Geomorphology

Erosion and plate tectonics (*April 2005*)

For about 15 years geomorphologists have been conscious that landforms are not merely 3-D shapes left behind after the erosion of valleys, but are dynamic in the vertical dimension as well as those in plan view. Between 1990 and 1992 Peter Molnar and Phillip England developed ideas about the way in which erosion unloads the crust and triggers an isostatic response, if the mass removed is sufficient for buoyancy to overcome viscous forces. In a general sense there is nothing new in the idea of isostatic uplift in response to erosion, but Molnar and England looked closely at some specific predictions for areas of rapid erosion. If a peak is surrounded or a ridge is separated off by rapidly deepening valleys, the peak is likely to rise continuously. Simple examples are seen in the Ethiopian-Eritrean Escarpment that forms the western flank of the Red Sea and Afar Depression of NE Africa. Massive erosion has been in response to uplift over the last 25 Ma, following initiation of the Red Sea and Afar rifts. The uplift is preserved by the Ethiopian Plateau that ranges from 2.4 to 3 km above sea level. Beyond the rim of the escarpment are numerous peaks and ridges that out-top the nearby plateau, and moreover are made of ancient basement, while the Plateau is capped by Tertiary flood basalts, which must have been eroded from the outlying highs. Molnar and England believed that similar processes contribute to the rise of the world's highest peaks in the Himalaya, and indeed entire mountain ranges, provided climatic conditions resulted in rapid erosion.

Uplift must also be accompanied by deformation in the deeper crust, and that may have some influence on tectonics itself. A group of structural geologists from MIT and Dartmouth College, New Hampshire has looked for signs of such an influence in the foothills of the Himalaya, where there is probably a rapid change in the pace of erosion due to changing precipitation from the South Asian monsoon (Wobus, C. *et al*. 2005. Active out-of-sequence thrust faulting in the central Nepalese Himalaya. *Nature*, v. **434**, p. 1008-1011; DOI: 10.1038/nature03499). The overthrusting has helped thicken the crust after subduction of the Indian plate beneath Asia. The thrust zone has progressively migrated southwards from the now inactive Main Central Thrust, which forms the southern flank of the Greater Himalaya. Most structural geologists believe that active faulting at the surface is concentrated on the southernmost Main Frontal Thrust, not far north of the Gangetic plains. However, the greatest erosion today is taking place where monsoon precipitation is most intense, between the two huge thrust faults where elevations start to rise rapidly towards the Greater Himalaya.

Using a mixture of Ar-Ar dating of the cooling ages of micas, and cosmogenic dating of quartz grains in the active sediments of rivers, Wobus *et al*. have been able to plot changing uplift and erosion rates in a N-S traverse, for the past and in recent times respectively. Their results show a sudden fall in erosion and uplift about 100 km north of the active Main Frontal Thrust, over a mere 2 to 3 km at most, that coincides with a regional muting of topographic relief. Such an abrupt break most probably relates to an active thrust system that breaks the accepted N to S shift in regional thrusting through time: hence, out-of-sequence. Rapid erosion and rugged topography makes it difficult to spot dipping faults, in the field and from satellite images. The inferred major thrust system coincides well with the maximum monsoon precipitation, so it is likely that increased erosion resulting from that has cause a response in deeper active tectonics.

See also: Burbank, D.W. 2005. Cracking the Himalaya. *Nature*, v. **434**, p. 963-964; DOI: 10.1038/434963a.