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Plate-mantle interaction through time explains two-phase uplift history of the eastern Australian passive margin

R. Dietmar Müller (1), Nicolas Flament (1), Kara J. Matthews (1), Simon E. Williams (1), and Michael Gurnis (2)
(1) Univ. of Sydney, School of Geosciences, Sydney, Australia (dietmar.muller@sydney.edu.au), (2) Seismological Laboratory, California Institute of Technology, USA

The origin of passive margin mountains is a hotly debated topic in geodynamics. The Eastern Highlands of Australia are a type example whose uplift history has been investigated for several decades, with suggested mechanisms ranging from flexural rift shoulder uplift, volcanism and underplating to mantle-convection driven dynamic topography. Most of the highlands have experienced a distinct two-phase uplift history, with the first phase being Late Cretaceous in age, followed by a mid-late Cenozoic renewal in uplift, but the timing and magnitude of uplift differs along strike.

We investigate the origin of the Eastern Highlands with a coupled plate-mantle model, using a thorough parameter space analysis, including two alternative subduction boundary evolution models. The first model includes a large (∼1000 km width at its maximum extent) Early Cretaceous (140-120 Ma) back-arc basin east of the Lord Howe Rise, representing the now subducted South Loyalty Basin which may have formed due to eastward rollback of the long-lived west-dipping eastern Gondwanaland subduction zone; the alternative scenario is based on the premise that west-dipping subduction is continuous to the East of the Lord Howe Rise between 140-85 Ma, without a large back-arc basin, and the South Loyalty Basin opening as a back arc basin from 85-55 Ma, which is subsequently consumed by subduction. We further investigate the influence of a low-viscosity asthenosphere and of the viscosity profile of the lower mantle on dynamic topography, as well as the effect of changing the buoyancy of the basal dense layer (LLSVP) that contributes to the long-wavelength Pacific superswell.

Our best-fit model produces a total uplift up to ∼400 m in the interval between 120 and 90-70 Ma, well-matched with recent published estimates from river profile inversion for the Snowy Mountains, New England and the Central Highlands. The driving mechanism is rebound from the eastwards motion of Australia over a sinking slab, first leading to transient subsidence and continental flooding followed by rebound and uplift. Our model predicts cessation of uplift from 70-40 Ma (Snowy Mountains), 90-60 Ma (New England), followed by renewed uplift of up to 200 m. In the Central Highlands we model continuing, but distinctly slower uplift from 90Ma to the present, also totaling ∼200m. The mechanism represents the gradual motion of Eastern Australia over the edge of the southwest Pacific superswell. The Central Highlands experienced the influence of the perimeter of the superswell first, due to their more northerly location, more proximal to the swell's edge, resulting in a continuous history of uplift since the mid-Cretaceous, whereas the Snowy Mountains started interacting with the superswell edge ∼40-50 my later, resulting in a distinct break in uplift. The magnitude of the 2nd phase of uplift from river profile inversion versus geodynamic modeling matches well for the Central Highlands, but not further south. We attribute this to the lack of plumes in our current geodynamic models; plumes have clearly played an additional, important role in exacerbating uplift in the Late Cenozoic in the southern highlands, as indicated by the abundant, time-progressive Late Cenozoic volcanism in Eastern Australia.