Geophysical Research Abstracts,
Vol. 10, EGU2008-A-07036, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-07036
EGU General Assembly 2008

The role of tectonic inheritance in simple sediment routing systems

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The topography of the Earth's surface evolves in response to a competition between tectonic deformation and the redistribution of mass by Earth surface processes. The fidelity of the surface as a recorder of deformation depends on both the development of the deformation field in time and space, and on the response times of sediment routing systems to changes in that deformation field. Inherited tectonic structures and their associated topography thus play a key role in the early stages of landscape development, obscuring or complicating the effects of active deformation. We use examples from the extensional Basin and Range Province of the western United States to probe the role of inherited structures in perturbing the topography and denudation rates of sediment routing systems in simple fault-block mountain ranges. We find that inherited topography is particularly important during the early stages (<1 Myr) of fault growth, when tectonically-generated relief may be low compared with pre-existing erosional relief. Erosion rates determined from cosmogenic radionuclide concentrations in fluvial sediment are dominantly controlled by inherited topography and show little relation to inferred rates of fault slip. As fault arrays develop, however, footwall topography becomes progressively decoupled from the underlying deformation field, and both footwall morphology and the spatial pattern of denudation rates evolve to reflect slip on the underlying fault. Cosmogenic radionuclide-derived denudation rates in larger footwalls appear to be dominated by non-steady erosion processes, and record little information about the early stages of fault growth and footwall development. We thus turn to low-temperature thermochronology, and show that both apatite fission-track and apatite (U-Th)/He samples from active fault footwalls show distinctive patterns of cooling in time and space. These patterns can be used to constrain the relative timing and rates of activity on different fault segments during long-term (1-10 Myr) fault array growth. Our results are consistent with expectations of fault growth models, and have important implications for (1) the usefulness of topography as an indicator of tectonic activity, and (2) the patterns and timing of sediment delivery to adjacent basins.