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Production and Preservation of Small Volume Rhyolitic Melts in the Midst of a Continental Arc Flare-up - The Caspana Ignimbrite of the Altiplano-Puna Volcanic Complex of the Central Andes

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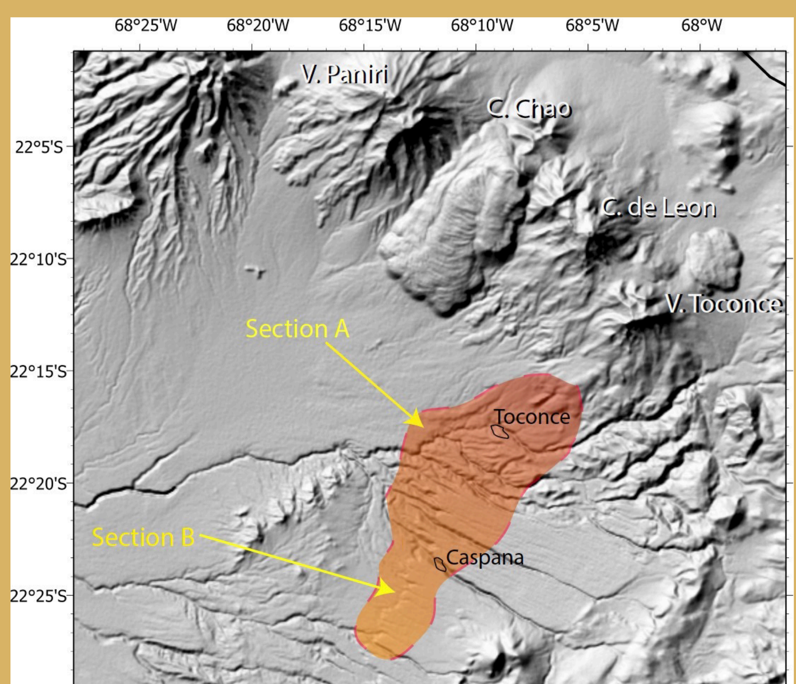
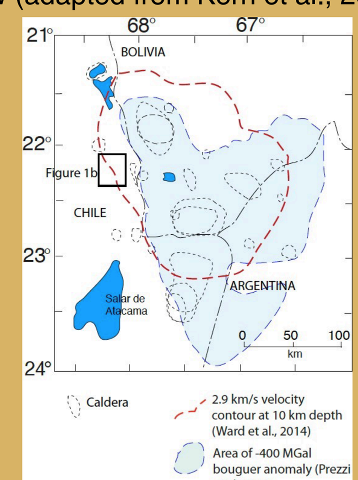
Introduction and Geologic Setting

