Origin of the Martian Moons and their Volatile Abundances

MIKI NAKAJIMA[1,2], ROBIN M. CANUP[3]

[1]Earth and Environmental Sciences, University of Rochester, Rochester, NY, 14627 (mnakajima@rochester.edu)
[2]Department of Terrestrial Magnetism, Carnegie Institution for Science, Washington, DC, 20015
[3]Southwest Research Institute, Boulder, CO, 80302

Originally, the Martian moons, Phobos and Deimos, were thought to have been gravitationally captured asteroids because their spectra are similar to those of D-type asteroids [e.g., 1]. However, this idea has been recently cast doubt on because intact capture is difficult to reconcile with the nearly circular, co-planar orbits. Alternatively, their orbits may be better explained by recent dynamical studies that suggest that the moons may have instead formed from a disk generated by a large impact [e.g., 2-4]. Key information to constrain their origin may be delivered by the planned sample return mission, Martian Moon eXploraiton Mission (MMX), but the connection between these hypotheses and observable quantities remains unclear. Here, we propose that their volatile abundances, particularly water, would provide a window to reveal their histories. Our numerical simulations show that a significant amount of water would have hydrodynamically escaped from the disk and dried out the moons if they formed by imapct, whereas the moons could be as water-rich as asteroids if they were gravitationally captured asteroids. In addition to water, sodium may have initially escaped from the disk, but it would have solidified before it completely escaped from the Martian gravitational well. Consequently, it may have eventually become part of the moons, and therefore sodium may not be the best element to differentiate the hypotheses. Thus, we predict that the moons' mode of origin may be determined by knowledge of their water abundances, given that detection of a substantial (non-exogenically delivered) water content would argue strongly against formation by impact. MMX will conduct detailed remote sensing of the moons, including a gamma ray and neutron spectrometer that will for the first time probe their sub-surface elemental compositions, and will return samples from Phobos for laboratory analysis. This should allow for characterization of the moons' volatile abundances and constrain their origin.

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