Ba, Sr and Rb feldspar/melt partitioning in the basanite-phonolite suite from Teide-Pico Viejo volcanic complex, Tenerife.

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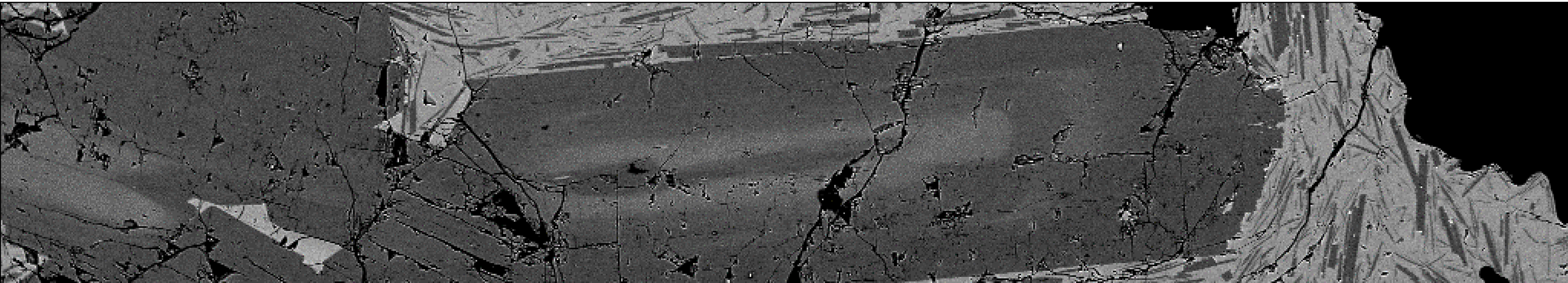
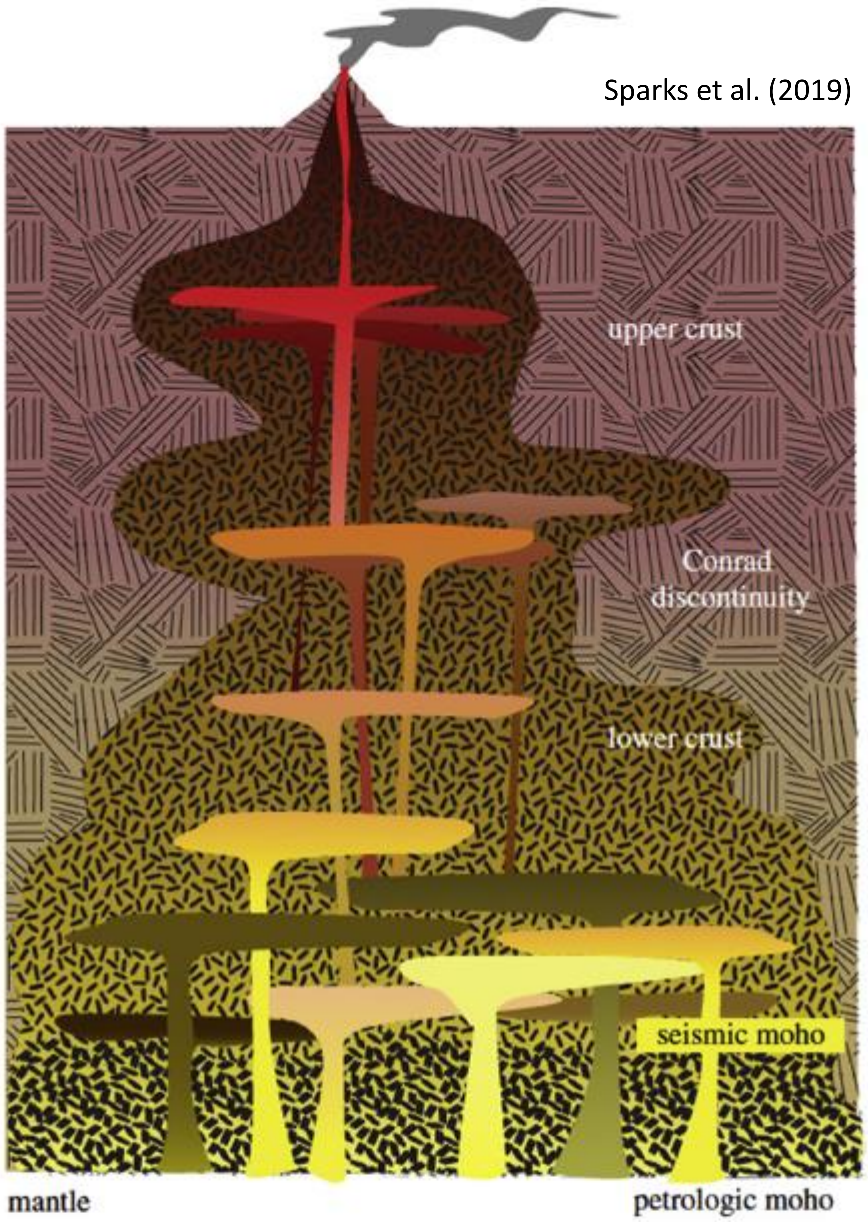




Sparks et al. (2019)

How are the magmatic systems that feed active volcanoes? Why is important?

Problems:

Studies mostly developed in silica-rich metaluminous rocks.

rifts

Alkaline felsic volcanoes are less studied.

Difficulty in modelling the behaviour of trace elements.

Critic to understand magmatic evolution and processes, and refine feldspar Ra/Th dating.

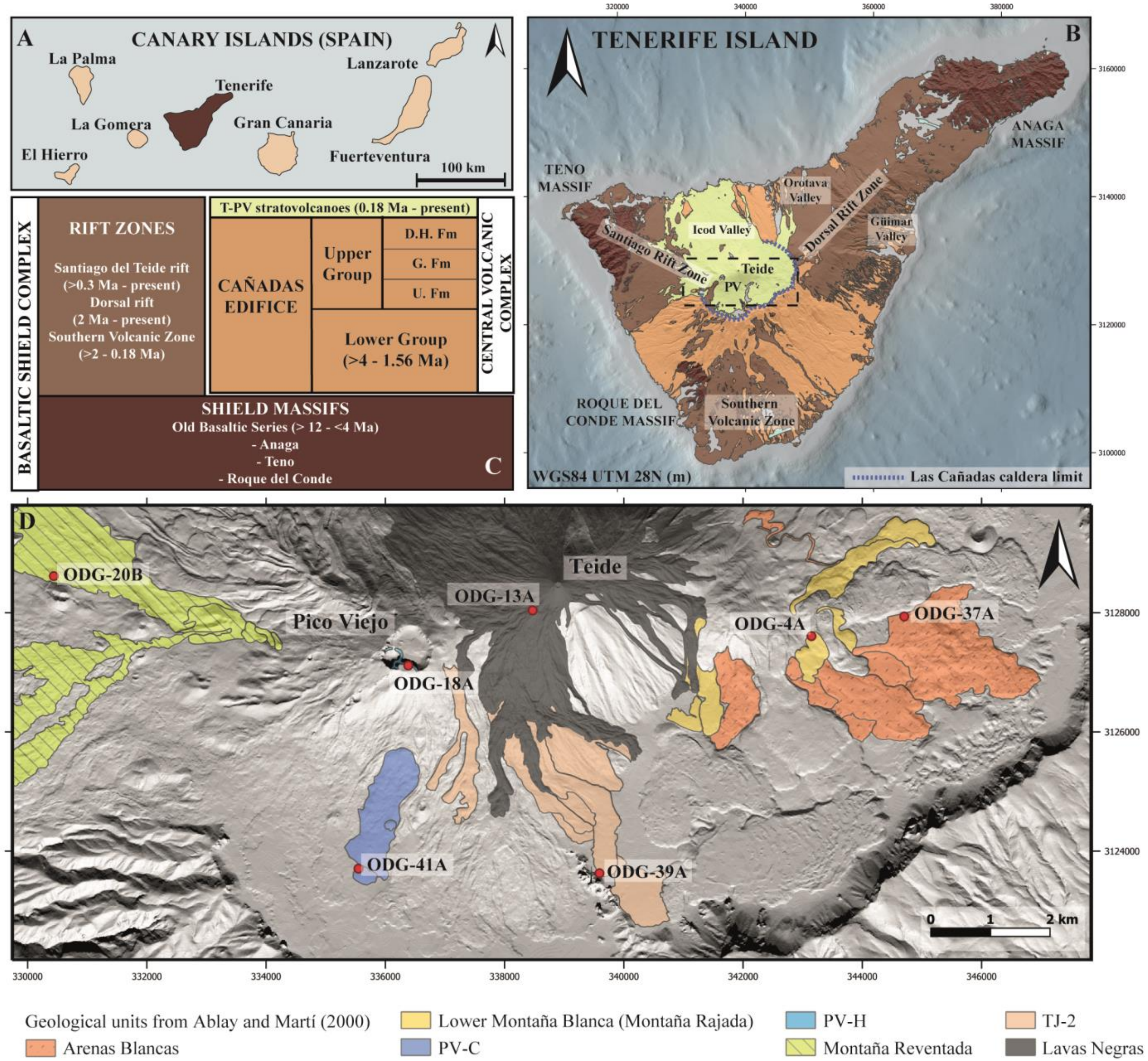
Actions:

Derive working values of partition coefficients for Ba, Sr and Rb in feldspar/plagioclase, **for all the compositional range**.

Apply these to modelling magmatic evolution of Holocene eruptions in Teide-Pico Viejo volcanic complex (Tenerife).

