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Shifting eruption dynamics: Constraints from mineral chemistry and plagioclase-hosted melt inclusions at Santiaguito volcanic dome complex, Guatemala

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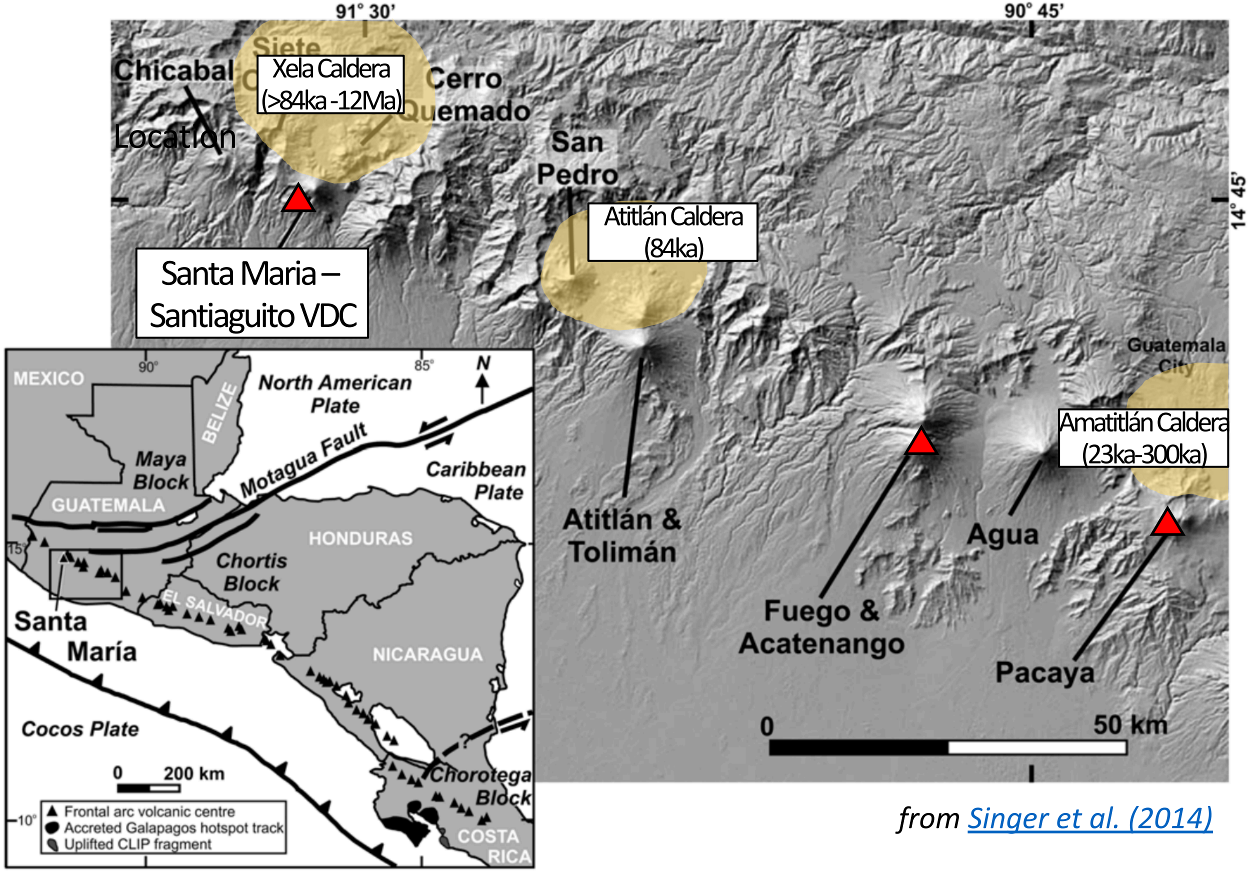
Santa María – Santiaguito Volcanic Dome Complex (VDC)

Santiaguito VDC is one of three currently erupting volcanic center in Guatemala.

Santiaguito VDC is the youngest part of Santa María volcano.

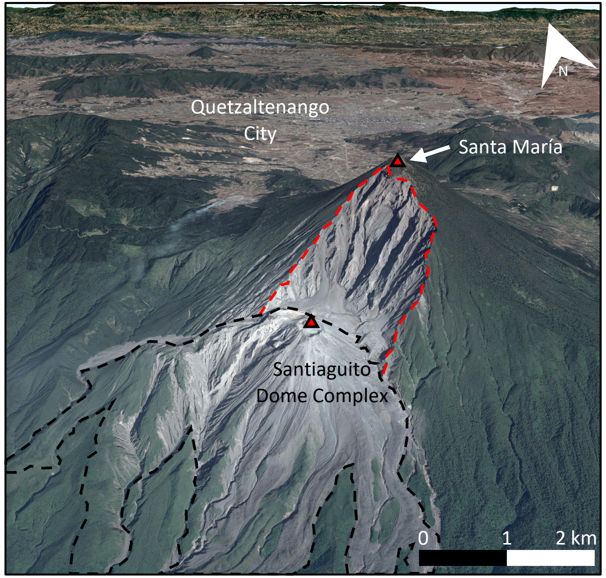
Santiaguito VDC is located on the western part of the volcanic front.

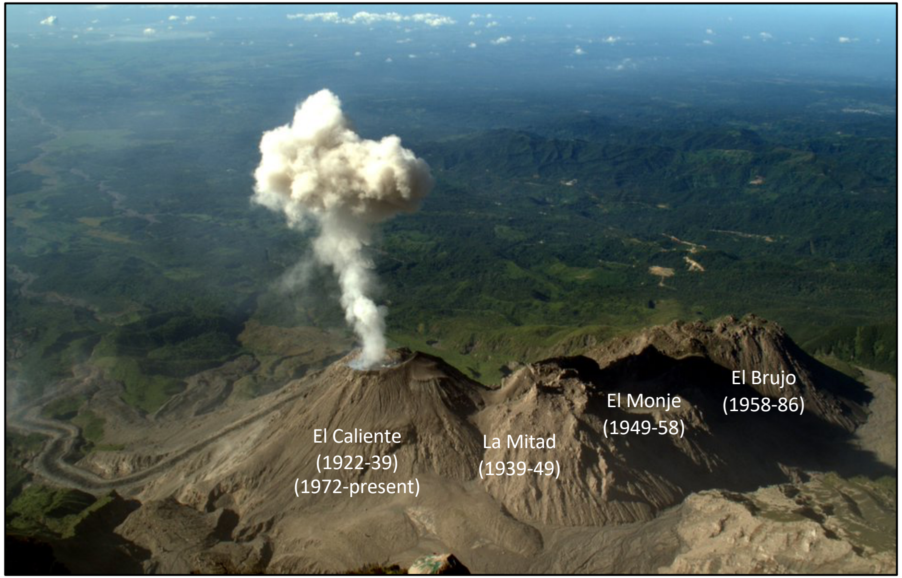
Santiaguito VDC is located at the southern margin of the Xela Caldera.



