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Understanding Sources and Modification of Primary Magmatic Volatiles in the Taupo Volcanic Zone: Evidence from Helium and Oxygen Isotopes

DAVID FARSKY[1], MICHAEL ROWE[1], ISABELLE CHAMBEFORT[2], SIMON BARKER[3], SHANE ROOYAKKERS[2], KEVIN FAURE[2] AND DAVID W GRAHAM[4]

[1]The University of Auckland
[2]GNS Science, New Zealand
[3]Victoria University of Wellington
[4]Oregon State University
Presenting Author: dfar197@aucklanduni.ac.nz

The Taupo Volcanic Zone (TVZ) is a rifting volcanic arc overlying westward subduction of the Pacific plate under New Zealand, with clockwise rotation of the north-eastern part of the North Island unzipping the TVZ from north to south. Despite numerous attempts, distinguishing between magma generation (varying flux versus decompression melting) and crustal contamination as the cause of geochemical variations in basalt from the TVZ have proven difficult from major and trace element geochemistry. Helium and oxygen isotopes in mafic magmas provide a new approach to understanding these processes in the TVZ. We analyzed the isotopic composition of helium and oxygen in phenocrystic olivine and clinopyroxene in basaltic tephra from the Central TVZ and in basaltic andesite from the Southern TVZ. $^{3}He/^{4}He$ ratios are typical for a subduction zone, ranging from 5.27-6.61 R_A in CTVZ olivine and from 5.01-6.23 R_A in STVZ olivine. Clinopyroxene yields a range from 4.66-5.26 R_A in CTVZ and 2.85-4.85 R_A in STVZ, indicating a greater distinction between the two regions for clinopyroxene than for olivine. Lower $^{3}He/^{4}He$ correlates with a decrease in total helium abundance for many samples, possibly from increased susceptibility to small additions of crustal ^{4}He. Oxygen isotope data in both phases reveal a narrow band between 4.8-6.3 ‰ (CTVZ) and 4.9-5.3 ‰ (STVZ) in olivine, and are 6.0 ‰ (CTVZ) and 5.3-5.9 ‰ (STVZ) in clinopyroxene. CTVZ samples record higher $\delta^{18}O$ than samples from the STVZ with one exception.

Melt generation models confirm two end-member processes that account for the observed helium and oxygen isotope ratios: (1) Mixing and/or assimilation of ^{3}He-rich melts derived from MORB-like mantle ($^{3}He/^{4}He = 8\ R_A$) with crustal material during ascent and storage in upper crustal reservoirs; and (2) a shift from MORB-like values due to influx of slab-derived fluids having lower $^{3}He/^{4}He$. Our results show that primary melt production in the TVZ is driven by similar mantellic processes as in other volcanic arc systems and that minimal crustal assimilation occurs in the lower continental crust where pyroxenes crystallize. Oxygen isotope variations indicate minimal crustal assimilation and variations possibly reflect varying contributions from the subducting slab.