Xenolith Constraints on Seismic Velocities in the Upper Mantle Beneath Southern Africa

David E. James, F. R. Boyd, Richard W. Carlson • *Carnegie Institution of Washington*

Derek Schutt • *Carnegie Institution of Washington*, *University of Wyoming*

David R. Bell • *Arizona State University*

Seismic velocities and rock densities are calculated for approximately 120 geothermobarometrically calibrated Cretaceous age mantle xenoliths from the Archean Kaapvaal craton and adjacent Proterozoic mobile belts (Figure 1) (James et al., 2004). Velocity and density estimates are based on the elastic and thermal moduli of constituent minerals under equilibrium P-T conditions at the mantle source. Results are consistent with tomographic evidence that cratonic mantle is higher in velocity by 0.5-1.5% and lower in density by about 1% relative to off-craton Proterozoic samples at comparable depths. Seismic velocity variations between cratonic and non-cratonic xenoliths are controlled dominantly by differences in geotherm, with compositional effects secondary. Differing geotherms between cratonic and non-cratonic regions have a relatively minor influence on density, where composition remains the dominant control.

Figure 2 shows computed velocities for low-T (equilibrium) cratonic xenoliths. The P-wave velocity-depth curve is positive over the depth range 50-180 km, whereas S-wave velocities decrease slightly over the same depth interval, consistent with recent surface wave studies (Larson et al., 2005). Seismic velocities and densities for the highly depleted cratonic xenoliths differ significantly from values predicted for both primitive mantle peridotite and mantle eclogite: Dense and more fertile primitive mantle peridotite, even for a cratonic geotherm, is characterized by velocities about 1% lower for P and about 1.5% lower for S relative to low-T garnet lherzolite at 150-km depth. For a cratonic geotherm, the calculated density of primitive garnet peridotite at 150-km depth is 2-3% greater than that for the Kaapvaal xenoliths.

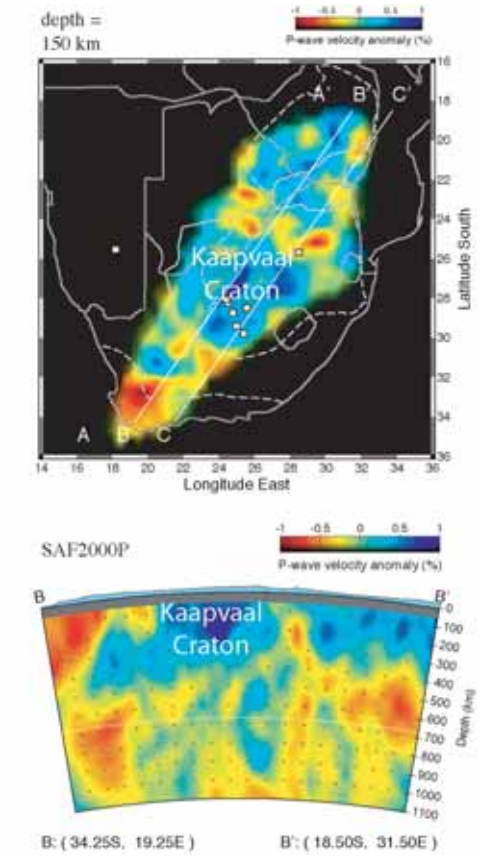

Figure 1. Relative P-wave velocity perturbations from inversion of seismic delay times (James and Fouch, 2002). Blues are positive velocity anomalies, red are negative. (Top) Horizontal section of velocity perturbations at 150 km depth with overlaid geologic provinces. (Bottom) Vertical cross-section along line B-B' of the horizontal section. Topography, scaled by a factor of 20, is shown in light green.

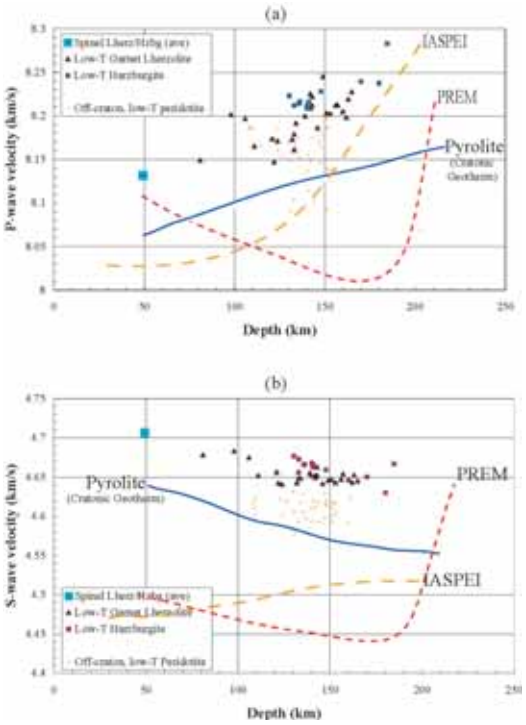

Figure 2. P and S velocities vs. depth for low-T (equilibrium) cratonic xenoliths (large symbols). Small orange symbols are for low-T off-craton xenoliths. The solid blue lines (pyrolite) are calculated velocities for primitive mantle peridotite based on a cratonic geotherm. The computed seismic velocities for cratonic xenoliths are substantially higher than are those for fertile mantle or for earth models IASPEI or PREM.

James, D.E., F.R. Boyd, D. Schutt, D.R. Bell, and R.W. Carlson, Xenolith constraints on seismic velocities in the upper mantle beneath southern Africa, *G-cubed, 5*, doi:10.1029/2003GC000551 (Q01002), 1-32, 2004.

James, D.E., and M.J. Fouch, Formation and Evolution of Archaean Cratons: Insights from Southern Africa, in The Early Earth: Physical, Chemical and Biological Development, edited by C. Ebinger, C.M.R. Fowler, and C.J. Hawkesworth, pp. 1-26, Geological Society, London, 2002.

Larson, A.M., J.A. Snoke, and D.E. James, S-wave velocity structure beneath the Kaapvaal Craton from surface-wave inversions compared with estimates from mantle xenoliths, *Geophys. J. Int.*, submitted, 2005.