Rejuvenation of magma mush preceding the eruption of the Rhyolite of Separation Creek, Three Sisters Volcanic Complex (TSVC), Central Oregon Cascades

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Questions

- What does the presence of mafic enclaves and mineral clots in rsc mean for pre-eruption conditions below the Three Sisters?
- What level of magma interaction occured to produce the crystal populations and characteristics present in rsc?
- Is rsc actually an eruptive product of South Sister, or could it be associated with Middle Sister?

TSVC Geologic Setting

- Part of the Cascade volcanic arc in a region that has a particularly high density of vents
- Meets the northern margin of the extensional Basin and Range Province [1]
- South Sister is underlain by the westward tip of a crustal melting anomaly [2]
- The north-south alignment of many vents in the TSVC is influenced by stress orientation from the combination of northward block rotations, microplate movements, and oblique convergence [2]

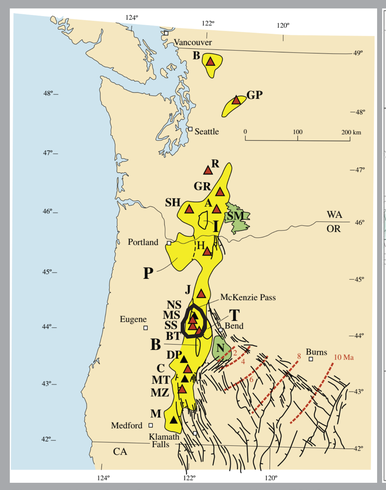

Figure 1: Map of the Cascades range, with the TSVC circled in black [2]

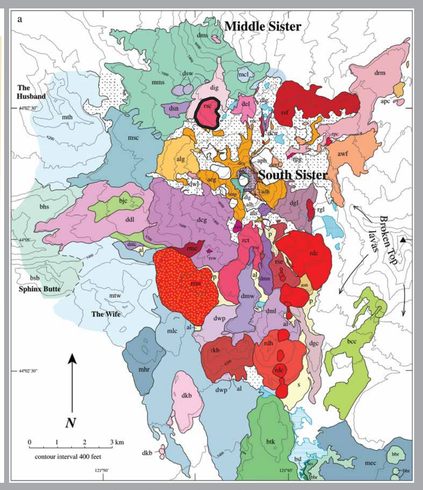

Figure 2: Map of Middle and South Sister eruptive units, with unit rsc circled in black [2]

South Sister Eruptive History

- Overview: South Sister erupted alongside Middle Sister, alternating between rhyolitic and intermediate modes, with the number of true rhyolites being unusual for the Quaternary Cascades [2]
- ~50 ka: Earliest rhyolites erupted
- 37-30 ka: Broad dacite-andesite cone built over the initial eruptive pile
- 30-22 ka: Explosive end to the silicic sequence, followed by profile building through summit focused, dacite-andesite activity. Four eruptions occurred in and near the saddle separating Middle and South Sisters, including unit rsc. Between the summit and peripheral eruptions, products ranged from 56 to 73% SiO_2, nearly representing South Sister's entire compositional range [2]
- 25.4±1.3 ka: **Rhyolite of Separation Creek (rsc)** erupted as a steep-sided rhyolite dome (69.6–73.9% SiO_2), approximately equidistant from the summits of Middle and South Sister [2]
  - Currently associated with South Sister
  - Contains trace amounts of hornblende, which is rare in South Sister lavas
  - Has lower FeO*/MgO and higher Rb content compared to other TSVC lavas
  - Contains abundant mafic, more phenocryst-poor enclaves, suggesting potential magma mixing or interaction [2]
- 2 ka: Venting from the flanks, forming several rhyolitic flows, domes, and tephra deposits [2]

Initial Observations

Based on preliminary SEM images and EDS results, observations of trends in characteristics have been made:

- Content- Clots and enclaves have similar mineral contents across samples: plagioclase>pyroxene>amphibole>oxides, with a few containing olivine as well.
- Habit- Most crystals, especially free, are subhedral with resorbed rims. Some, mainly those intergrown in clots and enclaves, have euhedral habit.
- Zoning- Various zoning patterns are represented, even within the same sample. Of the zoned crystals, normal zoning is most common.
- Textures- Several textures are present, most commonly coarse sieving and inclusions.

