Abstract

Brandt, Martin B.C. 2011. Imaging the African Superplume – Upper mantle, Tomography and Moment tensor. *Ph.D. thesis*, Faculty of Science, University of the Witwatersrand, Johannesburg, South Africa.

The African Superplume, African Superswell and East African Rift System are amongst the most prominent geophysical features on Earth, but the structure, evolution and interaction between these features is controversial. In my thesis I conducted a range of investigations in an effort to better understand these issues. The thesis presents the investigations into the structure and expressions of these features. These include:

(I) A study of the upper mantle shear velocity structure beneath southern Africa to investigate the source of the buoyancy that has powered the Superswell;

(II) Statistical hypothesis testing of middle-mantle shear velocity tomographic models to evaluate evidence for links between the Superplume and low velocity features in/near the transition zone; and

(III) Computation of three new regional moment tensors for South Africa to assess crustal stress in the Kalahari craton, and its link with mantle structure and dynamics.

Waveform data were obtained for the study on the upper mantle shear velocity structure and the moment tensor inversions from the Southern African Seismic Experiment Kaapvaal craton array. For the statistical hypothesis testing on global tomography images, new travel-time data from both global and AfricaArray stations were added to Grand's global shear velocity data set.

The principal findings of this study are summarized below.

I. The upper mantle shear velocity structure beneath the Kalahari craton is similar to that of other shields, except for slightly slower velocities from 110–220 km depth. The difference may be due to higher temperatures or a decrease in magnesium number (Mg#). If the slower velocities in the deep lithosphere are due solely to a temperature anomaly, then slightly less than half of the unusually high elevation of the Kalahari craton can be explained by shallow buoyancy from a depleted hot lithosphere. Decreasing the Mg# of the lower lithosphere would increase density and counteract higher temperatures. If an excess temperature of 90 K over a 110 km depth range and a corresponding decrease in Mg# of -2 between the Kalahari and the other cratons are assumed, this would match the seismic velocity difference but would result in essentially no buoyancy difference. We conclude that the high elevation of the Kalahari craton can only be partially supported by shallow mantle buoyancy and must have a deeper source.

We determined a thickness of 250±30 km for the mantle transition zone below eastern southern Africa, which is similar to the global average, but the corresponding velocity gradient is less steep than in standard global models (PREM and IASP91). Velocity jumps of 0.16±0.1 km/s (eastern) and 0.21±0.1 km/s (central) across the 410 km discontinuity were found. Our results indicate a thermal or chemical anomaly in the mantle transition zone, but this cannot be quantified due to uncertainty.

II. Statistical hypothesis testing on our global tomography images indicated that the African Superplume rises from the core-mantle boundary to at least 1150 km depth, and the upper mantle slow-velocity anomaly extends from the base of the lithosphere to below the mantle transition zone. The model that links the African Superplume with the slow-velocity anomaly in the upper mantle under eastern Africa has an equal probability to an alternative hypothesis with a thin slow-velocity "obstruction zone" at 850 to 1000 km depth.

III. Finally, we calculated three regional moment tensors for South Africa and made progress towards resolving the discrepancy between the local and moment magnitudes we observe for the region. Moment tensors/focal mechanisms in southern Africa change from normal faulting (extension) in the northeast near the East African Rift to strike-slip faulting in the southwest. This confirms previous studies stating that not only eastern Africa, but also southern Africa is being actively uplifted by lithospheric modification at its base and/or the African Superplume.