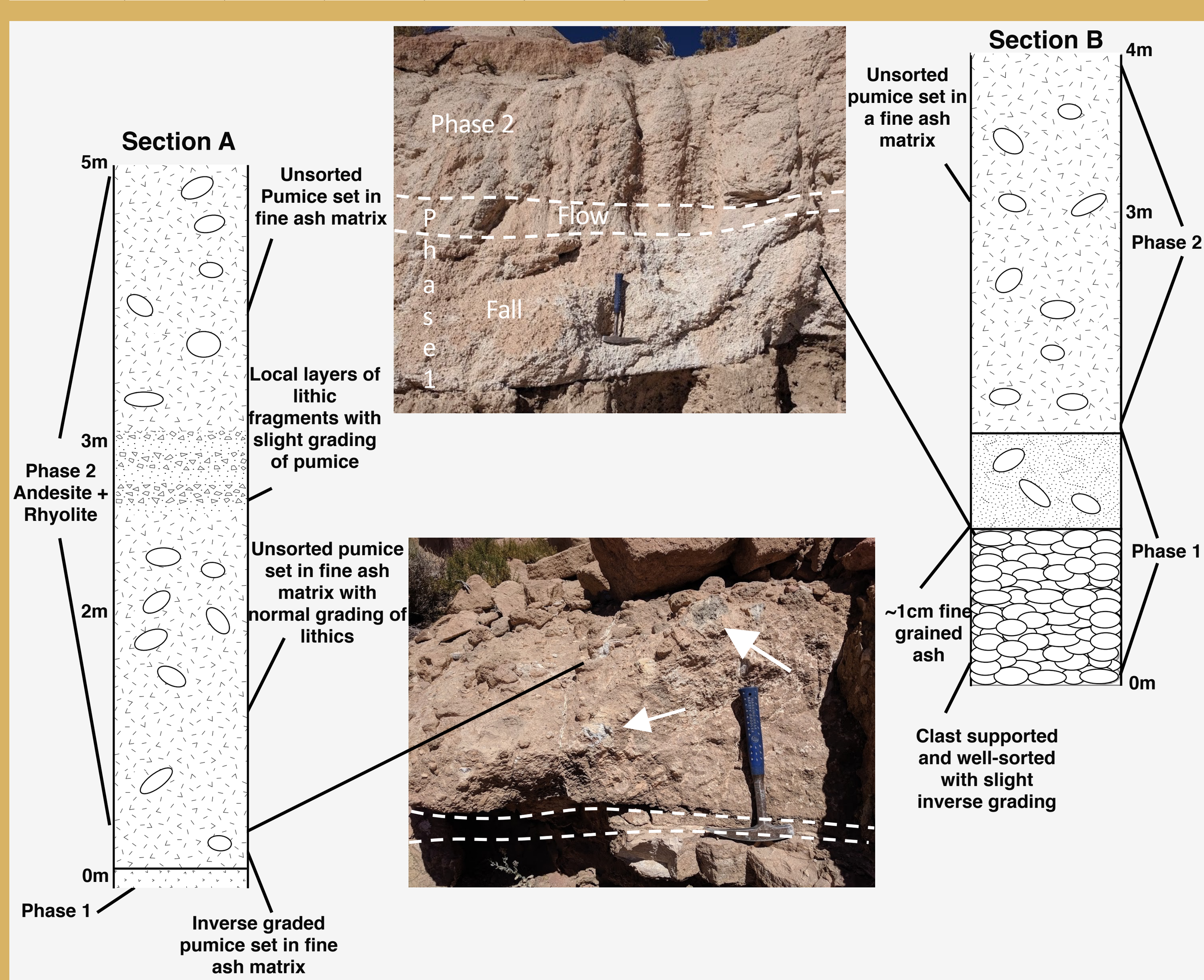
- **Flare-up magmatism is characterized by monotonous bulk rock compositions resulting from pre-eruptive homogenization. The Altiplano-Puna Volcanic Complex (APVC) of the Central Andes is a marked example of this (de Silva et al., 2006).**
- **Most of the ignimbrites in the APVC are large volume dacites with only a minor component of non-dacitic compositions. These were thermally sustained and recharged by a midcrustal batholith known as the Altiplano-Puna Magma Body (APMB; de Silva, 2008).**

- **Contrasting the montonous intermediates in the APVC is the ~5km^3 Caspana ignimbrite at the margins of the APVC.**
- **The occurrence of one andesite and two distinct rhyolites in this ignmbrite is of great interest for the development of compositional gaps and may illuminate the processes occuring in large silicic systems.**



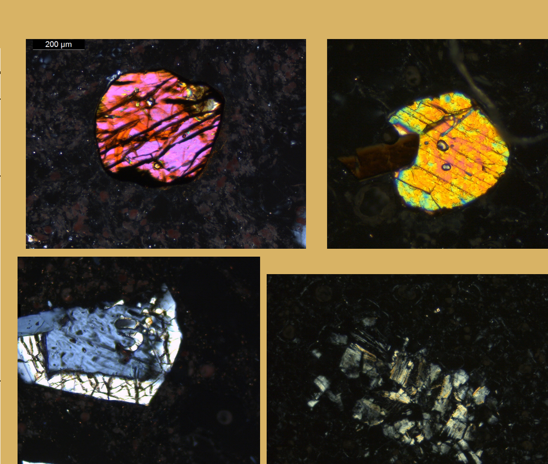


A generalized map showing the distribution of the Caspana Ignimbrite at the edge of the APVC. The stratigraphic sections below correspond to the points with arrows. The perimeter is shown in the reigonal map below (adapted from Kern et al., 2016).

