Fossil Carbon Release and Exports from Subsurface Sedimentary Bedrock Weathering in Mountainous Watersheds

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Abstract:

Chemical weathering of silicate rocks can be a sink for atmospheric CO_2, while weathering of sedimentary rocks can be a source of CO_2 emission. Because sedimentary rocks cover about 2/3 of the Earth's land surface and contain the Earth's largest C inventory as fossil organic carbon (OC_{petro}) and inorganic carbonate (IC_{petro}), it is important to understand contributions of rock weathering to the terrestrial C cycle. Predictive models on C transfer between rocks and atmosphere are based on the estimated rates of tectonic uplift, weathering, and erosion of exhumated rocks on the Earth's surface over geological time scales. Recent critical zone research has advanced towards greater recognition of *sub*surface rock weathering. However, quantifying subsurface weathering rates is limited by knowledge of where the most important weathering reactions take place and depth-dependent water fluxes. This research integrates a range of measurements to develop understanding of modern-day rock weathering impacts on C cycling.

This study was conducted in the East River watershed located in the Upper Colorado River Basin where recharge occurs primarily during snowmelt. Along a lower montane hillslope underlain by Mancos Shale, we drilled several deep boreholes and instrumented them with numerous samplers and sensors. We collected 5 years of time- and depth-resolved hydrological and biogeochemical data, including solid, porewater, and pore-gas chemistry, as well as ^{14}C signatures in solid C, DIC, DOC and CO_2. We found that (1) modern-day sedimentary rock weathering releases DIC_{petro} and DOC_{petro} from a narrow region below the soil, which we define as the weathering zone; the annual water table oscillation determines this zone's thickness and the deepest extent of the water table determines the weathering front. This finding combined with well-constrained subsurface flow

rates allowed quantification of weathering rates. Because vast areas of the Earth's surface are underlain by sedimentary rocks, this new insight on the weathering zone's role in the carbon cycle is important. (2) The dissolved carbon pool in the subsurface consists primarily of DIC_{petro} (~ 85%), which exports through groundwater for eventual CO_2 emission from surface waters. (3) The measurements-based annual release rates from shale bedrock weathering are 85 and 15 kg/ha of IC_{petro} and OC_{petro}, respectively. Our estimated global scale rate of C_{petro} release from subsurface shale bedrock weathering to the environment is about 0.32 Pg per year.