

Reference: Fouch, M.J., D.E. James, P.G. Silver, J.C. VanDecar, S. van der Lee, Jean N. Lee, and the Kaapvaal Seismic Group, Imaging broad ranges in structural variations beneath southern Africa, 13th Annual IRIS Workshop, Moran, WY, 2001.

Imaging Broad Ranges in Structural Variations Beneath Southern Africa

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Data from the Southern Africa Seismic Experiment provide a unique opportunity to image crust and mantle structure over a wide range of spatial scales beneath southern Africa. Results from the two seismic components of the experiment have documented structural variations over distances as small as 50 km from body wave analyses. This range is exemplified in two independent studies: 1) shear wave splitting analysis beneath the Kimberley array, a 32-station broadband array with 5 km spacing and an aperture of ~60 km x 30 km, which was located directly within the region of the diamondiferous kimberlite pipes near Kimberley, South Africa; and 2) tomographic inversion of body wave travel times from the Kaapvaal array, an 82-station broadband seismic array located in South Africa, Zimbabwe, and Botswana, with a footprint of ~1 million km².

Results from shear wave splitting analyses from the Kimberley array are particularly intriguing. Fast polarization directions across the array are well-constrained, and given the uncertainties in the analysis, have a consistent orientation of approximately N50E. Splitting delay times, however, reveal well-resolved, spatially coherent variations across the array, increasing from 0.25s in the southeast to 0.75s in the northwest. These variations are clearly observed from the array response to individual events. One particularly striking example shows clear, coherent radial energy for all stations across the array, while energy on the transverse component grades smoothly from strong to none over a distance of only 50 km. These results provide clear support that conventional views of Fresnel volumes may overestimate the average sampling region for seismic waves. Our preliminary results suggest that, even over small regions, there are structural variations in the crust and upper mantle that may be either Archean in age or due to more recent kimberlitic magmatism.

Results from body-wave tomography exhibit P-wave velocity variations of ~±1%, and S-wave variations velocities of ~±1.4% that generally mimic patterns of P-wave velocities. These tomographic images reveal well-resolved high velocity mantle keels that extend to depths up to 300 km in regions beneath the undisturbed Archean Kaapvaal and Zimbabwe cratons. Some of the strongest fast velocity anomalies in the keel exist near Kimberley. Beneath post-Archean terranes, however, we do not observe analogous keel structures. In the vicinity of the 2.05 Ga Bushveld magmatic event, seismic velocities are resolvably lower than for surrounding regions, suggesting that significant cratonic disruption occurred during the development of the Bushveld. Within cratonic regions, the maximum contrast in velocity perturbation is ~0.5%, consistent with compositional variations in mantle nodules. These results, combined with observations of younger Re/Os model ages of mantle nodules, suggest refertilization of the cratonic mantle during the Bushveld magmatic event.