THE ORIGIN OF A ZONED IGNIMBRITE: INSIGHTS INTO THE CAMPANIAN IGNIMBRITE MAGMA CHAMBER (CAMPI FLEGREI, ITALY)

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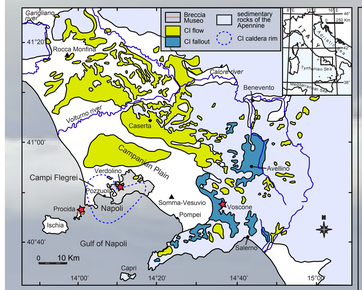
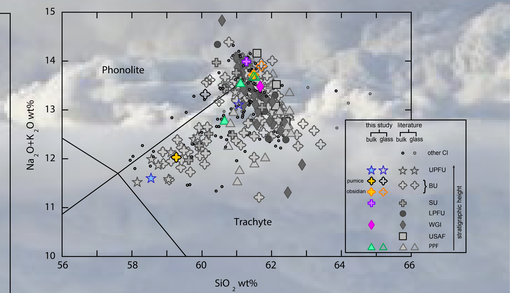
1. Introduction

Zoned ignimbrites, emplaced during large-magnitude explosive eruptions, record compositional and thermal gradients in shallow magma chambers. The origin of chemical and thermal zoning has been debated for many years, with hypotheses ranging from magma mixing to in-situ differentiation. The **Campanian Ignimbrite** (CI, ~ 39 ka[1]), erupted during the largest volcanic event in the Mediterranean area over the past 200 ka, is a voluminous and widespread **trachy-phonolitic** pyroclastic sequence composed of a basal fallout deposit and pyroclastic flow units. The CI is well-known for its bulk-rock geochemical variations, observed from the bottom to the top of the pyroclastic sequence, which have been attributed to eruption from a vertically zoned magma chamber[2,3,4].



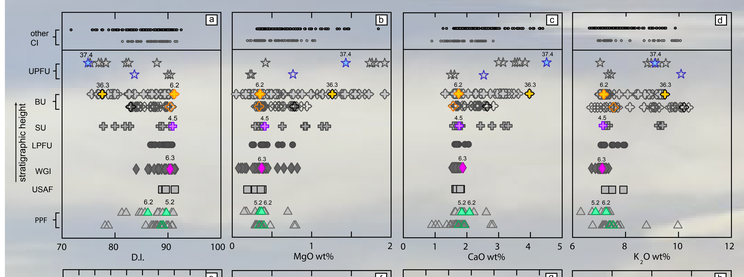
Distribution of the pyroclastic deposits of the CI eruption[5,6] and the reconstructed CI caldera rim[7]. Red stars=sampling localities.

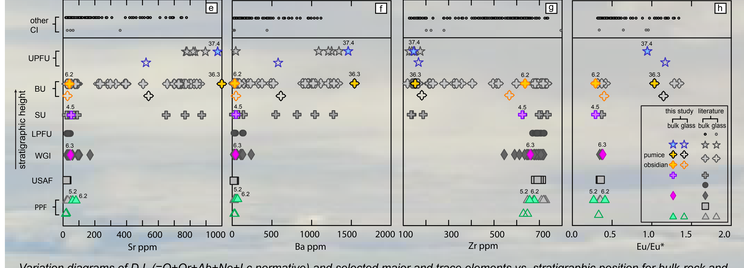


Total alkali-silica classification diagram showing the composition of bulk-rock and matrix glass of the CI.

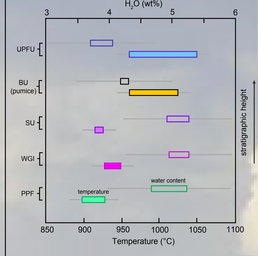
2. Geochemical and crystallinity gradients

Geochemical gradients in the CI are amplified by the remarkable increase in crystallinity from the bottom to the top of the sequence. We argue that protracted fractional crystallization promotes crystal settling and accumulation in a **mush zone** sitting at the bottom of the magma chamber, with residual melt efficiently extracted at an intermediate crystallinity stage (50-70% crystals[11]). These highly evolved and buoyant melts are able to pool at the top of the magma chamber, forming a crystal-poor and relatively water-rich cap[11].

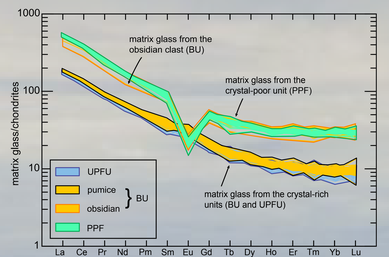




Variation diagrams of D.I. (=Q+Or+Ab+Ne+Lc normative) and selected major and trace elements vs. stratigraphic position for bulk-rock and average glass analyses. Numbers indicate the calculated relative crystallinity of corresponding samples.



