WATER IN ANHYDROUS MINERALS OF THE UPPER MANTLE: A REVIEW
OF DATA OF NATURAL SAMPLES AND THEIR SIGNIFICANCE

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To a depth of 410 km, the Earth's mantle is made of olivine, typically making up
55 to 95% in weight of the upper-mantle dominant rock-type, peridotite, and
orthopyroxene, clinopyroxene and an accessory phase such as spinel and/or garnet.
Although nominally anhydrous, these minerals (except spinel) can accommodate small
amounts of water, characteristically <5 to 600 ppm H2O in natural samples (Bell, 1992),
as protons inserted in mineral defects and vacancies. These apparently trivial water
contents actually have a disproportionate influence on many physical and chemical
properties of peridotite, and therefore on that of the entire upper-mantle (Hirschmann et
al., 2005). In particular, the presence of bound H in the structure of upper-mantle
minerals can lower their viscosity (Hirth & Kohlstedt, 2004; Mackwell et al., 1985; Mei
& Kohlstedt, 2000a; Mei & Kohlstedt, 2000b), enhance their radiative transfer
(Hofmeister, 2004), attenuate passing seismic waves (Karato & Jung, 1998), increase
their electrical conductivity (Hier-Majumder et al., 2005; Karato, 1990; Simpson &
Tommasi, 2005), and of course lower their melting temperatures and affect the speciation
As key processes of the Earth's dynamics find their origin in the upper-mantle, from plate
tectonics to magma generation, it is therefore crucial to determine in what form and how
much water is present in its prominent phases. A combination of our own data and that
available in the literature aims at addressing 2 key questions regarding water in the deep
Earth:

1) How representative is the water content measured in mantle samples from the real
content at depth?

Diffusion profiles of hydrogen across olivine grains from mantle xenoliths
suggest that olivine can lose a significant portion of its water during transport of the
xenolith to the surface (Demouchy et al, 2006; Peslier & Luhr, 2006). This phenomena is
particularly heightened in xenoliths brought up by alkali basalts, but not too prominent in
xenoliths brought up by kimberlites. This is likely the result of the higher temperatures
and lower ascent rates of alkali basalts compared to kimberlites (Peslier et al, 2007).
Pyroxenes, on the other hand, appear mostly immune to H loss during xenolith transport
(Peslier et al., 2002).

Abyssal peridotites minerals have water contents 2 to 3 times lower than those
from continental xenoliths, and lower than the water content of a typical N-MORB source
calculated from water contents measured in MORB glasses (Peslier et al, 2007). The low
water content of abyssal peridotites is likely the consequence of the slow adiabatic
decompression of the oceanic mantle beneath ridges. Both melting (H is incompatible
and goes into melt(s); Aubaud et al., 2007) and decreasing H solubility in mantle
minerals with lower pressures (review by Keppler & Bolfan-Casanova, 2006) combine to deprive abyssal peridotites minerals of their water.

Water contents measured in xenolithic olivines and in abyssal peridotites minerals should thus be used with caution to compare the water content of various upper-mantle settings and in assessing the water budget of the upper-mantle.

2) How much water is there in the Earth's mantle and does it vary between mantle settings?

Pyroxene water contents have similar ranges in cratonic mantle xenoliths, as represented by the southern African samples, than in those in off-cratonic settings, as represented by Western North American and Japanese samples of the lithospheric mantle beneath mobile belts. Our preliminary results suggest that beneath cratons, olivine and pyroxene water contents increase with increasing pressure and decreasing oxygen fugacity, up until about 4.5 GPa and 3.3 ∆FMQ beyond which water contents decrease, maybe in response to a change in water solubility in pyroxene (Mierdel et al., 2007) and/or a different fluid environment. Based on all data available, the water content of the continental lithospheric mantle ranges from 20 to 160 ppm H2O. This is similar to the range of water contents of 50-200 ppm for N-MORB source calculated from water analyzes of MORB glasses and melt inclusions (e.g. Dixon et al., 1988; Michael, 1988; Saal et al., 2002). Only mantle wedge environments may have low water contents in response to an oxidizing environment (Peslier et al, 2002), and the source mantle region of OIB have high water contents (several hundred ppm H2O; e.g. Moore & Schilling, 1973; Dixon et al., 2002; Asimow et al, 2004). Overall, water content variations in the upper-mantle appear larger vertically (change with depth) than laterally (various tectonic settings).

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