during the isobaric equilibrium crystallization of a magma with the bulk composition of the intermediate samples of SGP (SG0702) with 2 wt.% of H_2O content, obtained from rhyolite-MELTS version 1.0.2 (Gualda et al., 2012). Pressure values are (a) 1 kbar, (b) 1.5 kbar, and (c) 2 kbar. Dashed lines connect the solid and melt composition for diverse crystal fractions.

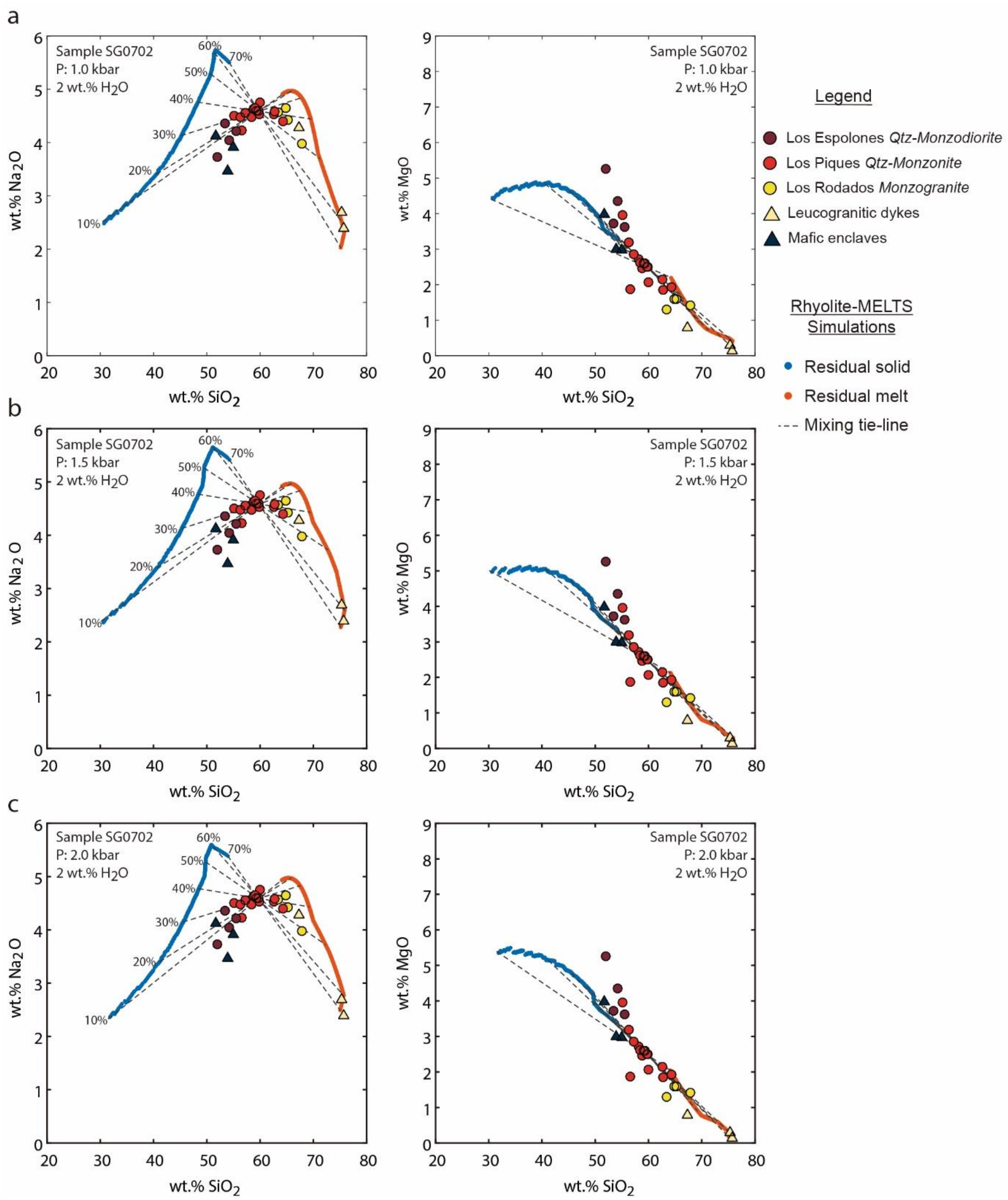

Figure S6: Simulation of Na_2O and CaO content in solid and melt counterparts during the isobaric equilibrium crystallization of a magma with the bulk composition of the intermediate samples of SGP (SG0702) with 4 wt.% of H_2O content, obtained from rhyolite-MELTS version 1.0.2 (Gualda et al., 2012). Pressure values are (a) 1 kbar, (b) 1.5 kbar, and (c) 2 kbar. Dashed lines connect the solid and melt composition for diverse crystal fractions.

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