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Cosmogenic Isotope Measurements of Erosion Rates in the Himalayas

Derek Vance[1], **Mike J. Bickle** (mb72@esc.cam.ac.uk)[2], **Susan Ivy-Ochs** (ivy@particle.phys.ethz.ch)[3] & **Peter W. Kubik** (kubik@particle.phys.ethz.ch)[3]

[1] Department of Geology, Royal Holloway, University of London, Egham, Surrey, TW20 OEX, UK
[2] Dept. Earth Sciences, Univ. Cambridge, Downing Site, Cambridge, CB2 3EQ, UK
[3] Institute of Particle Physics, ETH Honggerberg, HPK H30, CH8093 Zurich, Switzerland

Erosion is a critical process for the structural and thermal evolution of continental crust involved in collisional orogens and is probably a prime control on chemical weathering rates. However quantification of riverine particulate loads is difficult. Present-day erosion rates can be derived by direct measurement of sediment fluxes but only provide an instantaneous snapshot that may be biased by short-term fluctuations and anthropogenic activity. Time-integrated erosion rates can be estimated from the volumes of sediments in molasse basins but these do not provide information on spatial variations of rates within mountain belts. Cosmogenic isotope concentrations of river sediment provide a measurement of the integrated erosive flux from the area of catchment sampled at that point (e.g. Granger et al. 1996). Here we report preliminary estimates from ^{10}Be and ^{26}Al measurements on quartz in river bed sediments from the headwaters of the Ganges in the Garhwal Himalaya.

The estimation of erosion rates from the cosmogenic isotope inventory of river sediments depends on several assumptions that have been detailed elsewhere (Bierman and Steig 1996). The most serious potential problem for this study is that of contamination of ^{10}Be analyses by rain-water derived Be because the high erosion rates in the Himalaya result in low cosmogenic isotope concentrations (1 to 2x 10^4 atoms $^{10}Be/g$). As a result samples of quartz greater than 100 g need to be rigorously cleaned. Samples in this study have been cleaned by a combination of repeated magnetic and heavy liquid mineral separation alternating with etching in cold HF until Al concentrations are less than 100 ppm (c.f. Kohl and Nizhizumi 1992). The three samples for which we have Al data at this stage display $^{26}Al/^{10}Be$ ratios that are within error of the production ratio (~ 6.5 ±0.4, Kubik et al. 1998). In addition, duplicate samples in two localities have ^{10}Be concentrations within analytical error. Production rates vary rapidly with altitude and these have been estimated using the values of Lal (1991) as modified by Kubik et al. (1998) with altitudes digitized on a 9 km grid. Glaciated areas are assumed to have zero cosmogenic isotope production. Cosmogenic isotope-derived estimates of erosive fluxes within the catchments are here compared with Nd isotope ratios of the riverine bed load since large differences between geological units make the latter a good indicator of erosive yields.

Figure 1 is an outline of catchments sampled in the headwaters of the Ganges. The ^{10}Be concentration in the sediment allows calculation of two different erosion rates: 1) an average erosion rate for the whole catchment above that point; 2) average erosion rates for sub-catchments from subtraction of the fluxes from upstream sub-catchments. In the Alaknanda the calculated erosion rates are 1.5 mm/yr in the highest catchment (Malari), which drains the Tibetan plateau, 4.1 mm/yr in the Helong catchment, which drains the highest (average 4634 m) and steepest topography, and 1.3 mm/yr in the Srinagar catchment, which drains lower altitude (average 2532 m) terrain. These data imply that the single most important factor affecting erosion rates in these areas is the slope. The average erosion rate for the entire Bagirathi catchment is 1.4 mm/yr. For the Alaknanda, the relative inputs calculated from the ^{10}Be analyses (62% from the Malari + Helong catchments, 38% from the Srinagar catchment) are within error of the estimates of relative fluxes from Nd isotope compositions (54% from Helong + Malari and 46% from Srinagar).

The results from the lowest point sampled in the Ganges at Rishikesh are more complex. The sediment balance between the Alaknanda and Bagirathi sub-catchments derived from the ^{10}Be measurements (22% Bagirathi and 78% Alaknanda) is broadly consistent with the fact that the Bagirathi drains 36% of the total area. However, this estimate is completely at odds with the balance suggested by the Nd isotopic composition of the river sediment at Rishikesh (75% Bagirathi and 25% Alaknanda). Furthermore, the erosive flux at Rishikesh is less than the combined sum for the Bagirathi and the Alaknanda at Srinagar. These discrepancies are the subject of ongoing research and may result from sediment storage in the region just above Rishikesh or be due to anthropogenic disturbances. Calculations suggest that storage times of the order of 100 years would be required.

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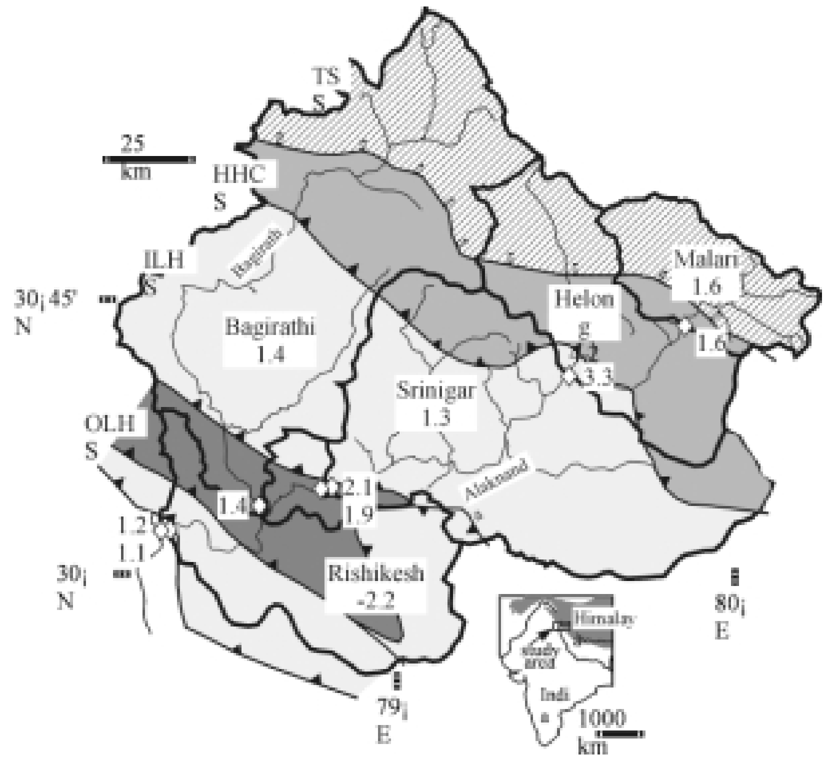

Figure 1: Map of the study area showing the major geological features and ^{10}Be-derived erosion rates. Heavy lines delineate sub-catchments and light lines the rivers. Measured erosion rate for the sub-catchments are given in mm/yr beneath the sub-catchment.

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