from Singer et al. (2014)

Santa María – Santiaguito Volcanic Dome Complex (VDC)



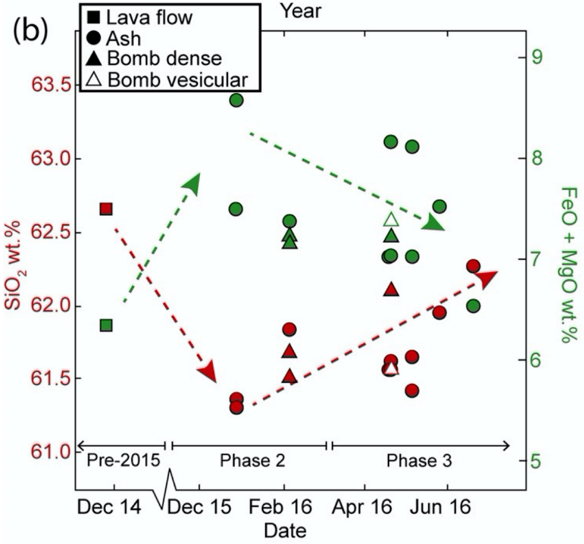


Santa María is a basaltic andesite strato-volcano. Santa María volcano experienced a flank collapse during a large explosive event in 1902 (*Rose 1987*).

New magma started extruding in 1922 forming the Santiaguito VDC through alternating effusive and mildly explosive events (*Rose 1972*). Santiaguito VDC consists of four domes. El Caliente is the currently active dome.

Change in eruption dynamics 2015-2016

from Wallace et al. 2020



In 2015-2016 activity at Santiaguito VDC is marked by a drastic change in eruption dynamics (*Lamb et al. 2019*, *Wallace et al. 2020*) .

Activity changed from frequent small eruptions to infrequent larger eruptions (shown in images).

The shift is marked by an initial decrease in silica content and increase in Mg number. The silica content decreased by about 1.5 wt.% from 62.7 to 61.3 wt.% before gradually increasing again.

This change in eruption dynamics and chemistry rises the question: "What processes are responsible for this change in eruption dynamics?"

Geochemical Evolution of Santa María and Santiaguito VDC

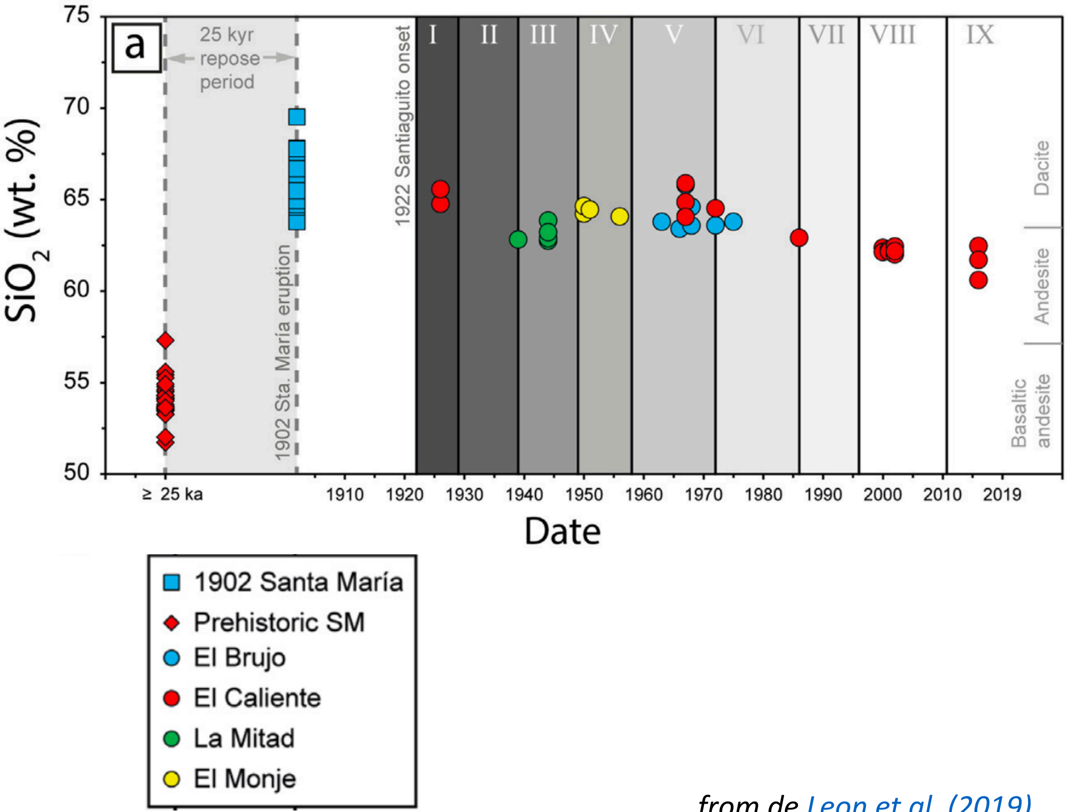
The prehistoric Santa María stratocone comprises basaltic andesite lavas that erupted between 103 ka to 25 ka (8 km^3; *Rose 1987*, *Escobar-Wolf et al. 2010*, *Singer et al. 2011*).

After a 25 kyr long repose period, a Plinian eruption and flank collapse occurred ejecting ca. 9 km^3 of dacitic magma (Rose 1987, *Escobar-Wolf et al. 2010*, *Singer et al. 2014*).