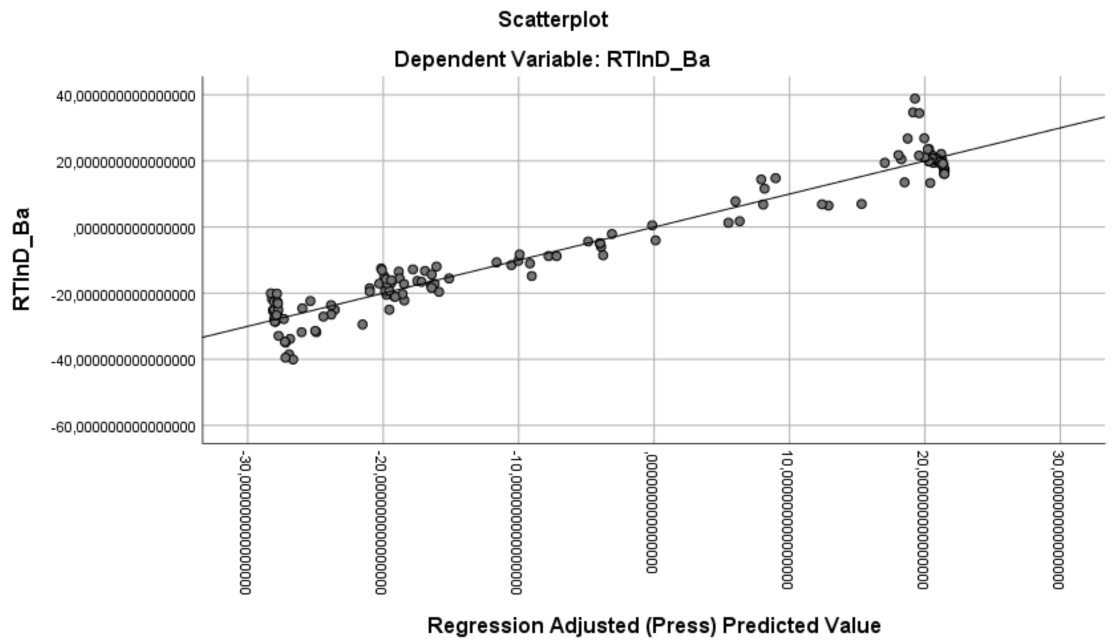
Tenerife: a little bit of context

- Tenerife: largest island in the Canary archipelago, with **highly populated areas**.
- The island started to grow **prior to 12 Ma** as a shield volcano (**Old Basaltic Series**). Basanitic-phonolitic **Las Cañadas Edifice**, began to develop in the central part of the island at ~ 3,8 Ma.
- **Active volcanism** is concentrated in the two **rifts** (basaltic volcanism) and in the central **Teide-Pico Viejo volcanic complex**, that started to grow in Las Cañadas Caldera (LCC) at 170-190 ka.
- The first stages of T-PV were dominated by mafic to intermediate magmas. **Phonolites began to appear at ~ 35 ka** and have become the **dominant** erupted composition since.



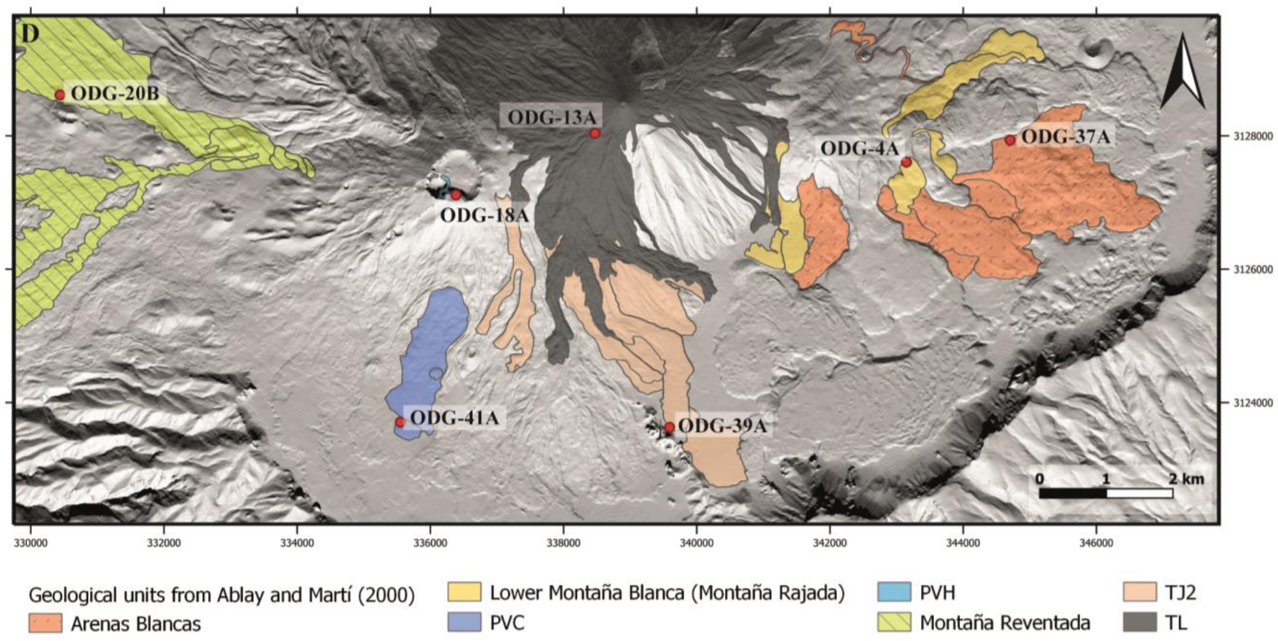
Multiple regression analysis of experimental partitioning data

- Compilation of experimental data available in the literature (11 studies, 145 partition experiments).
- Multiple linear regression analysis (MLR) using the IMB SPSS Statistics (Version 25.0).



Study of natural samples of T-PV complex

- Sampling of 7 natural samples of T-PV volcanic complex.
- Whole rock analyses (XRF and ICP-MS).
- Feldspar and glass analyses: EPMA and LA-ICP-MS.



Most suitable multiple regression equations

Ba $RTlnD_{Ba} = 11.643 + 0.653 * \boldsymbol{Or} - 0.406 * \boldsymbol{An} - 0.007 * \boldsymbol{Or}^2$

$$R^2 = 0.959$$

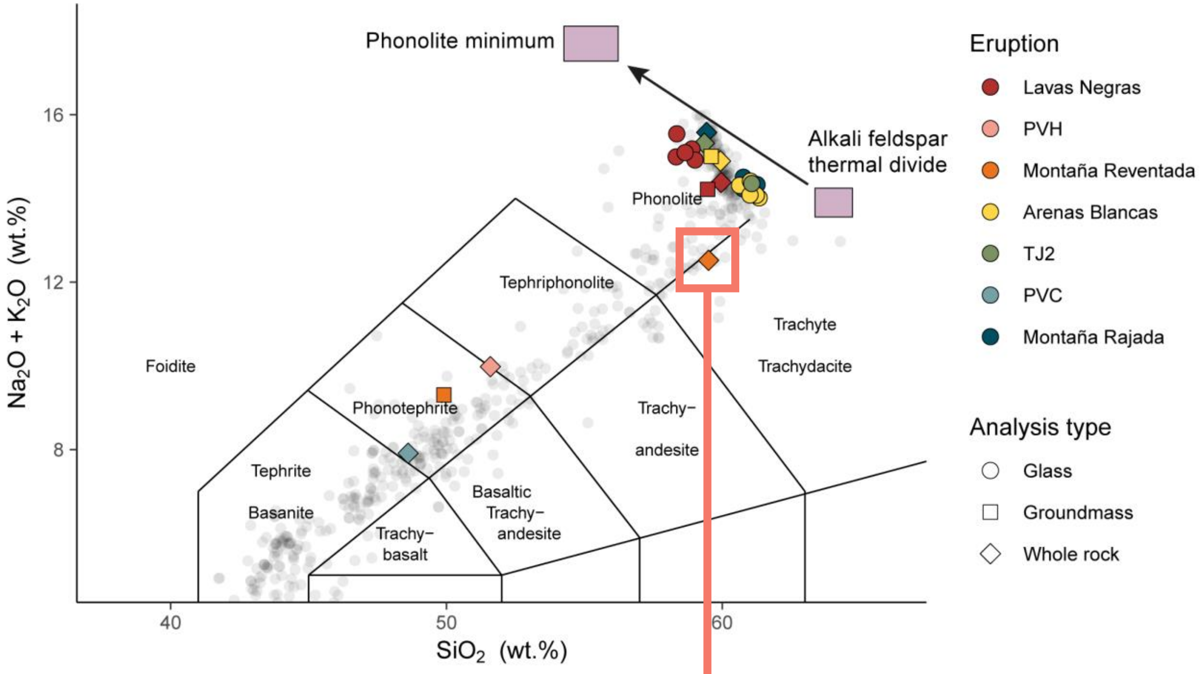
Sr $RTlnD_{Sr} = 21.277 + 0.460 * \boldsymbol{Or} - 0.164 * \boldsymbol{An} - 0.008 * \boldsymbol{Or}^2 - 0.001 * \boldsymbol{An}^2$

