Multiple Magma Batches: Understanding the Pre-Eruptive Architecture and Magmatic Processes of Supereruptions Based on Textural, Mineralogical, and Geochemical Features of Fiamme from the Ora Ignimbrite (Permian, Italy)

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November 22, 2022

Abstract

The investigation of the Ora Ignimbrite (˜275 Ma) helps further our understanding of how vast amounts (>1,000 km3) of melt are generated, stored, and erupted from the shallow crust. As the last eruptive product of a slab rollback ignimbrite flareup that lasted for 10 Ma, Ora's glacially incised outcrops tower over 1,300 m above Bolzano, Italy. Two key outcrops, early-erupted intracaldera vitrophyre and late-erupted outflow vitrophyre, provide well-preserved, glass-bearing juvenile material. Petrographic optical and electronic (back-scattered electron) analysis was used to document the textural features of minerals and glass. Glass and mineral major-element compositions were obtained using Energy-Dispersive X-ray (EDX) analysis on a Scanning Electron Microscope (SEM). Glass with low Na/high K concentrations and A/CNK ratios > 1.1 was deemed altered. Intracaldera vitrophyre contains two distinct fiamma types: very coarse-grained, crystal-rich (VCCR) and fine-grained (FG) fiamme. Glass in VCCR fiamme is homogeneous high-silica rhyolite (76.5-77.5 wt. % SiO2; normalized anhydrous) with low K2O values (3-3.5 wt. %). The FG fiamme have a broader SiO2 range (75-78 wt. % and 72-78 wt. %) and higher K2O values (3-4.5 wt. %). Outflow vitrophyre has medium-grained (MG) and fine-grained, crystal-poor (FGCP) fiamme. The MG fiamme have homogeneous high-silica rhyolite glass (76-78 wt. % SiO2) with lower K2O (2-3 wt. %). Glass in three FGCP fiamma form compositional continua from 68-78 wt. %, 67-79 wt. %, and 72-78 wt. % SiO2, and K2O varies substantially (0.5-3.5 wt. %). These results demonstrate mingling and mixing and suggest that multiple melt-rich zones contributed to the erupting magma. We propose that at least four separate magma bodies contributed to the Ora eruption. Each one evolved independently, leading to variable amounts of magma mingling and mixing. These results illuminate the subsurface architecture of a large silicic system during the final episodes of an ignimbrite flareup.

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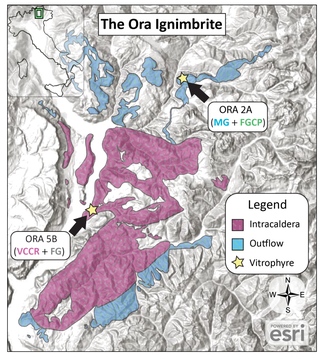
Motivations

- Understanding the structure and evolution of **large silicic magma systems** through time
- Investigating the pre-eruptive conditions of a **crystal-rich ignimbrite**
- Examining the plutonic-volcanic connections of a **supereruption-sized** magmatic system

The Ora Ignimbrite



- The Ora Ignimbrite (277 ± 2 Ma) has both **crystal-rich** and **crystal-poor fiamme** distributed throughout the >1,000 km^3 deposit
- **Vitrophyre** horizons contain well-preserved**, glass-bearing** juvenile material
- This study focuses on fiamme from two **vitrophyre** horizons:
  - **Early-erupted** intracaldera (ORA 5B)
    - **VCCR** + **FG**
  - **Late-erupted** outflow (ORA 2A)
    - **MG** + **FGCP**