-> "*1902 Pumice Eruption*"

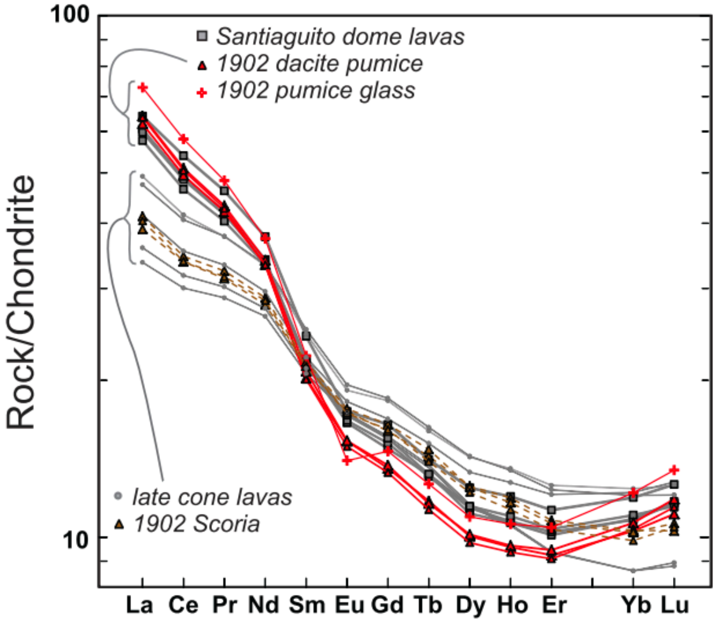
Since the Santiaguito onset in 1922, magma compositions have gradually decreased from dacite (~65 wt.% SiO_2) to andesite (~62 wt.%. SiO_2) (*Rose 1972*, Scott et al. 2012, 2013, *Wallace et al. 2020*)

Nine eruption cycles of Santiaguito VDC are identified based on lava domes and effusion rates (*Rose 1972*, *Harris et al. 2003*, *Scott et al. 2012*, *2013*).

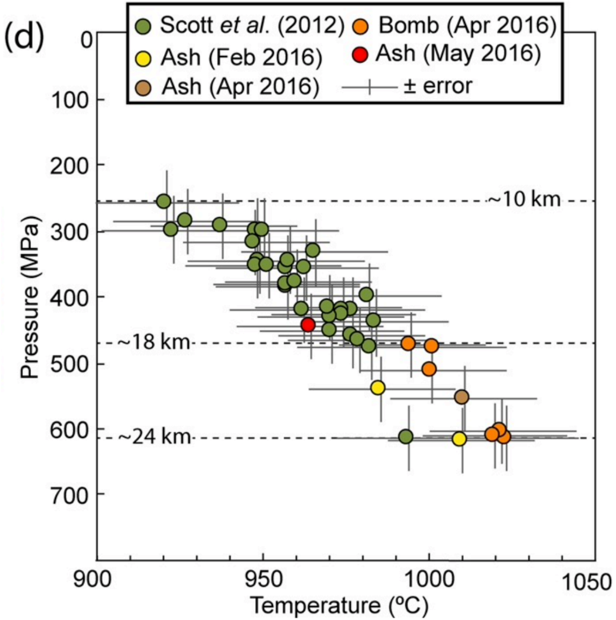


from de Leon et al. (2019)

Magma differentiation of Santa María and Santiaguito VDC



from [Singer et al. (2014)]



from [Wallace et al. 2020]

Magma differentiation is dominated by amphibole fractionation in the lower crust (*Singer et al. 2014*). Amphibole thermobarometry suggests crystallisation pressures between 10 and 24 km (*Scott et al. 2012*, *Wallace et al. 2020*).

Evidence of shallow magma storage

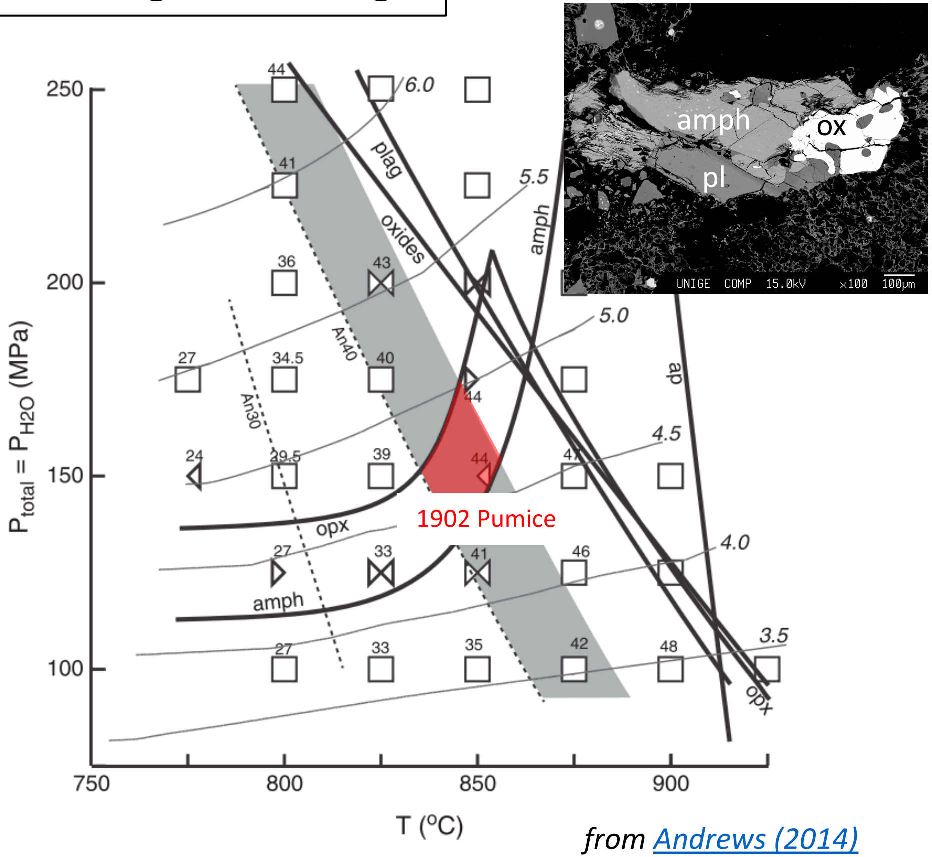
Crystallisation experiments by [Andrews (2014)] indicate a shallow storage zone of dacite magma at about 150 MPa and 850°C (red shaded area).

Magma of the 1902 Pumice eruption comprise:
- Plagioclase, orthopyroxene, amphibole and oxides (BSE image).
- Plagioclase rims have Anorthite contents of about 40-45 mol% (grey shaded area).

