The magnitude and implications of atmospheric CO_2 released by metamorphic processes in the Himalayan-Tibetan orogen

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Abstract:

Orogenic belts play a critical role in regulating the global carbon cycle, contributing to the movement of about 10^{14} grams of carbon through this carbon cycle every year. This includes a drawdown of ~1.75-2.40 × 10^{14} g of CO_2 by silicate weathering and organic carbon burial, which is balanced by ~1.10-2.40×10^{14} g of CO_2 released by carbonate weathering, petrogenetic organic carbon oxidation, and degassing from volcanoes and mid-oceanic ridges. However, this carbon cycle does not account for CO_2 released from metamorphic processes. In the Himalayan-Tibet orogen, hot springs in geothermally active areas are centered around structural discontinuities such as faults, fractures, and shear zones. These provide ample conduits for meteoric water to circulate and bring deep-derived volatiles to the surface under the influence of the geothermal gradient. In this study, we created a global compilation of temperature, pH, dissolved inorganic carbon (DIC) concentrations, $\delta^{13}C$ composition of DIC ($\delta^{13}C_{DIC}$) and degassed CO_2 ($\delta^{13}C_{CO2}$), hot spring discharge, soil CO_2 flux estimates, He concentrations and isotopic ratios ($^3He/^4He$) in different geothermal fields in the orogen. A Rayleigh fractionation model was used to quantify the fluxes of CO_2 degassed from hot springs located on the fault systems of the Himalayan-Tibetan orogen- the youngest orogen in the world. We show that the orogen could degas up to ~95% of the dissolved CO_2, releasing an order of magnitude of 10^{12} g of CO_2 yr^{-1}. When combined with diffuse soil CO_2 emissions, the orogen could degas up to ~10^{13} g CO_2 yr^{-1} to the atmosphere. Such an atmospheric flux of CO_2 is similar in magnitude to emission from continental rifts, volcanoes, and mid-oceanic ridges and could play a fundamental role in regulating long-term climate. A combined $\delta^{13}C_{CO2}$ and $CO_2/^3He$ mixing model further reveals that across the region, on average, metamorphic rocks contribute >66% of this degassed CO_2. We show that the addition of degassed metamorphic CO_2 fluxes to the geological carbon budget can offset the impact of the erosional carbon sink on million-year timescales.

Keywords: Metamorphic CO_2, Carbon Cycle, Himalayan Orogeny, Climate Change