

Tracing hydrothermal and metamorphic fluxes of CO₂ and solutes from the central Himalaya

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Geothermal springs are common near major faults and shear zones in central Nepal. Most systems are found either near the Main Central thrust shear zone (MCT) or in the N-S trending grabens such as the Thakola. We have collected data on spring and stream water chemistry and fluxes and use these to make estimates of the fluxes of heat, carbon dioxide, and other solutes derived from hydrothermal activity. Oxygen and hydrogen isotopic data demonstrate that the water is dominated by meteoric sources. However, high $\delta^{13}\text{C}$ values (up to +12‰) from dissolved inorganic carbon indicate that a substantial fraction of CO₂ in the geothermal systems is of metamorphic origin. Elemental mass balances, ⁸⁷Sr/⁸⁶Sr, and Ge/Si data show that the springs are a major source of solutes to Himalayan streams.

Ge/Si ratios are a particularly sensitive tracer of hydrothermal input, as hot spring waters have Ge/Si up to 1000 $\mu\text{mol/mol}$, while local surface waters are < 0.5 $\mu\text{mol/mol}$. The extreme values are produced by Rayleigh fractionation of the fluid during precipitation of low Ge quartz. In some springs very high Cl⁻ and/or ⁸⁷Sr/⁸⁶Sr are also useful tracers of hydrothermal input.

Carbon isotope mass balances indicate that a large proportion of silicate derived alkalinity in High Himalayan rivers is composed of carbon released by metamorphic decarbonation reactions at depth. Metamorphic CO₂ released at 300-400°C is entrained in meteoric circulation where it interacts with silicate wall rocks. Much of this CO₂ is neutralized within the hydrothermal system, implying that the hot springs act to "short circuit" the long term carbon cycle, i.e. degassed CO₂ is consumed by water rock reaction before it can even enter the surface weathering environment. Zones with abundant water-rock interaction at hydrothermal temperatures must be considered an extension of the weathering environment, with "high temperature" weathering reactions an important sink for CO₂. Hydrothermal systems are common not only near major thrust boundaries in the Himalaya, but also in arc environments where CO₂ degassing is important.

References

M. J. Evans et al., *Geology* 29, 807-810.

Biogeochemical carbon cycles during the Archean and early Proterozoic

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The carbon cycles offer clues about our early biosphere. The $^{13}\text{C}/^{12}\text{C}$ values of Archean sedimentary kerogens ($\delta^{13}\text{C}_{\text{ker}}$) reveal their biological origins. Some Archean stromatolites might indicate photosynthetic biota. But evidence for O₂-producing photosynthesis (e.g., 2-methylhopanes, steranes, environmental settings of stromatolites) is compelling only by 2.7-2.8 b.y. ago. The impact of O₂ photosynthesis is shown for modern Earth. Hydrothermal sources deliver $(0.13-1.1)\times 10^{12}$ mol yr⁻¹ of reduced S, Fe²⁺, Mn²⁺, H₂ and CH₄ globally; this could sustain at most ca $(0.2-2)\times 10^{12}$ mol C yr⁻¹ of biological production. In contrast, global primary productivity (GPP) due to O₂-photosynthesis is about 9000×10^{12} mol C yr⁻¹. Thus, although thermal fluxes were greater in the Archean than now, the onset of O₂ photosynthesis still increased GPP by at least 100 times. But sedimentary organic C concentrations might not reveal the effect of O₂ photosynthesis on GPP. For a pre-3.0 Ga Earth lacking O₂ photosynthesis but having a geothermal heat flow 2 to 3 times the modern value, GPP might have been in the range 10×10^{12} mol C yr⁻¹. Assuming an Archean global sedimentation rate that was equal to the modern rate (1.3×10^{16} g yr⁻¹), and assuming that half of the C from GPP was buried, the mean organic C concentration of sediments would have been about 0.4%. This is indistinguishable from modern values, which scatter widely but have a mean of 0.5-0.6%. Archean $\delta^{13}\text{C}_{\text{ker}}$ values exhibit multiple modes between >-10 to <60, indicating diverse C assimilation pathways in globally-prominent anaerobic ecosystems. Primary Archean $\delta^{13}\text{C}_{\text{carbonate}}$ values all cluster near 0, consistent with total control of the redox state of the Archean C cycle by the mantle. However, O₂ photosynthetic microbial ecosystems accelerated permanent environmental change. Initially, microbial O₂ production was totally consumed by biota and by volcanic species. However, some of the H₂ from fermentation traversed the anoxic atmosphere and escaped to space, perhaps at rates $>100\times 10^{12}/\text{yr}$. Such a large, permanent loss of reducing power would have exceeded the annual organic C sedimentation flux (today's flux is ca $10\times 10^{12}/\text{yr}$). Such an H₂ loss perhaps accelerated the permanent oxidation of the biosphere.

By 2.4 b.y. ago, O₂ photosynthetic GPP rose well above the levels sustained by mantle-derived fluxes of reduced species. Large positive $\delta^{13}\text{C}_{\text{carbonate}}$ excursions indicate high relative organic sedimentation rates and confirm the global impact of O₂ photosynthesis.