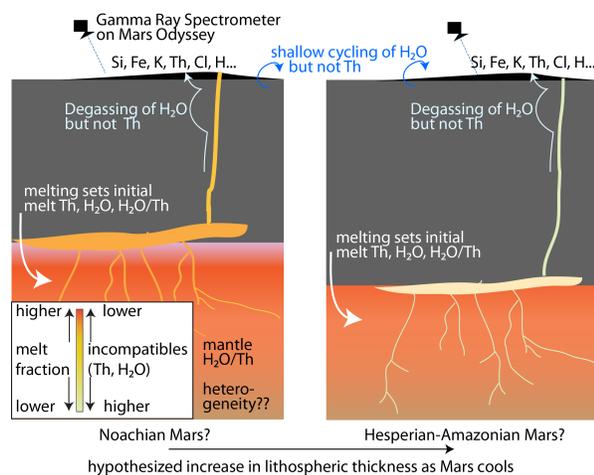


**PRIMARY H<sub>2</sub>O IN MARTIAN MAGMAS FROM REGIONAL THORIUM DISTRIBUTIONS.** B. A. Black<sup>1</sup>, M. Manga<sup>2</sup>, L. Ojha<sup>1</sup>, M.-A. Longpre<sup>3</sup>, S. Karunatillake<sup>4</sup>, and L. Hlinka<sup>3</sup>. <sup>1</sup>Department of Earth and Planetary Sciences, Rutgers University, Piscataway, NJ (bblack@eps.rutgers.edu) <sup>2</sup>UC Berkeley <sup>3</sup>CUNY Queens College and Graduate Center <sup>4</sup>Louisiana State University.

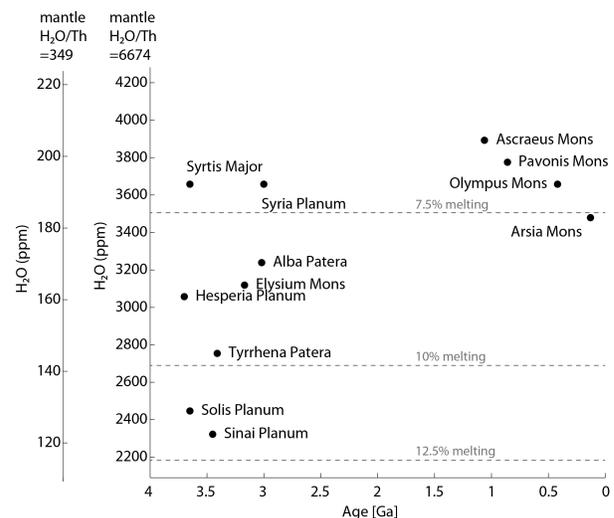
**Introduction:** Magmas deliver water and other volatiles from the Martian interior to the surface, thereby influencing surface processes and habitability through time. However, volatile inventories in Martian magmas are poorly constrained. Meteorite-based estimates of water concentrations in Martian magmas range widely, from a few hundred ppm to >10,000 ppm (i.e., 1 wt%) H<sub>2</sub>O [1-4], and are likely variably influenced by degassing. Gamma spectroscopy measurements of H (mapped as stoichiometric H<sub>2</sub>O as a likely combination of chemically bound, pore space molecular, and mineral hydroxyl) primarily reflect water cycled and stored in the regolith [5, 6] rather than original igneous water contents. Like water, Th behaves incompatibly during mantle melting, but unlike water, Th is not prone to degassing and is relatively immobile during aqueous alteration at low temperatures [7]. Here, we use Th as a proxy for primary H<sub>2</sub>O in Martian magmas. We use regional maps of Th from the Gamma Ray Spectrometer (GRS) instrument aboard Mars Odyssey [8] to assess variations in magmatic water across major volcanic provinces and through time.



**Figure 1.** Schematic diagram showing how Th can track H<sub>2</sub>O during melting but unlike H<sub>2</sub>O does not degas or participate as readily in post-emplacement chemical exchange with the atmosphere or hydrosphere.

