Erosion and weathering drive net CO₂ drawdown in the Mackenzie River Basin over geological time

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Erosion and weathering transfer carbon between the atmosphere and the lithosphere, thereby acting to modify Earth’s long-term climate. Over millions of years, atmospheric carbon dioxide (CO₂) is sequestered during the weathering of silicate minerals by carbonic acid, coupled to carbonate formation, along with the erosion of biospheric organic carbon and its burial in sediments. However, erosion and weathering also act together to release CO₂ from the lithosphere. Erosion enhances the rate of oxidative weathering of organic carbon in rocks (petrogenic OC, OCpetro), which is a major CO₂ source over geological time. In addition, the oxidation of sulfide minerals can produce sulfuric acid that weathers carbonate minerals and results in transient CO₂ release. Although these sources and sinks of CO₂ are well recognised, limited case studies exist where they have been measured alongside each other.

Here, we calculate the geological carbon budget accompanying weathering and erosion in the Mackenzie River Basin, Canada. The silicate weathering rate, carbonate weathering rate by sulfuric acid and the sedimentary burial of biospheric organic carbon have been constrained by prior work to be 0.4 tC km⁻² yr⁻¹, 0.7 tC km⁻² yr⁻¹ and 2 tC km⁻² yr⁻¹, respectively. Closing the long-term CO₂ budget therefore requires quantification of the OCpetro oxidation rate. To do this, we use dissolved rhenium (Re) flux as a proxy for OCpetro weathering with samples collected from 2009 to 2013. In the Mackenzie Basin, over 90% of dissolved Re appears to be derived from OCpetro; this is according to [Re]/[Na] and [Re]/[SO₄²⁻] ratios in OCpetros, sulphide and silicate mineral endmembers. Using estimates of the coupled mobility of Re and CO₂ during OCpetro weathering, we constrain the CO₂ flux from OCpetro weathering to be ~0.3 tC km⁻² yr⁻¹. Consequently, OCpetro oxidation cannot negate the large CO₂ sink driven by biospheric organic carbon erosion, and under the present climate state the Mackenzie Basin is a net CO₂ sink.