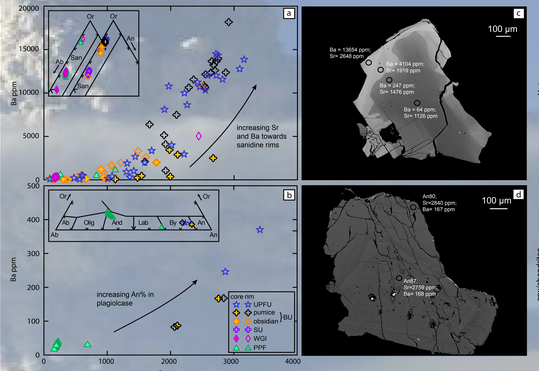
Temperature (°C) and H_2O content (wt%) calculated for the different stratigraphic units using geothermometers[8] and the hygrometers[9].



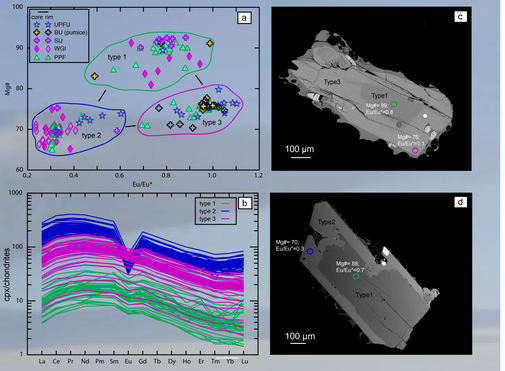
Chondrite-normalized REE patterns of matrix glass from the CI.

3. Thermal gradients

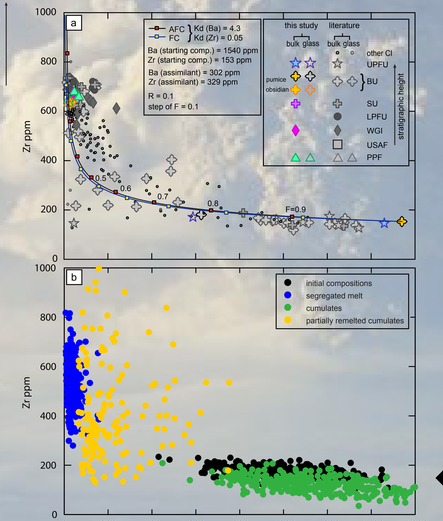
Cpx geothermometry indicate **increasing temperatures** towards the top of the pyroclastic sequence. The presence of slightly negative to positive Eu anomalies in type 3 clinopyroxene, together with Ba and Sr-rich feldspar rims requires the occurrence of other processes than a simple cooling trend, generating crystal fractionation. We suggest that the injection of mafic magma within the cumulate pile likely affected the stability of the low temperature mineral phases triggering partial melting and formation of melts locally enriched in Ba, Sr and Eu. **Partial melting of the cumulate pile** is essential to reduce the crystallinity of the cumulate mush making it rheologically eruptible.



Sr vs. Ba diagrams (a, b), BSE images (c, d) and classification diagrams (insets) of feldspars from the CI. images (c).



Eu/Eu vs. Mg# diagram (a) and chondrite-normalized REE patterns (b) of cpx crystals from the CI. BSE images showing type 1 cpx cores with type 2 (c) and type 3 (d) rims.*



Zr vs. Ba plots showing classical FC and AFC geochemical modeling (a) and trace element modeling for crystal accumulation, melt extraction and cumulate melting[10].

Schematic cartoon illustrating the main processes involved in the generation of gradients in the CI.

4. Conclusions

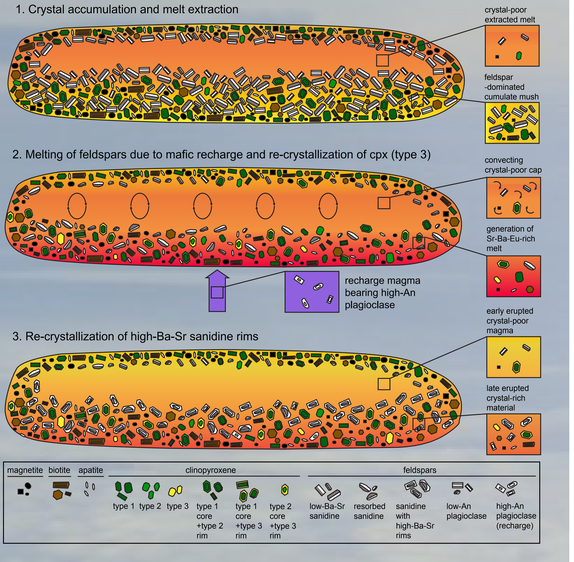
1) The CI pyroclastic succession represents the inversion of a **chemically zoned magma chamber** showing crystallinity and thermal gradients.

2) Magma evolves through **fractional crystallization**, happening in a mushy environment.

3) The **crystal-poor units** represent highly evolved melts extracted from the cumulate mush.

4) The **crystal-rich units** represent remobilized and partially re-melted portions of the cumulate mush, rejuvenated after mafic recharge.

5) Crystal accumulation and efficient melt extraction, followed by **cumulate melting and remobilization**, are responsible for the generation of gradients in the CI, as already demonstrated for other zoned ignimbrites around the world[12].



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