Questions regarding activity at Santiaguito VDC:

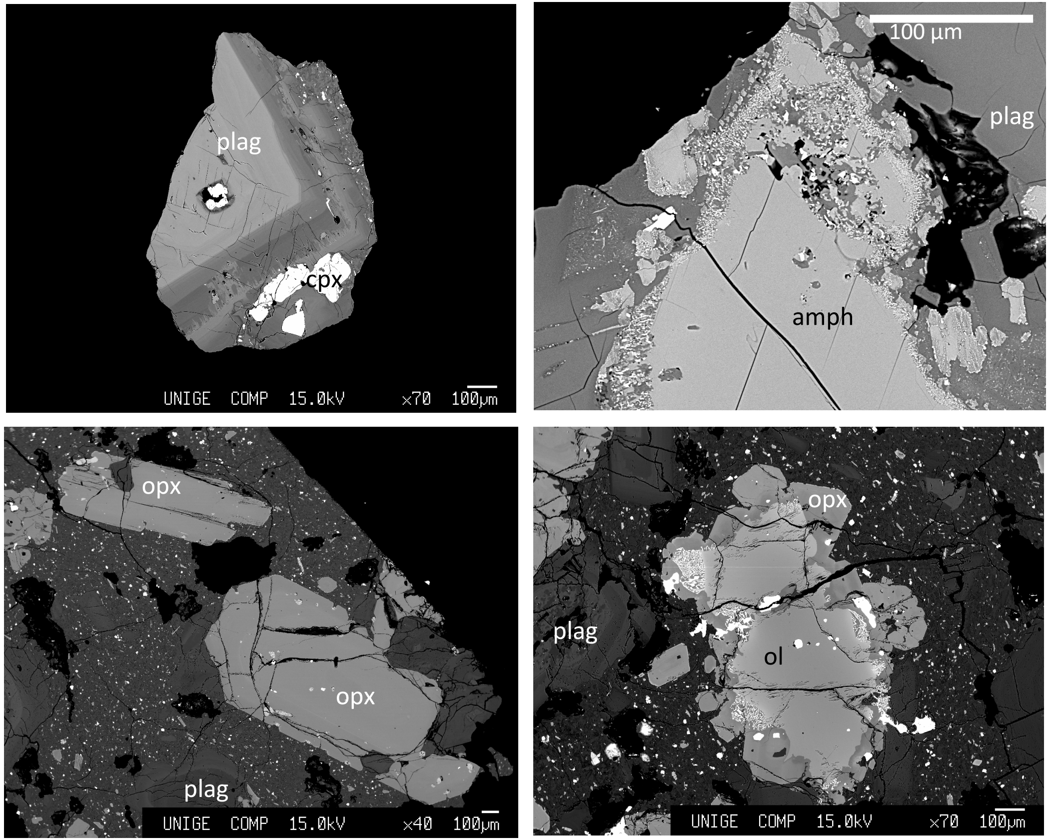
1) Is there evidence for shallow storage prior to eruption of Santiaguito magmas?

2) What processes control the recent shift in eruption dynamics?



from [Andrews (2014)]

Mineral assemblage of 2015-2016 Santiaguito magma



Magmas dominantly contain:

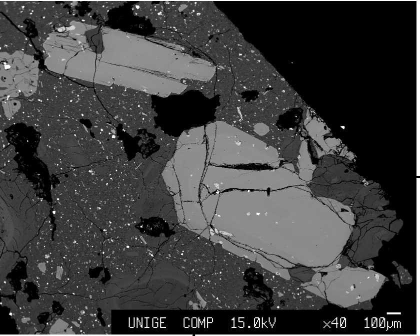
- **Zoned plagioclase**
- **Orthopyroxene**

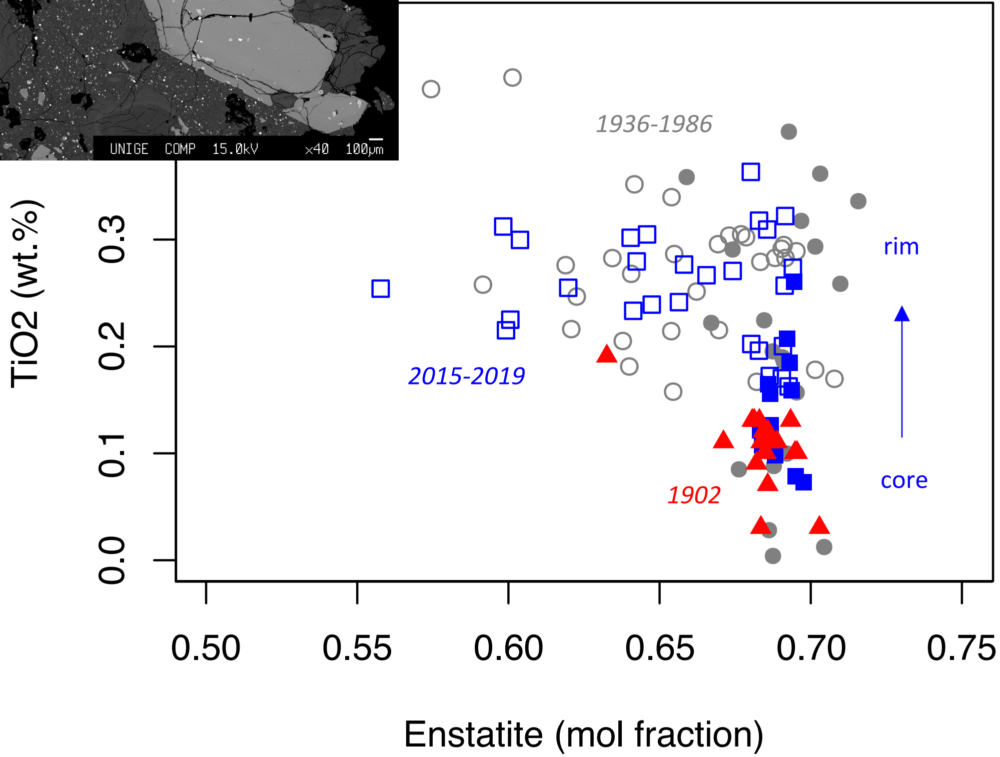
=> Focus of this study

Minor and trace amounts of:

- Fe-Ti oxides
- Decomposed amphibole
- Clinopyroxene inclusions
- Olivine overgrown by orthopyroxene
- Silica polymorph
- Apatite
- Zircon

Orthopyroxene composition





groundmass	*phenocryst*	
□	■	Santiaguito VDC (this study)
○	●	Santiaguito VDC (*Scott et al. 2012*)
	▲	Santa María 1902 Pumice eruption (*Singer et al. 2014*)

Phenocrysts show relatively constant En content of 68-70 mol%.

Rim and microlite composition are enriched in TiO_2 content compared to core composition.

Core composition are comparable to phenocrysts of the *1902 Pumice eruption* (*Singer et al. 2014*).

-> Increase in TiO_2 indicative of magma heating?

