Chemical weathering of Taranaki volcanics, North Island, New Zealand

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New Zealand's North Island watersheds in the Taranaki and Manawatu-Wanganui regions have been subject to volcanism since the Miocene. We sampled water and sediments from watersheds that contain both volcanic and sedimentary rocks. Water and sediment samples were collected and analyzed for major, minor and trace elements, in order to quantify the weathering intensities in the watersheds and to establish the relationship between physical and chemical weathering yields in volcanic lithologies.

Results reveal distinct chemical signatures, with waters draining the Taranaki region volcanics significantly enriched in K^+ and depleted in Sr^{2+} compared to those draining the Manawatu-Wanganui region volcanics, which also traverse expanses of sedimentary siltstones and mudstones. These depletions may reflect the relative absence of $CaCO_3$ in the Taranaki region watersheds. In addition, sediment samples from the Taranaki Region show significant enrichment in Ti, Al, Ca, Fe, Mg, Mn, Mg, Ca, and P and depletion in Si and Rb compared to those of the Manawatu-Wanganui region.

Mineral stability diagrams for streamwater samples show that primary feldspar minerals present would weather to kaolinite while clay minerals would likely be present as kaolinite, illite, or Mg-montmorillonite. Normalized sediment values for the Taranaki region exhibited a best fit pattern to average Mt. Egmont andesite values with relative soluble alkali and alkaline earth elements Na, K, Rb, Sr, and Ba and insoluble elements Ti, Al, and Fe, while normalized values for the Manawatu-Wanganui region exhibited a best fit pattern to near shore mud.

From total dissolved solids concentrations and annual volumetric water discharge, chemical weathering yields of 60–238 tons km^{-2} a^{-1} are obtained. These weathering yields fall within the middle to upper range of those previously reported for New Zealand's Southern Alps (93–480 tons km^{-2} a^{-1}) and East Cape (62–400 tons km^{-2} a^{-1}). Calculated silicate weathering yields of 12–33.6 tons km^{-2} a^{-1} and CO_2 consumption of $852–2390\times10^3$ moles km^{-2} a^{-1} for the rivers draining the Taranaki volcanic region are higher than those previously reported for watersheds hosted in sedimentary and metamorphosed rock terrains on HSIs. CO_2 consumption is found to be within the range which others have reported for the basaltic terrains of the Deccan Traps ($580–2450\times10^3$ moles km^{-2} a^{-1}) and Réunion Island ($1300–4400\times10^3$ moles km^{-2} a^{-1}). Calculated chemical weathering yields demonstrate the importance of taking into account weathering on high-standing oceanic islands, particularly those with volcanic terrains, when considering global geochemical fluxes.

The nature of the mantle source of Archean ferropicrites

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Although ferropicrites have been recognized as an unusually Fe-rich mafic igneous rock for some time, the nature of their mantle source remains unclear. Ferropicrites are most common in Archean terranes and four occurrences from the Superior craton form the basis of this study: the Steep Rock, Lumby Lake, Grassy Portage Bay, and Dayohessarah Lake greenstone belts. Ferropicrites from the first three belts occur as ash to lapilli tuffs, while those from the latter belt occur as coarse-grained intrusive rocks cutting basalts and komatiite flows. These ferropicrites are mafic to ultramafic rocks (15-23 wt% MgO) characterized by low Al_2O_3 (<8 wt%), high FeO* (15-21 wt%), and relatively high TiO_2 contents (1-2 wt%). They have fractionated REE profiles (La/Yb = 8-20; Gd/Yb = 3-4.5) and relatively high contents of HFSE (Nb = 10-18 ppm; Nb/La = 0.8-3.0). In contrast, coexisting komatiites from Dayohessarah have higher Al_2O_3 (9-11wt%) and lower contents of FeO* (~11 wt%), TiO_2 (~0.5 wt%), HFSE, and LREE, despite having similar MgO contents; they also exhibit flat REE profiles (La/Yb = 1-2).

These geochemical differences require that the two magma types have different mantle sources. Peridotite-basalt mixtures that have been proposed as possible ferropicrite mantle sources fail to reproduce ferropicrite Fe contents. A garnet pyroxenite mantle source does not have sufficient Mg to produce liquids with up to 20 wt% MgO, and an olivine-dominated source seems to be required. Melting experiments on model mantle compositions (KLB-1, Mg # = 89.6) suggest that komatiitic liquids like those at Dayohessarah can be produced at 45 kbar, but do not reproduce the Fe contents of ferropicritic liquids under any conditions. Experimental melts of a model Martian mantle composition (Mg # ~80) at 15 kbar have nearly identical Fe contents to our ferropicrites, and melts produced at 50 kbar have Fe contents significantly higher than our ferropicrites. Interpolation of these data shows that the mantle source of our ferropicrites would have a Mg # of ~80 at 15 kbar, which would require large degrees of partial melting, or a Mg # of ~85 at 50 kbar. In the latter scenario, these ferropicritic liquids would be the result of smaller degrees of partial melting, consistent with their fractionated trace element profiles and lower Al contents relative to komatiites, if garnet were not completely consumed during ferropicrite petrogenesis.