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Linking water contents of peridotite minerals and mantle lithosphere viscosities in continental and oceanic settings

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Nominally anhydrous minerals such as olivine, pyroxene and garnet can accommodate tens to hundreds of ppm H2O in the form of hydrogen bonded to structural oxygen in lattice defects. Although in seemingly small amounts, this water can significantly alter chemical and physical properties of the minerals and rocks, in particular modify their rheological properties. This effect will be examined here using Fourier transform infrared spectrometry (FTIR) water analyses on minerals from mantle xenoliths from the Kaapvaal craton (southern Africa) and from abyssal peridotites from the Gakkel ridge (Arctic ocean). A negative correlation between olivine water contents and pressure was found at depths corresponding to the lithosphere-asthenophere boundary (LAB) beneath the Kaapvaal craton (150-200 km). Low water contents in olivine may have resulted from the nature of fluids (methane-rich) and melts (miscibility with fluids) at these pressures. There consequently may be a layer of peridotite with water-free olivine beneath cratons. Using olivine creep equations to estimate viscosities in the cratonic mantle, we calculate that these water-free olivines could be responsible for a viscosity contrast between the LAB and the asthenosphere high enough to prevent the LAB to be delaminated over time. These findings provide a key mechanism for our understanding of the stability of cratonic roots. Gakkel ridge abyssal peridotites are exceptional in that they are minimally affected by hydrothermal alteration. Their olivines and pyroxenes have lower water contents than most of those found in continental peridotites. The low water contents may result from the incompatible behavior of hydrogen during decompression melting occurring while mantle upwells slowly beneath oceanic ridges. Viscosities in the oceanic mantle will be estimated to determine if the low water content of oceanic peridotite can be linked to the rigidity of oceanic plates.