



Self-cannibalisation of an active cumulate system (Blumone complex, Adamello, Italy)

Geochemical and experimental evidence

Manuel Pimenta Silva¹, Peter Ulmer¹, Othmar Müntener²

manuel.dossantos@erdw.ethz.ch

¹ Institute of Geochemistry and Petrology, ETH Zürich, Zürich, Switzerland

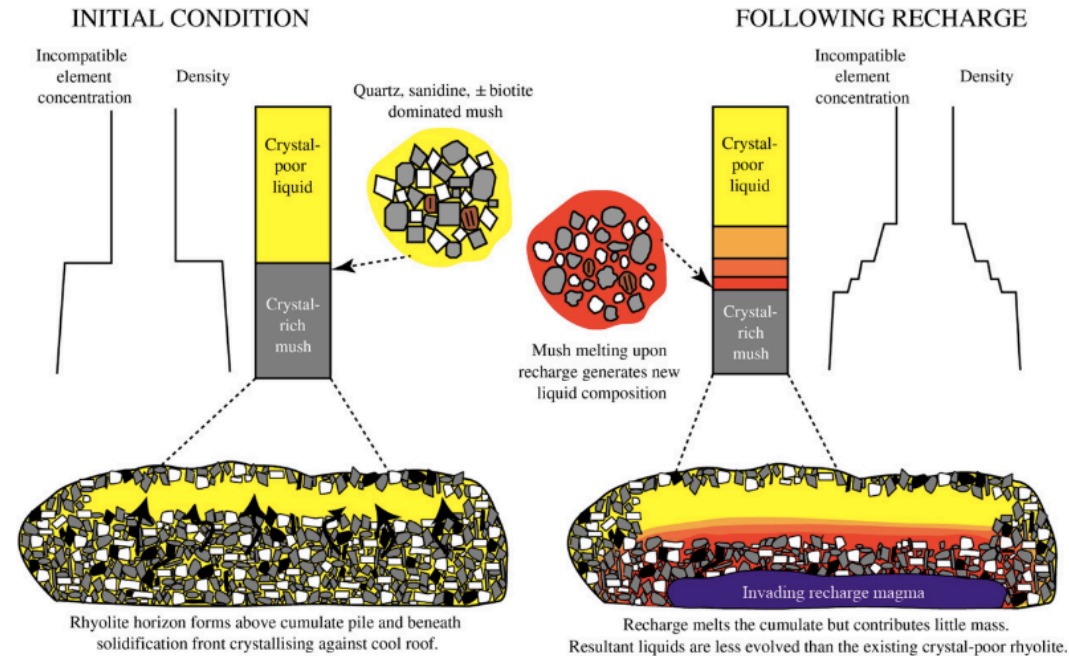
² Institute of Earth Sciences, Université de Lausanne, Lausanne, Switzerland

Key scientific question

- Can liquids deviating from a calc-alkaline liquid line of descent (LLD) be generated by partial melting of gabbroic cumulates?
- If this is occurring, what are the implications on the syn-magmatic reworking of plutonic roots in shallow calc-alkaline systems?
- Tools to investigate this question:
 - Case study in a fossil shallow cumulate complex
 - Field observations
 - Bulk rock and mineral major+trace element data
 - Experimental approach

What is petrological cannibalism?

- Syn-magmatic remelting of crystallised parts of a magma chamber **by subsequent injections**
- This has become a quite commonly studied process in calc-alkaline settings but there is yet no study that integrates field, geochemical and experimental approaches
- A combination of these three techniques is only possible in an ancient batholith where field observations and the **plutonic record** can be investigated

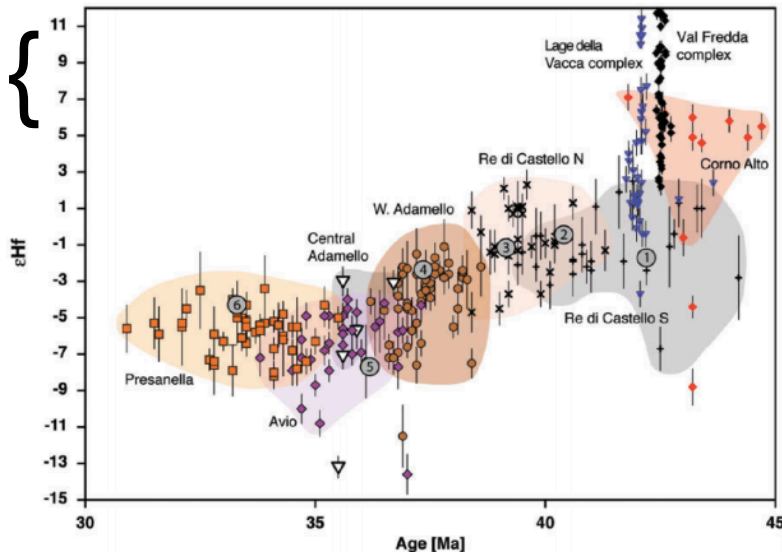
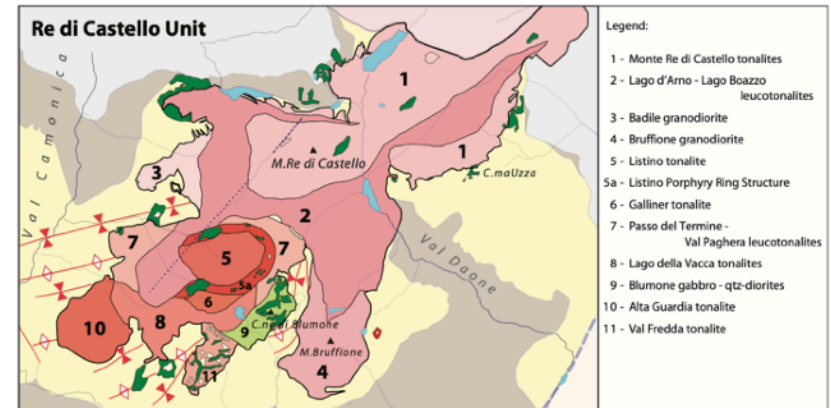
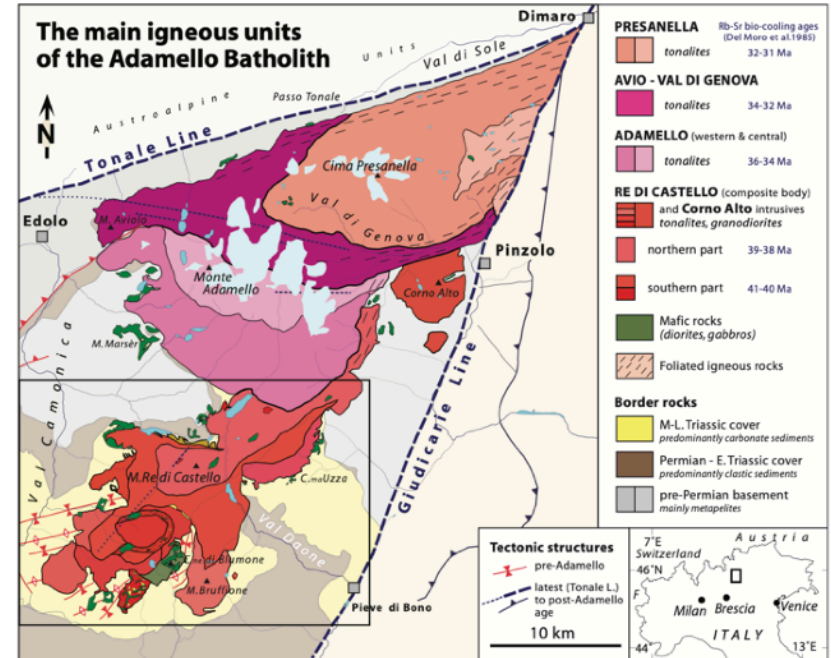