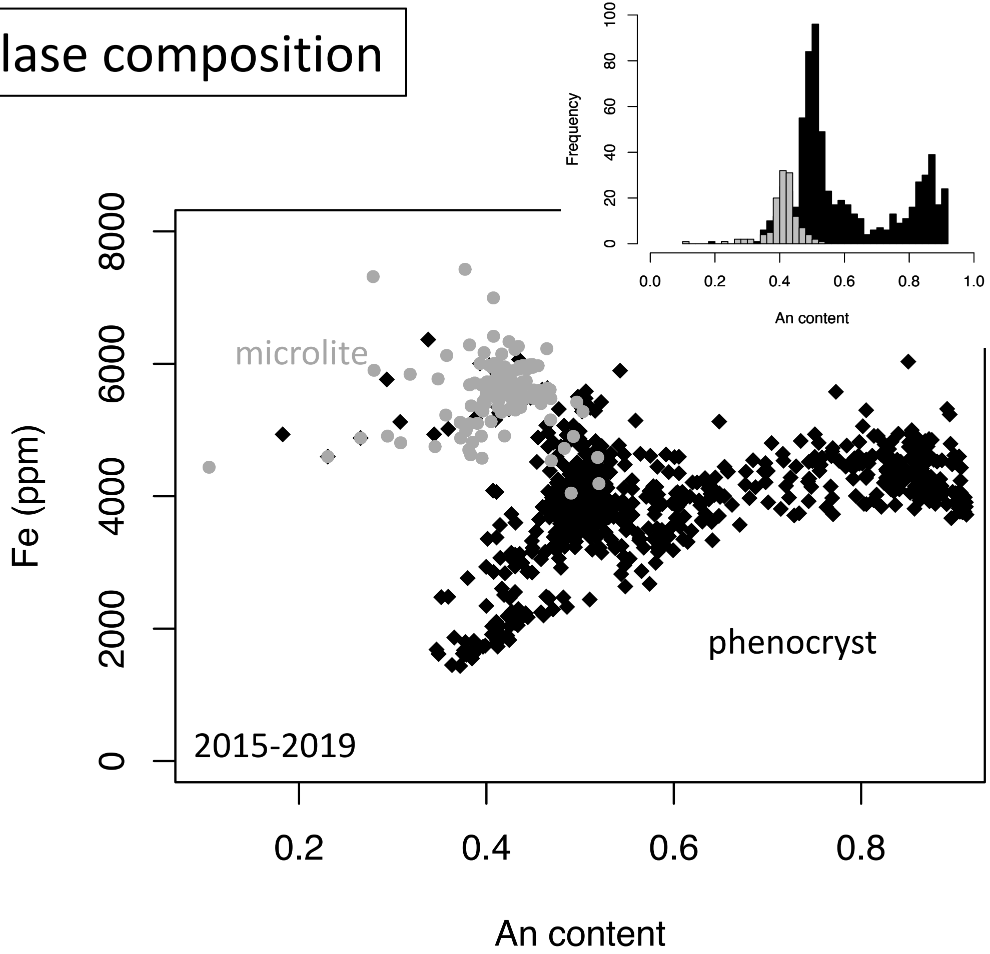
Plagioclase composition

Plagioclase composition are collected from core-to-rim transects of phenocrysts (black) and spot analyses of microlite crystals (grey).

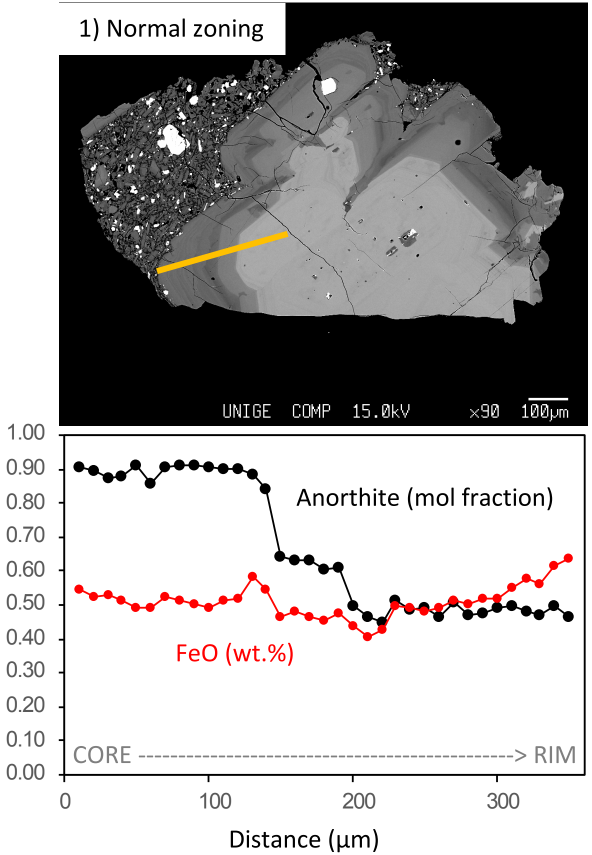
Microlite crystal have Anorthite (An) contents around 40-45 mol%. They are enriched in Fe content compared to phenocrysts.

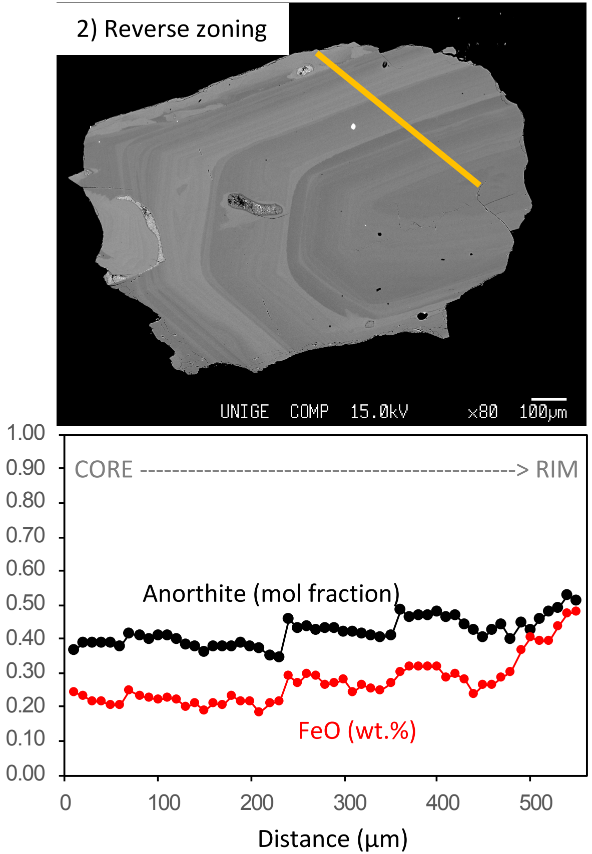
Phenocrysts generally range between 35 and 90 mol% An. Phenocrysts composition are bimodal with distinct peaks around 50 and 85 mol% An.