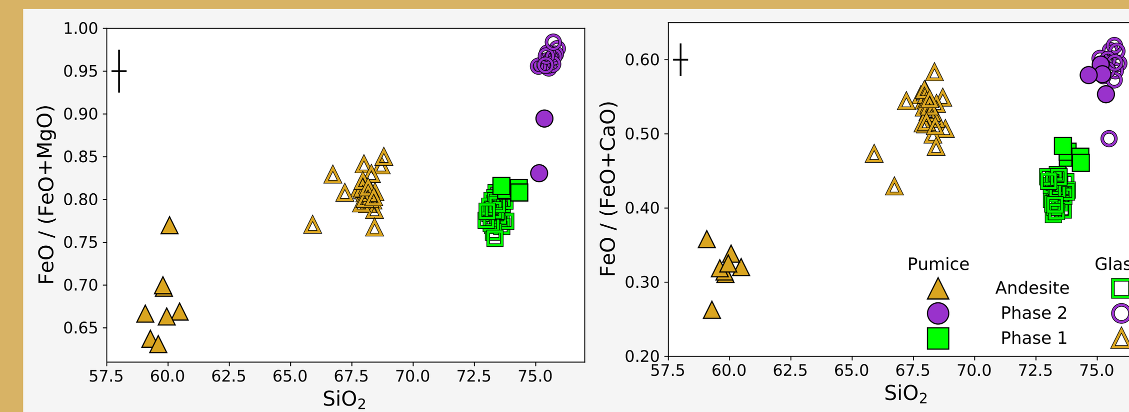


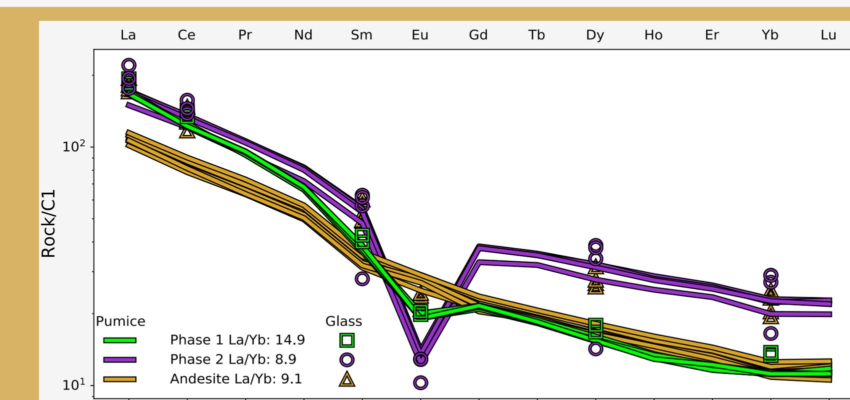
Questions that drive this study:
1) The mechanism responsible for creating the compostional gap 2) The unique phase assemblages and 3) The compositional heterogeneity

Petrographic features of Caspana pumice				Regional Norm
Rock	Andesite	Phase 2 Rhyolite	Phase 1 Rhyolite	Dacite
Crystallinity	25-45%	1-5%	0-2%	35-50
Vesicularity	40-50%	50-60%	50-60%	35-50
Groundmass	20-30%	35-45%	40-50%	25-55
Phases	Plag (75-80%) Orthopyroxene (15-20%) Oxides (1-5%) Apatite(1%) Amphibole (tr)	Plag (80%) Biotite (10%) Fayalite (5%) Oxides (3%) Allanite (tr) Apatite (tr) Zircon (tr) Quartz (tr)	Plag (>95%) Apatite (tr) Zircon (tr) Muscovite (tr) Titanite (tr)	Plag Dominant Cpx > Opx Amphibole FeTi Oxides +/- Biotite +/- Sanidine Zircon (tr) Apatite (tr)
Other Features	Ilm > Mag Plag + Opx + Ox Gloms (G2 - 5-10%) Plag gloms (G1 - 15%)	Ilm > Mag Allanite ~225 um	Mag > Ilm Xenoliths present	Mag > Ilm Cognate Enclaves

