

Whole-Rock and Ordered White Micas Major and Trace Element Chemistry: Implications for Volcanic-Hosted Geothermal and Epithermal Deposit Exploration

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New insights concerning chemical zoning in active geothermal systems of the Taupo volcanic zone refine the chemical footprint of both dilute meteoric-dominated and magmatic-hydrothermal fluids in the epithermal environment. Full litho-geochemical whole-rock analyses (via 4-acid digestion with Au super trace) contents of altered rocks at the Ngatamariki, Rotokawa, and Broadlands geothermal systems (n = ~100), show major variation with depth, due to the influence of past hydrothermal activity (i.e., at Ngatamariki where a shallow intrusion degassed at 0.7 Ma), natural variability of the reservoir rocks, and current active fluid-rock interactions. Correlations and chemical patterns were estimated by plotting trace element contents as a function of the depth. The concentrations of Au, Tl, Bi, Sn, Ag, Se, and Te generally increase upward toward the paleosurface, where they are 10 to 100 times greater than near the intrusions that may be the source of metals. Close to the paleosurface, samples show a clear depletion in Sr as well as Al and Sc inferred to be the result of the degassing of the intrusion. Samples distal to or post-dating this magmatic-hydrothermal alteration consistently contain less Au, Ag, As, Sb, Bi, and Te than samples of rock affected by the intrusion-related alteration, highlighting the intrusive complex as the likely source of the metals. In contrast to the pre-modern Ngatamariki enrichment, active geothermal fields do not show enrichment in Bi, Se, Mo, and Te, and only rarely are enriched in Ag and Tl (only detectable in Rotokawa mud samples), but show clearly zoning in As, Au, Sb, Sr, Li, and Cs.

Samples for clay in situ analyses were selected based on XRD and Terraspect results. We only analyzed samples that have been classified as illite (phengite/muscovite)-bearing as they likely represent the highest temperature clay in the systems. Major and trace element analyses of the white micas is dependent on temperature, water/rock ratio, and fluid composition. Illites can be classified by calculating the Al atoms per formula units and atomic Mg/Fe for each analysis. Clay trace element content is independent of the illite stoichiometry, and volatile and trace metal element contents correlate well with the whole-rock chemical footprint. “Shallow” illite is enriched in As, Te, Cl, S, Li, and B, whereas deeper samples show enrichment in Ba and Tl.

This complete set of whole-rock and clay compositions represents a major advancement in our understanding of the chemistry of active geothermal systems but also the footprint for epithermal ore systems. Chemical vectoring in geothermal systems toward a magmatic source in the TVZ is now documented. The intrusive complex and subjacent magma bodies feeding it are proposed as the source for metals, and thus the key element anomalies can be used to track the upflow paths of magmatic gasses in active geothermal systems. Enrichment in Bi, Ag, Sn, Se, Tl, Te, and possibly Zn, and depletion in Sr, Al, and Sc are apparently characteristic of the chemical zoning due to the magmatic intrusion and the intense associated acidic alteration toward the paleosurface.