Wolff et al. (2015)

**The Southern Adamello
as a case study!**

The Adamello Batholith (Southern Alps)

- Calc-alkaline batholith
- Shallow pressure (2-3 kbar)
- Incrementally assembled from 42 to 31 Ma
- SW-NE chronological, geochemical and isotopic gradients → increasing crustal contamination

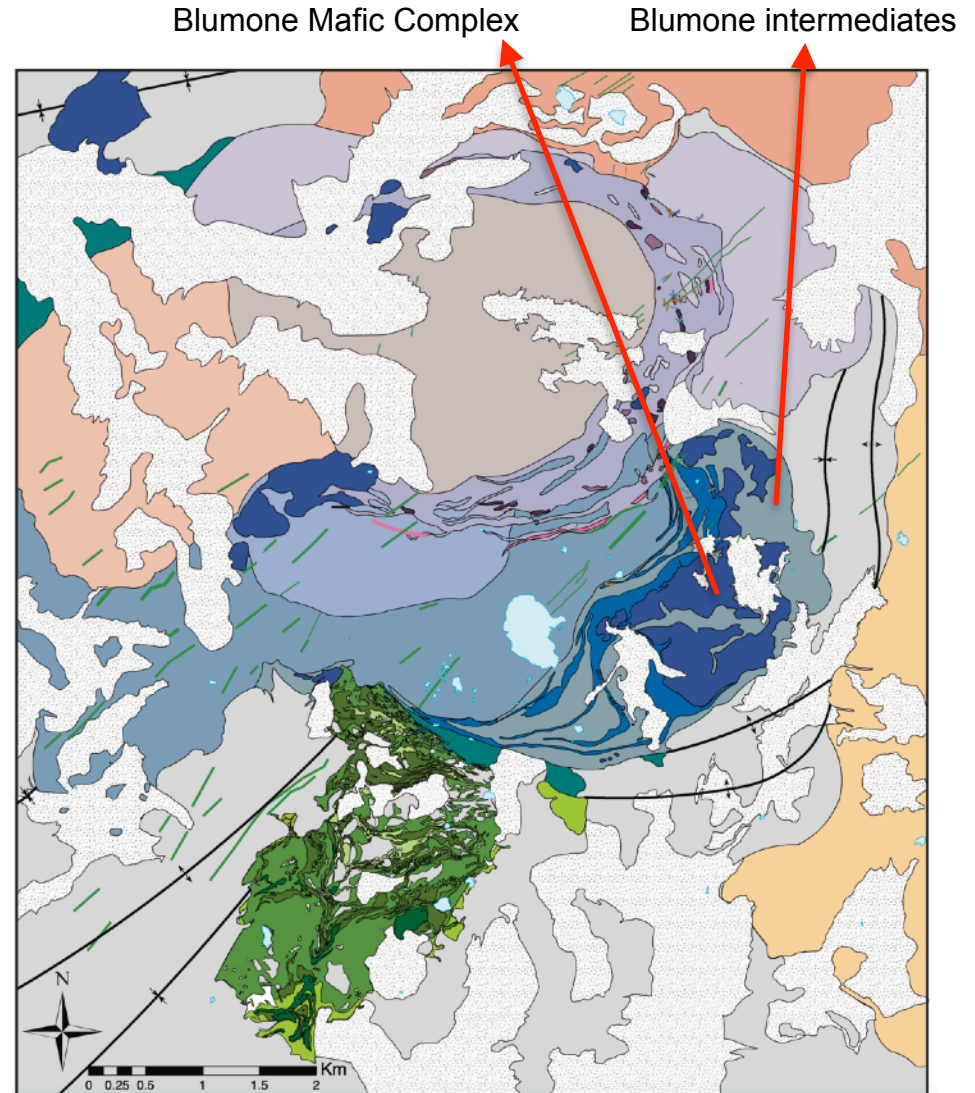


Schaltegger et al. (2019)

Verberne (2013)