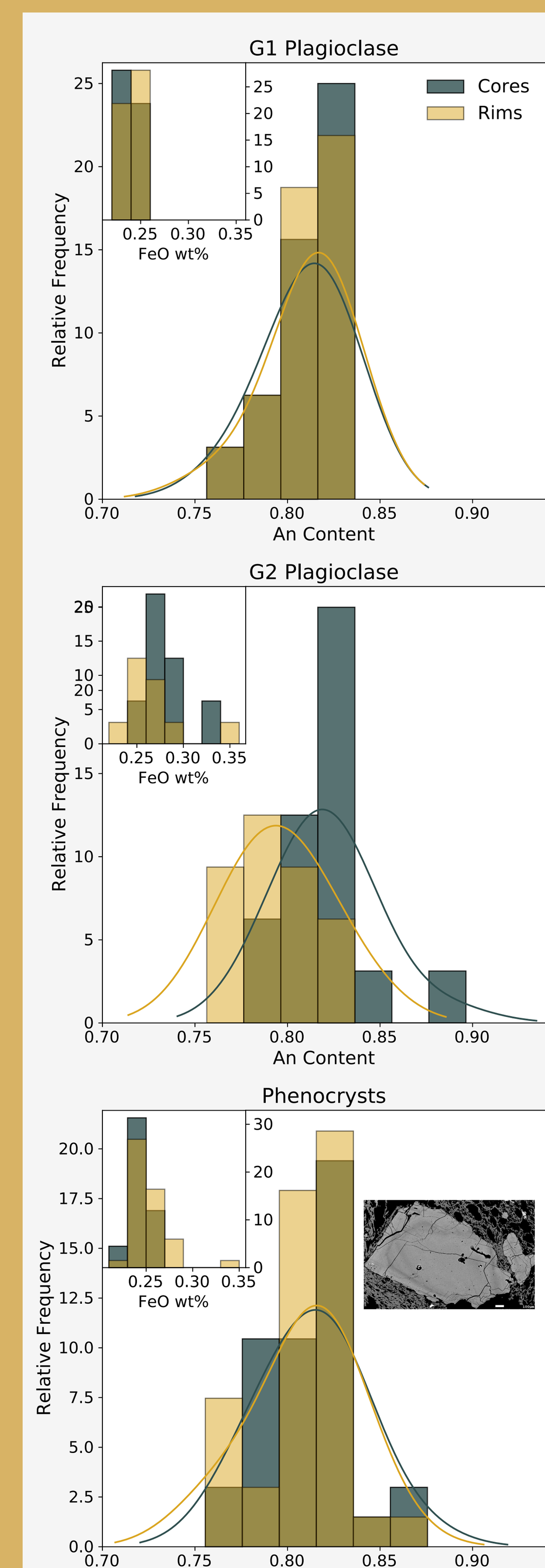


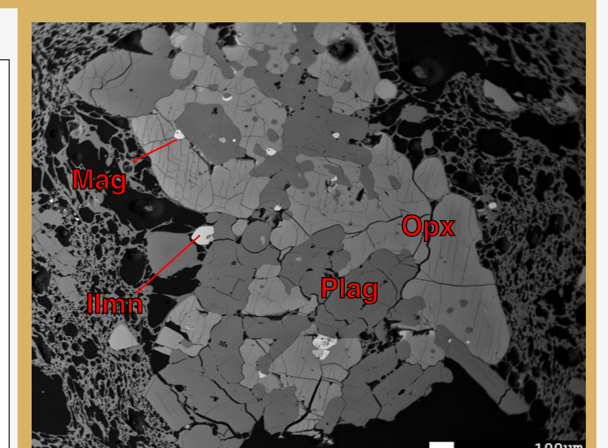
Results

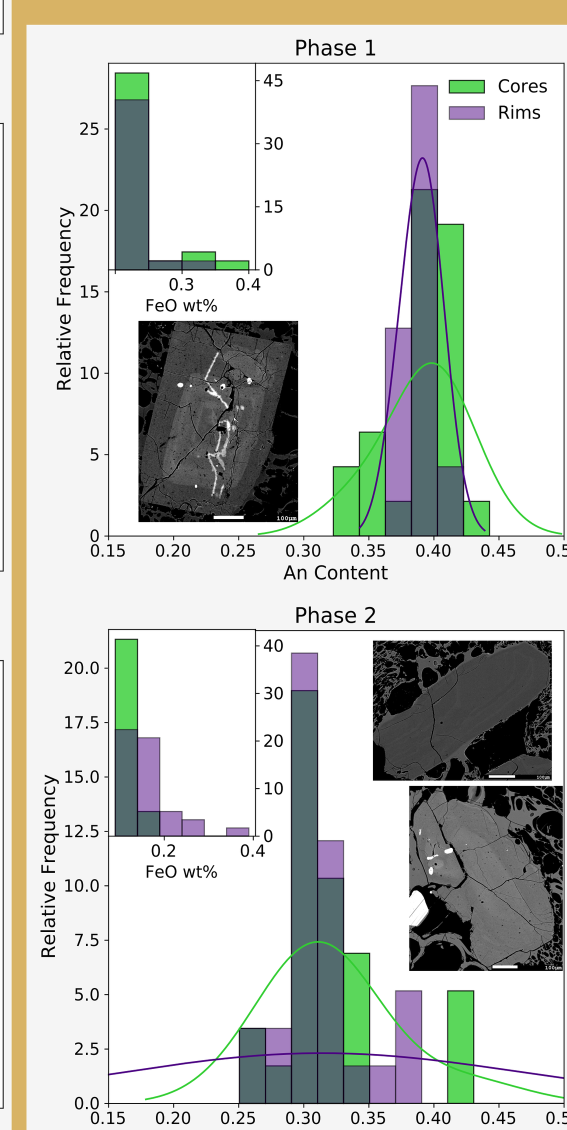


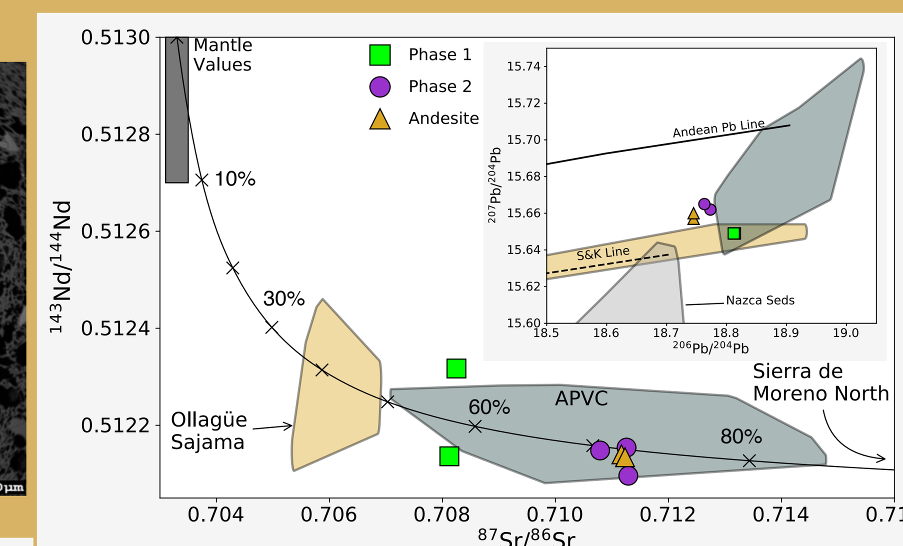


- Major and trace elements of glomerocrysts in the andesite are consistent with simple lever principle that drives andesitic bulk rock to the corresponding matrix glass and phase 2 rhyolite. The Phase 1 rhyolite is not on trend with andesite and Phase 2 rhyolite.
- Phase 2 rhyolite bulk rock and glass compositions are in agreement with the high Fe/Ca and Fe/Mg that is responsible for fayalite staiblity (Warshaw and Smith, 1988; Mysen et al., 1982, 1984).
- Andesite and Phase 2 rhyolite have nearly invariant isotopic composition. Phase 1 rhyolite is less radiogenic and does not represent assimilated basement based on Pb isotopes