Fiamma Type Classification

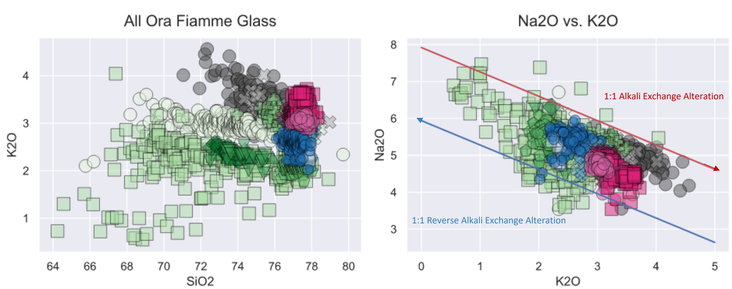
- Crystal content was calculated in ImageJ using **greyscale thresholding** on thin section scans

FIAMMA TYPES:	DESCRIPTION:	LOCATION	CRYSTAL CONTENT:	MAX PHENOCRYST SIZE:	MAFICS:
TYPE 1:	Very Coarse-Grained Crystal-Rich (VCCR)	Intracaldera	~40-50%	>5 mm	~2-3%
TYPE 2:	Medium-Grained (MG)	Outflow	~20-40%	1-3 mm	<0.5%
TYPE 3:	Fine-Grained (FG)	Intracaldera	~20%	≤1 mm	<0.1%
TYPE 4:	Fine-Grained Crystal-Poor (FGCP)	Outflow	~10%	≤1 mm	≤0.15%

- Fiamme were initially grouped into **four types** based on crystal content and biotite content

Glass Major Element Compositions

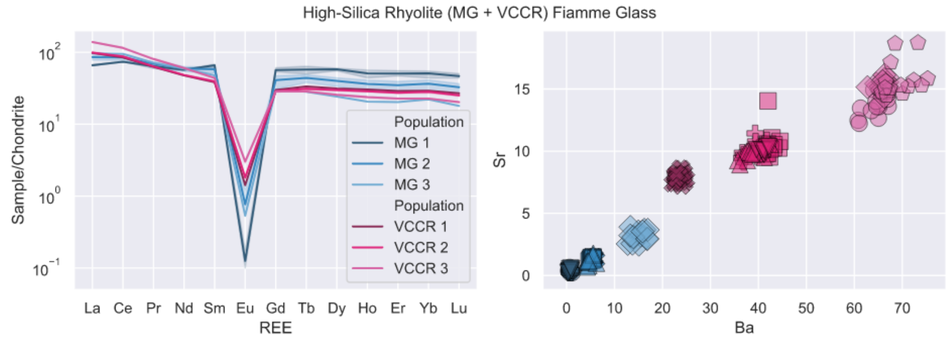
- **Glass** major elements were obtained using EDS analysis on an SEM at Vanderbilt University



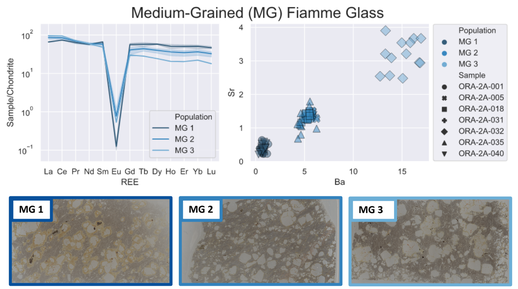
- Glass major elements verify the **four** different fiamma **types** from the textural-based classification
- The tight clustering of **VCCR** and **MG** fiamme suggests that these types have **unaltered** glasses

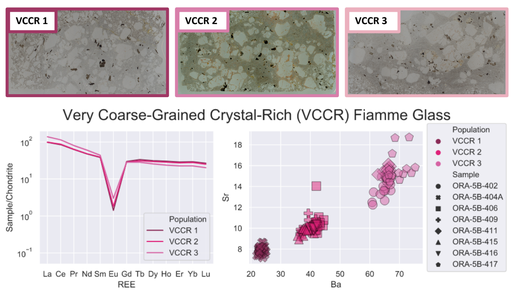
Glass Trace Element Compositions

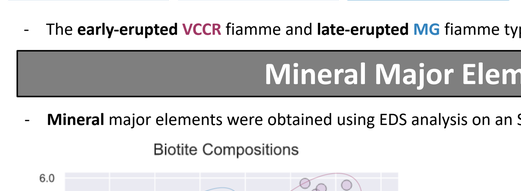
- **Glass** trace elements were obtained using a LA-ICPMS at Vanderbilt University and the data were processed with GLITTER



