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 ≥ 40°C and cooler fluids, which have T ≤ 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 $\Delta[Tl]_{uoc}$ 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) x 10^{17} kg/yr. This implies that the fluids have an average temperature anomaly of only about 0.1 to 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.