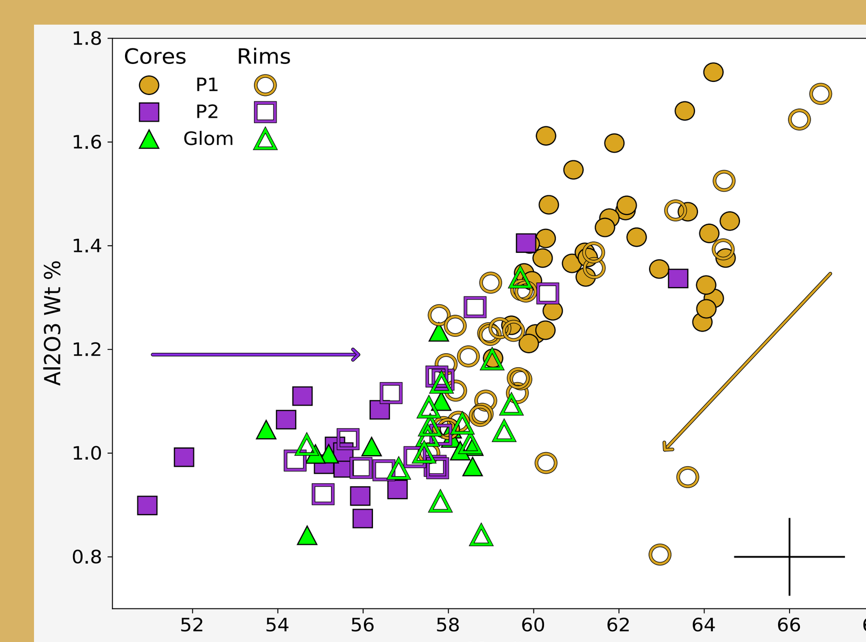


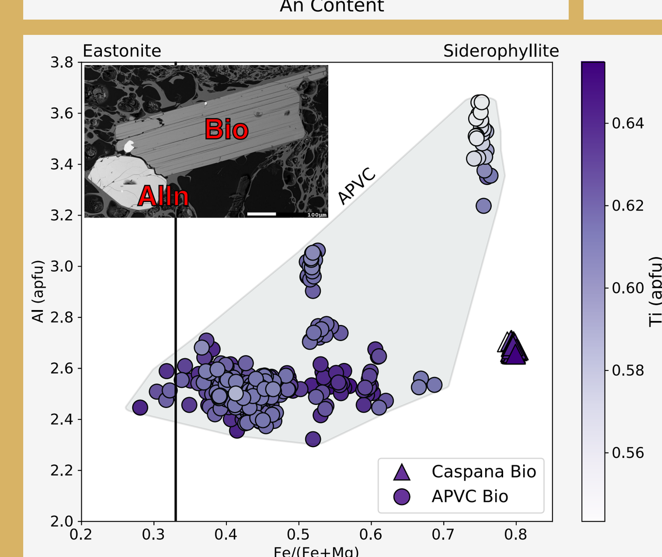




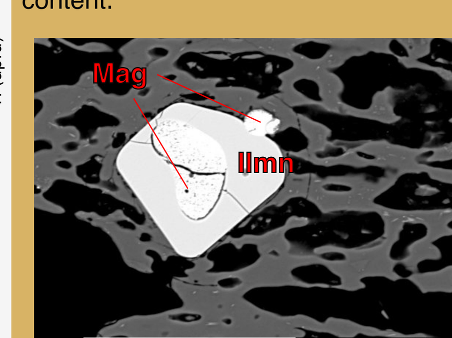


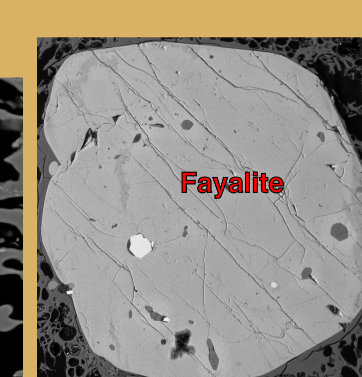
- **Phase 2 Phenocrysts:** Two populations: 1. High An overlapping with andesite. 2. Low An with two subpopulations. Rims are right skewed in FeO.
- **Phase 1 Phenocrysts**: Very tight An distribution. Peculiar unmixing texture.
- **G1 Plag:** Tight distributions and low FeO.
- **G2 Plag:** Wide distributions. Rim An and FeO is offset relative to cores.
- **Andesite Phenocrysts:** Normal distributions and right skewed FeO.
- **Opx:** Two populations of phenocrysts. First is high Mg# and is correlative with Al_2O_3. Second is lower MgO and has no correlation with Al_2O_3. Rims converge towards G2 glomerocrysts.