$$R^2 = 0.902$$

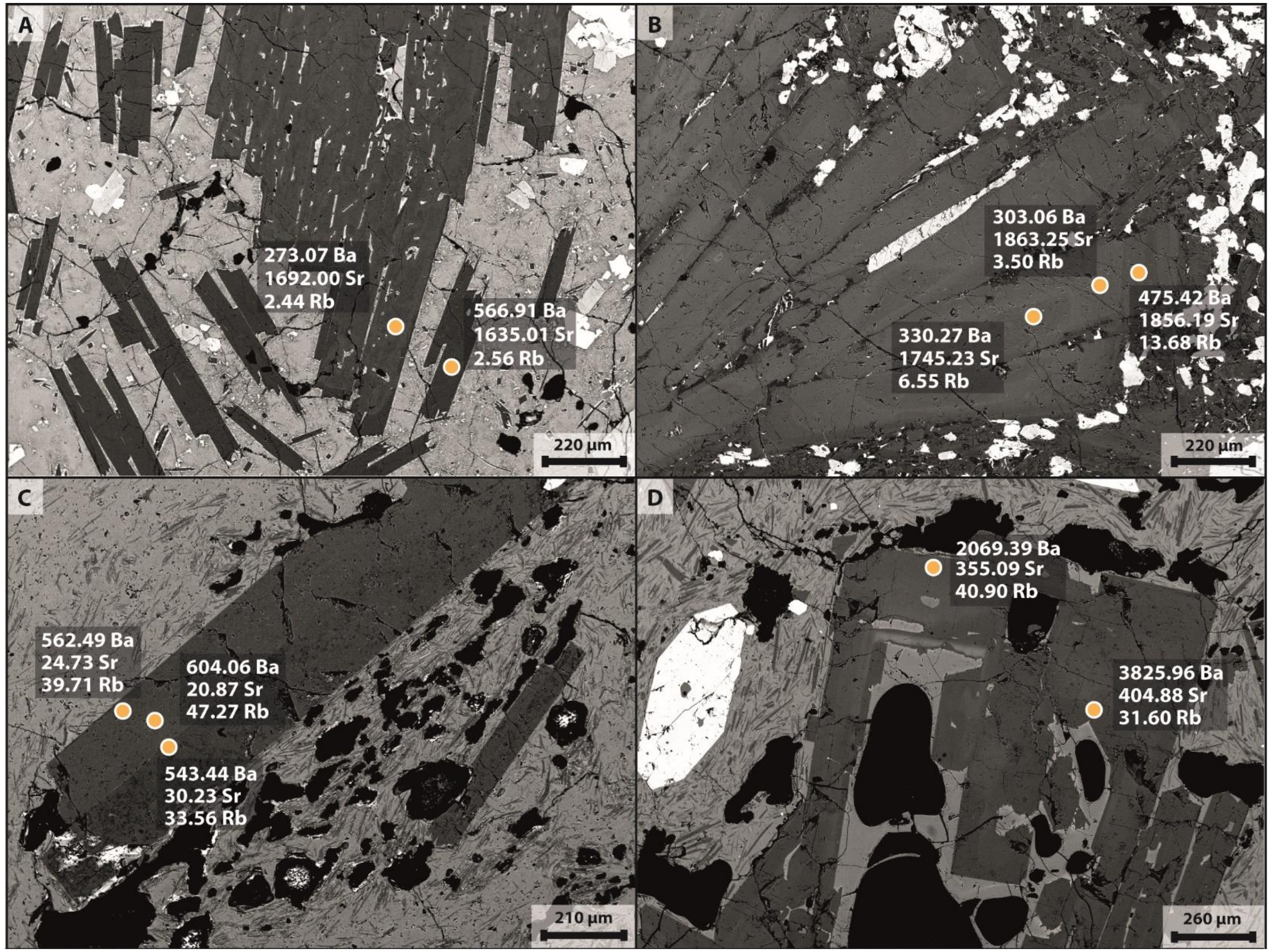
Rb $RTlnD_{Rb} = -35.655 + 0.801 * \boldsymbol{Or} - 0.188 * \boldsymbol{An} - 0.005 * \boldsymbol{Or}^2$

$$R^2 = 0.963$$

Whole rock, glasses and groundmass

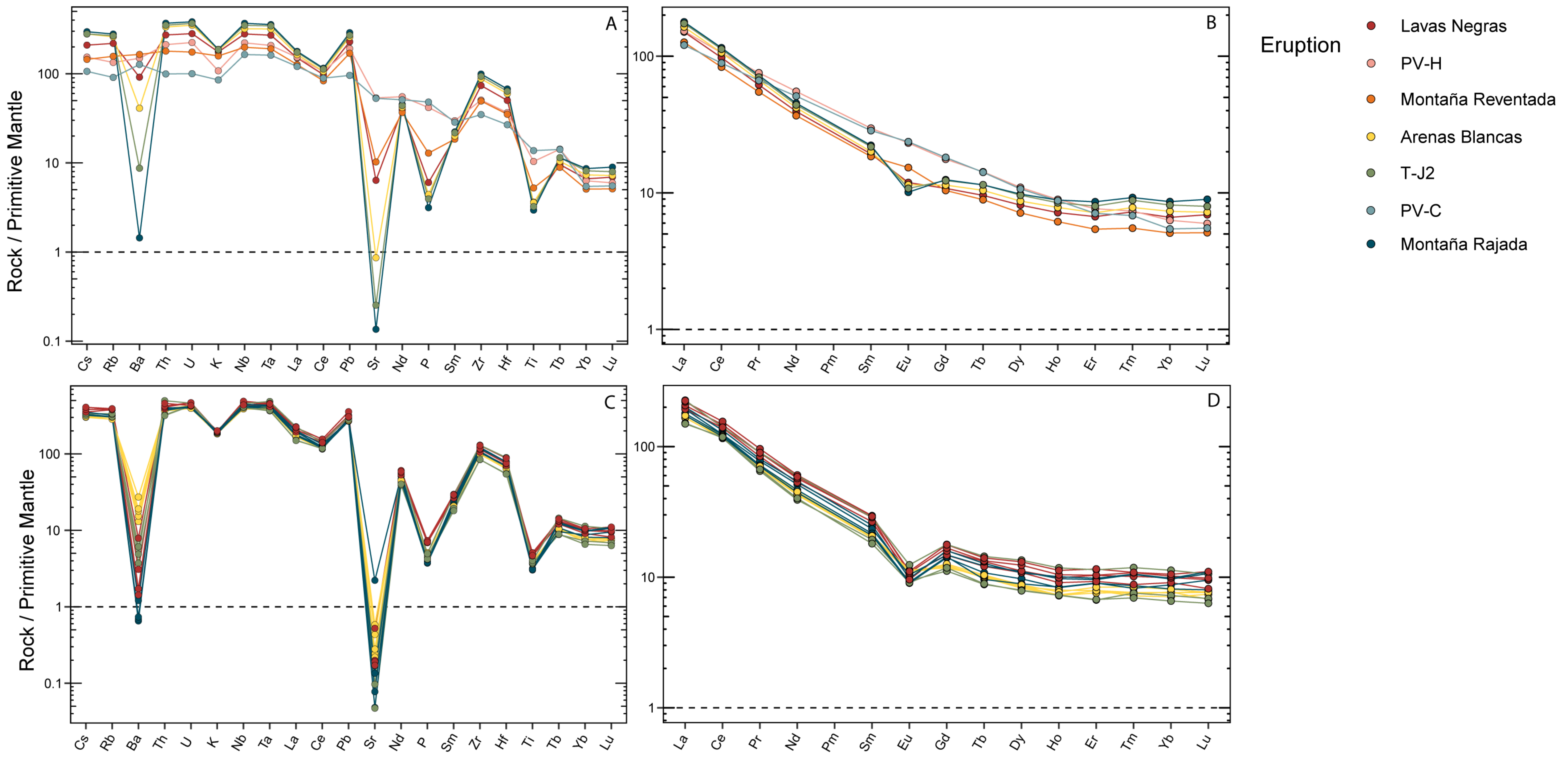


Montaña Reventada: less SiO2 undersaturated magma (trachyte rather than phonolite)

