Compositional variations in very small basaltic systems reveal near source processes

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The chemical compositions of primary basaltic magmas should reflect the conditions and processes of their sources but commonly this interpretation is hindered by mixing and fractionation processes during assembly, transport and storage prior to eruption. In the Auckland Volcanic Field, a small volume intra-plate basaltic province, individual eruptions are the products of very small batches of magma (typically ~0.1-0.01 km^3 DRE). Individual centres show a spread of compositions forming an array that encompasses that of all intra-plate basalt provinces worldwide. Primary magmas in the Auckland field were generated by 2-7% melting at >2.5 GPa from a uniform peridotitic source in which garnet remained as a residual phase. Thus although compositions in the field range from strongly alkaline to transitional to tholeiitic they all originate at comparable depths in the mantle.

Consistent chemical variations at each individual Auckland volcano can be explained by 40-50% fractionation of a primary magma at pressures of at least 1.4-1.9 GPa involving a high pressure mineral assemblage dominated by clinopyroxene forming on the walls of the conduit as the magma ascends from the zone of melting [1]. By this process the thermal structure of the source region imposes a barrier so that no truely primary magmas can ever reach the surface. The evidence for these near-source processes is observed in the Auckland Volcanic Field because the rates of magma production and volumes of individual magma batches are very small. Thus fundamental characteristics of the melting and melt extraction processes that would be overwritten by mixing during storage in a larger scale magmatic system are preserved. A major challenge is to integrate geophysical and geochemical anomalies to develop a model for the behaviour of the mantle at temperatures very close to the solidus.

[1] I.E.M. Smith *et al.* (2008) *Contributions to Mineralogy & Petrology* **155**, 511-527.

Tailings deposition in hyper-arid climate: Stable isotopes as tracer of geochemical and mixing processes

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A multiple stable isotope study ($\delta^{34}S_{sulfide}$, $\delta^{34}S_{sulfate}$, $\delta^{18}O_{sulfate}$, $\delta^{2}H_{water}$, $\delta^{18}O_{water}$) was used to trace the geochemical and mixing processes (fluid-fluid, fluid-sediment) in tailings discharged into the Talabre impoundment, Atacama Desert, Chile. The tailings originated from the exploitation of the giant porphyry copper deposit Chuquicamata, Chile. Processes which controlled the variability of the $\delta^{34}S$ and $\delta^{18}O$ values of the dissolved sulfate in the fresh tailings (5.7‰ $\delta^{34}S$, 6.9‰ $\delta^{18}O$) were dissolution of primary gypsum/anhydrite (2.1‰ to 16.9‰ $\delta^{34}S$, 7.5 to 11.6‰ $\delta^{18}O$) and oxidation of primary sulfides (–5.4‰ to 2.6‰ $\delta^{34}S$). In sedimented tailings, $\delta^{34}S$-depletion in dissolved sulfate (up to 2.4‰ $\delta^{34}S$ in tailings 5 years exposed to oxidation) clearly indicated the increased liberation of isotopically light sulfur from primary sulfides with time of exposure. This isotopically lighter signature was also found in secondary sulfates precipitating as superficial efflorescent salts (2.5 - 5.7‰ $\delta^{34}S$, 1.2 - 3.5 ‰ $\delta^{18}O$). Infiltration of brines and dissolution of sulfates from the underlying salt-pan (6.3‰ $\delta^{34}S_{sulfate}$, 11.6‰ $\delta^{18}O_{sulfate}$) and/or older oxidized tailings seemed to contribute to the changes of the $\delta^{34}S_{sulfate}$ (up to 9.6‰) and $\delta^{18}O_{sulfate}$ (12.1‰) values. The $\delta^{2}H$ and $\delta^{18}O$ values of water in fresh tailings (–61.2‰ to –58.8‰ $\delta^{2}H$, –7.0‰ to –6.7‰ $\delta^{18}O$) followed an evaporative trend indicating a high contribution of recycled water from the tailings impoundment into the flotation process. The isotopic enrichment of pore water from the uppermost sedimented tailings (–69.9‰ to –53.0‰ $\delta^{2}H$, –6.4‰ to –5.7‰ $\delta^{18}O$) was mainly due to evaporation in the local, hyperarid climate. A positive shift of the $\delta^{18}O$ and $\delta^{2}H$ values in the pore waters of the deep vadose zone was attributed to the partial evaporation and capillarity-driven upward diffusion and vapour-transport of water during residence in the upper meter of the tailings section. Mixing of isotopically heavy brine waters (–23.7‰ $\delta^{2}H$, 2.0‰ $\delta^{18}O$) and isotopically light groundwater (–71.5‰ $\delta^{2}H$, –9.8‰ $\delta^{18}O$) with tailings water combined with water-rock interaction (hydration, exchange) in tailings below the water table explained the $\delta^{2}H_{water}$ and $\delta^{18}O_{water}$-changes in different areas of the tailings impoundment.