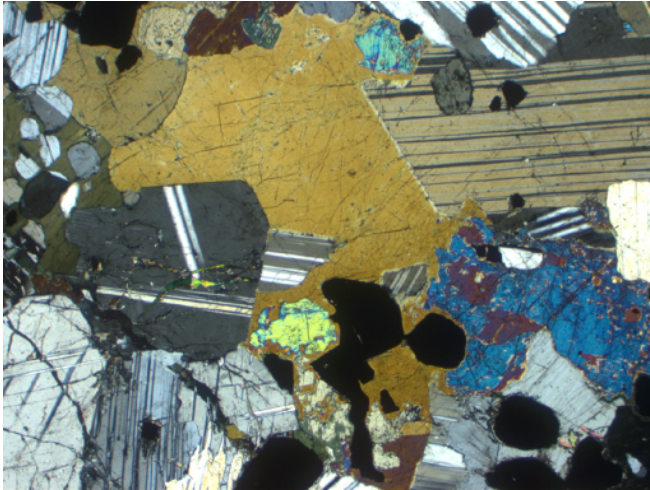
The Blumone Mafic Complex

- Part of the Re di Castello Superunit
- Final crystallisation at 42.07 ± 0.04 Ma (Schoene et al., 2012)
- The Blumone mafic complex is a layered unit (not shown in map) from plag-bearing wehrlite and ol-gabbro to **amphibole gabbro**, which is the **dominant lithology** in the uppermost part.
- The Blumone intermediates range from quartz-diorites to tonalites.
- **Why is the Blumone complex the ideal case study?**
 - High altitude and relief → lack of alteration and observation of 3D structures
 - Archetype of a shallow mafic cumulate system
 - Shortly after intruded by the Blumone intermediates (the remelting trigger?)

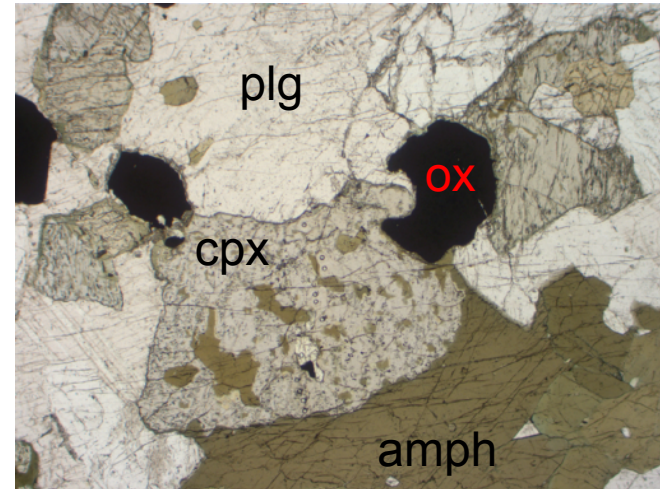


The Blumone Amphibole Gabbros

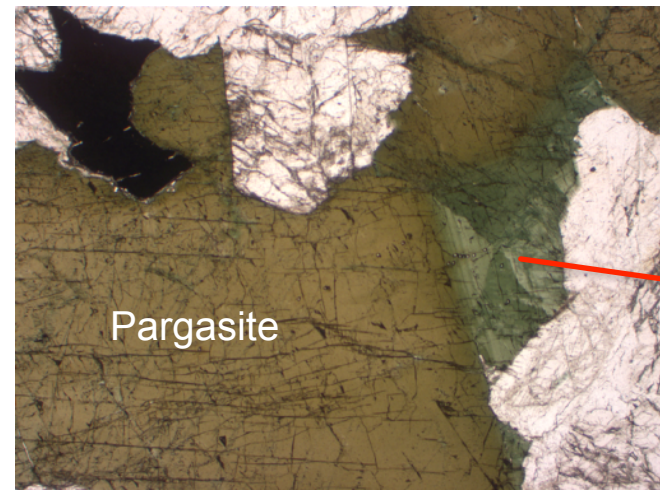
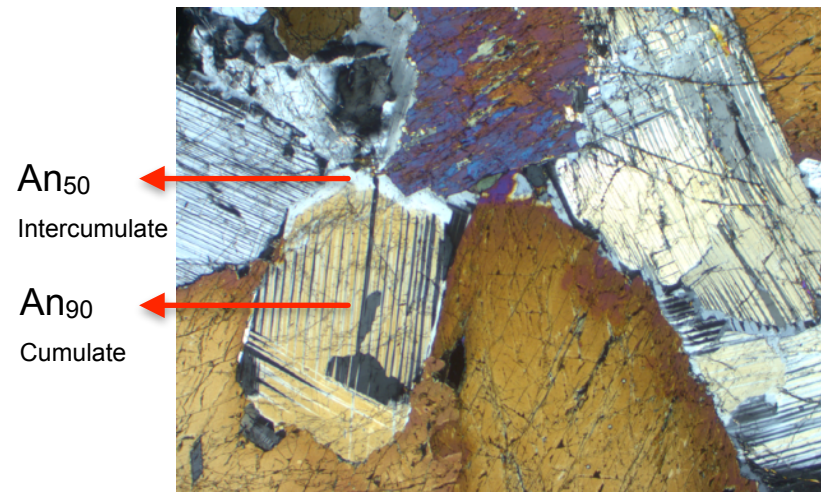
Corroded cpx and sp: peritectic crystallisation of amph