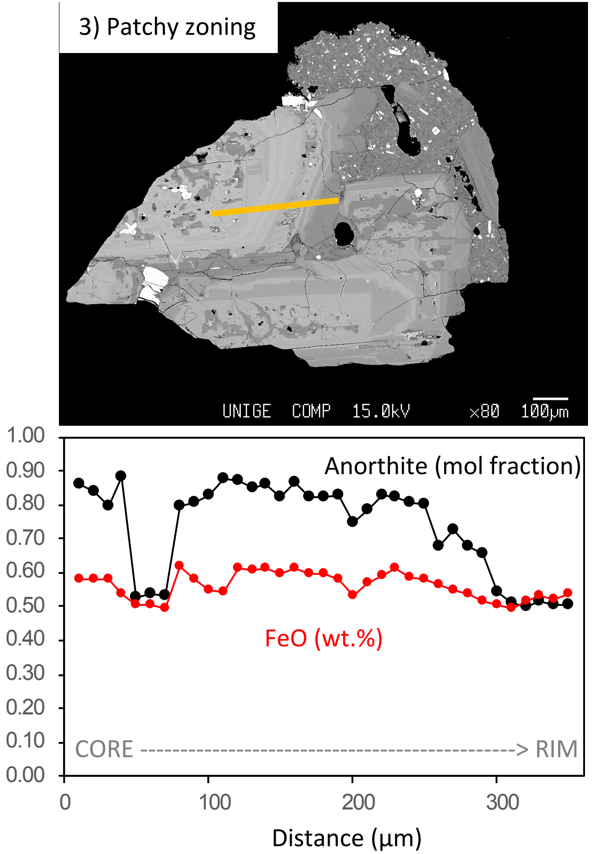
At An50, phenocrysts show a rimward increase in Fe content from about 3500 to 6000 pm Fe (see next slide)



Textural and chemical variations in plagioclase







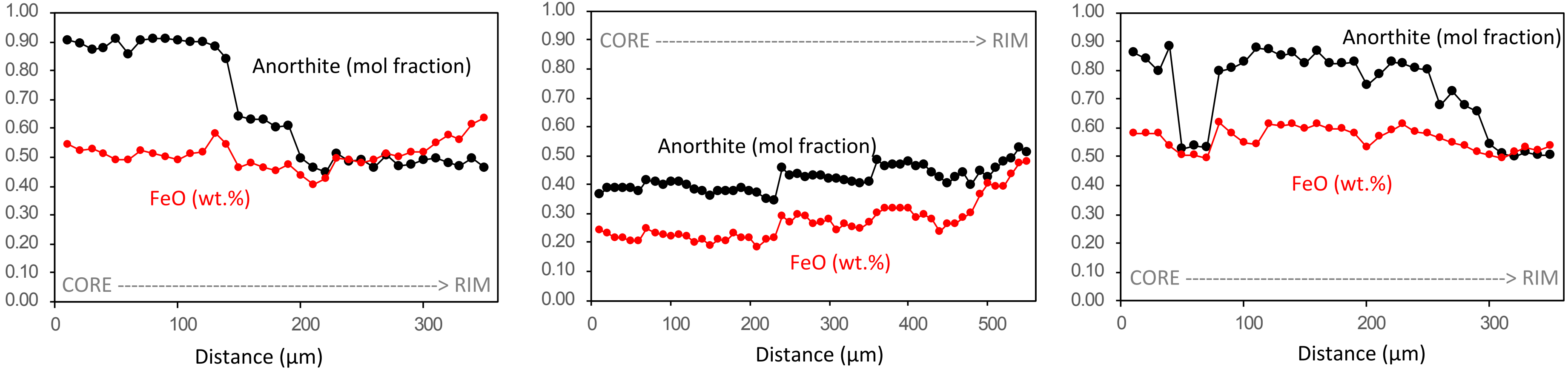
Textural and chemical variations in plagioclase

Three distinct zoning patterns are observed in Santiaguito samples:

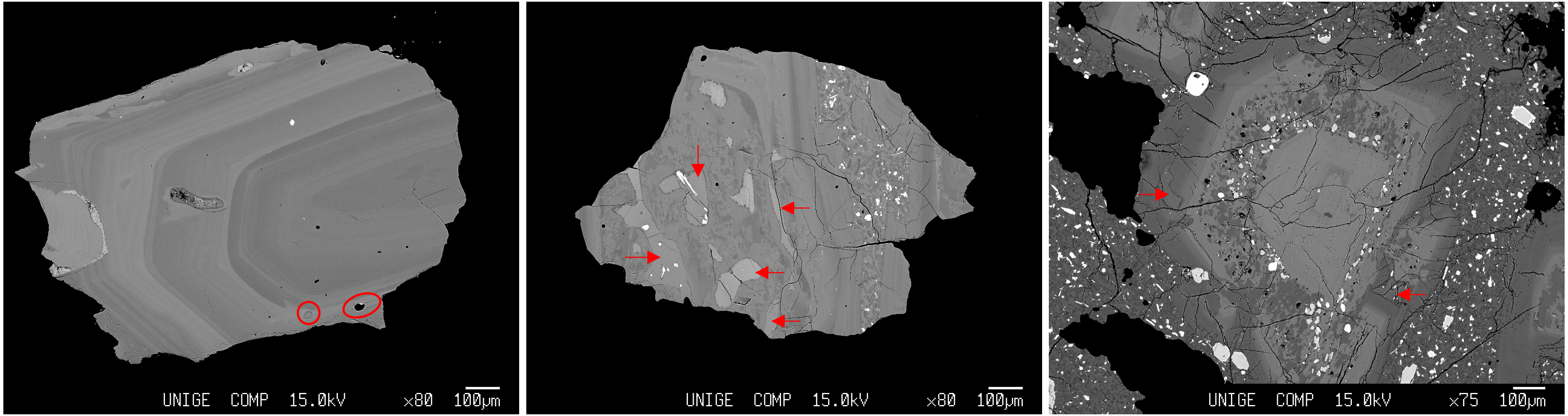
1) Normal step-zoned crystals with high-An cores (An_{90})
2) Reversely step-zoned crystals with low-An cores (An_{35-40})
3) Patchy zoned crystals with high-An cores (An_{80-90})

All crystals share a **common rim of An_{50}** and **rimward increase in Fe content** at constant An contents.

-> Rimward increase in Fe indicative of new magma and/or magma heating?



