Magmatic-tectonic triggers leading to the eruption of multiple isolated magma batches and twin caldera collapse in the Taupo Volcanic Zone, New Zealand

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Calderas, their associated structures, and the geometry of their pre-collapse magma reservoir(s) have been the subject of much scientific intrigue, largely because they represent the largest scale of volcanic eruptions and our knowledge has only been gleaned from ancient examples. However, detailed field, analogue, and petrochemical studies of several calderas reveal an often complex arrangement of magma bodies that are chemically distinct from each other. In addition, the arrangement and geometry of these magma bodies can be dictated by regional tectonic structures that are activated during eruption and collapse. Here, we present new petrochemical evidence for a complex subvolcanic plumbing system including multiple juxtaposed magma bodies that erupted over a remarkably short timeframe to form twin calderas 30 kilometers apart.

The Rotorua and Ohakuri calderas in the central Taupo Volcanic Zone (TVZ) formed 240 ka with the eruption of >245 km3 rhyolitic magma associated with the Mamaku and Ohakuri ignimbrites, respectively. As a consequence, a large volcano-tectonic depression spanning the area between the two calderas formed. New pumice glass and melt inclusion data (combined with the existing bulk-rock and mineral chemistry) supports a petrogenetic model for six different magma batches extracted from the same source region, i.e. a laterally extensive and continuous intermediate mush zone beneath the Rotorua and Ohakuri calderas. Minor geochemical differences in the batches, including fluid mobile elements U, Cs, and Li and volatiles (CO2 and H2O), suggest different extraction conditions for the emplacement of the magma batches. However, combining the chemistry with the timing of eruption for each batch (recorded in the deposit stratigraphy) suggests a more tantalising picture for the spatial distribution of the magma batches in the upper crust and a close interplay between tectonics, magmatism and volcanism. In particular, the initial plinian airfall eruption from Ohakuri erupted simultaneously with the Mamaku ignimbrite from Rotorua and they share a similar trend in Cs and Li concentrations, and CO2 values that suggest, if volatile saturation was reached, melt inclusion entrapment at pressures ranging from 75 to 150 MPa. The chemistry suggests that the magma batches for the earliest eruptions may have been fed by a connected rhyolitic dyke on the western margin of the large volcano-tectonic depression. An elongated rhyolite dome with the same 240 ka age and same chemistry also lies on the western margin of the depression between the two calderas; further supporting the idea of a laterally extensive dyke. The evacuation of these magmatically linked melt batches via a laterally extensive dyke could have initiated rupture of regionally linked faults enough to trigger the eruption of the chemically distinct magma batches associated with the Ohakuri ignimbrite and collateral subsidence of the area between the two calderas.