EGU2020-17755
https://doi.org/10.5194/egusphere-egu2020-17755
EGU General Assembly 2020

The origin of large zoned ignimbrites: the case of Aso caldera, Japan

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Silicic magmas are the most evolved, most viscous and potentially most explosive melts present on Earth. Despite their importance, the processes leading to accumulation of large amounts of silicic magma in the crust are still a matter of debate. Ignimbrite sheets of large caldera forming eruptions are interpreted to be unique snapshots of upper crustal magma reservoirs just prior to eruption and hence represent an exceptional possibility to study pre-eruptive magmatic conditions within silicic reservoirs.

The Aso System, in Central Kyushu (Japan), is an archetypical example of a multicyclic caldera-forming volcanic edifice; it was built by four catastrophic caldera forming eruptions, with the latest (Aso 4) taking place approximately 90 ka ago. The ignimbrite sheets produced during the Aso eruptions are some of the first ever described compositionally zoned pyroclastic flow deposits and are interpreted to be the result of extensive magma mixing of two compositionally distinct magmas in an upper crustal reservoir.

Here, we propose an alternative view of the Aso 4 ignimbrite sheets based on re-evaluation of whole rock data combined with mineral and glass geochemistry. The relatively scarce presence of mafic pyroxenes and plagioclases indicate recharge of hot, mafic magmas occurring shortly prior to eruption. However, the large amount of crystal-poor, felsic material in early erupted units in combination with late-erupted, crystal-rich basaltic andesite clasts, which are enriched in compatible elements and rich in compositionally highly evolved minerals, lead to the conclusion that magma mixing alone is not able to explain the complexities observed in Aso 4 deposits. Evidence for crystal accumulation in late erupted basaltic andesite clasts implies the formation of melt-rich lenses within a crystal-rich reservoir due to significant crystal-melt separation. We therefore propose an origin of the compositionally zoned Aso 4 ignimbrite largely by erupting a heterogeneous upper crustal reservoir, consisting of crystal-poor rhyodacitic melt pockets within a cumulate mush. The emptying of this heterogeneous magma storage zone was likely triggered by a recharge event from deeper in the system, initiating partial melting of previously-formed crystals (rejuvenation), mingling/ mixing, pressurization, and finally catastrophic evacuation of the eruptible portions of the subvolcanic reservoir, including parts of the cumulate mush.