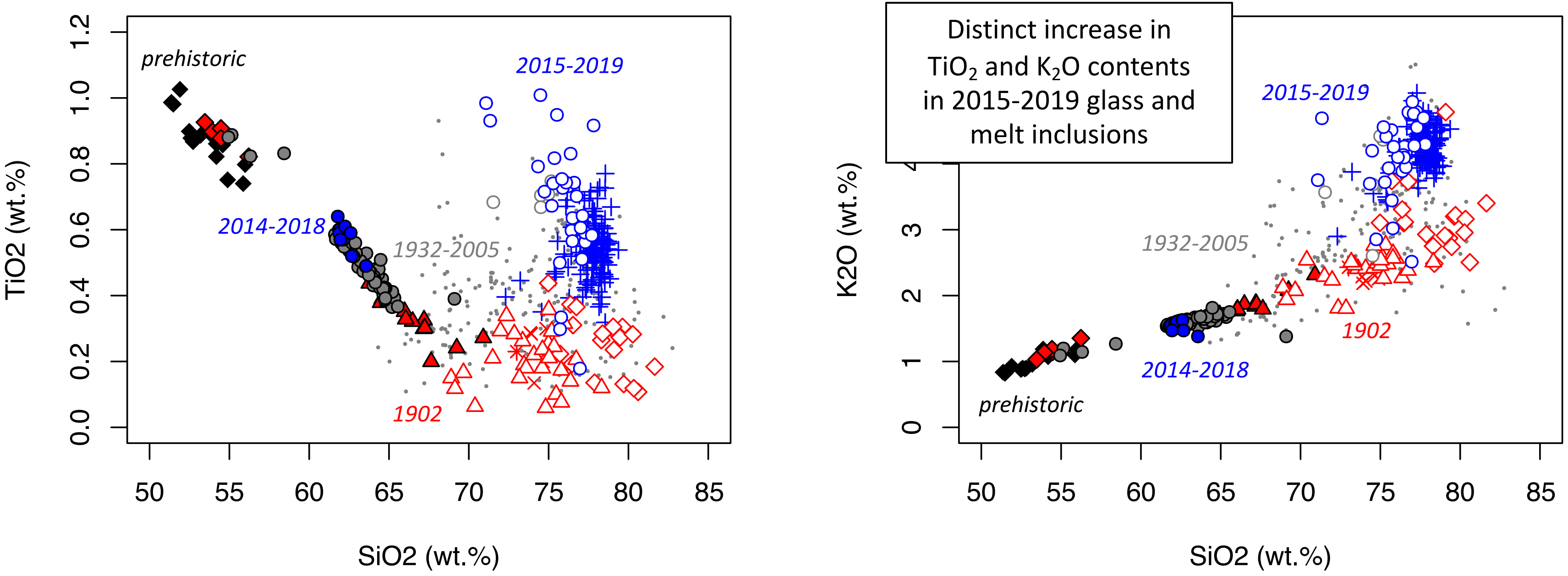
Plagioclase-hosted melt inclusions and pockets



Melt inclusions and pockets were analysed in:

- Reversely zoned crystals (left)
- in patchy-zoned crystal cores (middle)
- in plagioclase rims (right)

Bulk, glass and melt inclusion chemistry



BULK-ROCK

- Santiaguito VDC (Rose 1972, Avard & Whittington 2012, Scott et al. 2012, Singer et al. 2014, Wallace et al. 2020)
- Santa María 1902 Pumice eruption (Scoria/Pumice) (Andrews 2014, Singer et al. 2014)
- Santa Maria late cone (*Singer et al. 2011*)

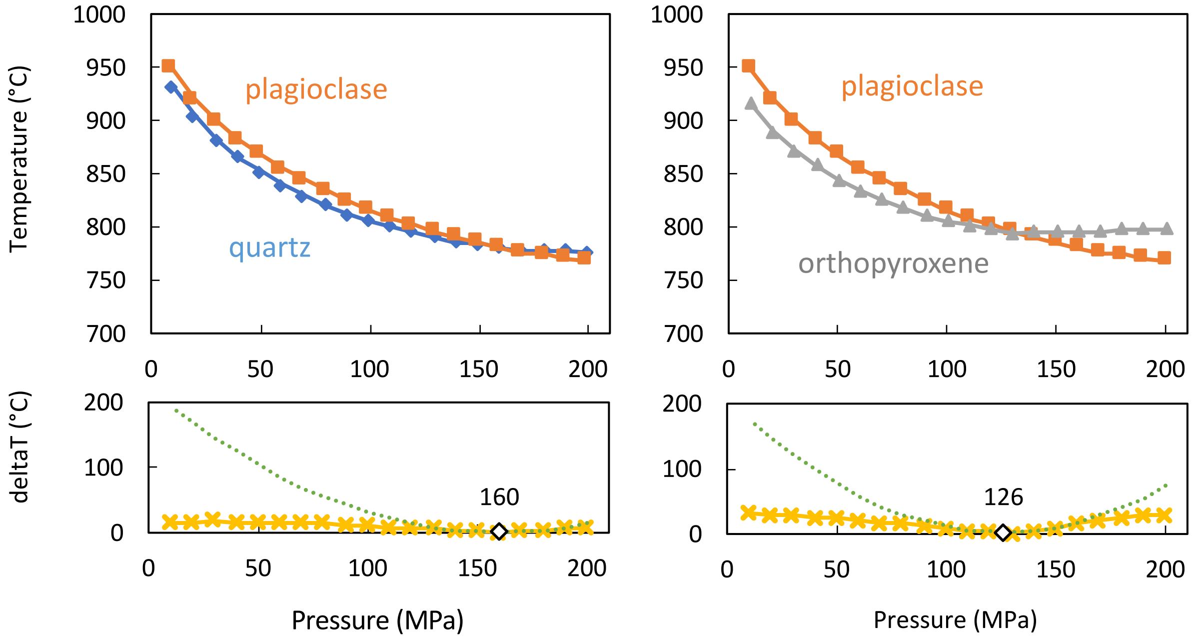
GROUNDMASS GLASS

- Santiaguito VDC *(this study)*
- Santiaguito VDC *(Scott et al. 2012)*
- Santa María 1902 Pumice eruption *(Andrews 2014)*
- Santa María 1902 Pumice eruption *(this study)*

MELT INCLUSION

- Santiaguito VDC *(this study)*
- Santiaguito VDC *(Scott et al. 2012)*
- Santa María 1902 Pumice eruption (Scoria/Pumice) (Andrews 2014, Singer et al. 2014)

Rhyolite-MELTS barometry of trapped melt



Amphibole is not stable in Santiaguito samples allowing the use of the rhyolite-MELTS barometer.

