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Long Term topographic Development, Denudation Histories, and vertical Motions of high-elevation rifted Continental Margins: a Review

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The persistence of significant topography for tens to hundreds of million years after break-up along high-elevation rifted margins (HERM) has remained a puzzling and controversial issue among geoscientists for most of the last century. Controversy has centred on the origin and timing of rifted margin uplift, the mode of landscape development and the requirements for preservation of high-relief topography on very long timescales. Significant progress has been made toward resolving the latter two issues in the last 10-15 years. Since the early 1990's numerical landscape evolution models have suggested two prominent modes of landscape development on HERM, controlled by the pre-existing topography and/or the syn-rift uplift pattern: (i) parallel retreat of an escarpment from a syn-rift position at or near the continent-ocean boundary to its present location or (ii) degradation of a plateau seaward of a pre-existing drainage divide by rivers responding to the drop of base level caused by continental break-up. Numerous authors have collected low-temperature thermochronology (mostly apatite fission-track but increasingly also apatite (U-Th)/He) data along HERM in order to elucidate their denudation history and topographic development. These data consistently indicate rapid denudation of the region seaward of the escarpment in the first 10-20 million years after break-up and significant diminution of the rates of landscape evolution after that time; this pattern has been argued to confirm the second mode of

HERM evolution described above. A growing database of short-term denudation rates on HERM from cosmogenic isotopes is generally consistent with the rates and patterns of denudation inferred on longer timescales from the thermochronology data. We have applied a 3D thermal-kinematic model that considers the effects of changing topography to predict thermal histories and thermochronological ages for both scenarios, in order to compare model predictions to observations at HERM. Applying the model to the SE Australian continental margin, for which the most complete thermochronological database is currently available, places tight constraints on the timing of denudation, the geothermal gradient and the flexural rigidity of the underlying lithosphere, but fails to discriminate between the two contrasting modes of escarpment development, mainly because of the relatively old age ($\sim$100 Ma) and low denudation ($\leq$ 3 km) of the margin. A more recent application of the model to the younger and higher Eritrean margin provides more definite support for the plateau-degradation mode of HERM development. Research should focus in coming years on the outstanding questions in HERM evolution, namely the timing and origin of uplift. Strong arguments for the relative timing of margin uplift with respect to rifting and break-up are still lacking, as the geologic record of surface uplift remains elusive. The persistence of topography on 10^7-10^8 year time-scales requires either crustal thickening through magmatic underplating (for which geophysical evidence is scarce) or dynamic mantle support. Dynamic topographic uplift may be sourced either in the lower ('superplumes') or upper mantle (dynamic uplift related to cessation of subduction). Progress in solving these questions may come from high-resolution studies of the denudation histories of HERM combining the onshore thermochronology and offshore sedimentation record, geophysical data focussing on crustal and deep mantle structure, and large-scale geodynamic models that include dynamic uplift mechanisms.