Lessons Learned from Regional Coupled Landscape and Stratigraphic Forward Models on the Role of Dynamic Topography in the Evolution of Drainage and Depositional Patterns and its Implication on the Last 40 Ma Evolution of South Africa

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Abstract

Over deep time, mantle flow-induced dynamic topography drives deposition moderated by higher-frequency fluctuations in climate and sea level. The effects of deep mantle convection impact all the segments of the source to sink systems at different wavelengths, which remain poorly quantified. Field observations and numerical investigations suggest that the long-term stratigraphic record along continental margins contains essential clues on the interactions between dynamic topography and surface processes. Yet, it remains challenging to isolate the fingerprints of dynamic topography in the geological record. We use the open-source surface evolution code Badlands (badlands.readthedocs.io), to quantify landscape responses to dynamic topography for both generic and regional models. The first set of experiments allows to test the impact of different wavelength of dynamic topography propagating under a tectonically stable continent, forcing the surface to undergo dynamic uplift and dynamic subsidence. We demonstrate that inland incision, spatial sediment accumulation, and depocenter migration strongly depend on the direction of sediment transport relative to the direction of dynamic topography propagation.

The migrating dynamic topography produces an asymmetric erosion of the hinterland, leading to a characteristic rerouting of the river network following the migration direction of dynamic topography. As a result, it induces contrasting stratigraphic record along the margin. We use these results to explore different dynamic topography scenarios and investigate their influence on landscape dynamic, stratal geometries and depositional patterns of South Africa over the past 40 Ma. We compare the evolution of the drainage organization, sediments flux, and stratigraphy obtained from our models with seismic, geochronological, and thermo-chronological data. Despite the relative simplicity to our coupling approach, these results provide insights to identify the dynamic topography scenarios inducing geomorphic and stratigraphic signals similar as the observed ones.