Thallium isotope constraints on the water fluxes of ridge flank hydrothermal systems

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Hydrothermal activity in the oceans is not restricted to the high-temperature (T) vents that are found at mid-ocean ridge axes. Rather, ridge flanks have a total hydrothermal power output which exceeds the axial output by at least a factor of 3. As the temperatures are comparatively low at ridge flanks, the respective water flux must be several orders of magnitude larger than on-axis, to remove the inferred power output. Even small changes in the composition of the circulating fluids can therefore produce very significant chemical fluxes. Our understanding of the importance of these chemical fluxes with respect to global geochemical budgets is limited, however, because the partitioning of heat between warmer, more reactive fluids with $T \geqslant 40$ °C and cooler fluids, which have $T \leqslant 20$ °C, is only poorly constrained.

In this study, we have used Tl isotope and concentration data for altered ocean crust and hydrothermal fluids to constrain the water fluxes and average fluid exit temperatures of ridge flank hydrothermal systems. The calculations are based on the observation that the upper ocean crust, which has been altered at low temperature, has fractionated Tl isotope compositions and elevated Tl concentrations. The observed systematics can be exploited to calculate the flux of low-T hydrothermal fluids (F_{LT}) by mass balance:

$$F_{LT} \times [Tl]_{sw} \times f_{upt} = F_{uoc} \times \Delta[Tl]_{uoc}$$

Here $[Tl]_{sw}$ is the Tl concentration of seawater, f_{upt} is the fraction of Tl removed from seawater by alteration, F_{uoc} is the mass flux of upper ocean crust affected by low-T hydrothermal alteration, and $D[Tl]_{uoc}$ is the average change of Tl concentration observed for low-T altered ocean crust.

The calculations indicate that the hydrothermal water flux of ridge flanks is $(0.2–5.4) \times 10^{17}$ kg/yr. This implies that the fluids have an average temperature anomaly of only about 0.1–3.6° relative to ambient seawater. Such low temperatures should severely restrict the effect of ridge flank hydrothermal systems on the marine budgets of $^{87}Sr/^{86}Sr$ and Mg. This conclusion is in accord with the results of previous rock alteration studies, which concluded that the fluxes of low-T hydrothermal systems are insufficient to balance the oceanic budgets of these elements.

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Lateral persistence of the Merensky Cyclic Unit and the significance of footwall reconstitution within normal to Regional Pothole Reef types in the Bushveld Complex

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At Northam Platinum Mine, in the Western Limb of the Rustenburg Layered Suite of the Bushveld Complex, South Africa, a regional-scale (km-scale) excursion, or "pothole" structure, commences at the level of the Merensky Reef (Normal Reef sub-facies) and transgresses underlying cumulate lithologies as part of the Regional Pothole Reef sub-facies. At several discrete levels within this sub-facies, the Merensky Cyclic Unit (MCU) becomes conformable to cumulate layering and results in four distinctive Regional Pothole Reef types, namely the NP2, P2, FWP2 and FWP1 Reefs. The immediate footwall (<1–3 m) to the MCU in Normal and Regional Pothole Reef types displays mineralogical and textural evidence for thermal and chemical interaction with the MCU magma, referred to as "reconstitution fronts," and carry significant PGE grade. In this contribution, we present the results of a petrological and whole-rock geochemical investigation of Normal and two Regional Pothole Reef types (NP2 and P2), with a particular focus on the petrogenesis of reconstitution fronts, that was undertaken to test magmatic versus hydrothermal models of PGE mineralization and the potential role of fluids in the formation of the Regional Pothole Reef sub-facies.

The petrology and geochemistry of reconstituted rocks indicates that the erosional surface to the MCU in Normal and Regional Pothole Reef sub-facies at Northam was affected by the influx of the Merensky magma rather than fluid-related processes. Reconstitution occurred in response to thermal and chemical gradients at the local interface between the Merensky magma and variable footwall lithologies (a function of the level of transgression). These observations suggest that the Regional Pothole Reef sub-facies was not a site of significant fluid streaming and that pothole formation was most likely associated with thermomechanical erosion. Significantly, the asymmetrical magmatic PGE signature persists from Normal Reef sub-facies into the Regional Pothole Reef sub-facies and indicates that PGE mineralization inherent to the Merensky magma occurred as a drape over a variably eroded footwall surface.

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