Habit, zoning, and textures observed suggest changes in magma conditions including composition and temperature during the formation of these crystals.

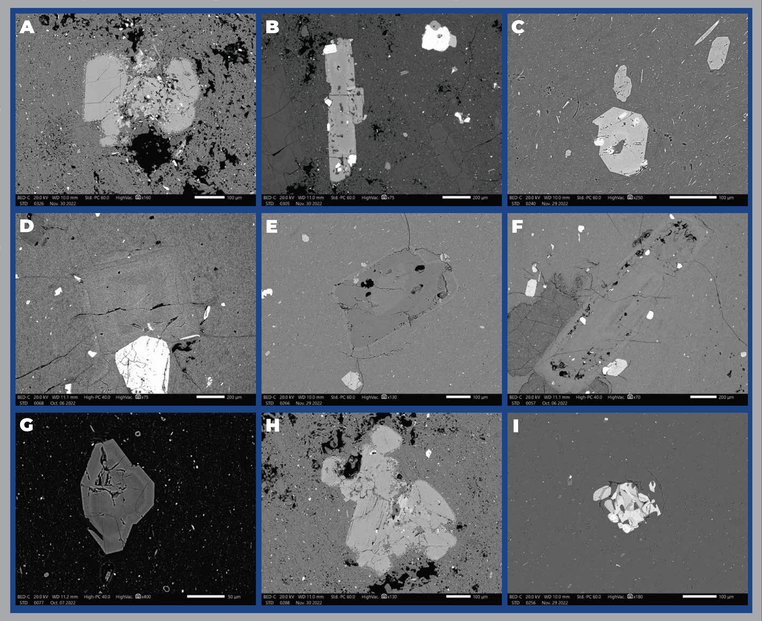

Figure 3: BSE images of nine free crystals from three different rsc samples.
A) Pyroxene, no zoning, with reaction rim, oxide inclusions
B) Pyroxene, slight gradual reverse zoning, oxide inclusions
C) Pyroxene, no zoning, oxide inclusions
D) Plagioclase, gradual normal zoning, euhedral
E) Plagioclase, step normal zoning, thin resorbed layer
F) Plagioclase, oscillatory zoning, coarse sieving
G) Amphibole, gradual normal zoning
H) Amphibole, no zoning, resorbtion rim
I) Oxides, small clot, three different kinds