High-An plag and sp: near-liquidus phases



0.5 mm



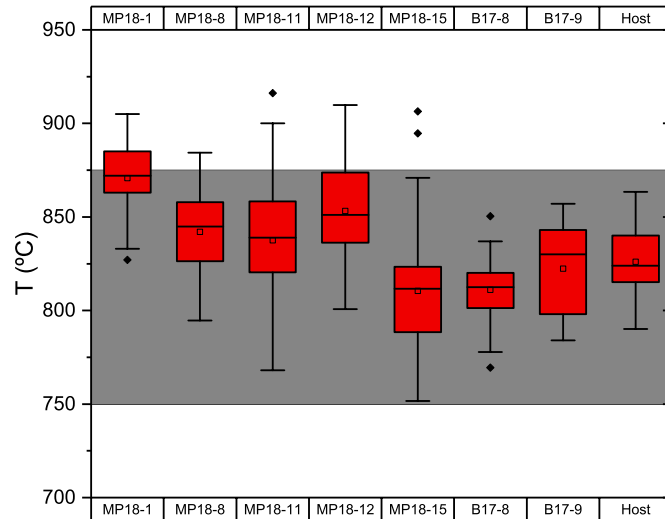
Amph: large compositional range

Exotic Dikes intruding the Blumone intermediates



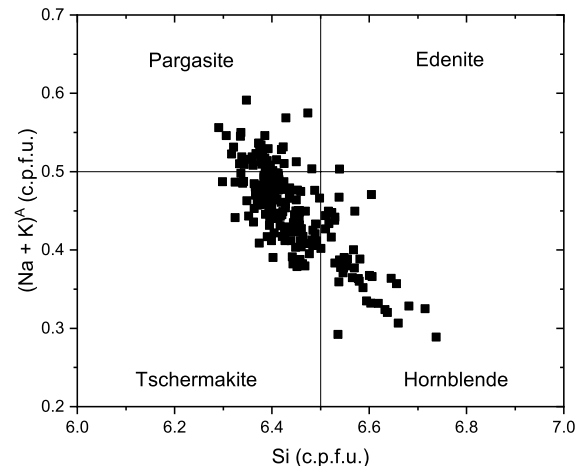
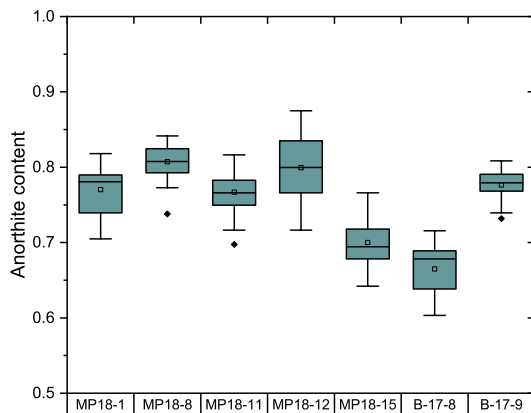
Equilibration temperatures of the exotic dykes

edenite + richterite \rightleftharpoons richterite + anorthite (Holland & Blundy, 1994)

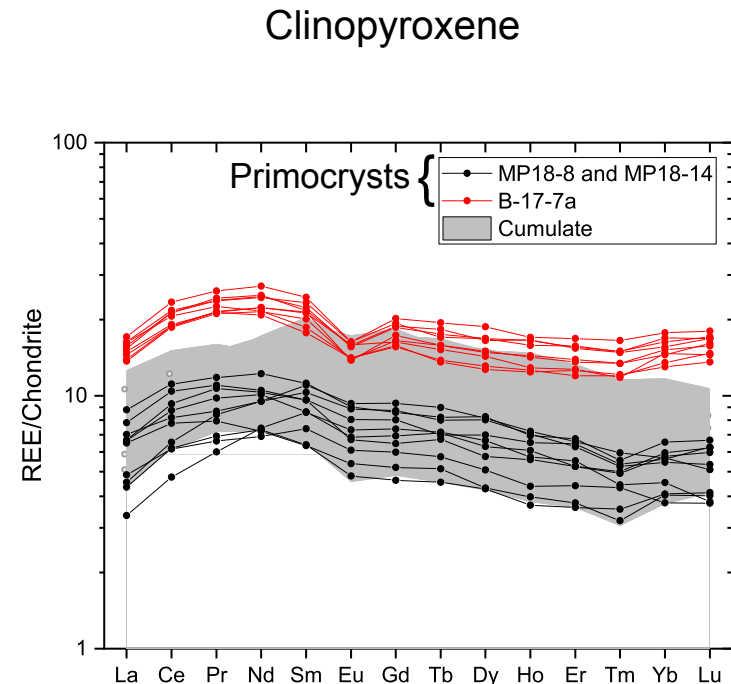
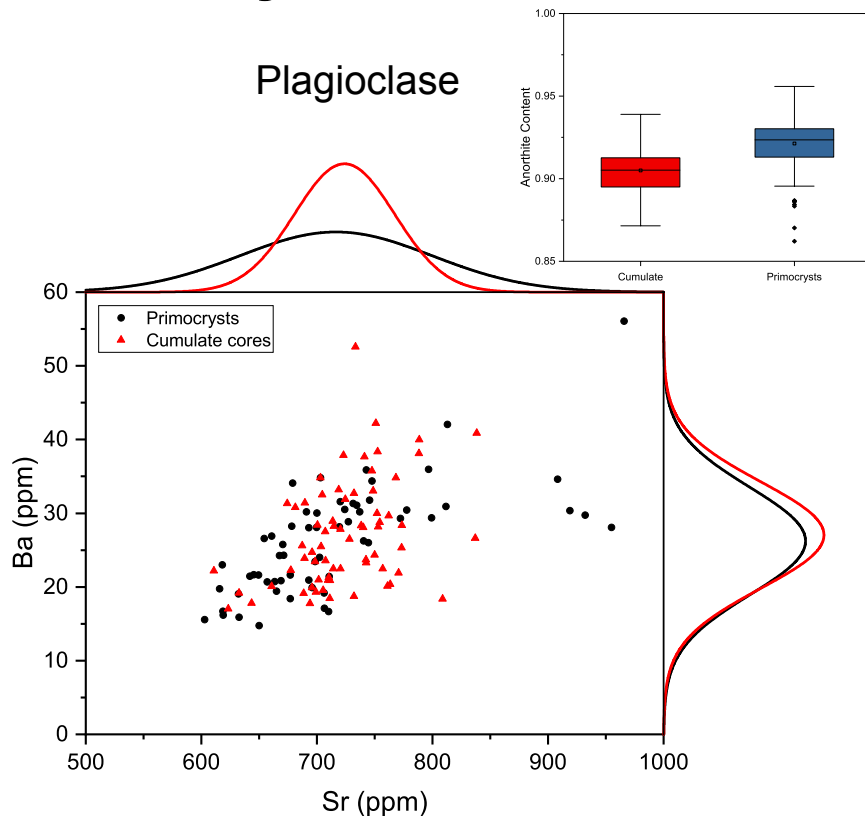


- Emplacement at brittle-ductile transition of quartz-dioritic to tonalitic system (shown in grey; Marxer & Ulmer, 2019)
- Sharp contacts are evidence of elastic behaviour upon emplacement
- Dismembering suggests warm condition
- Abundant large crystals in the dykes

Matrix composition



Primocrysts vs Cumulate Crystals

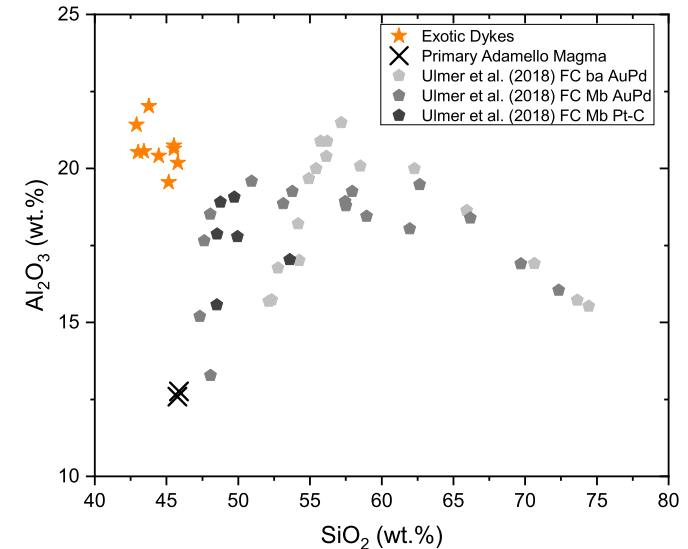


- Mineral chemistry of primocrysts displays a striking similarity to that of plagioclase and cpx present in the Blumone amphibole gabbros.
- The different trace element content of some primocrysts suggests these dikes incorporated crystals from slightly different regions of the mafic proto-cumulate.

