Geochemical Fluxes through the New Zealand Arc System

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The hydrothermal-magmatic activity occurring in high and low temperature hydrothermal systems in New Zealand provides a unique opportunity to trace mass transfer and coupled magmatic-hydrothermal processes in a convergent plate boundary, using the suite of elements that include: Ag, As, Au, Bi, Cd, Co, Cu, Fe, Ga, Ge, Hg, In, Mn, Mo, Ni, Pb, Pd, Pt, Se, Sn, Sb, Te, Tl, and Zn. Most of these elements behave incompatibly during crystallization, and all are commonly found in hydrothermal solutions (e.g., Williams-Jones and Heinrich, 2005; Simmons and Brown, 2006; Simon and Ripley, 2011). Recent analyses of deep, hot solutions from the Taupo Volcanic Zone show that there is an enormous hydrothermal flux of precious and base-metals, and related trace elements, but that there is considerable heterogeneity in the compositions of these deep fluids. This suggests that these constituents derive from mafic to intermediate composition magmas as well as the crust (Simmons and Brown, 2007). We propose to identify the sources of metals (listed above) and quantify their budgets and fluxes throughout the subduction zone factory (geochemical cycling), by broadening analytical studies and comparison of results to rocks/minerals occurring in the west Pacific ocean crust, sediment subducted in the Hikurangi trench, basement rocks of the North Island, young volcanic rocks of mafic, intermediate, and felsic composition, and to hydrothermal fluids from volcanoes and geothermal systems in low and high temperature systems. This information can also be used to place constraints on the petrogenesis of arc magmas and continental crust, and generalized to other well-studied arcs (e.g., Central American arc, and the Mexican Volcanic Belt).

Hydrothermal and Magmatic Activity in New Zealand

High temperature hydrothermal systems are concentrated in the Taupo Volcanic Zone where ~20 separate centers exist. These systems involve circulation of meteoric water to ~8 km depth, where it is heated and modified by mixing with magmatic volatiles, and subsequent water-rock interaction as the hybrid fluid(s) rises to the surface (e.g., Giggenbach, 1995; Rowland and Simmons, 2012). Chemical analyses of aqueous and gaseous species show that each center has a unique composition despite flowing through a similar stratigraphy of rocks. This likely reflects the variability of magmatic fluid compositions from compositionally distinct magmatic intrusions and the ratio of magmatic to meteoric fluid. One other high temperature hydrothermal system called Ngawha occurs in an intraplate setting, 300 km northwest of the magmatic arc (Simmons et al., 2005).

Additional hydrothermal activity is associated with low temperature systems that occur in sedimentary basins, along faults, and within the uplifted portion of the accretionary prism (Reyes et al., 2010). These occur scattered throughout the North Island, but in the South Island, they are clearly restricted to the Alpine Fault and related trans-tensional basins (Fig. 1).

Focus on Metals

While hydrothermal precious and base-metal transport is a salient feature of magmatic arcs, there are few studies that simultaneously examine the behavior of metals in magmas *and* hydrothermal fluids to understand the overall budget and flux of components in a convergent plate margin. The trace metal contents of magmas show considerable variability, suggesting heterogeneities in the source regions as well as modification during crystallization (e.g., Jenner et al., 2010; Jenner and O'Neil, 2012; de Ronde et al., 2012; Wysoczanski et al., 2012). Similarly, trace metal contents of hydrothermal fluids show variability that relates to magmatic inputs and hydrothermal water-rock interaction (Simmons and Brown, 2006 and 2007). Figure 2, for example, shows the contrast in trace metal patterns in hydrothermal fluids from two adjacent centers separated 10 kms apart despite sharing very similar host rocks. Without doubt, the enrichments in precious and base-metals seen in Rotokawa compared to Wairakei (Fig. 2) are due to varying supplies of metals from intruding magmas, which for Rotokawa is likely to be andesitic and for Wairakei basaltic (Giggenbach, 1995).

