**CIDER 2015: Climate, Erosion and Weathering Tutorial**

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Chemical weathering controls the evolution of the Earth’s surface, shaping landscapes, determining nutrient supply to ecosystems, and regulating global biogeochemical cycles. Weathering is a key control on global climate through the consumption of atmospheric CO2 (which is eventually stored as carbonate in the oceans), although only weathering of silicate (*cf* carbonate) minerals results in permanent removal of CO2.

The identification of the dominant control on chemical weathering, is a source of debate. Some advocate that climate, in particular, temperature, is the critical factor, such that an increase in atmospheric CO2 would raise global temperatures, accelerating weathering rates. The increase in weathering rates, in turn, would drawdown atmospheric CO2, lowering temperatures through a negative feedback process. In contrast, others propose that mountain building enhances erosion rates, exposing fresh minerals to chemical weathering processes. The increased supply of fresh minerals drives higher chemical weathering rates, drawing down atmospheric CO2 and lowering temperatures.

In this tutorial, we will explore the relationships between weathering, climate and erosion by analysis of (i) a new data set from the Southern Alps, New Zealand, and (ii) a global data compilation.

***1. Southern Alps, New Zealand***

If you open the spreadsheet, you’ll find river water chemistry, erosion rate, temperature and runoff data for two rivers in the Southern Alps, New Zealand in the first worksheet. River water chemistry data have been corrected for atmospheric inputs. The catchment of the River Haast lies on the West of the Southern Alps, where runoff and erosion rates are exceptionally high, and the River Rakai lies on the East of the Alps, where runoff and erosion rates are substantially lower.

(a) Your first task is to use the data to calculate chemical weathering rates. Total chemical weathering rate (Wchem), silicate weathering rates (*W*sil) and carbonate weathering rates (*W*carb) are given by:

*W*chem = (Ca + Mg + Na + K + Si) × *R* (1)

*W*sil = (Casil + Na + K + Si) × *R* (2)

*W*carb = (Cacarb + Mg ) × *R* (3)

*W* resolves to units of g/km2/yr where the solute concentrations (Ca, Mg, etc) have units of g/L and runoff (*R*) has units of mm/yr. The chemical + physical denundation rate is given by the sum of the erosion rate and *W*chem. Na, K and Si are assumed to be derived only from weathering of silicates, and Mg is assumed to be derived only from weathering of carbonates (as biotite, the most common Mg-bearing silicate mineral in the Southern Alps is primarily weathered to vermiculite, which retains Mg), but as calcium (Ca) is derived from weathering of both silicates and carbonates, it must be apportioned between silicate (Casil) and carbonate (Cacarb) weathering with the equations:

 Casil = (Ca/Na)plag × Na (4)

and

 Cacarb = Catot – Casil (5)

where (Ca/Na)plag is the mass ratio of calcium to sodium inferred to exist in Southern Alps plagioclase (~0.56), and Catot is the total dissolved calcium concentration.

(b) Use these data to discuss the following:

* What is the relationship between runoff and erosion rate on (i) silicate weathering rates, and (ii) carbonate weathering rates, in the Southern Alps?
* Rates of uplift and erosion on both sides of the Southern Alps are exceptionally high. What can you infer about the likely controls on silicate and carbonate weathering, in rapidly uplifting mountain belts? Think about the rate of supply of material, versus the kinetics of rock weathering.
* What are the implications of the presence of rapidly uplifting mountain belts for regulation of atmospheric CO2 on (i) short term, and (ii) long term (geological) timescales?

***2. Global data compilation***

In the next worksheet, you’ll find erosion rate, temperature, runoff and chemical weathering rate data for catchments from all over the world. The aim of this exercise is to distinguish the influence of erosion rate, temperature, and runoff on chemical weathering rates.

(a) Insert your data for the Southern Alps into the worksheet.

(b) Use you preferred graphics package to plot total chemical and physical weathering rate versus silicate weathering rate.

* How does the silicate weathering rate compare to the total chemical + physical weathering rate?
* Summarise the relationship between these variables at (i) low total chemical + physical weathering rates, and (ii) high total chemical + physical weathering rates.
* Provide an explanation for any difference you observe.

(c) Plot chemical weathering rates versus (i) erosion rate, (ii) runoff and (iii) temperature.

* What are the main controls on silicate and carbonate weathering rates? Provide an explanation for your observations. Give possible reasons for any scatter in the broad relationships you observe.
* What are the implications of your observations for regulation of the carbon cycle on long term (geological) timescales?