Hydration state of the Martian lithosphere constrained from gravity and topography

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Widespread aqueous alteration of the Martian crust suggests that metamorphic hydration reactions may have played a critical role in the sequestration of water early during the planet' s history. The presence of hydrous phases in the Martian crust reduce its bending strength, and we show that observations of the Martian gravity anomaly may be used to constrain the fate of Martian surface water.

Using the gravity anomalies associated with notable topographic features, such Olympus Mons, as well as the global gravity and topography, we construct yield strength envelopes for hydrous and anhydrous end-member crustal sections, and derive the predicted elastic thicknesses, Te, a proxy for the long-term lithospheric strength of Mars. We also use spherical harmonic coefficients that describe the Martian gravity anomaly and topography fields to quantify the role of isostasy in contributing to crustal and upper mantle structure. Power spectra of these fields reveal that the gravity effect of topography and its flexural compensation contributes significantly to the observed free-air gravity anomaly spectra for spherical harmonic degree 8 < n < 50, corresponding to wavelength 300 < \lambda < 3000 km. The best-fit global average is for an elastic plate (flexure) model with T_e of ~126 km. All isostatic models under-predict the spectra at 2 < n < 5, and we interpret the low-order Martian gravity field, at least in part, to be the result of processes that formed the Northern Basin. By comparing the observed Martian T_e to that predicted for our metamorphic mineral assemblages, we iterate on the water content until convergence. In short, we show the bending strength of Mars places constraints on the amount of hydration of the Martian crust, which in turn we use to calculate the planetary water budget. Notably, the stiffer flexural response of Olympus Mons is consistent with its younger age and eruption predominantly into a dry environment.

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