Probing the water content of the Earth's mantle: H mobility under extreme conditions

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It has been established that the majority of nominally anhydrous minerals (NAMs) in Earth's mantle can incorporate water in the form of structurally bound hydrogen and that, as a result, there may be a significant volume of water stored in the mantle. The total water content of the mantle can be estimated through the analysis of MORB, OIB and xenolith material but samples typically derive from shallow depths and these estimates may not be representative of the whole mantle.

Due to being highly mobile, hydrogen is thought to act as the dominant charge-carrying species in mantle minerals and, consequently, electrical conductivity is sensitive to even small changes in water content. Large scale electrical conductivity studies may therefore offer a complimentary method for 'mapping-out' mantle water content, provided the influence of hydrogen can be adequately determined. Unfortunately, obtaining mineral electrical conductivity data relevant to mantle conditions has traditionally been problematic due to difficulties inherent in measuring conductivity in 'wet' samples - with different groups of researchers in different laboratories obtaining calculated mantle reservoir water contents that differ by several orders of magnitude.

Our experimental design investigates electrical conductivity in synthetic hydrous olivine by considering hydrogen-deuterium exchange in single crystals. Hydrogen-saturated crystals are synthesised under mantle conditions (such that the hydrogen incorporated is relevant to the conditions being studied), then sealed in a capsule with deuterium oxide, allowing deuterium to exchange with hydrogen under controlled (mantle) pressure and temperature conditions for a specified time period. The resulting H-D exchange profiles can be characterised using SIMS depth profiling and fitted to Fick's law; extrapolated diffusion data for hydrogen self mobility can then be directly related to electrical conductivity through the Nernst-Einstein equation.

Following experiments on synthetic olivine, the method can be used to investigate high pressure phases, providing data on hydrogen mobility across all parts of the mantle.