The magmatic-hydrothermal transition: Observations from the 2012 eruptions of White Island and Tongariro, New Zealand

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The 4 August 2012 phreatomagmatic eruption of White Island was the first significant activity from this volcano since February 2001. Although small in size and duration, the eruption was followed by the building of a 20 m high tuff cone, and subsequent extrusion of a small lava dome. Some 6 months prior to the eruption, low temperature (100 ℃ - 200 ℃) fumaroles on the main crater floor began to show increasing trends in CO_2/CH_4, CO_2/H_2O, C/S and CO/CO_2 ratios, constituting shifts from hydrothermal to increasingly magmatic signatures. These changes were also accompanied by a progressive isotopic shift in $\delta^{15}N_2$ from +2.9 ‰to +5.5 ‰. This is the heaviest $\delta^{15}N$ signature yet encountered in the Taupo Volcanic Zone, and provides new insights into the TVZ magmatic N_2 end-member composition. These anomalies were coupled to an increase in harmonic and broad spectrum tremor during the same period. Together, these observations provide an unequivocal context for recognising future eruptive activity, but also criteria for constraining hydrothermal system response, and gas-magma transport behaviour in this volcano.

Similarly, and just two days after the White Island eruption, the 6 August 2012 phreatic eruption of Te Mari, Mt Tongariro marked the re-awakening of this volcano which last erupted in 1896. This eruption was accompanied by precursory volcano-tectonic earthquakes, and by marked changes in chemical signatures of gases emitted from the Lower Te Mari fumaroles. Fumarolic gas sampled from the western rim of Lower Te Mari crater on 22 May 2012 showed no significant changes from baseline values. Earthquake activity commenced on 13 July, and intensified over the period of 18-21 July with approximately 120 located hybrid and volcano-tectonic events. Fumarolic gases collected on July 21 revealed significant changes in gas signatures from the Lower Te Mari fumaroles by this time, with key ratios of CO_2/CH_4 and N_2/Ar increasing from 5,400 to 91,200 and 91 to 1,245 respectively, and increasing further to 121,000 and 1,300 respectively by 27 July. During this time there were no significant changes in fumarolic temperatures or pressures, suggesting that permeabilities in the hydrothermal system were low, and were throttling gas transfer from below. Baseline C/S mole ratios for Te Mari fumaroles are close to 5. Immediately prior to the Aug 6 eruption, C/S had fallen to ca. 3, and post eruption fell to < 1, consistent with extensive degassing of a small magma volume. A second, short-lived pulse of CO_2-rich gas was recognised in late September, but this did not lead to further eruption activity. The current model for this activity involves open-system degassing of shallowly emplaced dike intrusion(s) beneath the volcano.