- Trace elements further **confirm** the fiamma type classification scheme and show **distinct populations** for the **intracaldera VCCR** fiamme and the **outflow MG** fiamme**,** suggesting the presence of **multiple magma batches** within the Ora system







- The **early-erupted VCCR** fiamme and **late-erupted MG** fiamme types each have **three** discrete glass populations

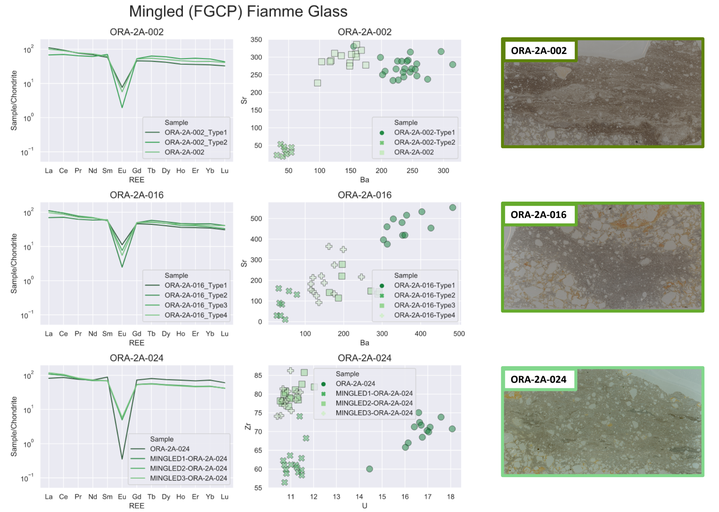
Mineral Major Element Compositions

- **Mineral** major elements were obtained using EDS analysis on an SEM at Vanderbilt University

- We observe variations in **biotite** and **plagioclase** major element compositions between the intracaldera and outflow units
- Biotite compositions can be used to infer both fiamme **type** and **population** in fiamme with no preserved glass

Mingled Glass Trace Element Compositions

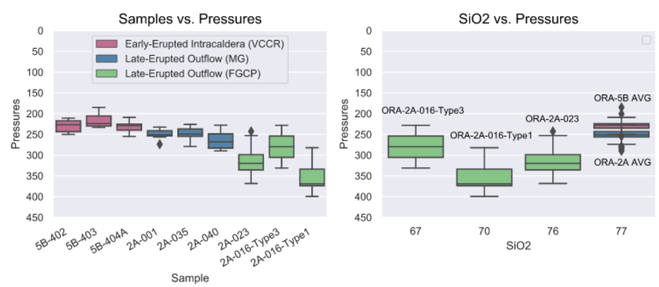
- **Mingled glasses** were identified **texturally** prior to major and trace element analysis



- The presence of **multiple different types** of glass in a **single fiamma** demonstrates magma mingling with limited mixing just prior to (days? weeks? years?) or during eruption

Rhyolite-MELTS Geobarometry

- **Pre-eruptive storage pressures** were calculated using the **rhyolite-MELTS (Q2F)** geobarometer



- The fiamme types return **different** storage pressures, suggesting (1) progressive withdrawal of **deeper magmas** or (2) the tapping of **separate** magma batches over the course of an eruption

Conclusions

- The variation in trace elements, biotite content, plagioclase and biotite major element compositions, and rhyolite-MELTS pressures reveals the tapping of either (1) **two distinct mush zones** or (2) **heterogeneous zones within a continuous crystal mush**
- Different fiamme **types** and **populations** can be identified with **biotite** and **plagioclase** major element compositions in samples with no preserved glass
- We would like to better constrain **timescales** of **magma mingling** for the Ora system