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Orogenesis as a carbon dioxide source or sink? New insights from the organic carbon cycle of Taiwan (Penck Lecture)

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Mountain building can promote the sequestration of atmospheric carbon dioxide (CO_2) by the erosion of organic matter from the terrestrial biosphere ($OC_{biosphere}$), and its transport in sediment-laden rivers to sedimentary deposits. However, erosion and exhumation can expose rock-derived organic carbon to chemical weathering. Oxidation of this petrogenic organic carbon (OC_{petro}) is a source of CO_2which is very poorly constrained. Here, the OC budget of a mountain belt is quantified to better understand whether erosion in mountain belts results in a net source, or sink of CO_2.

The erosion, transport and offshore fate of $OC_{biosphere}$ has been tracked through mountain river systems in Taiwan, using a suite of elemental (C, %), stable isotope (δ^{13}C) and radiocarbon (Δ^{14}C) measurements. During floods at high suspended sediment concentrations, $OC_{biosphere}$and $OC_{petro}$is transferred rapidly to the deep ocean. Marine sediments show evidence for efficient, long-term preservation of $OC_{biosphere}$. Large amounts of terrestrial OC and sediment are also delivered to the surface ocean, dispersing OC over a larger area. Marine sediments sourced by this delivery mechanism have C, δ^{13}C and Δ^{14}C values which suggest $>$70% of the terrestrial OC is preserved offshore.

To quantify OC_{petro} oxidation rates in mountain catchments, the trace element Rhenium (Re) is used as a proxy. Existing measurements of physical erosion in Taiwan rate also allow the controls on OC_{petro} oxidation to be assessed. Re is associated with OC_{petro} in rocks and following oxidation during chemical weathering forms a soluble anion which contributes to the dissolved load of rivers. Soils in Taiwan confirm that Re loss is coupled to OC_{petro} loss during weathering, and so the dissolved Re flux is used to provide a first order estimate of the corresponding release of CO_2 in river catchments. OC_{petro} oxidation increases with erosion rate. It is likely that the OC_{petro} oxidation rates estimated from dissolved Re flux are an upper bound. Nevertheless, the estimated CO_2 release from Taiwan by OC_{petro} oxidation does not negate the estimates of CO_2 sequestration by burial of $OC_{biosphere}$ offshore. The findings from Taiwan are compared to OC transfers estimated for the Himalaya, where OC_{petro} oxidation in the mountain belt remains unconstrained. Together, these cases suggest that mountain building in the tropics can result in a net sink of OC which sequesters atmospheric CO_2.