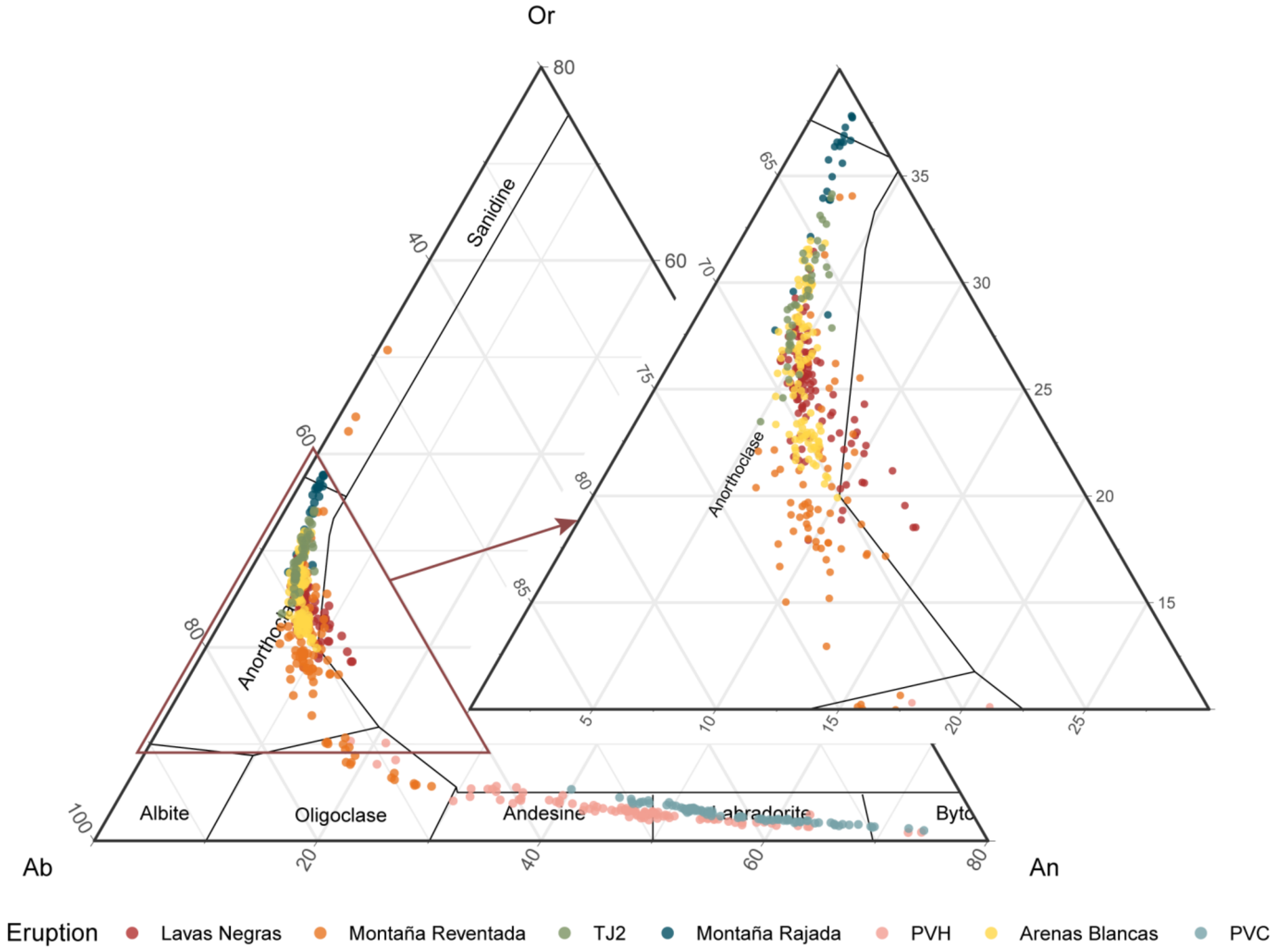


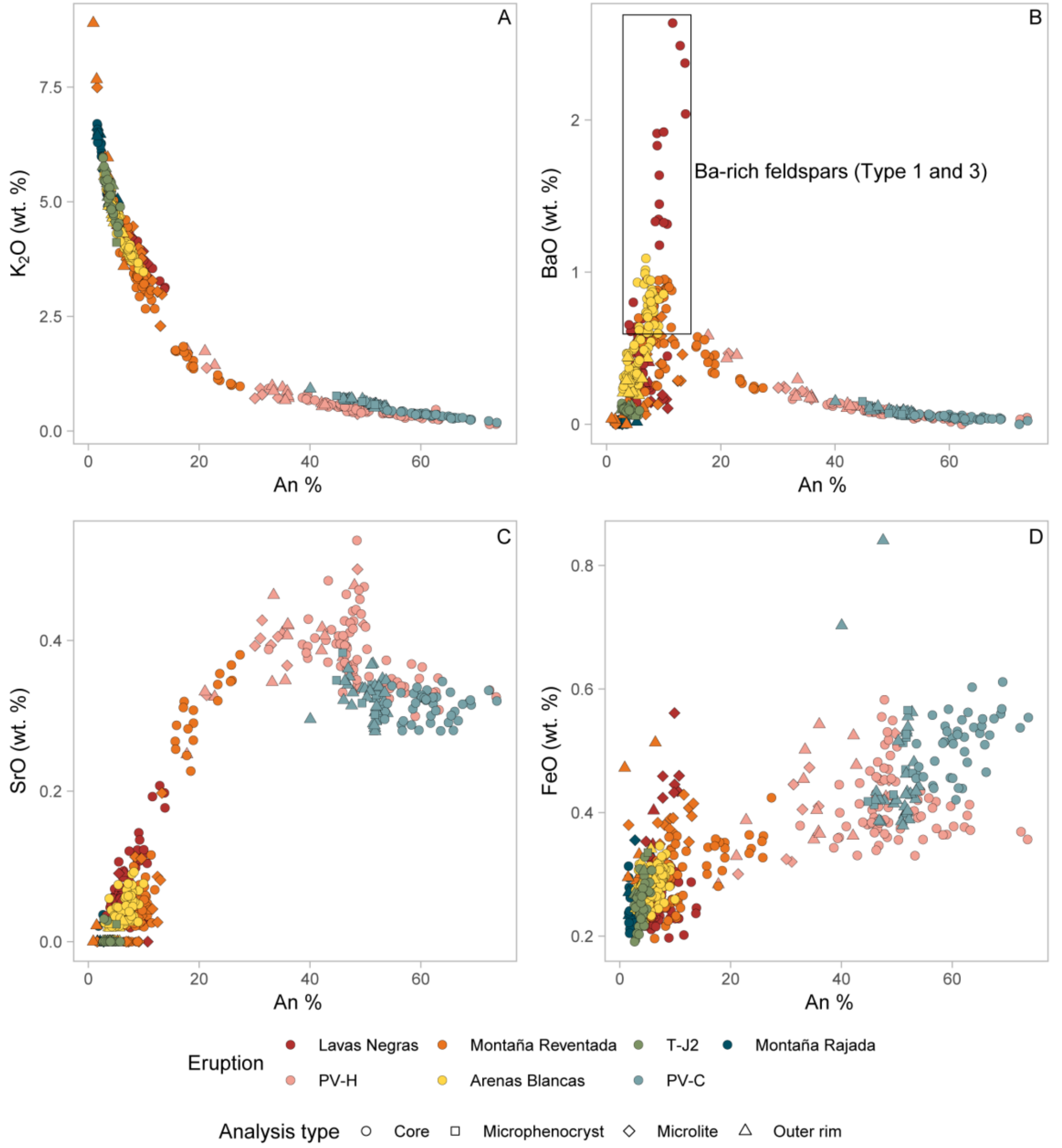
Back scattered electron images of representative feldspars from Tenerife samples. Yellow circles represent analytical spots by LA-ICP-MS. Values for Ba, Sr and Rb are also given next to the appropriate analysis point. (A) PVC (B) PVH (C) TJ2 (D) Lavas Negras (E).

RESULTS: Petrology and geochemistry



Mineral chemistry (mayor elements)





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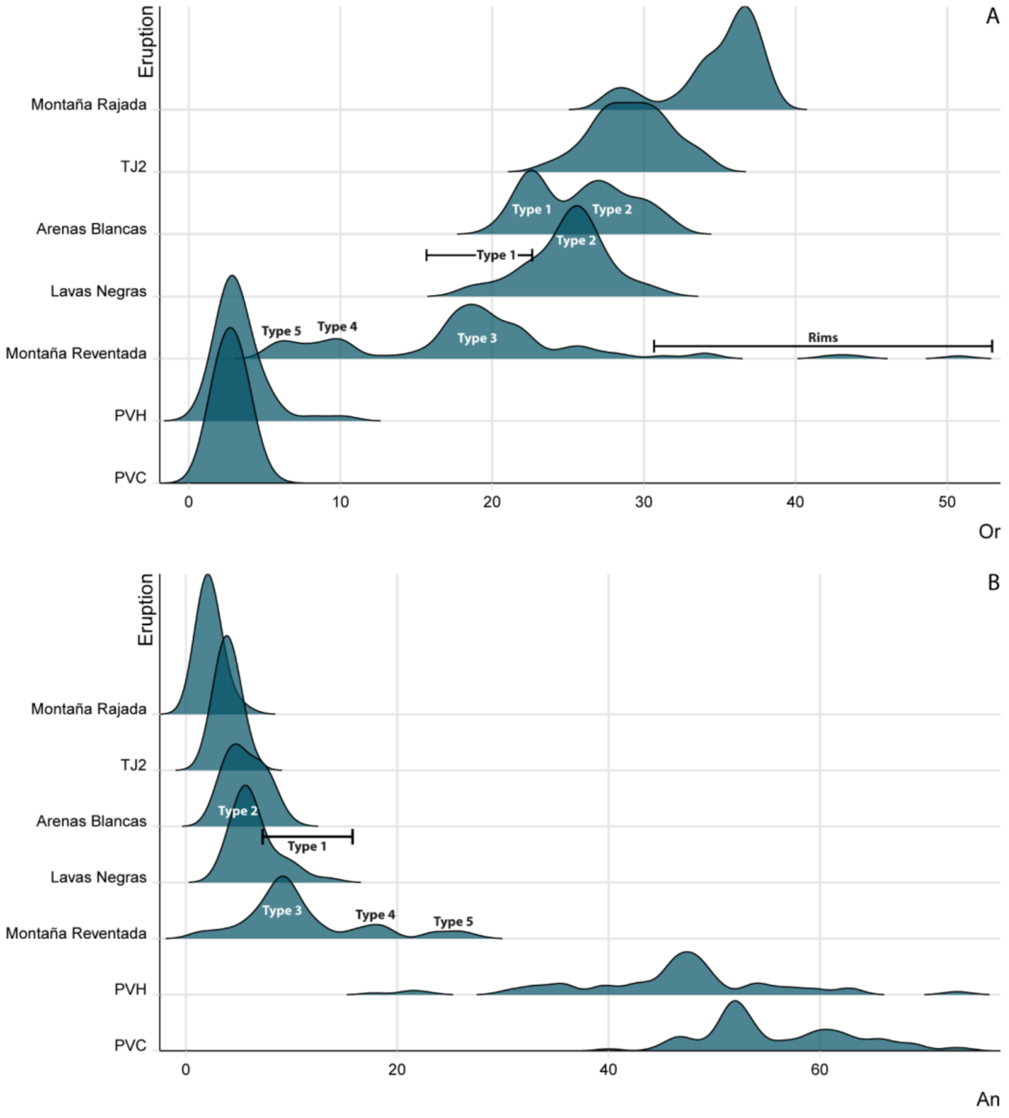
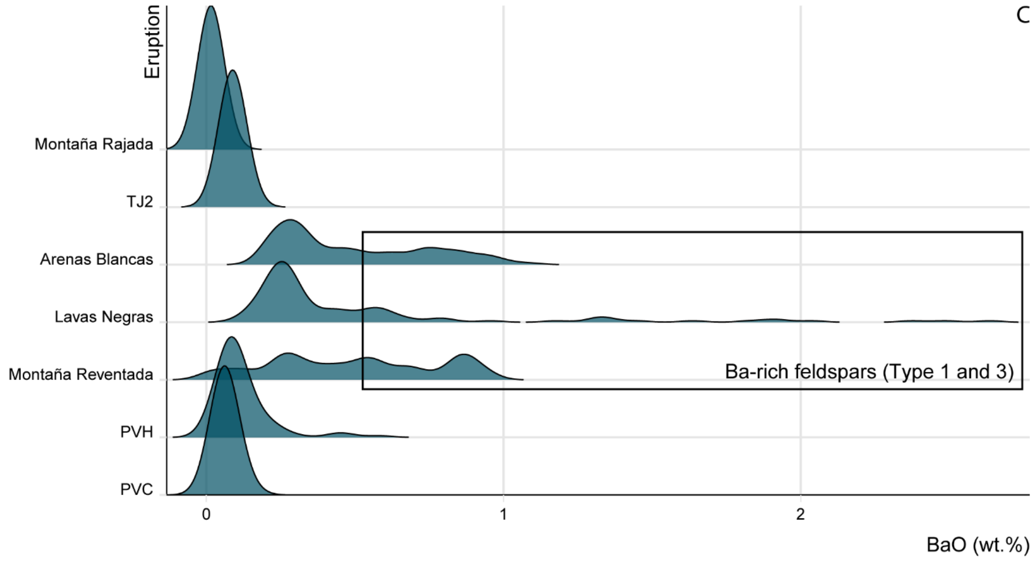
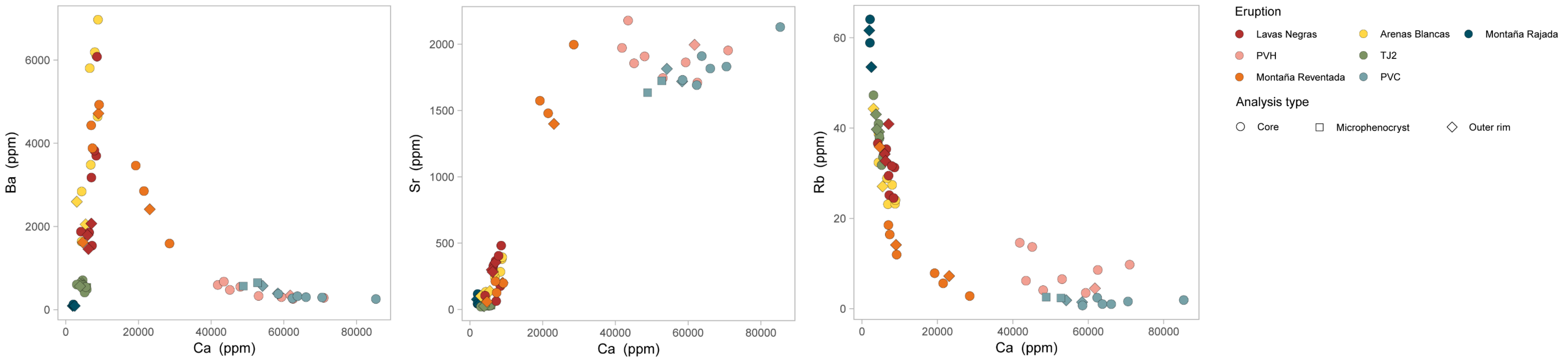


- Lavas Negras and Arenas Blancas: Two feldspar populations: Type 1 feldspars (Ba-rich and with An ~ 7-10 wt.%) and Type 2 feldspars (Ba-poor and with An ~ 5 wt.%).
- Montaña Reventada: Basanite + Trachyte. Three feldspar populations: Type 3 (more abundant and poorer in An), Type 4 and 5 (progresively more richer in An and Sr and depleted in Ba).