Bio: Fe content is high and similar to another highly evolved rhyolite in the region. This clearly reflects bulk rock composition and fractionation of Ca and Mg rich minerals. Caspana biotite differs in its notably high Ti content.



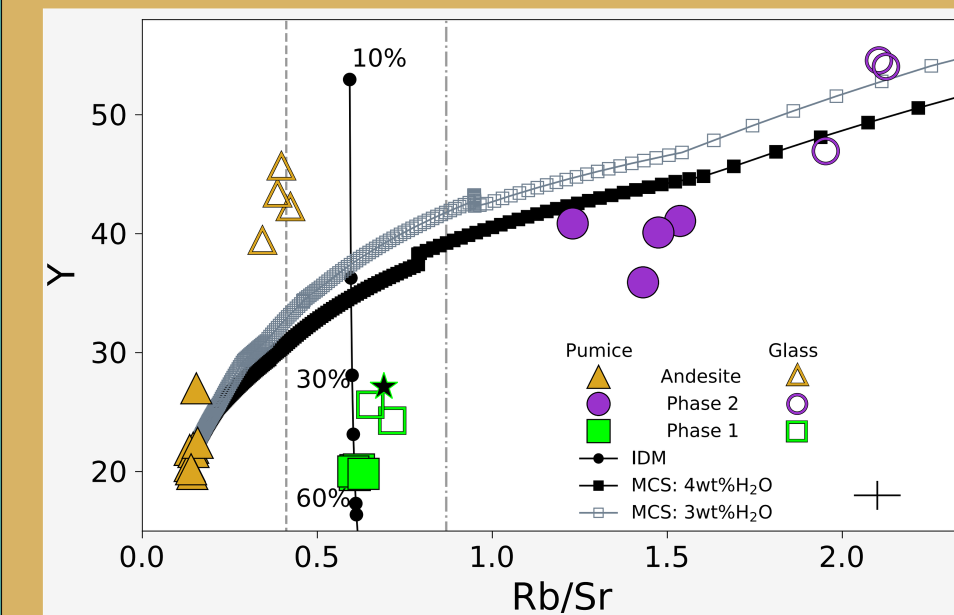


PTX: Note the water contents are typical of arc magma with low fO_2. Temperature of Phase 2 rhyolite shows 'hot' fayalite rhyolite

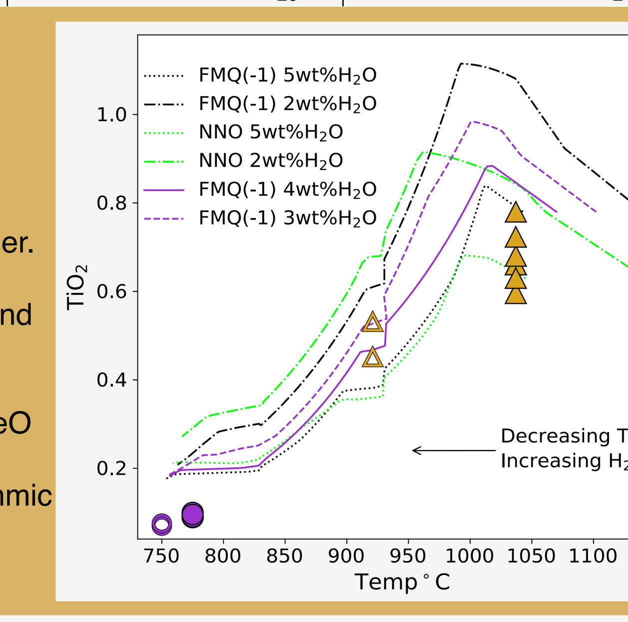
PTX Conditions	P (MPa)	T (°C) Est.	H_2O(wt%)	Δ FMQ
Andesite	400[1]	930[1]	4[2]	≤ FMQ[5]
Phase 2	200[3]	775[4]	5.1[2]	-1[4]
Phase 1	200?	870[1]	4.1[2]	-

