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The mantle driving force behind Earth's most productive silicic volcanic system

Finnigan Illsley-Kemp (1), Simon J. Barker (1), Colin J. N. Wilson (1), Martha K. Savage (1), Michael C. Rowe (2), and Stephen Bannister (3)

(1) School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand (finnigan.illsleykemp@vuw.ac.nz), (2) School of Environment, University of Auckland, Auckland, New Zealand, (3) GNS Science, Avalon, New Zealand

The Taupō volcanic zone (TVZ), New Zealand, is a global end-member of continental volcanic arcs. The central TVZ features exceptionally high heat-flow and hosts one of the most productive and frequently active silicic magmatic systems on Earth, which is ultimately driven by large volumes of mafic magma from the mantle. We here consider the possible causes of these anomalous characteristics by combining geophysical and geochemical techniques to interrogate the supplies of mantle melts to the TVZ. By accurately locating seismicity in the subducted Hikurangi slab, we consider the distribution of brittle faulting and inferred volatile release from the overthickened slab. We then perform shear-wave splitting tomography on measurements of seismic anisotropy to invert for a model of three-dimensional flow in the mantle wedge. These geophysical observations are then compared with geochemical data using the composition of primitive magmas along the length of the TVZ, obtained by analysing melt inclusions in high-Mg olivine crystals erupted within the last ∼100 ka. Using this multidisciplinary approach we are able to directly constrain the depth and degree of mantle melting that has fed recent eruptive activity. Results reveal that faulting in the downgoing slab is focused at ∼175 km depth, along a zone parallel to but offset to the northwest from the TVZ. Directly above this region, in the mantle wedge, we observe sub-vertical mantle flow extending upwards to ∼40 km depth. Horizontal mantle flow varies from trench-parallel beneath the central TVZ, to trench-perpendicular at the northern and southern extents of the TVZ. Large differences in primitive melt compositions are also observed between the central and southern segments of the TVZ and between volcano types. Mafic melt compositions associated with large rhyolitic caldera volcanoes in the central TVZ differ from those feeding nearby small inter-caldera basaltic centres or andesitic stratovolcanoes in the southern TVZ. Geochemical models suggest that central-TVZ calderas are fuelled by distinctive mantle melts resulting from higher degrees of partial melting, a more depleted mantle-source and relatively smaller amounts of a slab fluid signature. The extended release of volatiles from the slab, coupled with and linked to decompression melting in the mantle wedge is what has led to the exceptional magmatic and volcanic productivity of this area in at least the last ∼100 kyr.