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Shear-Velocity Structure and Azimuthal and Radial Anisotropy beneath the Kalahari Craton from Bayesian Inversion of Surface-Wave Data: Evidence for Stratified Lithospheric Fabric

Matteo Ravenna (1), Sergei Lebedev (1), Javier Fullea (1), and Joanne Adam (2)

(1) Dublin Institute for Advanced Studies, Dublin, Ireland (mravenna@cp.dias.ie), (2) Institut de Physique du Globe, Paris, France

Seismic anisotropy provides important information on the deformation history of the lithosphere. Especially beneath cratons, where the mechanisms of formation of the lithosphere remain poorly understood, the detection of radial and azimuthal anisotropy yields essential clues on the early evolution of the crust and upper mantle.
We use Rayleigh and Love-wave phase velocities and their azimuthal anisotropy measured in broad period ranges across the footprint of the Southern Africa Seismic Experiment (SASE), to determine, for the first time, the lateral and vertical distribution of the isotropic-average S velocity and its radial and azimuthal anisotropy beneath the Kaapvaal Craton and Limpopo Belt, from the upper crust down to the asthenosphere. We invert the data using our recently developed, fully non-linear Markov Chain Monte Carlo method (1), which provides a way to quantify non-uniqueness, using direct parameter-space sampling, and assess model uncertainties.
Our results provide important constraints for the thermochemical structure of the lithosphere. The positive (isotropic-average) velocity gradient observed in the uppermost mantle across the whole region suggests compositional and phase changes related to the gradual emergence of garnet. The gradient is underlain by a high-velocity anomaly indicative of the cold cratonic lithosphere. The imaged velocity profiles provide evidence for a gradual thickening of the lithosphere from the central and south-western Kaapvaal to the Limpopo Belt, from ∼200 km to ∼300 km. Surface elevation decreases with increasing lithospheric thickness, an anti-correlation that highlights the effect of the deep lithosphere on topography (2).
The layered pattern of azimuthal anisotropy obtained in our inversions provides new, robust evidence for a stratification of the lithospheric fabric beneath the Kaapvaal Craton. A mid-lithospheric discontinuity in azimuthal anisotropy is detected at around 80 km depth, this depth likely to vary somewhat laterally. The layer with distinct anisotropy revealed in the shallow lithosphere is interpreted as fabric that underwent pervasive, ductile deformation a few million years after the formation of the craton, whereas the deep lithospheric layer is instead explained as older anisotropic fabric, developed at Archean times prior to the assembly of the craton. The orientations of anisotropy below and above the MLD prompt intriguing inferences on the early evolution of the craton.

References

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