How exotic are these dykes?

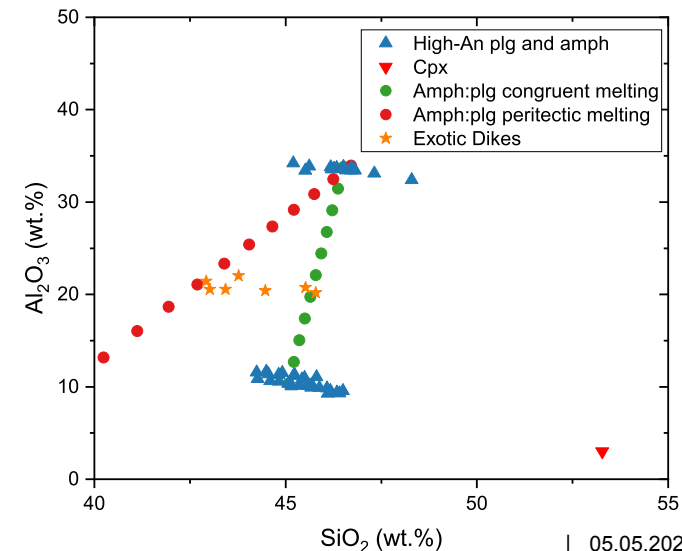
- Compositions are not consistent with a calc-alkaline LLD!
- 5 — 7.2 wt.% MgO
- 18 — 40 ppm Ni
- $x_{\text{Mg}} = 0.46 — 0.56$
- Normative nepheline

This excludes
a primary origin



The Cumulate Melting Hypothesis

- Exotic compositions can be replicated by pargasite-anorthite peritectic melting with cpx crystallisation
- Pargasite and high-An plagioclase are abundant phases in the Blumone amphibole gabbros!
- How can we test this hypothesis?



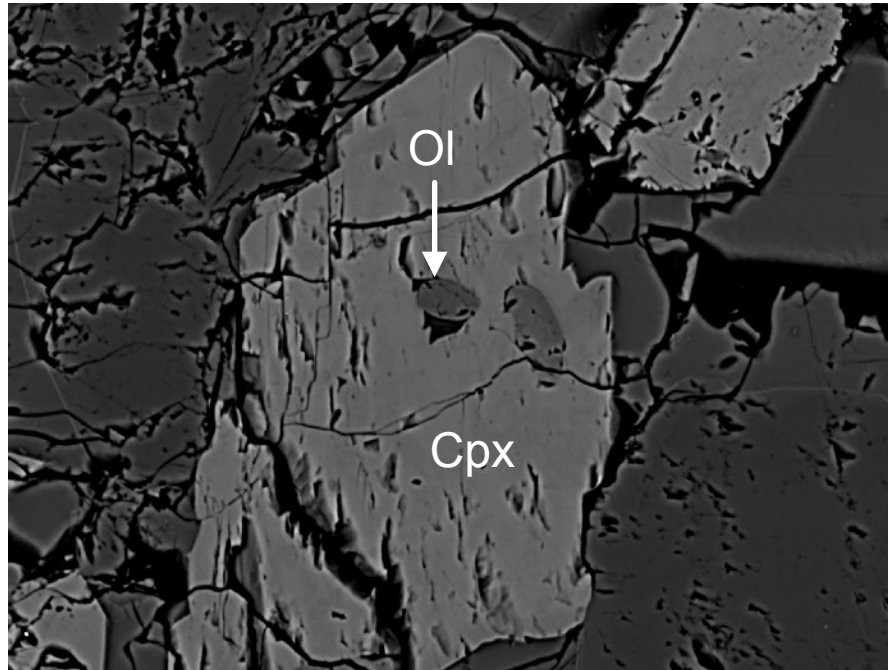
The Experimental Approach

- Externally-heated pressure vessel (*Cold Seal*)
 - $P_{\text{H}_2\text{O}} = 2 \text{ kbar}$
 - f_{O_2} at Ni-NiO (NNO)
 - 1000 to 1100 °C (25 °C step)
-
- Melting amphibole gabbroic cumulates with different cpx:amph proportion
 - Phase equilibria experiments of an exotic dyke

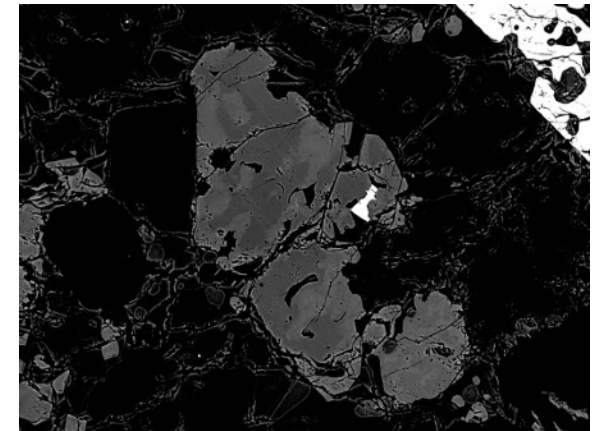


Textural Observations - Amphibole gabbro

1000°C, 48h



1025°C

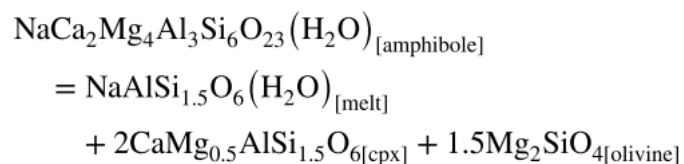


Cpx cores with Blumone-like composition are evidence of their presence in the supposedly cpx-free SM



