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# Erosion Processes and Fluxes in the Central Himalaya from Geochemical Constraints

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The Himalaya are exposed to a large variety of erosion and weathering processes that are in turn controlled both by the regional tectonics and the monsoon climate. Tectonic processes determine the rapid exhumation of the range which maintains high elevation and steep relief. In addition, high heat flow favors thermal circulation which alters the rocks at medium temperature. The monsoon climate generates intense orographic precipitation over the south flank of the range. This seasonal flux of water controls weathering in the Himalayan soils and in the river, and is the agent of transport for the particle load. The major processes of erosion are certainly landslides and glaciers which deliver most of the particle load of the rivers. However their relative importance and distribution is not as well understood as the role of the other less important processes such as soil development. Using geochemical tracers on dissolved and particle loads of the rivers in the Himalaya, combined with available data on river fluxes, we analysed the different active processes of erosion and determined, for some, their spatial distribution. We sampled the main Trans-Himalayan rivers of the Narayani watershed in Central Nepal. This basin drains a 250 km wide section of the Himalayan range from the southern edge of the Tibetan plateau to the Gangetic plain. Sampling has been performed between 1992 and 1998 at different periods of the year including the high flow period of the monsoon. The sampling allows for the estimation of the mean annual composition of dissolved and particle load fluxes.

The budget of chemical erosion is relatively easy to establish using the dissolved load of the river (Galy and France-Lanord, 1999). It is essentially related to carbonate dissolution which represent 80 to 90% of the non-atmospheric dissolved load. There is a clear positive correlation between the rate of chemical erosion and the runoff of the rivers. This indicates that for most rivers in the system, dissolution of carbonate is limited by the precipitation. This is supported by the presence of carbonate in the particle load of the rivers which tends to decrease towards the south. Overall, chemical erosion of carbonate is around 0.05mm/yr for the Narayani basin and ca. 0.005mm/yr for the silicates. Part of the chemical erosion actually occurs in the thermal water circulation systems associated with the zone of preferential exhumation and erosion. Hot springs deliver highly saline waters with alkalinity up to 100 times higher than that of the river and up to 5000 time higher chlorine content. Overall, 5 to 10% of the dissolved load of the river is derived from deep water circulation.

Particle load of the river, either suspended or bedload, contains both silicates and carbonates. The mineralogical composition is dominated by primary minerals derived from physical grinding of metamorphic rocks. The average content of carbonate is 8wt% in both suspended and bedload. Clay minerals are dominated by illite and chlorite which reflect moderate weathering. Chemical and Sr-Nd isotopic compositions show that silicates are mostly produced in the zone of high relief of the high range. Comparisons between Himalayan rocks, soils and river sediments imply that less than 5% of the erosional flux is derived from soil. Landslides and glacial erosion are therefore by far the main processes which deliver particles to the river. Using available data on suspended load flux and assuming 15% for the rate of bedload transport, the rate of physical erosion is 15 to 20 time higher than the chemical erosion rate. Total erosion rate for the Narayani watershed is around 1.4mm/yr. The heterogeneous distribution of erosion over the range suggest that erosion could be as high as 4mm/yr over the south flank of the high range.

Galy A & France-Lanord C, *Chemical Geology*, **159**, 31-60, (1999).