

Water storage in the Martian mantle

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Geological evidence supports the persistence of water on the surface of Mars throughout its history [1] and especially implies the existence of voluminous surface oceans on early Mars [2]. Water can also be stored in the Martian mantle, primarily in nominally anhydrous minerals (NAMs). The short-lived early hydrosphere as well as intermittently flowing liquid water may have been formed and/or replenished by magmatic degassing of water from the mantle [3]. Estimating the water storage of the Martian mantle would place important constraints on its water inventory and help elucidate the sources, sinks, and temporal variation of water on Mars.

Here, for the first time, we quantify the water storage capacity of the Martian mantle along a series of atherms at different mantle potential temperatures (T_p). We recently developed a thermodynamic model of maximum water solubilities in NAMs to parameterize the effects of pressure (P), temperature (T), and composition (X_{Fe}) on the water storage capacities of major rock-forming minerals based on high P - T experimental data [4]. Using this model, we integrated these storage capacities through the phase assemblages of an FeO-rich Martian mantle composition computed using PerpleX [5, 6]. We report that the Martian mantle has a water storage capacity equal to a 5.2 km Global Equivalent Layer (GEL) at the present-day $T_p = 1600$ K [7]. Due to the lack of an efficient rehydration mechanism such as subduction, the present water content of the Martian mantle must be less than the storage capacity at its temperature of formation ($T_p = 1800$ K, near the Martian mantle solidus [8]), which was 2.1 km GEL, corresponding to a low hydration state today ($< 2.1/5.2 \sim 40\%$). This is an upper bound; if Mars accreted wet [9] subsequent volcanic degassing may have removed water from the mantle and constituted a primary source of surface water.

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