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Higher Erosion Rates in the Himalaya: Geochemical Constraints on Riverine Fluxes

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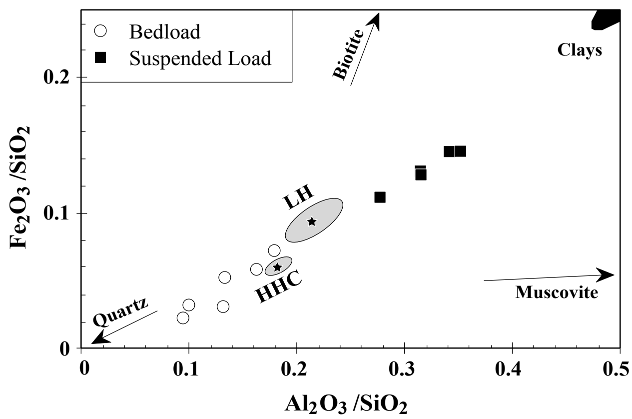
The modern erosion rate of continental-scale mountains is difficult to estimate and is usually based on measurement of the suspended load flux and assumptions about bedload and sedimentation rate in floodplains. These two parameters are almost impossible to measure by physical methods in large-scale basins. Assessing the erosional flux from the Himalaya is of first-order importance for studies of the global impact of Himalayan erosion on the carbon cycle, Himalayan tectonic models, or instantaneous topographic evolution of the range. Since the original investigation made by Rennell in 1781, measured suspended load fluxes of the Ganga and Brahmaputra rivers can be used to assess the Himalayan erosion rate. However such estimates reflect only a part of the Himalayan particle flux because 1) sediments are deposited in the floodplain and 2) measured suspended load fluxes do not include bedload transport. The later, commonly considered to be 10% of the suspended load flux, is essentially unknown for this type of river. In this study, we examine the chemistry of the suspended, bed and dissolved loads for the Ganga and Brahmaputra by comparison with the dissolved flux (Galy and France-Lanord, 1999) and the pristine chemistry of Himalayan formation (France-Lanord and Derry, 1997). We use Sr and Nd isotopic compositions of the silicate fraction of the river sediments to estimate the proportion of the different units in the erosional flux. The data show that the principal source of silicate phases corresponds to the High Himalaya Crystalline (HHC). For the Ganga the slightly lower ε_{Nd} indicates that the Lesser Himalaya (LH) represents a secondary source. A mixture of 10-20% of LH with HHC could explain the measured values. The Brahmaputra in winter tends towards slightly less radiogenic compositions for Sr and more radiogenic compositions for Nd. This indicates that distribution of erosion in the Brahmaputra basin is more sensitive to climatic seasonal variation than for the Ganga. During the monsoon, the Brahmaputra sediments have Sr and Nd compositions almost equal to those of the HHC, which is the dominant lithology in that part of the range. A mass balance equation of erosion flux shows that a Si-rich component is missing in addition to suspended and dissolved load fluxes. It corresponds to bedload and floodplain sediments, which are enriched in Si by mineral sorting during transport (Figure 1). The budget of Si, Al and Fe in the river system allows estimation of this additional Si-rich flux. By this method, the total Himalayan erosion is estimated to be 2.1 10^9 t/yr., double of the measured flux of suspended load. The comparison between the Brahmaputra and the Ganga shows that the Eastern Himalaya has a higher erosion rate (2.9mm/yr.) than the Western Himalaya (2.1mm/yr.). This is likely a function of different erosional conditions within the range such as the lithology, the morphology, the climate, and the rate of uplift. In the absence of major morphological and lithological differences between the two portions of the range, the eastward increase of the erosion rate suggests that the intensity of the monsoon, which is much higher over the eastern Himalaya, determines the erosion rate. However, little is known on the east-west variation of the tectonic style along the range. If a higher erosion rate has been permanent over the eastern Himalaya on a Ma time scale, the lack of significant morphological difference within the whole range implies a higher tectonic uplift for the eastern Himalaya. More information on modern uplift and erosion rates associated with thermo-chronological data from the Eastern Himalaya are clearly needed. At the global scale, higher erosion rate for the Himalaya reinforces the effect of the Himalayan erosion processes on the carbon cycle throughout organic carbon burial which is directly linked to the magnitude of the particulate flux (France-Lanord and Derry, 1997). The Himalayan erosion is clearly dominated by physical processes over a chemical denudation and therefore floodplain sequestration and bedload transport are certainly higher than for other major river systems of the world. However, this case study underlines the importance of bedload transport and floodplain sedimentation, suggesting that modern global erosion rate based only on suspended and dissolved discharge of rivers should be reexamined.



Al_2O_3/SiO_2 versus Fe_2O_3/SiO_2 for Himalayan source rocks and riverine suspended load and bedload

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