Geophysical Research Abstracts
Vol. 15, EGU2013-5498, 2013
EGU General Assembly 2013

Anorogenic plateau formation induced by a heated lithosphere

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Plateau formation processes in geodynamic settings outside of orogens have not been unambiguously established. Those anorogenic plateaus are topographic barriers that reach medium elevations of approximately 1500 m, e.g. South African-, East African- or Mongolian Plateau. They are inferred to be closely link to mantle plumes away from plate boundaries. Such a heat source at the lithosphere-asthenosphere boundary (LAB) have an influence to the density structure of the crust and lithosphere, due to thermal expansion and mineralogical changes. Consequently, these density variations affect topography and thus we hypothesize topographic variations by lithospheric thermal expansion, due to heating processes at the LAB. Based on this hypothesis, we calculated the density distribution along a one-dimensional depth-profile using two different approaches – with and without mineral reactions. Therefore, we present a new petrologic aspect for plateau uplift, because models on plateau uplift generally do not take into account the effects of metamorphic phase transitions and ignore the fact that chemical reactions influence both, the stability of mineral assemblages and rock density. Our model underscores how metamorphic density of the lithosphere varies with depth and reveals how combination of chemical composition of rocks, mineralogy, and geothermal gradient all have significant effects on the density distribution within the lithosphere and ultimately the evolution of anorogenic plateaus.

Furthermore, in order to better understand the temporal characteristics of mantle plume related topography we calculated the timing to generate significant topographic uplift. Our results suggest uplift rates of >20 m/Myr within the first 20 Myr after the onset of heating and considerable primary thermal uplift of approximately 700 m after 20 Myr as a viable mechanism for anorogenic plateau formation. In this way, our model may help to explain pre-rift topography of the East-African Plateau, related to heat generated and transferred by the activity of a mantle plume. In addition, we show that density-change models that ignore metamorphic processes and/or mineral reactions will result in a reduced amount of uplift or may require inadequate temperatures to explain uplift scenarios. Thus, we show that metamorphic phase transitions in crust and lithospheric mantle due to heating at the lithosphere-asthenosphere boundary by a mantle plume are key processes that drive significantly uplift and the generation of long-wavelength topography.

Further Reading:

Duesterhoeft, Bousquet, Wichura & Oberhänsli (2012), Journal of Geophysical Research