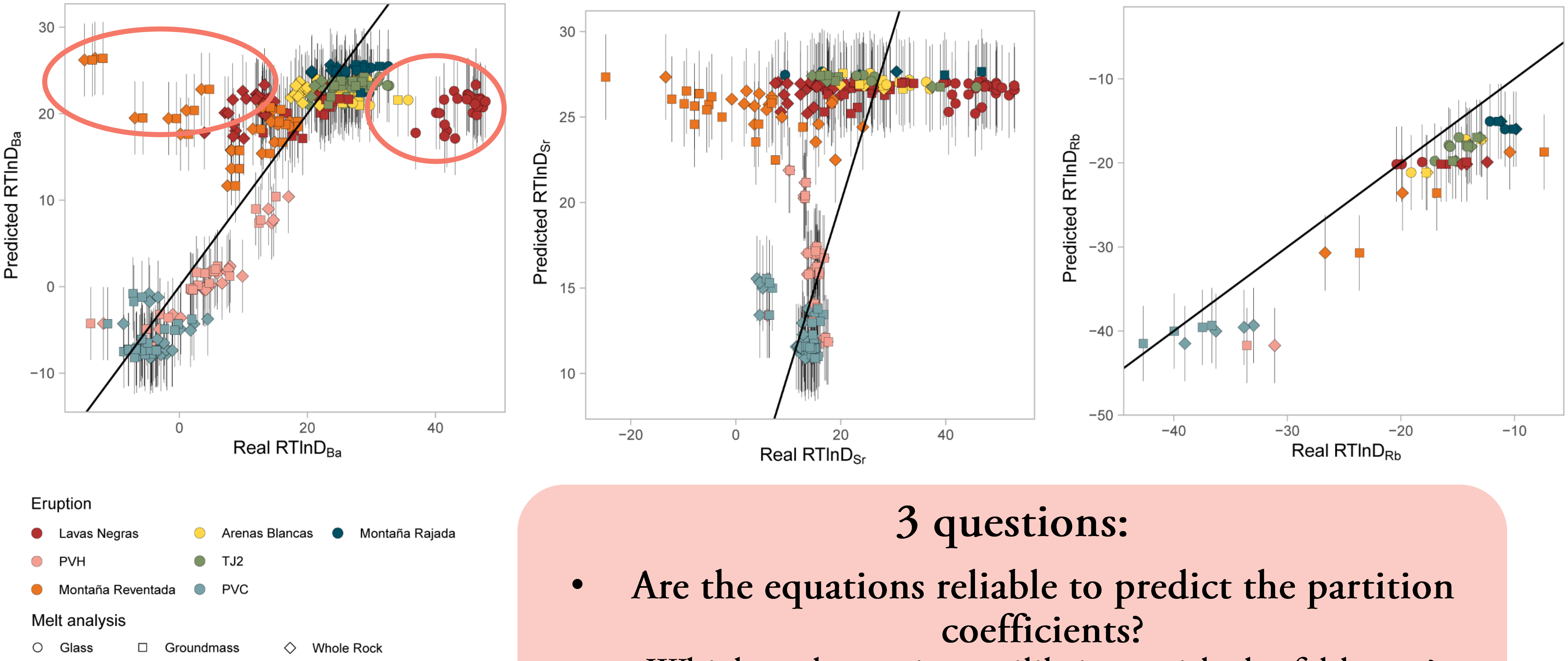
LA-ICP-MS analysis for Ba, Ca and Rb (in ppm).

Calculation of partition coefficients:

$$D_i = \frac{C_i \text{ in the mineral}}{C_i \text{ in the melt in } \textbf{equilibrium}}$$

What do we use as melt?

- Whole rock.
- Residual glass.
- Groundmass.



3 questions:

- **Are the equations reliable to predict the partition coefficients?**
- Which melts are in equilibrium with the feldspars?
- Are there xenocrystic populations? Origin?

DISCUSSION: Applicability of regression models

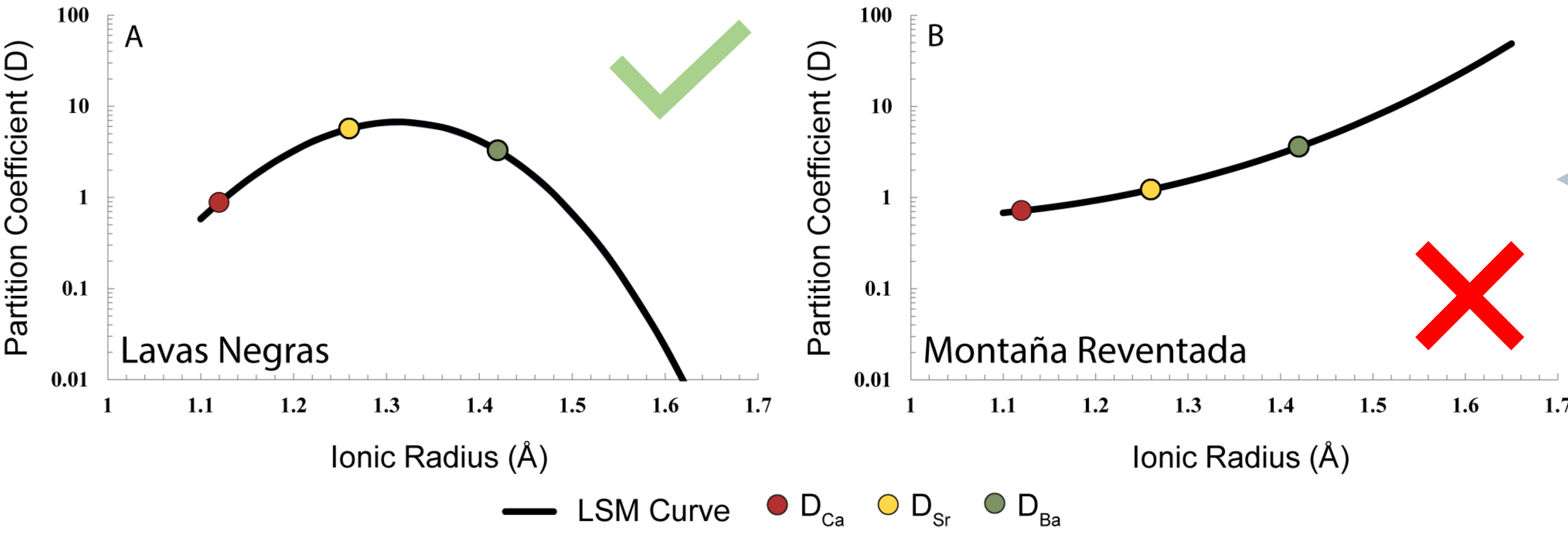
Based of the **Lattice Strain Model**:

- Onuma Curves (constructed using DCa, DSr and DBa) should be parabolic.
- Elastic modulus (E) should be between 120 ± 40 GPa.

If not: feldspars are not in equilibrium with the melt

E = 129

E = -61

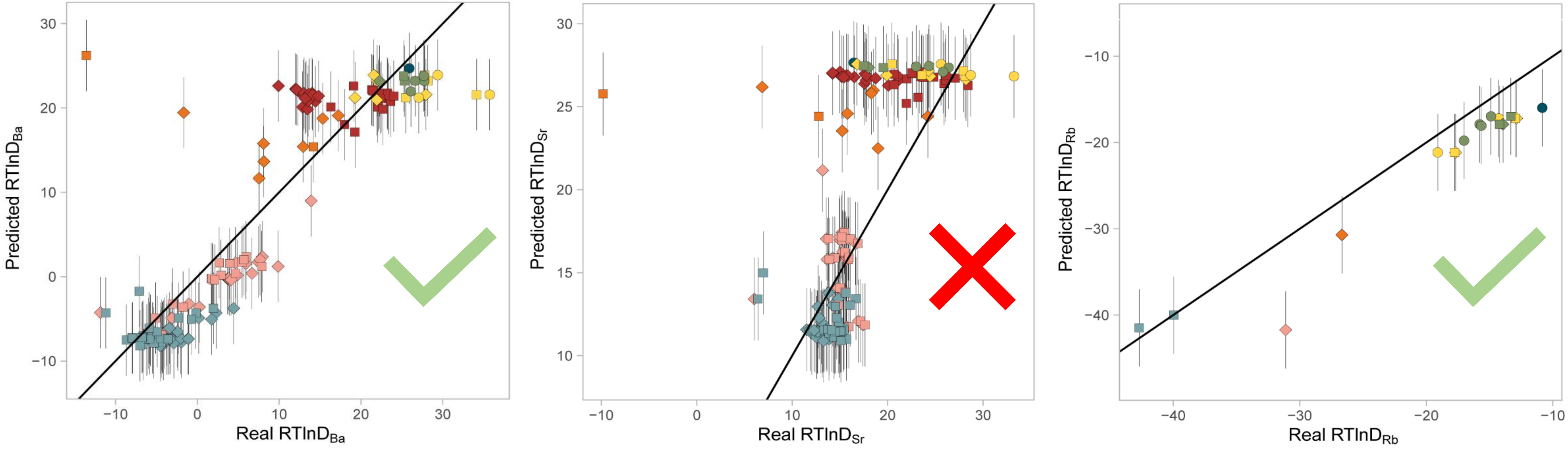


ONUMA CURVES

Ba, Sr and Rb feldspar/melt partitioning in the basanite-phonolite suite from Teide-Pico Viejo volcanic complex, Tenerife.