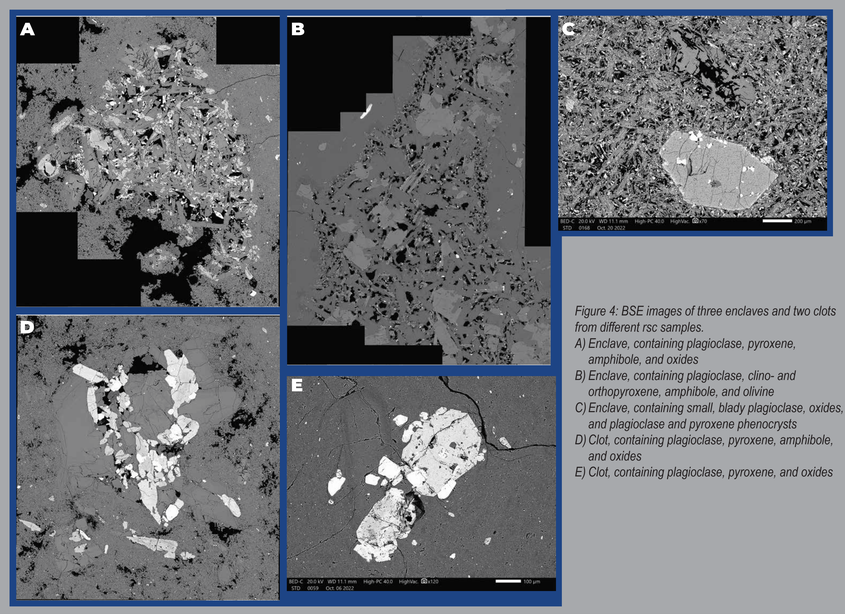

Figure 4: BSE images of three enclaves and two clots from different rsc samples.
A) Enclave, containing plagioclase, pyroxene, amphibole, and oxides
B) Enclave, containing plagioclase, clino- and orthopyroxene, amphibole, and olivine
C) Enclave, containing small, blady plagioclase, oxides, and plagioclase and pyroxene phenocrysts
D) Clot, containing plagioclase, pyroxene, amphibole, and oxides
E) Clot, containing plagioclase, pyroxene, and oxides

Intentions and Future Work

The goal of this project is to use textural and chemical analysis of the enclaves, clots, and phenocrysts found in rsc to gain further understanding of the history of the magma. Including how potential interaction between magma bodies, the intrusion of new magma, and rejuvination of existing mush generated eruptable material.

I will continue to gather data through major and trace element analysis with the intention of gaining deeper knowledge into the history of the magmas and their ascent paths.

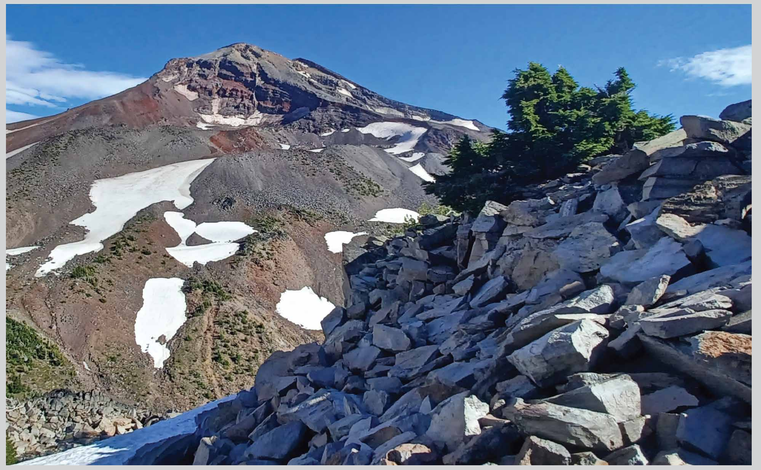

Figure 5: Photo of South Sister in the background and unit rsc in the foreground, taken from an outcropping of rsc looking southeast toward South Sister.

Methods

- Sample collection conducted during summer of 2022, representative of both whole rock samples and larger individual enclaves (1-2 cm diameter).
- Thin and thick sections were then created for petrographic and scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS), for information about the characteristics of crystal populations and preliminary element quantification.
- Major element quantification will use electron microprobe analysis.
- Trace element quantification will use laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).

Impact

The continuing inflation centered several kilometers west of South Sister could reflect similar processes to those involved in the eruption of rsc. Understanding of past eruptions can help to inform current and future potential.

Acknowledgements

Klah Klahnee is located on the ancestral lands of the Confederated tribes of Warm Springs, including the Klamath and Molalla peoples.

References

[1] Hildreth, W., Fierstein, J. & Calvert, A. T. Geologic map of Three Sisters volcanic cluster, cascade range, Oregon. U.S. Geological Survey Pamphlet (2012). doi:10.3133/sim3186

[2] Fierstein, J., Hildreth, W. & Calvert, A. T. Eruptive history of South Sister, Oregon cascades. Journal of Volcanology and Geothermal Research 207, 145–179 (2011).