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Scales of Transient Convective Support Beneath West Africa

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It is generally accepted that a significant proportion of present-day African topography is dynamically maintained by mantle convection. Beneath sub-equatorial Africa, there is convincing evidence for a gigantic slow velocity anomaly within the lower mantle which is inferred to be a thermochemical superplume. Dynamical calculations have shown that this superplume can account in general terms for the surface elevation and uplift rate of southern Africa. Despite important advances in seismic imaging of the sub-lithospheric mantle beneath the African plate, our understanding of the temporal and spatial variation of sub-African convective circulation remains sketchy. When did the superplume appear? How has the superplume evolved through time and space? Does two-layered mantle convection occur? If so, what is the spatial and temporal relationship between upper and lower mantle convection? Our approach is predicated upon the fact that changes in the convective circulation should have an important effect on the geomorphological history of Africa.It is instructive to examine Africa as a whole and to compare it with other continents. The relationship between gravity and topography in the frequency domain is an important guide and shows that long-wavelength gravity anomalies result from mantle convection. On most continents, however, much of the topography results from crustal thickening and so is not a direct expression of mantle convection. Africa is the most obvious exception where many important geological features must be dynamically supported by mantle convection. The relationship between gravity, topography and drainage imply that patterns of uplift and subsidence change on timescales of millions of years. Offshore, especially in river deltas, there is excellent evidence for temporal variation in the solid flux of clastic sediments.

Despite these useful observations, there is a pressing need for better resolved measurements of the spatial and temporal variation of Cenozoic uplift. The main problem is that it is very difficult to measure rock uplift on length scales of 10-1000 km and on timescales of 1-10 Ma. An important exception is the coastal shelf where stratal geometries are likely to be especially sensitive to small vertical motions. Here, we constrain the spatial and temporal pattern of uplift across the northern edge of the putative superplume by analyzing stratal geometries and stacking velocities of Neogene sedimentary rocks. These marine deposits are imaged on a dense grid of seismic reflection profiles which traverse the West African coastal shelf. Inverse modeling of stacking velocity profiles demonstrates that there have been two discrete phases of uplift. A post-Pliocene uplift event increases from zero to about 500 m over a distance of about 1000 km, in close agreement with the variation of dynamic topography estimated from long-wavelength gravity anomalies and with the results of higher mode surface wave tomography. An earlier phase of uplift occurred in Middle Oligocene times (about 30 Ma). This phase has an amplitude of up to 1 km and, crucially, its spatial distribution does not correlate with the observed pattern of present-day dynamical support. We infer that this earlier phase of uplift records initiation of a relatively static superplume whereas the post-Pliocene phase records vertical motions associated with upper mantle convection which varies on timescales of several million years. These inferences are supported by a range of other geomorphological and geophysical observations. Our results support the existence of a rapidly evolving pattern of two-layered mantle convection beneath Africa.