Consistent with centimetric variability of upper Blumone cumulate assemblage

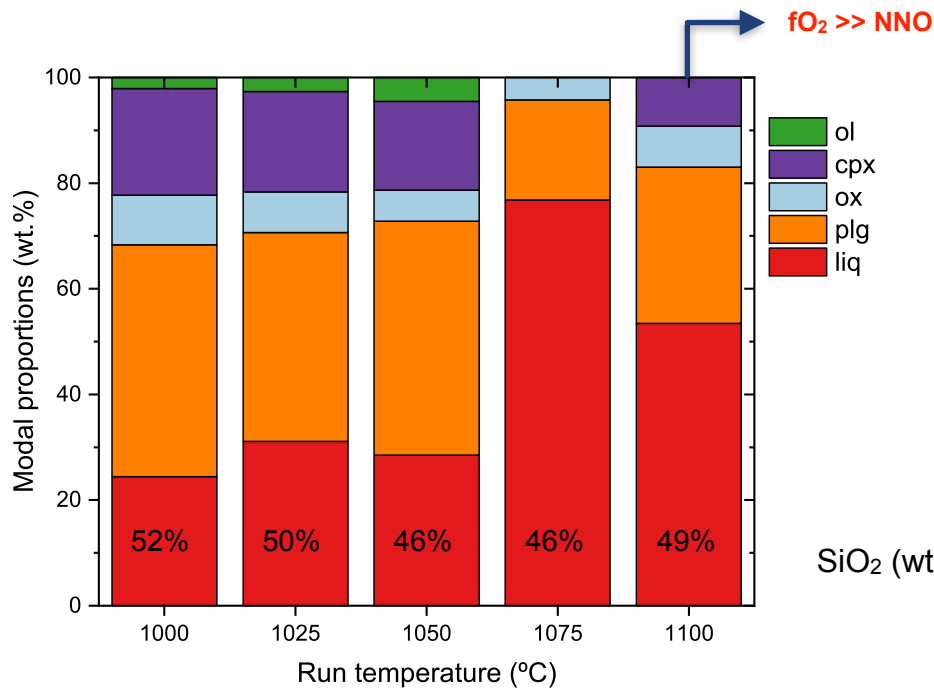
Breakdown of amphibole



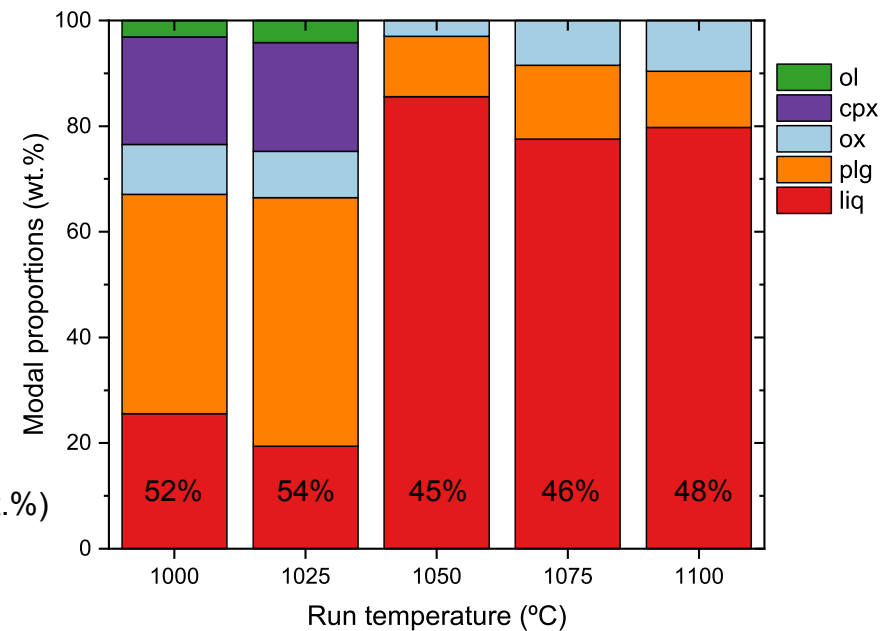
The effect of cumulate composition

t = 48h

Amph-cpx gabbro

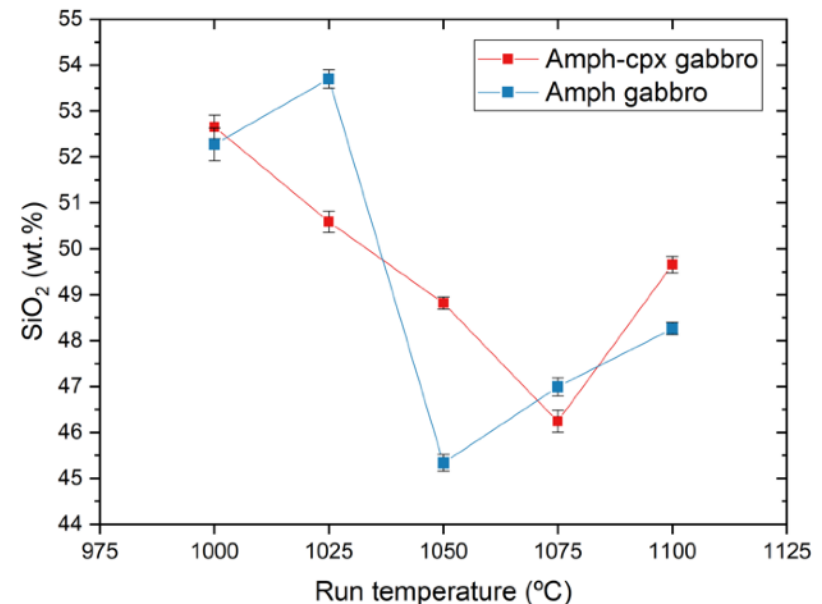


Amphibole gabbro

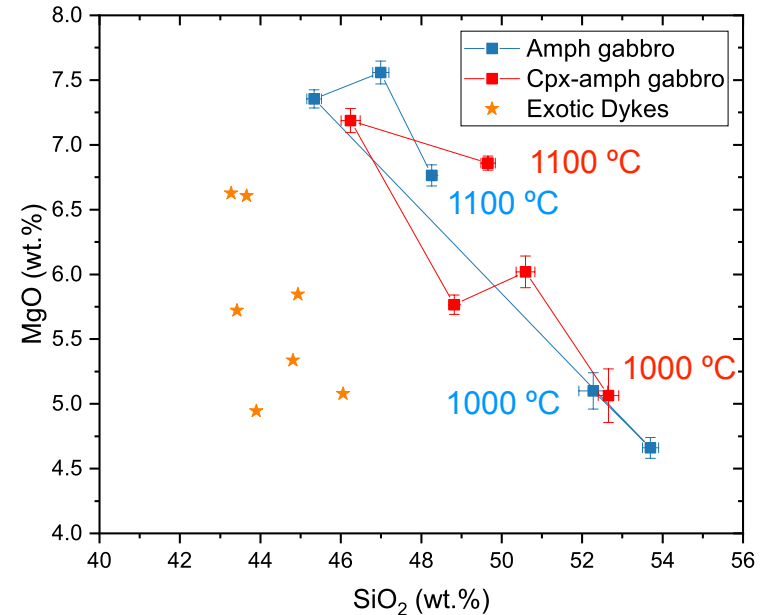
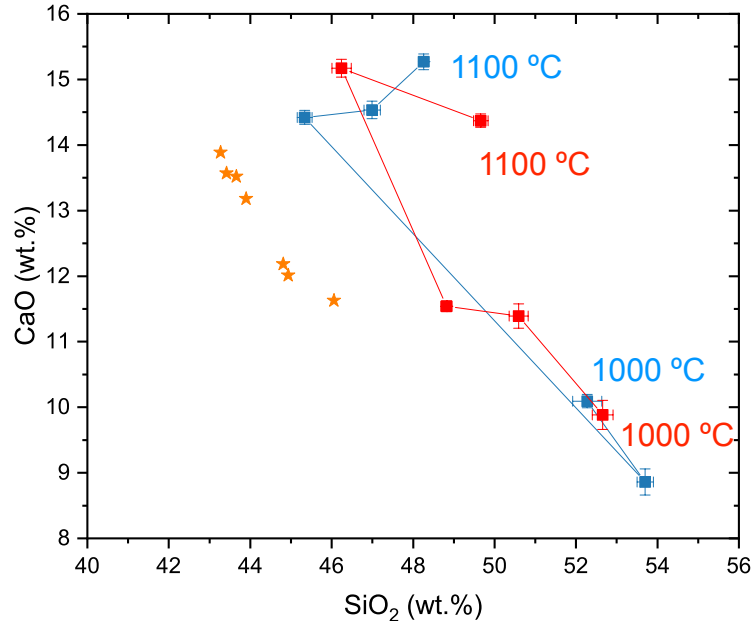


SiO₂ melt content with T

- Initial decrease with increasing T due to melting of mafic phases
 - This is especially evident upon cp-ol exhaustion in the amphibole gabbro
