Chemical weathering rates in the subarctics: The exemple of the Mackenzie river system

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The Mackenzie basin rivers and adjacent Pacific rivers draining the Western Cordillera have been poorly documented. These rivers are, however, unique in a weathering study perspective. Based on Sr isotopic ratios and elemental ratios, we have applied a box-model in order to derive for each soluble element the contribution of silicate/carbonate/evaporite weathering. The main conclusions are as follows.

The overall picture that emerges is that chemical denudation of silicates is weak. A significant difference is observed between the volcanic terranes of the Western Cordillera and the granitic shield of the Slave Province, but at a global scale, chemical weathering rates of silicate in the Mackenzie river system are among the lowest in the world. By contrast, carbonate weathering rates, are not different from the other places of the world. The abundance of sulfate ions in the dissolved load of rivers probably reflects the preferential dissolution of sedimentary sufides.

The Rocky and Mackenzie mountains show silicate denudation rates similar to those of the granitic Slave Province. There is no evidence, in the Mackenzie river basin that mountains are a preferential locus of chemical weathering

The chemical weathering rates in the interior plains are enhanced by a factor of 3-4 compared to those of the mountains. This increase in chemical weathering rates is equivalent to an increase of 6 °C ! In contrast to what is observed in the other river basin having contrasted relief (Amazon, Ganges), the higher chemical denudation rates are found in the lowlands. A positive correlation between chemical weathering rates and dissolved organic carbon in the rivers is observed. We propose that the organic complexation, for example of Al, by organic matter is responsible for the release of solutes and silicate weathering enhancement.

As a whole, we do confirm, based the present data on large river system, that low temperature, in the absence of counteracting parameters, exerts a negative action on silicate weathering rates. This conclusion disagrees with those of Edmond and Huh (1997), based on the geochemistry of Siberian rivers.

References

Edmond J.M., Huh Y. (1997), in: W.F. Ruddiman (Ed.), Tectonic uplift and climate change, Plenum Press, New York, pp. 329-351.

New perspectives on the crust-mantle invariant ratio mass balance

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The mass balance of the so-called "invariant ratios" Nb/U and Ce/Pb (or Nd/Pb) between the crust and mantle (Hofmann et al., 1986) has been used to determine elemental abundances in, and sizes of mantle reservoirs. But such estimates remain very uncertain: First, the absolute abundances of the elements in question are not known very precisely in either the bulk continental crust (BCC) or the bulk silicate Earth (BSE), and second, the mass of the continental crust is only known to about 10%. By casting the mass balance in terms of the proportion of an element in the continental crust, uncertainties are diminished substantially. The reason for this is that the balance is done solely in terms of the elemental ratios in the reservoirs, and does not involve knowledge of any absolute concentrations or reservoir masses.

Using various literature Nb/U and Ce/Pb estimates for BCC, the mass balance implies the following elemental proportions in the continental crust: Nb 11 to 20% (±5%), U 44 to 50% (±15%), Ce 18 to 29% (±3%), and Pb 62 to 67% (±9%), where the errors in brackets show the effects of uncertainties in the Nb/U and Ce/Pb ratios in oceanic basalts. The elemental proportions in the “complementary mantle” (CM) follow by difference. These simple considerations suggest that the U/Pb ratios of BCC and CM are lower and higher, respectively, than that of the bulk silicate Earth, which is the reverse of what is often assumed.

Primitive mantle normalized abundances for other elements in CM can be derived via their respective ratios to Nb, U, Ce or Pb in the BCC. The resulting abundance pattern for CM is "depleted", but too enriched in highly incompatible elements, such as Ba and Rb, to be a viable depleted source for MORB. This feature is also supported by the inferred Sm/Nd ratio of CM, suggesting ε_{Nd} of about +3.2 in CM today, which is far lower than the ε_{Nd} of around +10 in the depleted mantle. These results underscore the importance of enriched mantle sources in the crust-mantle budget of incompatible elements in the silicate Earth.