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# Geodynamics, geomorphology and denudation rates across Africa

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On a global scale it seems self evident that tectonics has a primary role in creating topography: all the worlds high mountain belts are formed along convergent plate boundaries and the interior of continents tend to be lower and with lower relief. Even at smaller spatial scales there are numerous beautiful examples of where faults or folds can clearly be associate with the formation of mountains and basins (e.g. Basin and Range, Zagros Mountains). On the other hand, the vigour and longevity of debate about the origin of landscapes and how they evolve over geological time scales suggests that the interaction and feedback between tectonics and surface processes is not quite as simple as these observations suggest. The debate has been fuelled by a complete lack of any robust, quantitative data on the rates of surface processes measured over appropriate temporal and spatial scales, and the fact that it is virtually impossible to constrain changes in the elevation of the Earth's surface in the geological past with any certainty. Consequently, some of the most influential paradigms in long-term landscape geomorphology over the previous century are routed in qualitative conceptual ideas of how landscapes evolve, and not underpinned by physically based theory substantiated by quantitative, empirical measurements (e.g. Molnar, 2003). But times and tactics have changed.

Technical advances in low temperature thermochronometry (such as apatite fission-track and U-Th/He analysis) methodology and interpretive strategies can now be used to robustly quantify long-term ($\geq$ 107 yr) erosion rates. Cosmogenic isotope analysis provide estimates of the pattern and variability of erosion rates over the key intermediate spatial and temporal scales between thermochronometry and direct observation

and thus a means of extrapolating the wealth of information gleaned from short term process studies to the broader spatial and temporal information obtained from both apatite fission-track and U-Th/He thermochronologic data. The other critical advance has been in the construction of advanced theoretical surface processes models (SPMs). These advances are important because, although we cannot realistically expect to routinely determine the chronology and rates of surface uplift directly from the landscape, different uplift mechanisms proposed would generate significantly different temporal and spatial patterns of erosion as zones of uplift cause increases in river gradients and basin relief, and the propagation of base level changes throughout the landscape. The recent development of SPMs applicable to sub-continental scale landscapes means that we now have the capability of modelling and measuring the erosional response to specific uplift scenarios (at appropriate spatial and temporal scales) in a way which incorporates the transmission of base level changes across the landscape.

This approach will be discussed in the context of understanding the tectonic and geomorphic evolution of Africa, and in particular of southern Africa. Using this approach we have been able to show that the short and long-term rates and pattern of denudation across key escarpment segments are incompatible with a steady, parallel retreat model for the evolution of these important landscape features. An alternative model emerged from this analysis where the escarpment is formed by rapid post-break-up river incision seaward of a pre-existing drainage divide located just inland of the present escarpment location, with the escarpment subsequently pinned at this divide and characterised by moderate to low retreat rates ($\leq$ 10-100 m/Ma). Our studies have also identified a wide spread and apparently discrete erosional pulse which was initiated during the mid Cretaceous and has affected interior regions across southern Africa. We believe this episode of enhanced denudation is associated with the development of the so called African Superplume and the generation of a major componenet of Africa's anomalous topography. A younger episode of intra-continental tectonic reactivation during the latest Cretaceous has also been documented which involved reactivation of major, pre-existing crustal structures. This event seems to be spatially restricted, and is associated with discrete tectonic features, unlike the more regional event that occurred during the mid Cretaceous.

Molnar P. 2003, Nature, nurture and landscape, *Nature*, 426, 612-614.