Geomorphic controls on Andean denudation rates

R. AALTO, T. DUNNE, J.L. GUYOT

While Andean rivers supply over 99% of the total sediment load for the Amazon basin, only a fraction of this material reaches gauged tributaries of the mainstem Amazon river; an unknown amount is deposited in large foreland basins along the range front. We present a regression analysis of sediment discharge for Bolivian basins which concludes that mean catchment hillslope and lithology account for up to 88% of the variance in yield. Unlike previous studies of fluvial denudation rates for large basins throughout the world, our analysis finds erosion rates uncorrelated to either basin area or elevation, both non-physical parameters that often show strong but spurious correlation when continental-scale basins are treated as geomorphically-homogeneous units. By identifying and separating zones of production (e.g., steep topography and weak lithology) from zones of storage and deposition (e.g., foreland basins and cratonal shields), mass flux sources can be isolated for a more rigorous standard of denudation analysis. For these erosional basins, runoff is not correlated with denudation, suggesting that river incision into bedrock may be driven more by bedload scour than by the stream power of water alone. Theoretical models of mass-wasting are tested to estimate cell-based yield from the individual hillslope pixels of a digital elevation model. The best-fit model (R^2 = 92%) predicts an annual Andean sediment flux to the Amazon Basin of 3.0 Gtonnes. Since ~ 1.3 Gtonnes/a of sediment reach the lower mainstem Amazon river, the intervening foreland basins intercept over half of the total mass flux out of the Andes.

We present a procedure for mass flux analysis in large, continental-scale basins. By separating the Amazon Basin into geomorphic process zones, we are able to focus our attention on appropriate process rates in the rapidly-eroding region that supplies most of the sediment: the Andes of Bolivia, Columbia, and Peru. After selecting erosional Bolivian basins that are demonstrably free from major sediment sinks and the non-physical scaling effects of basin area, we can test geomorphic models of mass wasting and determine which physical parameters best predict modern denudation rates: lithology and average hill slope. The statistical unimportance of runoff in determining erosion rates is both perplexing and complex, especially given the range of our runoff data (16-2700 mm/y); we explore this conundrum and the intriguing relationship between runoff and mean basin slope. We test various deterministic cell-based mass flux models to identify which best predicts present-day erosion rates for our study basins. Our model can easily be applied to estimate flux rates for similar ungauged basins elsewhere in the Andes.

This initial success is encouraging, suggesting that this approach to mass flux modeling is viable and may improve further as new high-resolution digital elevation data become available, such as the 25m NASA SRTM DEM, which would enable more appropriate modeling of hillslope mass wasting processes. We can refine our lithologic index with a comparison of field-measured rock strength (using a Schmidt hammer) to local rock type and observed rate and process of hillslope failure. An improved mass-flux model employing a globally-consistent data set could feasibly be applied outside of the relatively uniform climate and lithology of the Andes to predict denudation rates elsewhere in the world.

Finally, the strategy of breaking large, continental-scale basins into geomorphic process zones is now being applied farther downstream to study rates of sediment transport and deposition on a reach-scale characterized by homogenous processes and morphometry (e.g., valley slope, sinuosity, discharge, lateral migration rate, and channel and floodplain width). By quantifying first-order transport and trap efficiency of reach-scale segments of lowland fluvial systems, we may be able to better understand and model problems of intracratonal mass flux and sediment discharge to the oceans.

MANAUS 99

International Symposium
Hydrological and Geochemical Processes in Large Scale River Basins

November 15-19, 1999, Manaus, Brazil

PROGRAM and ABSTRACTS

Organized by HiBAm
Hydrology and Geochemistry of the Amazon Basin

ANEEL CNPq IRD

HiBAm

manaus99@apis.com.br http://www.unb.br/ig/hibam/hibam.htm

Manaus-99