1. Putirka (2017), 2. Waters & Lange (2015), 3. Gualda & Ghiorso (2014), 4. Ghiorso and Evans (2008), 5. Blatter & Carmichael (2001)

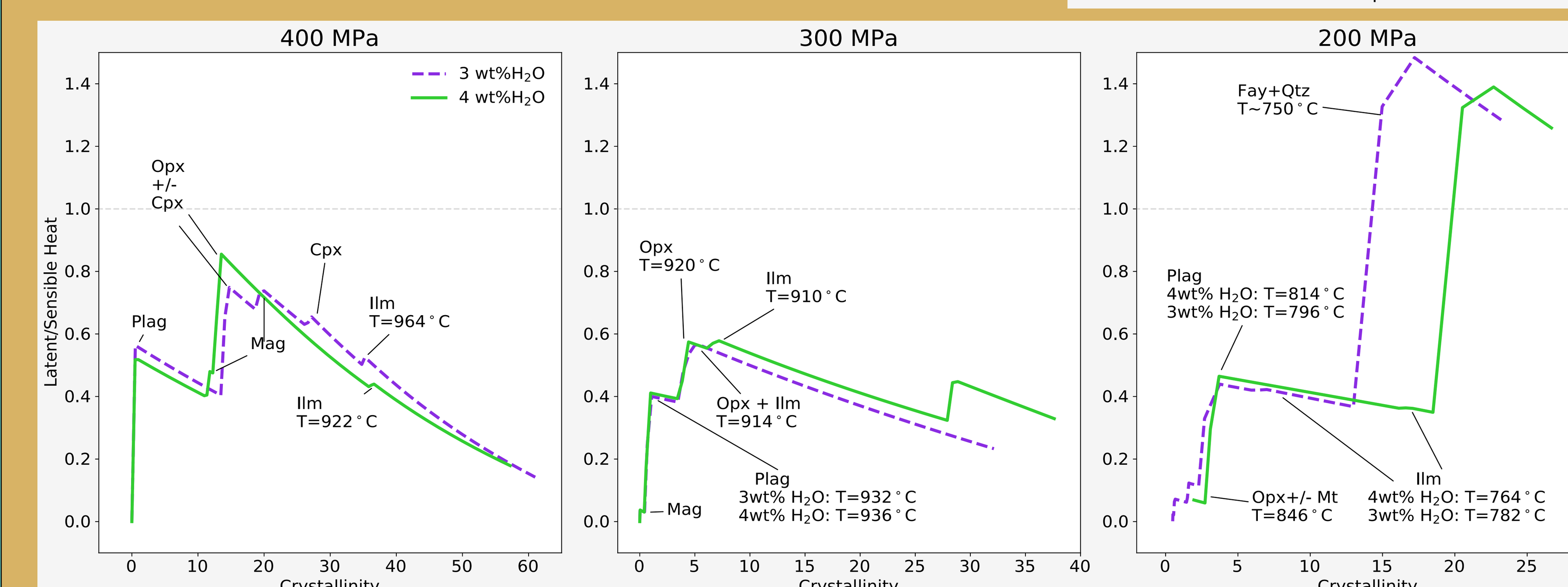
Modelling and Conclusions



Modal Percentages from r-MELTS Outputs						
H_2O	3 wt%			4 wt%		
r-MELTS version	1.2	1.2	1.1	1.2	1.2	1.1
P (MPa)	400	300	200	400	300	200
T start	1100	950	856	1100	980	846
T End	760	750	740	760	748	740
T increment	2	2	2	2	2	2
T stop*	930.15	830.22	-	929.92	830.92	-
fO_2	ΔFMQ (-1)	ΔFMQ (-1)	ΔFMQ (-1)	ΔFMQ (-1)	ΔFMQ (-1)	ΔFMQ (-1)
Plag	78	78	35	75	77	43
Mag	2	4	1	2	3	1
Opx	17	16	3	16	18	6
Cpx	3	-	1	7	-	-
Ilm	1	3	0	-	2	0
Fay	-	-	1	-	-	1
Qtz	-	-	32	-	-	28
San	-	-	26	-	-	21