DISCUSSION: Applicability of regression models

Filtered data: only pairs in “equilibrium”



- DBa is well predicted in most cases, except in some analysis from Montaña Reventada. **Most usefull!**

Knowing the whole rock concentration of a trace element "i" and the theoretical Di calculated from the model, it is possible to predict the concentration of this element in the groundmass and in the crystal for any crystallinity of the sample:

$$C_{WR} = (X_{xt} {}^{*} C_{xt}) + \left(X_{gm} {}^{*} C_{gm}\right)$$

$$X_{xt} = 1 - X_{gm}$$

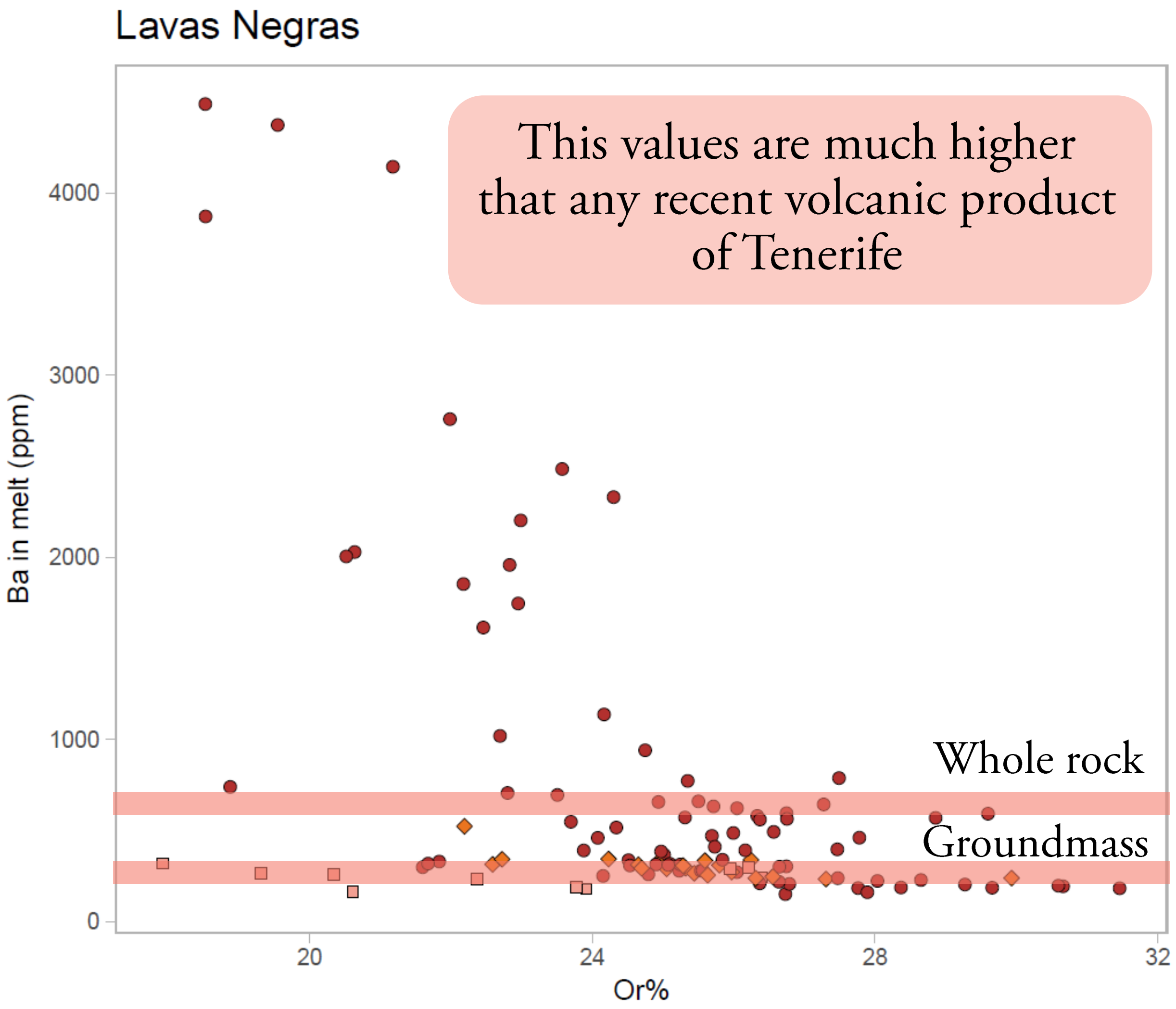
$$D = \frac{C_{xt}}{C_{gm}}$$

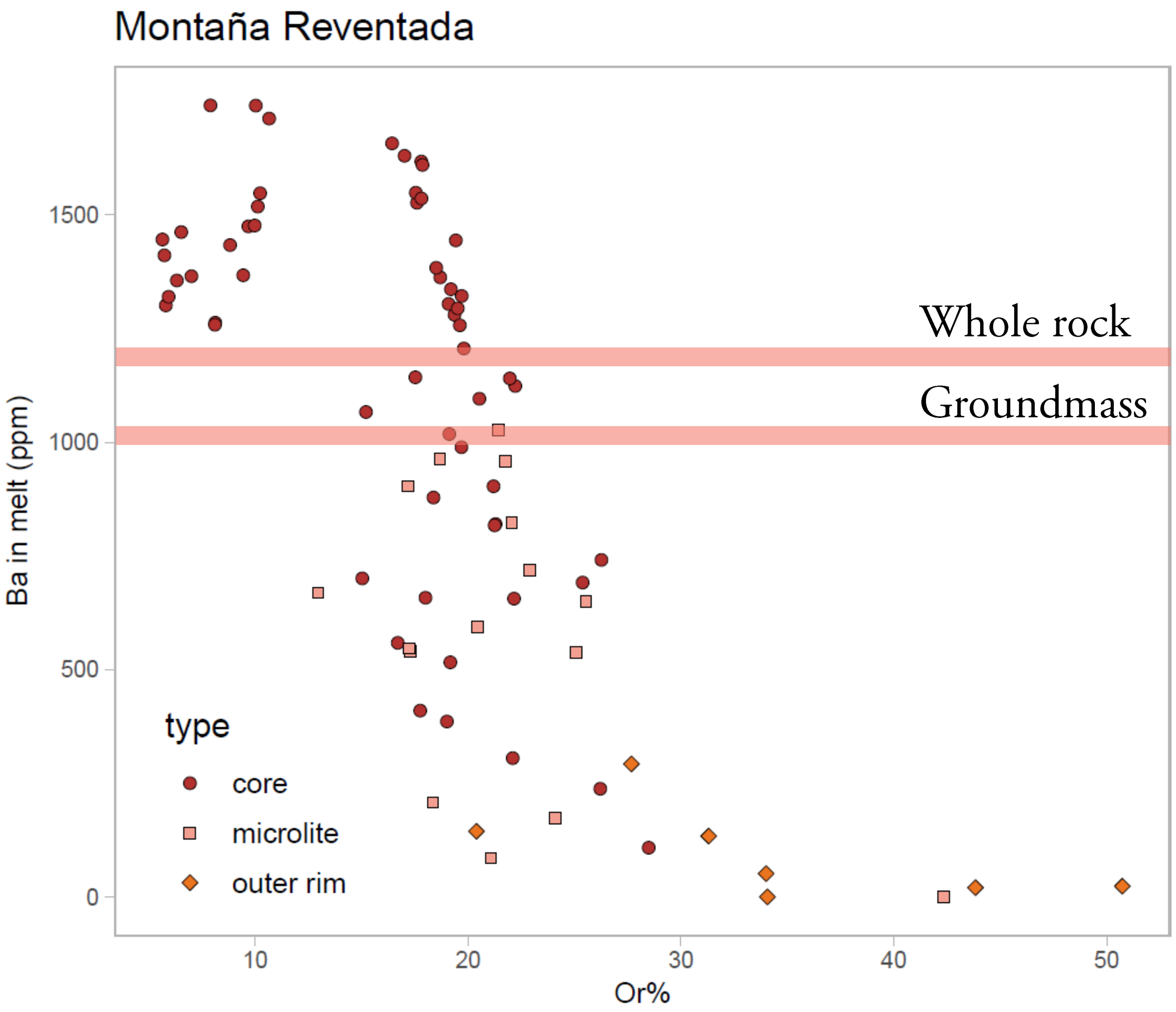
TABLE 2 Table showing a summary of the theoretical D_i ranges calculated by equations E1, E2, and E3 for each Teide-Pico Viejo eruption studied in this work, as well as the predicted quantities of Ba, Sr, and Rb that feldspars in equilibrium with the whole rock composition should contain.

