

2001 Canberra Workshop, Canberra, Australia

Reference: James, D.E., M.J. Fouch, and the Kaapvaal Working Group, Formation and evolution of Archaean cratons: Insights from the Kaapvaal Project of southern Africa, Canberra Workshop, 2001.

Formation and Evolution of Archaean Cratons: Insights from the Kaapvaal Project of Southern Africa

David E. James, Matthew J. Fouch* (Carnegie Institution of Washington, D.C.); Kaapvaal Working Group (<http://www.ciw.edu/kaapvaal>)

Archaean cratons are the stable remnants of Earth's early continental lithosphere, and their structure, composition, and survival over geologic time make them unique features of the earth's surface. The Kaapvaal Project of southern Africa was organized around a broadly diverse scientific collaboration to investigate fundamental questions of craton formation and mantle differentiation in the early Earth. The principal aim of the project was to characterize the physical and chemical nature of the crust and mantle keel of the cratons of southern Africa in geologic detail, and to use the 3-D seismic and geochemical images of crustal and mantle heterogeneity to reconstruct the assembly history of the cratons. Seismic results confirm that the structure of crust and tectospheric mantle of the cratons differs significantly from that of post-Archaean terranes. Three-dimensional body-wave tomographic images reveal that high velocity mantle keels extend to depths of at least 200-250 km nearly everywhere beneath the undisturbed cratons, and locally to depths of 300 km or more. No low velocity channel has been identified beneath the cratonic keels, although prominent low velocity structures are present in the lower mantle beneath southern Africa. The Kaapvaal craton was modified ca. 2.05 Ga by the massive Bushveld magmatic event. The mantle beneath the Bushveld terrane is characterized by distinctly lower seismic velocities, an effect that appears to be more chemical than thermal in origin. The crust beneath undisturbed Archaean craton is relatively thin (~35-40 km), unlayered, and characterized by a strong velocity contrast across a sharp Moho. In contrast, post-Archaean terranes and Archaean regions disrupted by large-scale Proterozoic magmatic or tectonic events are characterized by thicker crust, complex Moho structure and higher seismic velocities in the lower crust.

Re-Os depletion model age determinations confirm that the mantle keel beneath the cratons is Archaean in age. All samples of the cratonic mantle carried to the surface in kimberlite pipes exhibit ages similar to those of the surface rocks through which they were erupted, both on and off craton. The Re-Os data indicate also that there is no age progression of rock samples with depth in the cratonic keel, suggesting that root thickness has not increased over geologic time. Both laboratory experiments and geochemical results from eclogite xenoliths demonstrate that subduction processes played a central role in the formation of the Archaean crust, the melt depletion of Archaean mantle, and the assembly of early continental lithosphere. Coordinated geochronological studies of crustal and mantle xenoliths have revealed that both crust and mantle have experienced a multi-stage history. The lower crust in particular retains a high-fidelity record of the tectonothermal evolution of the lithosphere. Analysis of lower crustal xenoliths has shown that much of the deep craton experienced a dynamic and protracted history of tectonothermal activity that is temporally associated with events seen in the surface record. Cratonization may thus have occurred not as a discrete event, but in stages, with final stabilization postdating crustal formation.

* Now at Department of Geological Sciences, Arizona State University, Tempe, Arizona