Sampling opportunities

New Zealand is an ideal natural laboratory because of the detailed understanding of the geological context for most of the hydrothermal and volcanic activity. Spring water samples are easily obtained from many high and low temperature hydrothermal centers, including those occurring in the forearc region, and on White Island volcano. In addition, some repeat sampling of production wells, using the titanium down-hole sampler, can be done on a limited basis assuming access to wells is possible during power plant shutdowns. A full suite of igneous rocks are easy to obtain from all the young volcanic centers, and DSDP/ODP drill sites in the western Pacific ocean, east of the Hikurangi trench, provide rock samples of oceanic sediment/crust that represent subducted material.

We discussed our proposed science plans with Dr. Shaun Barker at the University of Waikato, Dr. Julie Rowland at the University of Auckland, and Dr. Kevin Brown at the University of Canterbury, and envision collaboration with them and students to enrich the science and increase broader impact for all team members, including students.

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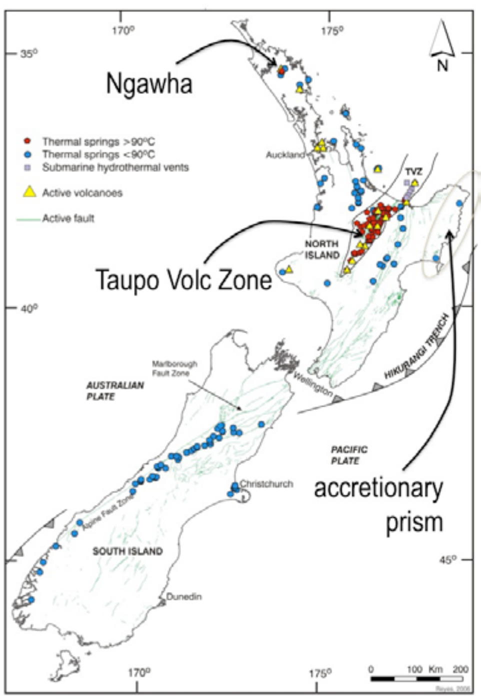

Figure 1 shows the distribution of hydrothermal activity in New Zealand. High temperature systems occur in the Taupo Volcanic Zone (TVZ), which is a young extensional volcanic arc with exceptional heat flow ~4200 MW (Bibby et al., 1995; Hochstein, 1995; Rowland and Simmons, 2012). Volcanism in the northern and southern segments is dominated by cone-building eruptions of andesite, whereas the central segment is dominated by explosive eruptions of rhyolite, with more than 15,000 km^3 of air-fall deposits, ignimbrites, and lavas. Within the TVZ, the thermal output of volcanic eruptions is ~25% of the total heat flow due to hydrothermal activity, which is the dominant mode of heat transfer on the time scales of ten thousands to hundred thousands of years (Hochstein, 1995). Other young isolated volcanic centers occur along the west coast of the North Island (Mt Egmont-andesite cone), and in the north part of the North Island (Auckland, Whangarei, and Kerikeri volcanic fields), the latter of which are made up of predominantly basaltic volcanoes.

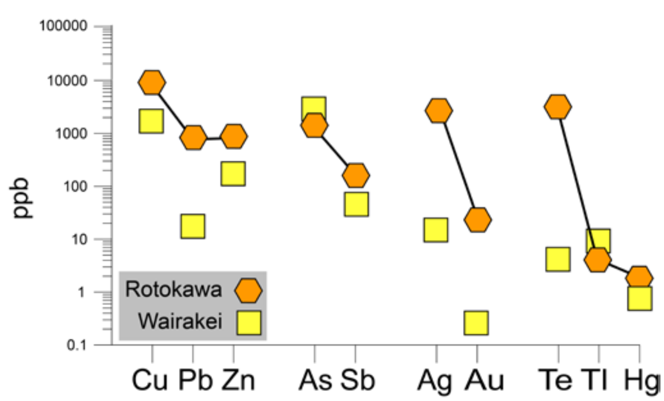

Figure 2. The graph shows the trace metal patterns for deep hydrothermal fluids sampled with a titanium-sampler in production wells from Wairakei and Rotokawa fields. These two fields are separated ~10 km apart in the TVZ, and they share a common geological setting. Note the strong enrichments in Au, Ag, Cu, Pb, Zn and Te in Rotokawa, whereas As, Sb, Tl, and Hg are similar (Simmons and Brown, 2007, unpub).