

Continental erosion and CO₂ uptake. Inferences from the Himalayan system

C. France-Lanord
L. Derry

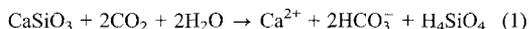
Cornell University, Ithaca, NY 1485, USA

A. Galy

CRPG-CNRS, BP 20 54501 Vandœuvre les Nancy, France

Continental erosion via silicate weathering or organic carbon erosion/burial is considered has a first order control on long term changes in the level of CO₂ in the atmosphere and thereby on climatic changes. While the basic concepts of these processes are well-known, the effectiveness of the different reactions involved remains underconstrained, and recording their importance in the past or even on the modern system is difficult. The controls on erosion and weathering are tightly linked to climatic conditions such as temperature and precipitation leading to complex feedbacks (Walker *et al.*, 1981; Berner, 1995). Tectonic processes may also be important as orogenic belts are preferential places for erosion. At the global scale, attempts have been made to use the marine limestone record of Sr or C isotopic composition to decipher the fluxes of silicate weathering or organic carbon burial in the past. During the Cenozoic, the global cooling of climate roughly parallels the rise in seawater Sr isotopic ratio, leading to the hypothesis that enhanced silicate weathering increased both consumption of CO₂ and the riverine flux of Sr (Raymo and Ruddiman, 1992). By studying Himalayan erosion in both the modern river system and the erosion record in synorogenic sedimentary basins we can examine the role of several processes which affect the CO₂ budget, and their relationship with seawater tracers.

Silicate weathering and CO₂ uptake. The weathering of silicate rocks on the continental surface consumes atmospheric CO₂ to produce alkalinity as schematically represented by the classic 'Urey reactions':

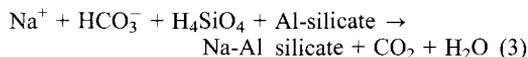


In order to withdraw CO₂ from the atmosphere-ocean system over the long term, the alkalinity transported by river must be precipitated as carbonate in the ocean. The reverse of reaction (1) will release half of the CO₂ balanced by silicate alkalinity. The other half will be stored in the sedimentary reservoir as

carbonate:



Weathering in the Himalayan is not a particularly efficient system for uptake of CO₂ for two reasons. First, Himalayan silicates are mostly alkaline, and in order to precipitate the alkalinity associated with Na⁺ and K⁺, these cations must be exchanged with Ca²⁺ prior to precipitation as calcite. The exchange of Na and K for Ca and Mg adsorbed on detrital clays can occur in estuarine zone or in the continental shelf but Na and K are also involved in reverse weathering reactions that produce secondary silicates (clays, feldspars or zeolites):



In this case all CO₂ consumed during the Na-silicate weathering reaction is finally returned to the atmosphere-ocean system. Because most Himalayan silicate alkalinity is in the form of Na and K, a large part of the reacted CO₂ ultimately returns to the atmosphere. Second, the intensity of silicate weathering in Himalaya is low. Despite creation of high surface area by physical processes such as glaciation or landsliding, detrital loads are transported fast enough to prevent significant alteration. This is illustrated by the fact that 5–8% of the detrital load in the modern Ganges is carbonate. While high levels of precipitation are usually considered to enhance weathering, one of the important effects of the monsoon regime is to flush out the disaggregated material very rapidly. This effect is particularly clear when comparing the Ganges, whose basin receives 1 to 3 m/yr precipitation, with the Brahmaputra basin which receives 3 to 6 m/yr. The smectite and kaolinite proportion of clays of the Ganges is *c.* 60% whereas for the Brahmaputra it is less than 20%. Similarly, the dissolved flux of the Ganges is *c.* 9% of the dissolved + particulate flux, while it is *c.* 3% for the Brahmaputra.

