03EGD-02.

THE SPATIO-TEMPORAL EVOLUTION OF SURFACE DYNAMIC TOPOGRAPHY DRIVEN BY DEEP MANTLE PROCESSES SINCE THE CRETACEOUS

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Mantle convection can have a profound influence on basin evolution, but progress has been slow in quantifying this relationship or making these concepts available for exploration. Many regional continental basins and margins have experienced long-wavelength tilting and subsidence/uplift, leading to sea-level change that deviates from a global reference standard. We evaluate the evolution of large-scale surface dynamic topography since 150 Ma using a mantle convection model (TERRA) constrained by a global tectonic model. We impose 150 Myr of plate motion histories, generated by the plate reconstruction software GPlates, as a surface kinematic boundary condition for our global convection simulations. Employing a fine discretisation of ~25 km globally allows us to model mantle convection at Earth-like vigour with a Rayleigh number of 10^9. As initial conditions for our models we approximate the unknown Jurassic mantle structure by applying the oldest plate velocity configuration until a quasi steady-state is reached. We use a radial viscosity profile involving three layers: lithosphere (10^23 Pas), non-lithospheric upper mantle (10^21 Pas), and lower mantle (10^23 Pas). Dynamic topography is derived from normal stresses at Earth's surface after replacing the lithosphere with a homogeneous shell. The models generate a global flow and dynamic topography pattern with hemispheric upwellings focused on the antipodal low-velocity seismic-shear-wave regions above the core–mantle boundary, even though the basal thermal boundary layer evolves dynamically in our models. Subduction along the western Pacific and northern Tethys margins drives a pronounced return flow centred on the reconstructed position of India in the Cretaceous, resulting in positive dynamic topography from India and Madagascar to the south eastern African margin from 120 and 60 Ma. In the mid-Cretaceous a strong surface topography high starts straddling the margins of northwest Africa and western Europe. Our model predicts large-scale dynamic subsidence for both the Arabian Peninsula as well as India during the Cenozoic as they move from a mantle upwelling into the downwelling region associated with the closure of the Meso-Tethys during from 90 to 30 Ma. Our model also predicts large topography variations along-strike passive margins especially where they straddle boundaries between large-scale upwellings and downwellings through time. We use this global model to define "geodynamic rules" for how different surface tectonic settings and associated sedimentary basins are affected by mantle processes. Locations within a ~4000 km distance from subduction zones show large negative amplitudes while everywhere else the signal is positive. We find that rapid variations in vertical motion rates occur at locations along the margins of overriding plates (e.g. Western US) and at points that are located on a plate that rapidly approaches a subduction zone (e.g. India and Arabia). Our models provide a predictive framework linking mantle convection with plate tectonics and sedimentary basin history, to improve our understanding of how subduction and mantle convection affect basin evolution over time.