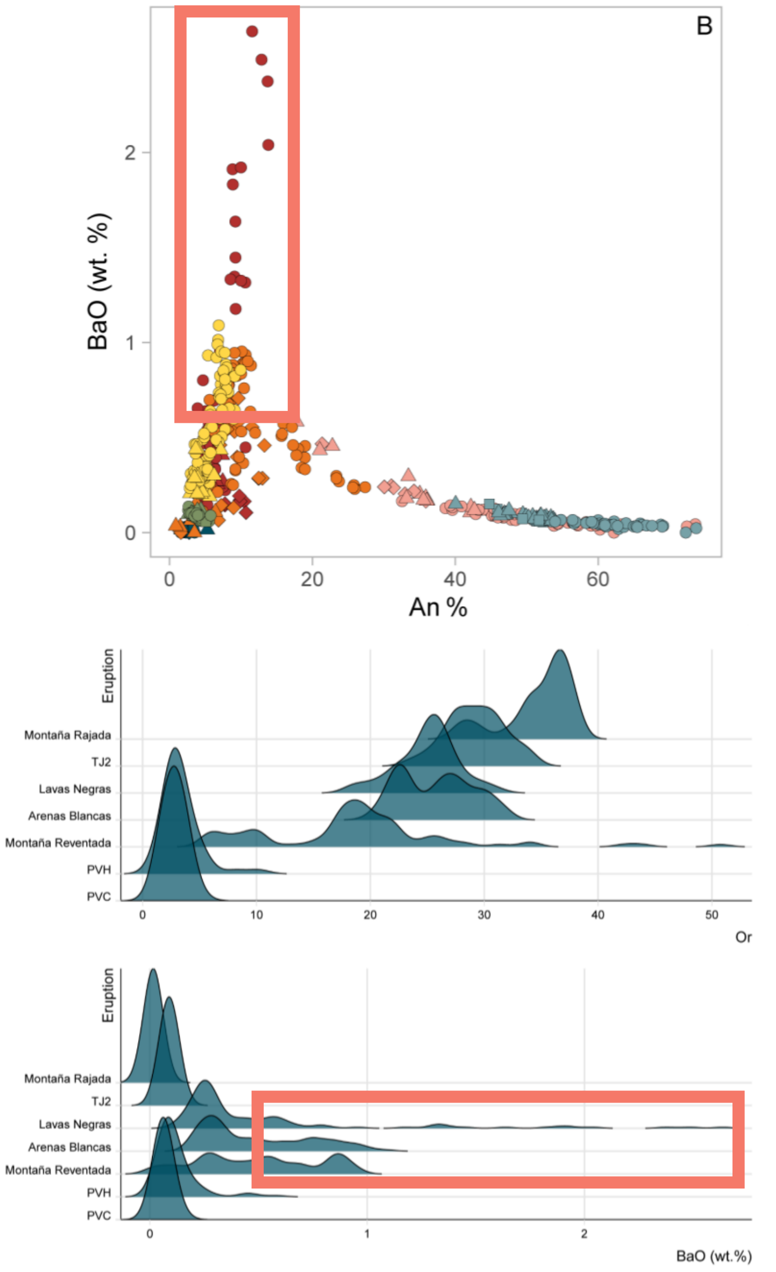
	Theoretical D calculated by equations E1, E2, and E3						Theoretical amount of Ba, Sr, and Rb in feldspars (in ppm)					
Eruption	Minimum DBa	Maximum DBa	Minimum DSr	Maximum DSr	Minimum DRb	Maximum DRb	Minimum Ba	Maximum Ba	Minimum Sr	Maximum Sr	Minimum Rb	Maximum Rb
Montaña Rajada	11.02	15.56	17.84	19.30	0.15	0.25	82.08	103.70	32.17	33.72	26.89	45.86
TJ2	9.15	12.80	16.65	17.90	0.12	0.20	442.62	567.21	59.48	62.30	20.10	34.56
Arenas Blancas	8.48	11.48	15.16	16.65	0.12	0.20	1,517.81	1785.36	128.86	134.03	20.48	34.84
Lavas Negras	5.42	10.00	12.02	14.60	0.09	0.19	1,588.54	1877.32	409.69	423.60	16.01	33.52
Montaña Reventada	3.15	13.40	9.13	14.71	0.05	0.45	3,181.30	8,579.09	1,296.28	1,690.44	5.18	46.78
PVH	0.52	2.67	3.03	7.90	0.02	0.05	769.98	1,371.03	1,520.51	1,699.09	3.68	10.65
PVC	0.46	0.93	2.80	4.34	0.02	0.02	474.04	837.70	2,145.77	2,625.63	1.28	1.86

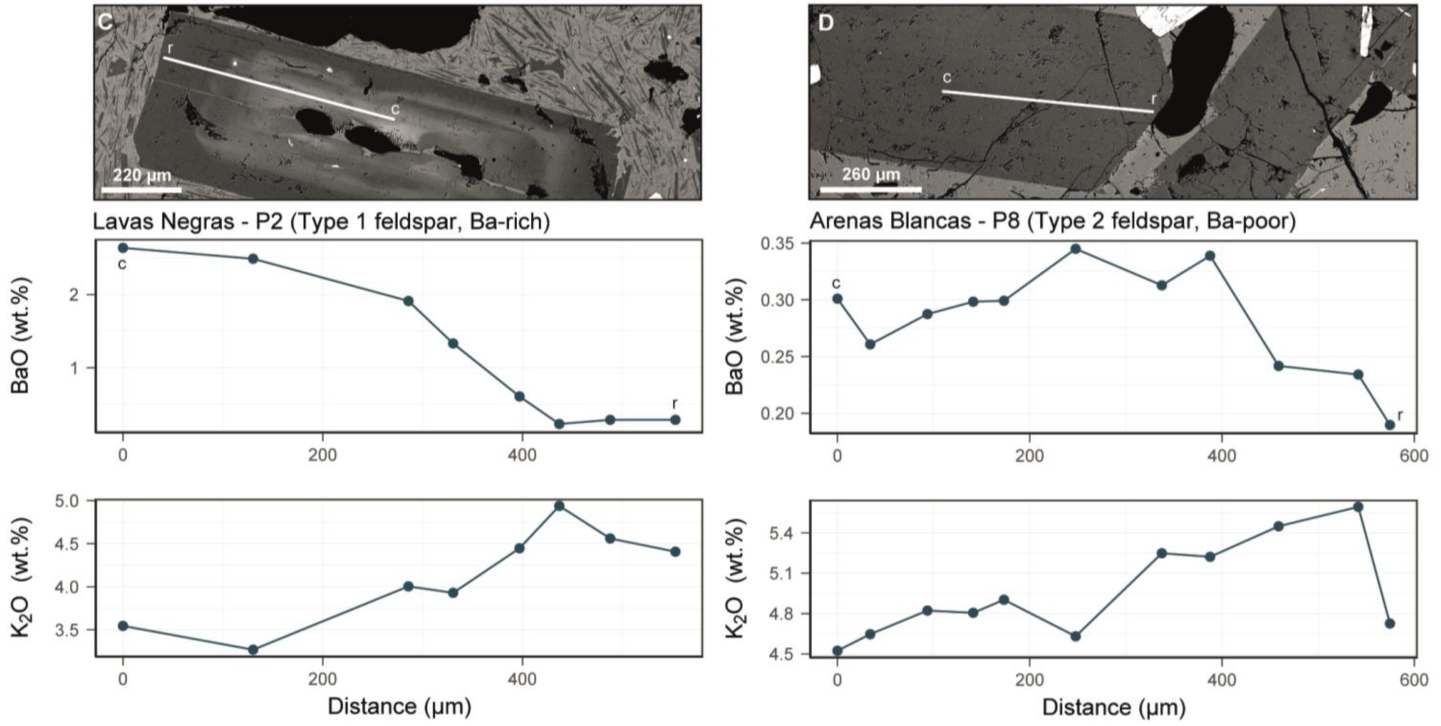
Table from Dorado et al. (2023)

Theoretical amount of Ba for feldspar cogenetic melts:







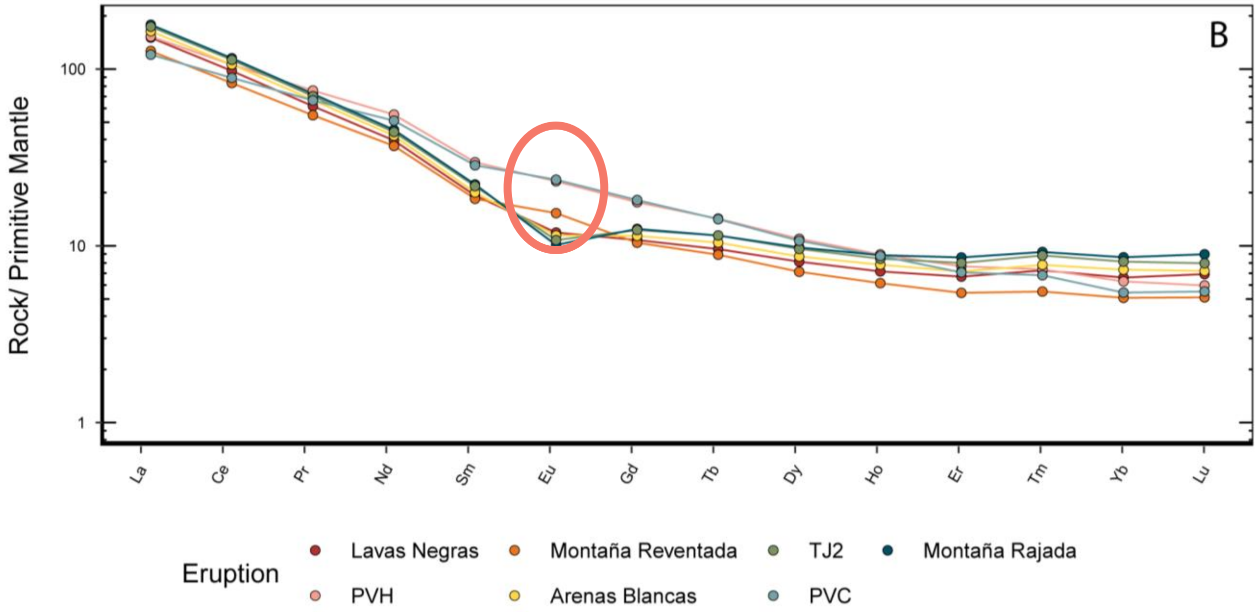


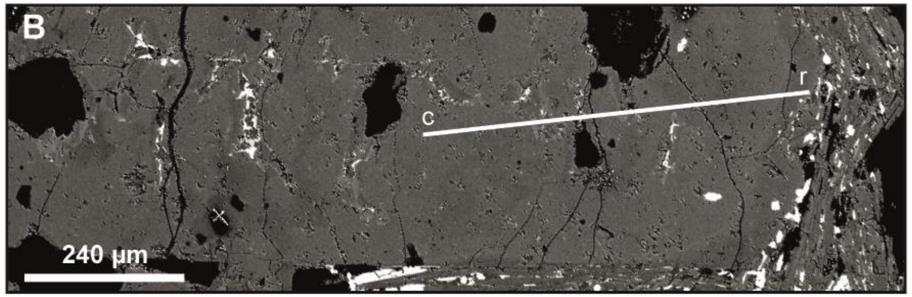
Two feldspars populations in Lavas Negras and Arenas Blancas eruptions:

