How are large eruptions different? Reconstructing changes in magma reservoirs in the Taupo Volcanic Zone

Kari Cooper, Chad Deering, and Adam Kent

The largest volcanic eruptions are rare events but when they occur can represent a global catastrophe. This project focuses on examining recent caldera-forming eruptions from the highly active Taupo Volcanic Zone (TVZ) in New Zealand, focusing on the Okataina and Taupo Volcanic Centers (OVC and TVC). Our approach is primarily a petrological and geochemical one and focuses on studying full caldera cycles. The overarching project goal is to develop a better understanding of how the compositional variability, temperature and mobility of the magma reservoir below the surface changes before, during, and after a major eruption. As such the project contributes to an emerging understanding of the magmatic processes leading to large eruptions, and provides context for interpretation of hazard monitoring. The project also included field research experience for two K-12 teachers (one in the US and one in New Zealand) and K-12 course content development based on this experience.

Highlights of the results to date are:

1. Zircon age and trace-element data from unpolished rims and polished grain interiors provide a record of compositional changes within the reservoir spanning tens of thousands of years. Comparison of the compositional and thermal diversity of interiors vs. surfaces indicates that magmas drew crystalline material from a compositionally diverse crystal-rich reservoir, and that more than one compositionally distinct magma body was present at the time of the most recent caldera-forming eruption at both the OVC and TVC. In addition, the composition and ages of zircon hosted within plagioclase are distinct from those in the whole rock, providing insights into the nature of the crystal-rich source region.

2. New high-precision Sr, Nd, and Pb isotopic data for glasses from the complete caldera cycles show that the OVC and TVC erupted magmas that are largely isotopically distinct from each other, with temporal changes in composition evident for each center. Furthermore, some samples show Pb isotopic compositions that are more radiogenic than existing data for the local crustal rocks, suggesting that there is unsampled diversity in crustal materials contributing to the TVZ magmas, and/or that additional components (enriched mantle or lower crust) are contributing significantly to the melts.

3. Polytopic vector analysis, a multivariate statistical analytical tool, was used to determine the variability in plagioclase compositions among eruptions from the OVC spanning the time before, during and after the large, caldera-forming event. The results show that distinct crystal populations were shared (i.e. recycled) throughout the eruptive history, but specific end-member compositions dominate the crystal cargo following caldera collapse. This suggests that new, distinct magma compositions began accumulating following caldera collapse with limited recycling of material from the previous magmatic system.

Overall, the picture emerging from these combined data is one of a complex and compositionally diverse magma system present at any given time, with rapid assembly of the erupted magmas before eruptions. Although final data collection and synthesis has been delayed due to covid-19, additional data for the full sample suite will provide a more nuanced view of the evolving magma reservoir beneath the TVZ. ■

Right page, top photo. Tephra sequence from Okataina Caldera Center (including Rotorua eruption, ~15 ka) in quarry section. Left to right, Tyler Schlieder, Lydia Harmon, Elizabeth Grant, Damien Cranney, Nicole Rocco. Photo credit: Kari Cooper

View of Mount Nguarahoe along the Tongariro crossing. Photo credit: Kari Cooper