 - Later increase due to stabilisation of Mg-spinel and relative SiO₂ enrichment in the melt
- ↓
- Consequence of higher fO_2 due to high T and run duration (48 h) that promote **H₂ diffusion** out of the capsule

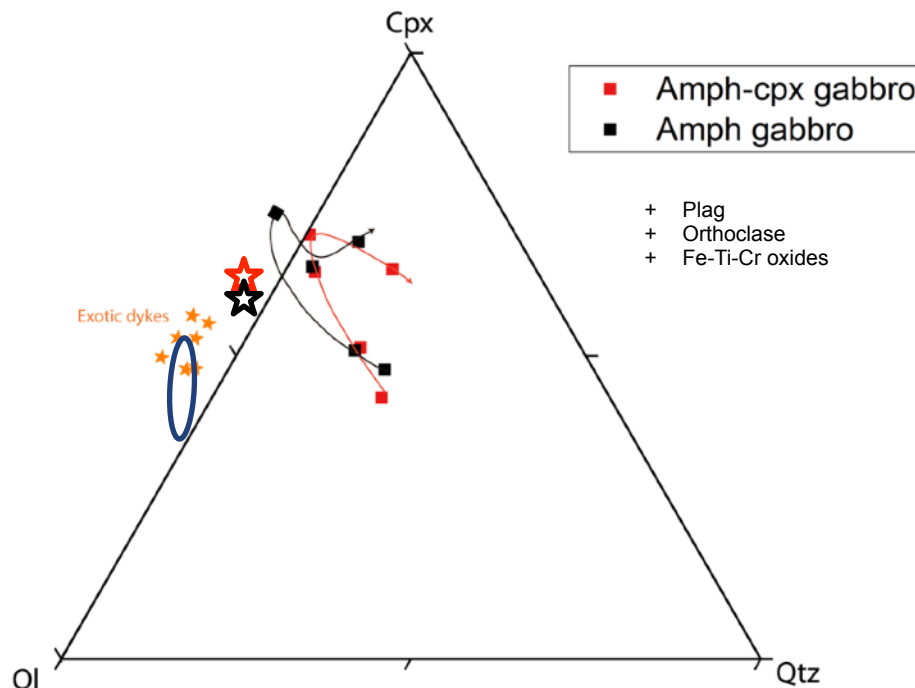


Experimental Harker Diagrams



- Initial increase of CaO and MgO → ol+cpx melting and decrease in plag fraction
- Decrease of CaO and MgO at 1100 °C → stabilisation of cpx and Mg-spinel ↔
↑ **fO₂**
- Experimental melt composition trends are **parallel** to that of the exotic dykes!