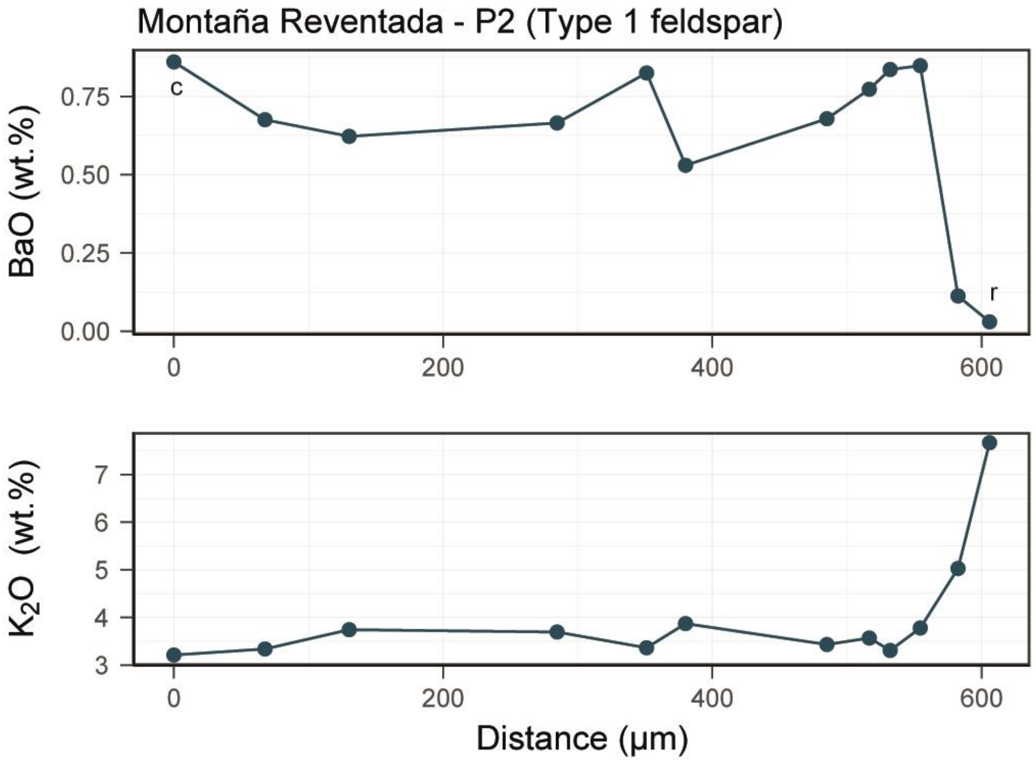
- Type 1: Ba-enriched cores: **xenocrysts → formed in a cumulate mush zone that had undergone multiple dissolution-crystallisation processes**
- Type 2: Ba-poor cores: in equilibrium.

Anomalous composition of Montaña Reventada:

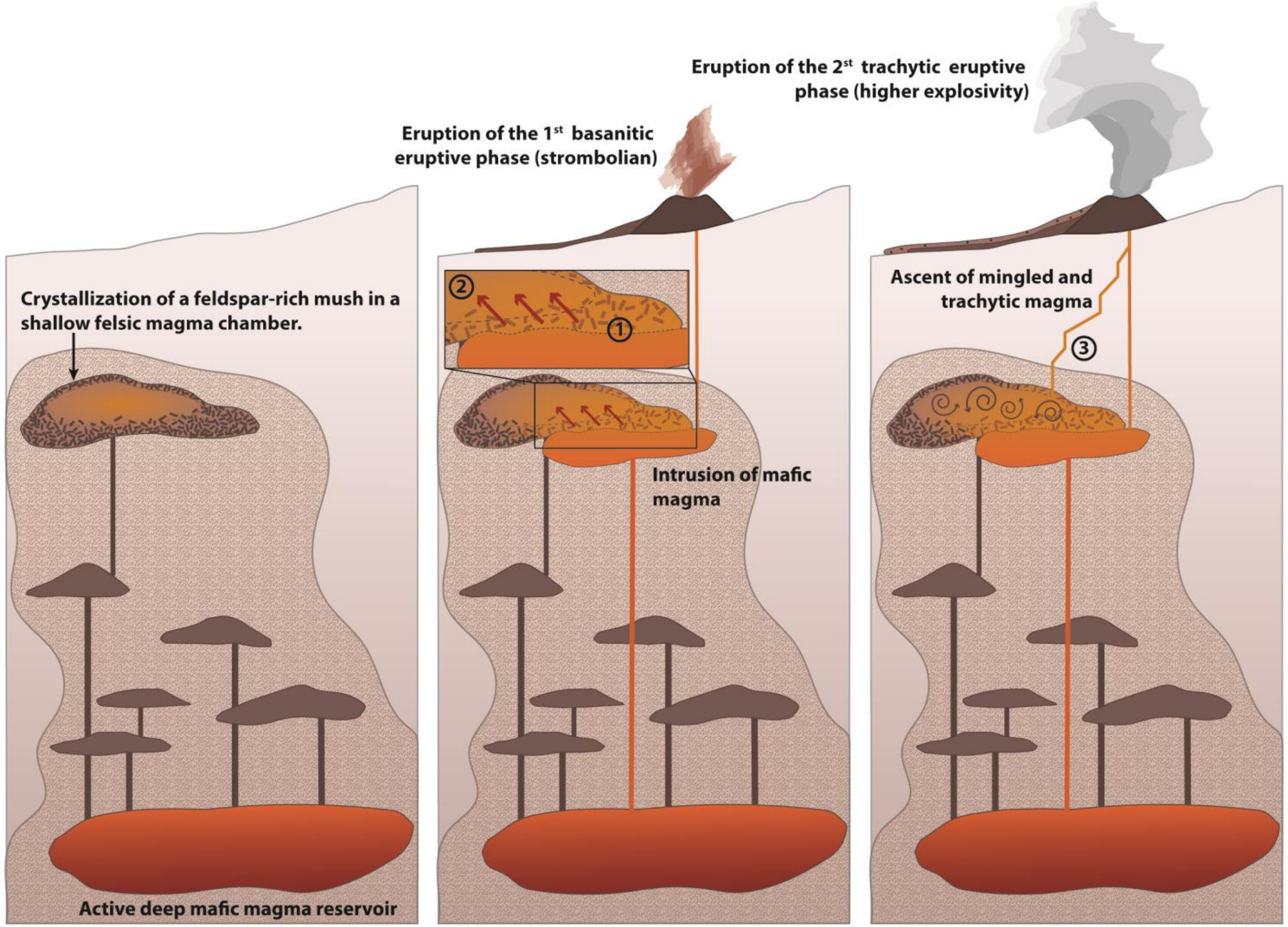
- Eruption with clear magma mixing between trachyte and basanite.
- Multiple feldspars populations.
- Less SiO_2 undersaturated (trachyte).
- Positive Eu anomaly: **melting of feldspar cumulates.**







Anomalous composition of Montaña Reventada:



Pre-eruptive processes:

1. Mafic magma intruded into an evolved magma chamber containing a crystal-rich cumulate zone at the bottom. Crystallization of less evolved feldspars (Type 4 and 5). First basanitic phase of the eruption.
2. Widespread melting of the crystal mush that mixed with the phonolite and produced the trachytic magma. Type 3 feldspars grew along with regrowths in Type 4 and 5 feldspars.
3. Rapid crystallisation of these phenocrysts and rapid ascent: sudden evolution of the residual magma and depletion in Ba and Sr, as reflected in the feldspar outer rims.

- The study provides expressions that can model partition coeffcients between feldspar and melt for Ba and Rb using only the major element composition of feldspars.
- Ba is the element best suited for tracking magmatic fractionation processes, cumulate formation, and remobilization.
- A population of cumulate-origin feldspars enriched in Ba has been identified in Lavas Negras and Arenas Blancas eruptions. This population of feldspars has undergone multiple disequilibrium and re-equilibration events due to reheating of the magma chamber.
- The study found clear evidence of cumulate melting as the origin of the Montaña Reventada trachytic magma.

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Ba, Sr, and Rb feldspar/melt partitioning in recent eruptions from Teide-Pico Viejo volcanic complex, Tenerife: New insights into pre-eruptive processes

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The behaviour of Group I and II elements during the petrogenesis of felsic igneous rocks is largely controlled by feldspar-liquid relationships. Numerous experimental studies have addressed plagioclase/melt element partitioning, with fewer studies devoted to potassium feldspar, and very few to albite-rich ternary-composition feldspar (An ~ Or < Ab). However, the partition coefficient for Ba is known to increase by at least an order of magnitude through the crystallisation sequence sodic plagioclase–anorthoclase–potassium feldspar that is typical of sodic alkaline suites. Feldspars, glasses, and whole rocks in such suites may exhibit strong enrichments and depletions that can be used to track processes of crystal fractionation, cumulate formation, and cumulate recycling. Here, we review experimental feldspar/melt partitioning data for Ba, Sr, and Rb for all feldspars. Regression of available data provides expressions that appear to adequately model the compositional and temperature dependence of partition coefficients for albite-rich compositions. We have applied this model to feldspar and melt compositions of the products of several Holocene eruptions (Pico Viejo C, Pico Viejo H, Teide J2, Lavas Negras, Arenas Blancas, Montaña Rajada and Montaña Reventada) of the basanitic-phonolitic suite of the Teide-Pico Viejo volcanic system (Tenerife, Spain), using EPMA and LA-ICP-MS analyses. Comparing analysed feldspar/groundmass pairs with predicted partition coefficients obtained with the models provides a way of distinguishing between feldspars that are in or out of equilibrium with their host melt, and of reconstructing feldspar histories. The results demonstrate the existence of a distinct population of feldspars that had undergone accumulation, fusion and recrystallisation events, in Lavas Negras and Arenas Blancas flows. In addition, the anomalous trachytic composition of Montaña Reventada is due to melting of a feldspar-dominated cumulate. Application of these techniques to active magmatic systems will allow us a better understanding of different pre-eruptive processes, and ultimately improve volcanic hazard assessment.

KEYWORDS
crystal mush, cumulate melting, alkaline magmatism, reservoir dynamics, multiple regression analysis, partition coefficients, trace elements, barium enrichments