

Orogenesis, Erosion and the Long-Term Carbon Cycle

Mike Bickle (mb72@esc.cam.ac.uk)

Dept. Earth Sciences, Downing St., Cambridge, CB2 3EQ, UK

Continental collision and the associated Himalayan-style orogenesis may have two important consequences for the global carbon cycle and long-term controls on global climate (e.g. Raymo & Ruddiman, 1992; Kerrick & Caldeira, 1993; Bickle 1996). Metamorphic decarbonation reactions may supplement the solid earth-atmosphere CO₂ flux, warming climate, whereas the increased erosion rate may enhance the weatherability of crustal materials and cool climate. Bickle (1996) argued that both consequences were necessary to reconcile evidence for an increased chemical weathering flux in the change of seawater ⁸⁷Sr/⁸⁶Sr ratio over the last 40Ma with the general cooling of global climate over the same period, given that weathering rates and climate must adjust rapidly so that the CO₂ flux consumed by silicate chemical weathering rates equals solid earth CO₂ degassing rates on a 1Ma timescale. The change in the weathering rate feedback function due to increased erosion rates must exceed the increase in solid earth degassing so that climate cools. Tests of these hypotheses are compromised by the difficulty in quantifying past weathering rates (i.e. the chemical flux to the oceans) and the lack of consensus as to how increased erosion impacts on chemical weathering rates. Kerrick and Caldeira (1999) have recently questioned whether the Himalayan orogen can act as both a source and sink for atmospheric CO₂. They argue that the Himalayas produced < 10¹⁹ mol of CO₂ over 20Ma, a rate small compared with the global annual degassing rate of ~10²⁰mol over the same period. However Kerrick and Caldeira base their figure on an unreliable estimate of total erosion (9x10⁶km³) based only on the overburden removed from the presently exposed area of metamorphic rock. As succinctly modelled by Rowley (1995), convergence of the Himalaya at ~25mm/yr along shallowly dipping thrust planes requires removal of ~4x10⁷km³. Geochronology on garnets shows high grade metamorphic conditions evolving continuously through Himalayan crust from > 40Ma to 6Ma and ages on detrital metamorphic muscovites, monazites and K-feldspars reflect the continuity of metamorphism over this period. Estimates of the magnitude of CO₂ degassing rates are still frustrated by uncertainty of the nature of the rock units involved. It is not possible to preclude significant CO₂ production given that carbonate-rich units at the base of the Tibetan Sedimentary Series metamorphosed to upper greenschist facies are widely exposed along the STDS

and that calc-silicate units of the Lesser Himalayan Series are currently being buried to metamorphic depths. The role of increased erosion in mountain belts in enhancing the weatherability of the crust is equally controversial. Geochemical studies of Himalayan river chemistry conclude that silicate chemical weathering rates in the catchments of the Ganges and Brahmaputra are no greater than the world average which is curious given that erosion rates may be a factor of 5 higher. Much effort has been put into partitioning the chemical river load between carbonate and silicate sources but it should be remembered that these estimates are largely empirical. The marked increase in seawater ⁸⁷Sr/⁸⁶Sr ratio since 40Ma was taken by Richter et al. (1992) to imply as much as a ~50% increase in Sr weathering flux over the last 100Ma with implication that this implied a corresponding increase in silicate chemical weathering flux. This conclusion could only be avoided if the mean ⁸⁷Sr/⁸⁶Sr of river water had increased significantly over this period. The discovery that Sr in Himalayan rivers is now significantly sourced by carbonates with very elevated ⁸⁷Sr/⁸⁶Sr ratios has lent considerable support to the hypothesis that seawater ⁸⁷Sr/⁸⁶Sr composition is forced by changes in the mean ⁸⁷Sr/⁸⁶Sr of the riverine flux. However, as Richter et al. point out, if the changes in seawater ⁸⁷Sr/⁸⁶Sr ratio are entirely due to changes in riverine ⁸⁷Sr/⁸⁶Sr ratio, this would have had an impossibly low value of ~0.709 at 40Ma, implying no contribution from silicates. Testable aspects of these hypotheses await the development of oceanic records of past chemical weathering fluxes as well as understanding of the sensitivity of silicate chemical weathering rates to the volume and mechanisms of physical erosion.

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