Pseudo-ternary Ol-Cpx-Qz diagram



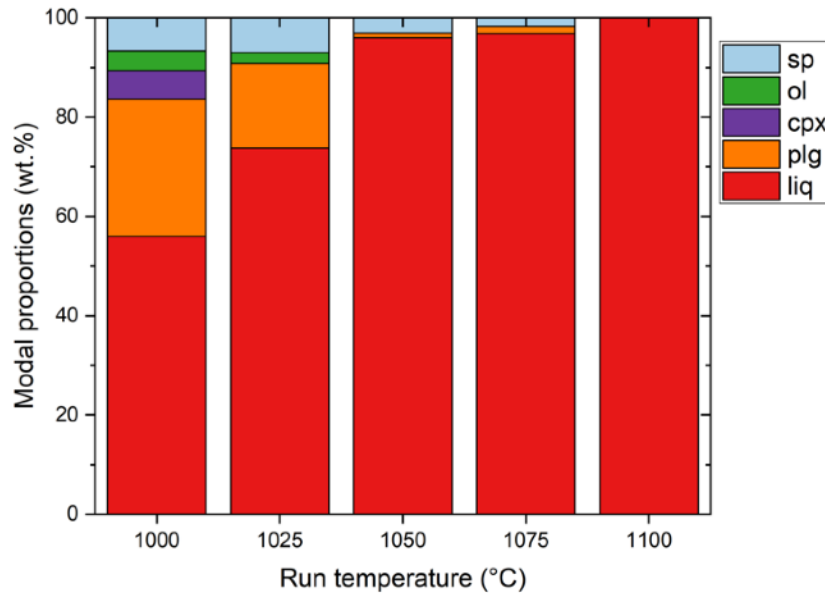
After Grove et al. (1992), Grove (1993)

- Cotectic melting of mafic phases drives liquid to **lower normative quartz compositions**
- Increase at higher temperature: consequence of higher fraction of spinel
- Natural starting materials do not represent a proto-cumulate → these experiments simulate **remelting from subsolidus** rather than from a **partially crystallised state!**

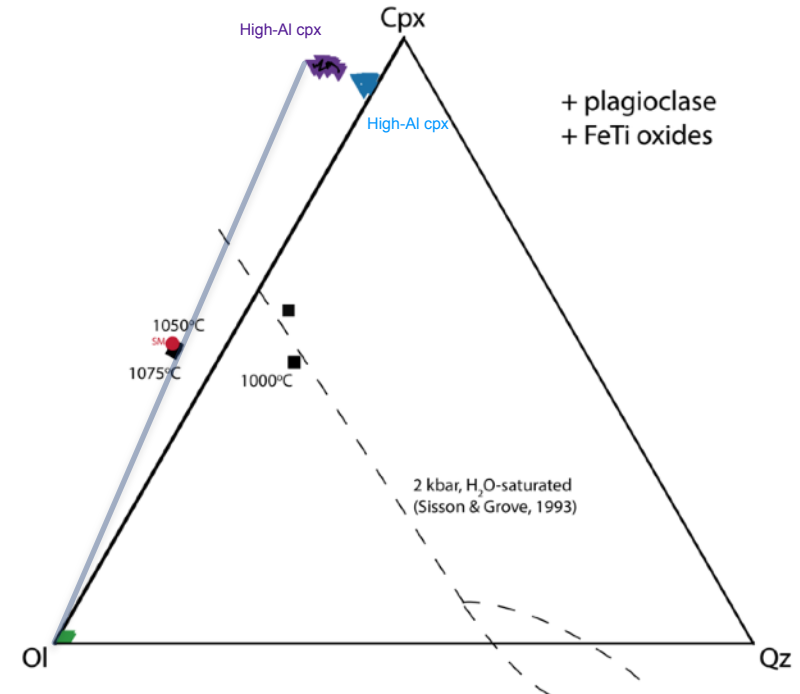
- ★ Natural cumulate samples used as starting material
- Modeled range of proto-cumulates

Phase Equilibria of the Exotic Dykes

Phase Proportions



Pseudo-ternary ol-cpx-qz diagram



- Sp and plag as near-liquidus phases
- Ol-cpx tie-line is collinear with the high-variance experiments
- This shows the maximum extent of melting of a shallow amphibole gabbroic cumulate

Conclusions and further work

- The Exotic Dykes
 - Composition cannot be reproduced by a calc-alkaline LLD.
 - Emplaced at the brittle-ductile transition of the host quartz-diorites → **while the system was active!**
 - Entrained portions of the mafic mush → evidence for **physical interaction**
- Experimental Approach
 - Some methodological problems: natural starting material, experimental fO_2
 - Cotectic cpx-ol relationships play a major role in decreasing SiO_2 saturation
 - Cumulate melting and saturation experiments display the **same near-liquidus assemblages!**
 - Cotectic melting occurs at a similar temperature to that of a **basaltic-andesite to andesite liquidus!** → Blumone intermediates...
 - These preliminary results, despite the experimental problems, show that there is a **petrogenetic link** between the exotic dykes and mafic cumulate remelting.

Thank you for your attendance!



References

- Grove, T. L. (1993). Corrections to expressions for calculating mineral components in “Origin of calc-alkaline series lavas at medicine lake volcano by fractionation, assimilation and mixing” and “Experimental petrology of normal MORB near the kane fracture zone: 22°-25° N, mid-atlantic ridge”. *Contributions to Mineralogy and Petrology*, 114(3), 422-424.
- Grove, T. L., Kinzler, R. J., & Bryan, W. B. (1992). Fractionation of mid-ocean ridge basalt (MORB). *Mantle flow and melt generation at mid-ocean ridges*, 71, 281-310.
- Marxer, F., & Ulmer, P. (2019). Crystallisation and zircon saturation of calc-alkaline tonalite from the Adamello Batholith at upper crustal conditions: an experimental study. *Contributions to Mineralogy and Petrology*, 174(10), 84.
- Schaltegger, U., Nowak, A., Ulianov, A., Fisher, C. M., Gerdes, A., Spikings, R., ... & Vervoort, J. D. (2019). Zircon Petrochronology and $^{40}\text{Ar}/^{39}\text{Ar}$ Thermochronology of the Adamello Intrusive Suite, N. Italy: Monitoring the Growth and Decay of an Incrementally Assembled Magmatic System. *Journal of Petrology*, 60(4), 701-722.
- Verberne, R. (2013). *The role of magma rheology during emplacement of the Listino Suite, Adamello Massif, Italy* (Doctoral dissertation, Université de Lausanne, Faculté des géosciences et de l'environnement).
- Wolff, J. A., Ellis, B. S., Ramos, F. C., Starkel, W. A., Boroughs, S., Olin, P. H., & Bachmann, O. (2015). Remelting of cumulates as a process for producing chemical zoning in silicic tuffs: A comparison of cool, wet and hot, dry rhyolitic magma systems. *Lithos*, 236, 275-286.