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A conceptual model for the asthenosphere: redox melting in the C-O-H-bearing mantle vs. geophysical observations

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The asthenosphere has classically been considered as a convective layer, with its viscosity decreased by the presence of 100's ppm water in olivine, and being overtopped by a rigid and dry lithosphere. It, however, needs a new conceptual definition as the presence of water seems not able to affect the rheology of olivine; furthermore, properties such as electrical conductivity and seismic wave's velocity are not sensibly affected by water content in olivine, leaving the geophysical features of the asthenosphere unexplained.

An asthenosphere impregnated by low melt fractions is consistent with constraints on melting behavior of C-O-H-bearing peridotites and may also better explain electrical conductivity and seismic features. The challenge is therefore to confront and reconcile the complexity of mantle melting in the C-O-H system with geophysical observations. This work reviews and discusses several key properties of the asthenosphere and relates their vertical and lateral heterogeneities to geodynamic processes.

The first discussion is about the top of the Lithosphere-Asthenosphere boundary in the oceanic mantle. The discontinuity identified by seismic and electrical surveys is located at an average depth of 65km and is weakly influenced by the age, and therefore, the temperature of the lithosphere. This puzzling observation is shown here to be in perfect line the onset of peridotite melting in presence of both H_2O and CO_2. Mantle melting is therefore expected at 65 km depth, where the melt is essentially carbonatitic, inducing weakening and imposing transition in the regime of thermal transfer. Deeper, the melt evolve to silica-richer compositions.

Twenty years of petrological investigations on processes that control mantle redox state unanimously concur on an increasingly reduced mantle with increasing depth. The conventional wisdom defines garnet as being increasingly abundant and increasingly able to concentrate ferric iron with increasing depth. Such oxygen pump results in an increasingly reduced mantle with depth. Recent surveys have calibrated the carbon-carbonate redox transition at mantle pressure and have located its depth around 180-250 km (depth of redox melting); Deeper, only diamond is stable; Shallower, carbonates, mostly in its molten state, are expected. This petrological model is confronted to the most recent geophysical observations. Such observations indicate that melting must occur at depth down to 400 km, which conflict with the concept of redox melting. What is the composition of the melt? Hydrous silicate melt or hydrous carbonated melt? What does it mean in terms of deep upper mantle redox state?