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Structure and extent of the southern African cratons: Integrated images from receiver functions and teleseimic tomography

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We present a high resolution seismic model of the South African cratonic region from receiver function and telesemic tomography interpretations of the P- and S- body wave data from the South Africa Seismic Experiment (Carlson et al, EOS 77, 1996) across the Kaapvaal and Zimbabwe cratons and the Bushveld complex.

Both P- and S-wave (PdS and SdP) receiver functions are calculated by iterative deconvolution processing, which lead to estimates of Moho depth and the Vp/Vs ratio via the HK-stacking method, as well as parameters describing anisotropy in the crust (strength dt and trend phi). The calculated strength of the crustal anisotropy is, surprisingly, comparable to the contribution from the mantle (to depth of 170 km by S. Gao 2001, JGR). This anisotropy is well constrained as it is based on good azimuthal coverage, which defines a clear polarity variation of the RFs signals versus back azimuth within the Kaapvaal and Zimbabwe boundaries. Modelling with theoretical receiver functions we find a best model with an average fast polarization axis trend=30º and an average strength 50% (dt = 0.5sec) for the crustal fabric of the total 170 km deep. By stacking and analysis of the SV and SH components we find that most of the strong anisotropy is confined to the lower crust.

Using finite-frequency kernels, we inverted the P- and S- wave delay times to obtain 3-D images of compressional and shear velocity perturbations in the mantle by use of three frequency bands: 1, 0.5 and 0.25 Hz for P-waves and 0.1, 0.05 and 0.02 Hz for S-waves. All P- and S- wave arrivals were hand-processed. Crustal corrections are based on the receiver functions model. Checkerboard resolution tests show good model recovery for anomalies of size 8°x8° with Vp and Vs variations of ±1.5% and ±0.5% respectively; whereas 4°X4° checkerboards show moderately good recovery. To isolate the depth extent of anomalies in the model we ran two suites of squeezing tests: 1) For maximum depth of the model being 1000, 700 and 410 km. 2) For the 1000 km deep model, we increased the damping parameter in the deeper layers progressively and examined the rms misfit and the imaged structure. Visual inspection shows that the lateral distribution of structures remains unaffected by the depth extent of the model, and that deep structures remain present for strong damping. This indicates to us that the deep structures are real.

The Receiver Functions show a thin crust with a flat and sharp Moho discontinuity throughout the entire Kaapvaal and Zimbabwe cratons. These results are consistent with expectations for Archean areas. The lowest Vp/Vs value sites are found around the locations of diamondiferous kimberlite pipes at flat Moho in the heart of the Kaapvaal craton.

The new P- and S- wave tomography models show velocity variations between the Archean and modified regions (such as the Bushveld complex) and the mobile belts surrounding the cratons. The high velocity (Vp=+1.0% and Vs=+0.4%) cratonic roots extend to 220-250 km depth beneath the Kaapvaal and Zimbabwe cratons. Smaller velocities are found under the Bushveld complex and the mobile belts. We also image significant positive and negative anomalies (Vp= ±3.0% and Vs= ±0.5%) unconnected to the cratons under the cratonic keels and in the transition zone. Inverting the P wave data using different reference models provide robust results without significant change in the anomalies. To get more vertical resolution about this case, we are currently examining the surface wave tomography using the two wave approximation approach.