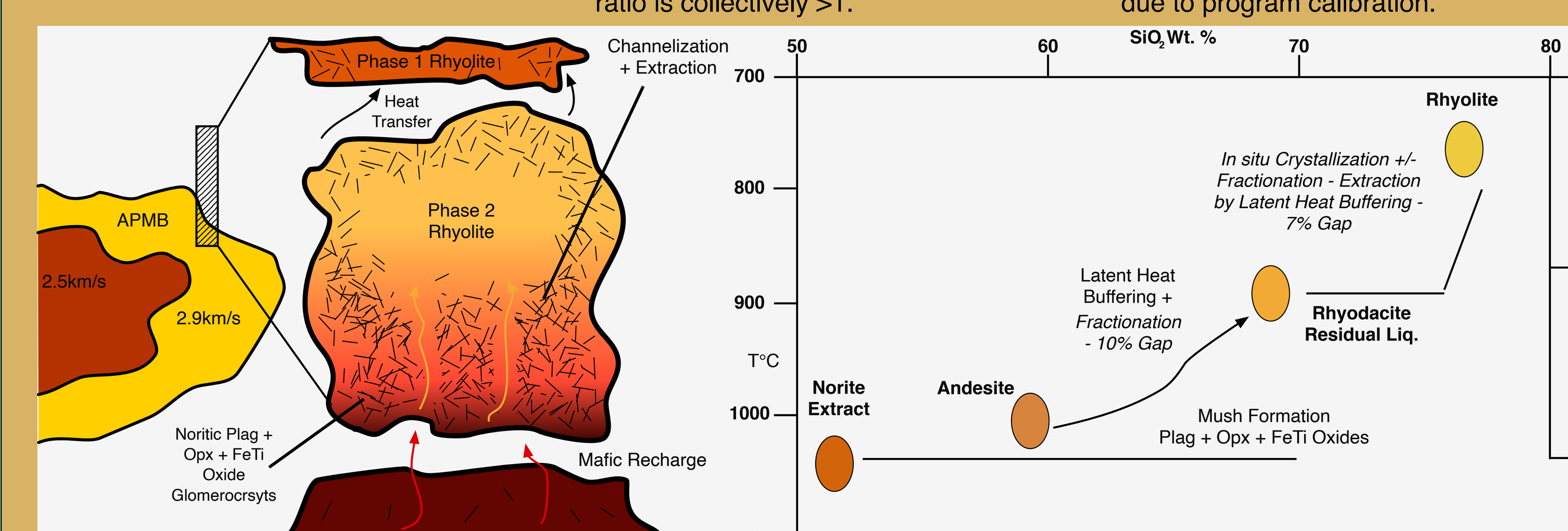
- The andesite and Phase 2 rhyolite are nearly perfectly fractionated from one another. Magma Chamber Simulator models (Bohrson et al., 2020) model this well and reproduce the crystallization sequence. The best fractionation model is ΔFMQ(-1) and 3-4 wt% H_2O in the andesite.
- With increasing differentiation and water content increases, Fe^{3+}/Fe^{tot} variation changes due to crystallization and the dominant oxide, as tracked by plagioclase FeO content. This results in a water rich, fayalite rhyolite.
- The Phase 1 rhyolite has geochemistry typical of APVC magmas. Incongruent dynamic melting (IDM) models (Zou and Reid (2001) were used to model the Phase 1 compostion as a recycled granodiorite from an earlier phase of the flare-up.



400 MPa: No latent heat spike >1. Ilmenite has a small spike between 964-922 °C and 35-38% crystallinity.

300MPa: Opx and ilmenite turn on at 920-910°C, approximately ilmenite crystallization at 400MPa. The latent heat ratio is collectively >1.

200MPa: Fayalite and quartz turn on at 200MPa and ~750°C, in disagreement with observed T. Discordant T is likely due to program calibration.



Conclusions: 1) In situ crystallization +/- fractionation, followed by melt extraction facilitated the compositional gap.
2) The unique phase assemblage is facilitated by low fO_2 and high H_2O. Fayalite is the result of this petrologic environment and crystallization of Ca and Mg rich minerals in the parent melt that increased Fe indices.
3) Phase 1 is a crustal melt of a granodiorite or tonalite associated with earlier flare-up magmatism.
4) Heterogeneity between fractionates and would-be assimilants is preserved due to the low V system (de Silva and Wolff, 1996), high thermal contrast away from the thermally primed central APMB (de Silva and Gregg, 2014; de Silva and Gosnold, 2014), and the crystal poor nature of the extracted rhyolite that did not need thorough pre-eruptive homogenization (Gualda and Pamukcu 2010; Huber et al., 2012).