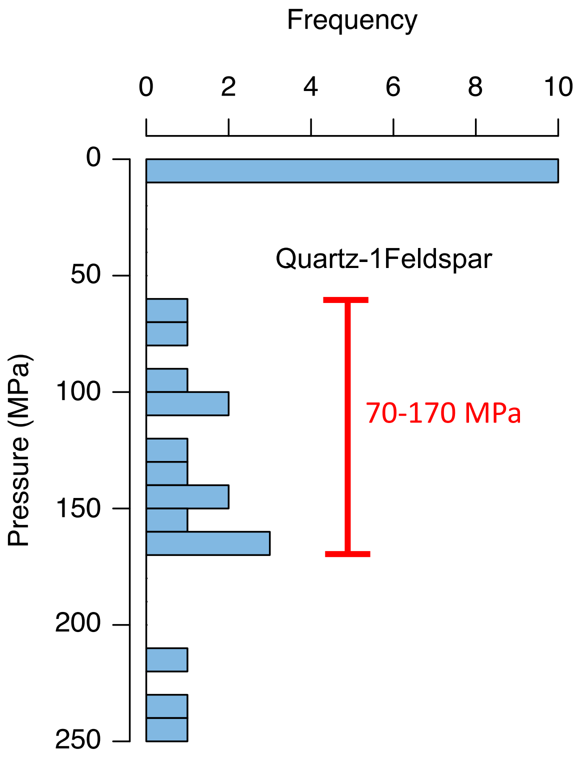
First, thermodynamics simulations are performed for each analysis. Simulations are run from liquidus to near solidus under isobaric conditions at dQFM+1.5 using temperature intervals of 2°C and pressure intervals of 10 MPa.

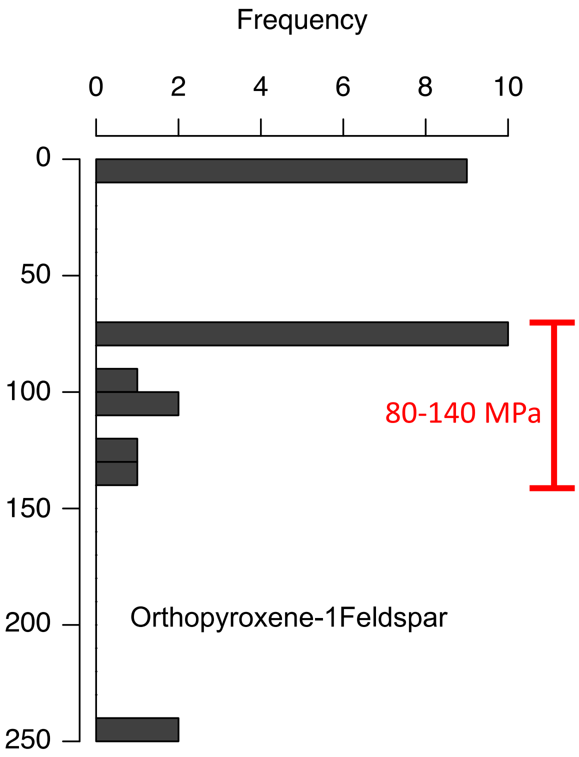
Liquidus curves for quartz-plagioclase and orthopyroxene-plagioclase are shown in PT-space.

Equilibration pressures of melt inclusions and pockets are estimated using the method of *Gualda & Ghiorso 2014* and *Harmon et al. 2018*.

Calculations for this sample reveal equilibration pressures of 126 - 160 MPa

Rhyolite-MELTS barometry





Equilibration pressures are calculated for all melt inclusions and pockets using two rhyolite-MELTS barometers (qtz-plag & opx-plag).

Some inclusions re-equilibrated at surface pressures, while other reveal entrapment deeper in the conduit or in a shallow reservoir.

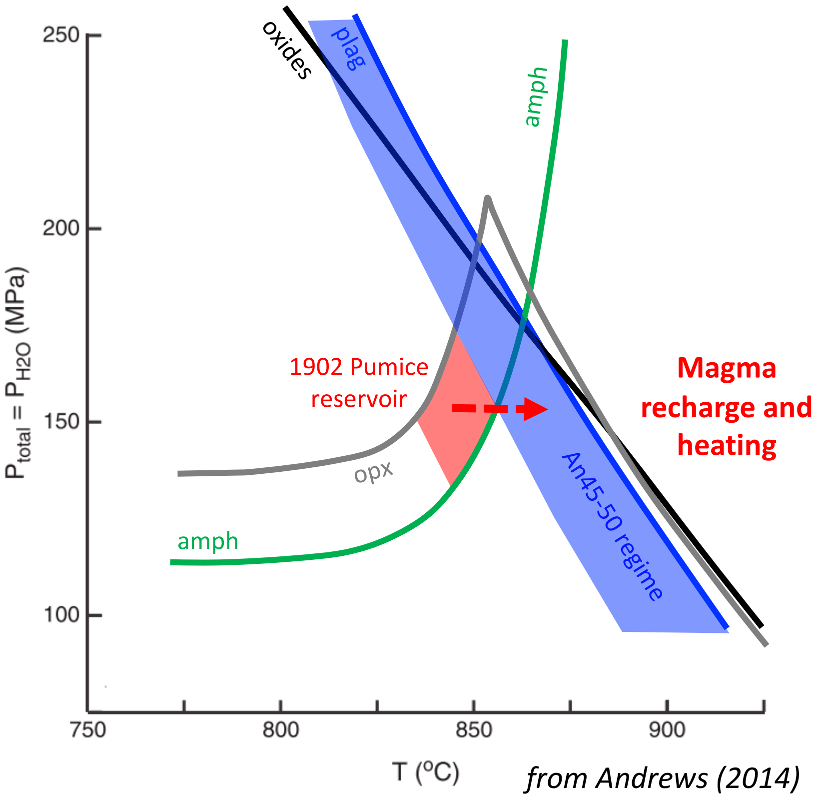
Results could indicate a shallow storage zone between ca. 70 and 170 MPa.

Evidence for reactivation of shallow storage zone

New recharge of hotter magma into shallow reservoir likely led to shift in eruption dynamics in 2015-2016. This is supported by:

-> Reversely zoned plagioclase crystals
-> Homogeneous An_{50} rims in plagioclase and rimward increase in Fe content
-> 1902 Pumice type orthopyroxene cores in orthopyroxene phenocrysts and rimward increase in Ti content
-> Amphibole decomposition
-> Olivine crystals with orthopyroxene overgrowth show disequilibrium textures
-> Plagioclase-hosted melt inclusions and pockets indicate melt entrapment around 70-170 MPa (ca. 2.5 to 6 km depth) using the rhyolite-MELTS barometer

Also see findings by *de Leon et al. 2019* and *Wallace et al. 2020*



from Andrews (2014)

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