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Metamorphic density changes as key process to form anorogenic plateaus

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Anorogenic plateaus are those 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. Actually, plateau formation processes in geodynamic settings outside of orogens have not been unambiguously established. Recently, Wichura et al. [1] have clearly shown a pre-rift uplift of the East African plateau. They suggested pre-rift topographic variations by lithospheric thermal expansion, due to mantle plume-lithosphere heat interactions. Following their assumption, we developed an one-dimensional model, which calculates density as a function of pressure, temperature, and chemical composition, based on the fact that heat variations in the continental lithosphere and crust influences metamorphic density. Thus, we present a new petrologic aspect for plateau uplift [2], 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. 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. 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 are very instructive and suggest considerable primary thermal uplift of approximately 1400 m 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.

References:
[1] Wichura, Bousquet, Oberhänsli, Strecker & Trauth (2011), Geological Society, London, Special Publications, 357, 285-300.
[2] Duesterhoeft, Bousquet, Wichura & Oberhänsli (2012), submitted to Journal of Geophysical Research.