The role of low-temperature, off-axis, hydrothermal circulation in the long-term C-cycle and seawater $^{87}Sr/^{86}Sr$

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With a few notable exceptions, most long-term C-cycle models have played-down the role of low-temperature (T), off-axis, alteration of the oceanic crust as a feedback on the climate system. However, the C-content of Cretaceous-age (hot-house) oceanic crust is much higher that of late-Cenozoic-age (ice-house) oceanic crust [1]. This difference can only be explained if reactions in off-axis hydrothermal systems produced more alkalinity in the Cretaceous than late-Cenozoic [2]. While several possible feedback mechanisms have been proposed, the simplest is that higher bottom water temperatures in the Cretaceous enhanced reaction rates leading to greater alkalinity production [3]. An indirect approach to determining the T-dependence of reactivity of the crust in off-axis hydrothermal systems comes from the Sr-isotopic composition of carbonate minerals formed within these systems. Different crustal sites have different local hydrological regimes leading to different alteration temperatures. Combined O-isotope thermometry and Sr-isotope analyses of carbonates show the crustal contribution to the Sr-isotopic composition of the hydrothermal fluid increases significantly for a 10°C increase in hydrothermal fluid temperature. While this observation does not directly constrain alkalinity production, it is consistent with a decrease in the intensity of "chemical weathering" of the oceanic crust with decreasing bottom water temperature.

The temperature dependence of the amount of unradiogenic crustal Sr in off-axis hydrothermal fluids provides a direct constraint on the role of these fluids in controlling the Sr-isotopic composition of seawater. Feeding the T-dependence derived above into a seawater box-model shows that small changes in bottom water temperature can have a substantial (>0.001) impact on seawater $^{87}Sr/^{86}Sr$.

We hypothesize that late Cenozoic cooling led to decreased fluid-rock reaction rates within off-axis oceanic hydrothermal systems decreasing CO_2 consumption and decreasing the flux of unradiogenic Sr in the ocean. This would have helped stabilize atmosphere CO_2 and led to an increase in seawater $^{87}Sr/^{86}Sr$ (as observed). This model could decouple enhanced (continental) silicate weathering due to India-Asia collision from the negative feedback (oceanic) required to stabilize atmospheric CO_2.

[1] Gillis & Coogan (2011), *EPSL* **302** p385;[2] Coogan & Gillis, G3 p1771; [3] Brady Gislason (1997), *GCA* **61** p 65.