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Are cratons heavy?–The effects of melt depletion on the density structure of cratonic mantle

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To explain the stability of cratons, *Jordan* [1979] suggested that cratonic mantle is neutrally buoyant with respect to hotter asthenospheric mantle. This study hypothesized that extraction of partial melt–which removes the incompatible elements and modifies the mineral proportions from that of fertile peridotite–reduces the density of the rock enough to counteract the effects of temperature. Many studies have elaborated on this phenomenon, and it is still generally considered that cratonic mantle is either neutrally or positively buoyant with respect to hotter advecting fertile mantle. To quantify the density effects of melt removal we have evaluated the melting relations of peridotite and have modeled its subsolidus compositional evolution. We find that above about 140 km depth no amount of melt depletion can counteract the density effects of temperature. This suggests that cratonic mantle from the Moho to $\sim$140 km depth is negatively buoyant. To confirm this observation, we have examined density variations in more than 100 Kaapvaal craton xenoliths using principle component analysis to separate the effects of melt depletion from other geochemical variations such as silica enrichment. Similar to the isobaric melting results, we find a density cross-over at around 140 km. This implies that uppermost cratonic mantle is stabilized by its high viscosity with respect to asthenosphere, and not its density structure. A test of this hypothesis would be to see if reducing the viscosity of this uppermost mantle would cause it to convectively destabilize. This may have happened when Laramide aged subduction brought the Farallon slab to shallow depths beneath much of the western U.S. Hydration from the slab could have reduced the viscosity of the Wyoming craton, causing it to drip away. Notably, teleseismic P-wave tomog-

raphy finds a high velocity “drip” under the Wind River Range in western Wyoming. This feature is within a region of maximal Laramide foreshortening which would have promoted nucleation of the instability. Finally, we quantify the P- and S-wave velocity effects of melt depletion and silica enrichment as a function of pressure. We find that S-wave velocity is somewhat increased by melt depletion, P-wave velocity is decreased by silica enrichment, and subsolidus compositional effects (such as due to the opening of the pyroxene solvus) modify density but not velocity.