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Deformation and hydration of the lithospheric mantle beneath the Kaapvaal craton, South Africa

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To constrain the relations between deformation and metasomatism in the subcratonic lithospheric mantle, we have analyzed the microstructures and crystal preferred orientations in 50 mantle xenoliths from the Kaapvaal craton. Water contents in olivine and pyroxenes were measured in 14 samples equilibrated at different depths. Coarse-granular microstructures recording deformation by dislocation creep followed by annealing predominate. Mylonitic (sheared) peridotites with partially or totally recrystallized microstructures are however common below 140 km. Refractory compositions predominate, but multiple metasomatic events resulted in orthopyroxene enrichment or secondary crystallization of clinopyroxene and phlogopite. Coherent orthopyroxene and olivine CPO in most coarse-grained peridotites implies in pre- to syn-kinematic orthopyroxene enrichment or epitaxial growth on primary orthopyroxene. Undeformed, interstitial orthopyroxene, clinopyroxene, and phlogopite with random orientations in coarse-grained peridotites record post-kinematic modal metasomatic events. Deformation of these phases in the sheared peridotites implies that mylonitization results from a later event, which affected locally the deep cratonic lithosphere. Olivine CPO recording dominant [100] glide predominate at all depths. Only two samples, equilibrated at ∼3.3 GPa show olivine [001] and orthopyroxene [001] axes subparallel, suggesting dominant [001] glide. Water contents in olivine are maximum (150 wt. ppm H_2O) in peridotites equilibrated at ∼160 km depth. Peridotites equilibrated below 180 km depth are, in contrast, almost dry. Lack of correlation between olivine mg# and water content indicates that the high water contents in olivine record re-hydration after the extensive partial melting, which produced the cratonic root. The vertical variation in water contents in olivine observed in the Kaapvaal peridotites may result from hydrogen addition or loss during extraction by the kimberlites. Comparison with magnetotelluric electrical conductivity data suggests, however, that the observed vertical variation of water contents in olivine may be representative of the present-day state of the Kaapvaal mantle, implying that extensive metasomatism resulted in hydration of the cratonic mantle at intermediate depths. The annealed microstructures of Kaapvaal peridotites indicate however that this metasomatism was not followed by remobilization of the cratonic root.