WATER IN THE EARTH'S MANTLE

Dreibus, G., Jagoutz, E., Wänke, H.

Max-Planck-Institut für Chemie, Saarstraße 23, 55122 Mainz, Germany.

The Earth is the only terrestrial planet having larger quantities of water at its surface. The amount of water in the Earth's crust (+ hydrosphere) is with 6.95 % well known. The amount of water in the Earth's mantle is much more difficult to assess. Three approaches have been used by us.

1. The accretion model:

The heterogeneous accretion model (Wänke, 1981) proposed that most of the Earth's current water inventory was derived from the late veneer at the very end of accretion when the mean oxygen fugacity of the accreting material became so high that metallic iron could not exist any longer. Prior to this moment, all the H_2O would have been used up for the oxidation of Fe to FeO and H_2. Huge quantities of hydrogen would continuously be produced in this scenario which escaped. In the same moment the hydrogen on its way to the surface would lead to an efficient degassing of the growing Earth's mantle. But towards the end of accretion metal became unstable and even the highly siderophile elements remained in the mantle in their CI abundance ratios. The concentration of 3.2 ppb Ir in the Earth's mantle corresponds to 0.44 % CI carbonaceous chondrite material representing the late veneer. With a CI H_2O^+-content of 12.8 % recently determined by us in 2 specimens of Orgueil with a multiphase carbon/hydrogen/moister determinator from LECO the estimated water content of the primitive mantle (mantle + crust) is 830 ppm. Subtracting the amount of water contributed by the Earth's crust (410 ppm) one finds for the Earth's mantle 420 ppm. Our earlier estimates of 60 ppm mantle-water based on the 7.2 % CI H_2O content measured by Boato (1954).

2. Water in oceanic basalts glasses:

Recently we measured the F- and H_2O-contents in N- and P-type oceanic basalts glasses and found a good correlation for these two elements. The F contents in the enriched type (P) classes range from 530 ppm to 210 ppm. The water concentrations measured in these type of oceanic basalts range between 0.84 % and 0.46 %. The respective data for the depleted oceanic basalts (N-type) are 120 ± 30 ppm for fluorine and about 0.2 % for H_2O. The obtained F/H_2O ratio in these upper mantle derived rocks is 0.05. Assuming the same F/H_2O ratio in the mantle derived basalts as for the source region we calculated with the F-data for the upper mantle of 16 ppm a water content of 330 ppm. This value of 330 ppm water for the Earth's mantle agrees well with our new estimate from the late veneer with the high water content of 12.8 % in CI carbonaceous chondrites but not with the earlier used lower value.

3. Water in upper mantle xenoliths:

We also attempted to measure the water concentration in upper mantle xenoliths. Therefore we looked for primitive undisturbed mantle xenoliths containing a pristine water content. To avoid measurements of a late contamination and serpentinisation we determined the water content in very clean hand-picked minerals of spinel-olivine harzburgite SC23 with a modal composition of 77 % OL, 21 % OPX and 2 % CPX (Zindler a. Jagoutz, 1988). We extracted the water from the minerals by stepwise heating up to 1200 ^{o}C and determined the released water by the dead-stop method using a Karl Fischer titrator. The obtained water concentrations of 73 ppm in OL, 162 ppm in OPX, and 548 ppm in CPX yield 100 ppm for the clean bulk sample reflecting a low water content in the upper Earth's mantle.

The Earth's mantle water content of 420 ppm as derived from the heterogeneous accretion model and the value of 330 ppm obtained from the observed correlation of F with H_2O in mantle derived basalts indicate that today a considerable portion of the Earth's total water inventory resides in the mantle. It is also clear that over the history of the Earth the water of the Earth's oceans has been recycled many times through the mantle. This is the consequence of plate subduction. In a similar way mantle convection was probably responsible to bring water into the originally dry mantle. As a consequence, today the Earth is wet both inside and outside.

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