**Methods:** To calibrate Th abundance as a proxy for H<sub>2</sub>O abundance during melting of the Martian mantle, we combine experimental Th and H<sub>2</sub>O partitioning data with models for Mars' mantle mineralogy. GRS measurements, including the Th concentrations we use as a proxy for H<sub>2</sub>O, represent

the column-averaged chemistry of the uppermost decimeters of the Martian regolith. Therefore, whether such measurements reflect the chemistry of global-scale dust redistribution versus local geochemistry represents an important question when using GRS data to infer igneous compositions [9]. Following previous studies, we interpret these data as representative of regional geochemistry based on several lines of evidence. GRS compositions do not fall along a mixing line with estimates of global dust composition [8]. Furthermore, GRS data from regions with and without thick mantles of fine sediment (based on thermal inertia, albedo, and orbital imagery) reveal statistically significant compositional distinctness even among heavily mantled regions [10].



**Figure 2.** Inferred primary H<sub>2</sub>O in Martian magmas across major volcanic provinces as defined by [8] for a range in end-member H<sub>2</sub>O/Th ratios (dual left axes), after correction for degree of melting using Th concentrations. Ages for each province are as tabulated in [12]. Younger or older phases of volcanism within each province may exist. For example, SE Elysium's volcanic units are younger than 3 Ga [13]. There is also some uncertainty whether the observed Th concentration corresponds to the age of the landscape over which it was averaged or the age of paterae within the landscape.

**Results and Conclusions:** For a range in mantle H<sub>2</sub>O/Th determined from estimates of mantle H<sub>2</sub>O and trace element abundances [1-4, 14], after correcting for slight differences in H<sub>2</sub>O and Th partitioning during

melting, the observed range in Th concentrations reported by [8] for Martian volcanic provinces yields estimated pre-degassing magmatic H<sub>2</sub>O of ~120-4000 ppm (Figure 2). This range falls at the low end of estimated magmatic H<sub>2</sub>O [1], but is consistent with recent experimental data [3], with measurements of H<sub>2</sub>O in meteorite apatite and amphibole suggesting ~2000 ppm H<sub>2</sub>O [2], and with the lower end of estimates from sulfur degassing calculations of 2000-4000 ppm H<sub>2</sub>O [15]. Magmatic water concentrations of ~120-4000 ppm combined with estimates of the total volume of post-Noachian magma generation [16] imply cumulative outgassing of a global-equivalent layer of H<sub>2</sub>O at most a few tens of meters since the Hesperian, consistent with Mars' present-day surface and near-surface water inventory [17] and estimates of sequestration and loss rates [18].

**Acknowledgments:** We acknowledge underlying data in the form of cumulative gamma photon spectra (available via the PDS: <https://pds-geosciences.wustl.edu/missions/odyssey/grs.html>) from the Mars Odyssey Gamma Ray Spectrometer suite, which were processed into chemical distributions by [8] using the methods described collectively by [6, 19,20]. BB and MM acknowledge support from NASA grant 80NSSC19K0545.

**References:** [1] H. Y. McSween, et al. (2001) *Nature* 409(6819), 487-490. [2] F. M. McCubbin, et al. (2010) *Earth Planet. Sci. Lett.* 292(1), 132-138. [3] J. Filiberto and A. H. Treiman. (2009) *Geology* 37(12), 1087-1090. [4] J. Filiberto, et al. (2016) *Meteoritics & Planetary Science* 51(11), 1935-1958. [5] W. C. Feldman, et al. (2002) *Science* 297(5578), 75-78. [6] W. Boynton, et al. (2007) *Journal of Geophysical Research: Planets* 112(E12), . [7] G. J. Taylor, et al. (2006) *Journal of Geophysical Research: Planets* 111(E3).[8] D. Baratoux, et al. (2011) *Nature* 472(7343), 338-341. [9] C.E. Viviano et al. (2019) *Icarus* 328 [10] H. E. Newsom, et al. (2007) *Journal of Geophysical Research: Planets* 112(E3). [11] S. W. Ruff and P. R. Christensen. (2002) *Journal of Geophysical Research: Planets* 107(E12), 2-1-2-22. [12] A. Broquet and M. Wieczorek. (2019) *Journal of Geophysical Research: Planets* 124(8), 2054-2086. [13] D. Susko, et al. (2017) *Scientific Reports* 7(1), 1-11. [14] G. J. Taylor (2013) *Treatise on Geochemistry*. [15] F. Gaillard, et al. (2013) *Space Science Reviews* 174(1-4), 251-300. [16] R. Greeley and B. D. Schneid. (1991) *Science* 254(5034), 996-998. [17] M. Carr and J. Head. (2015) *Geophys. Res. Lett.* 42(3), 726-732. [18] E. L. Scheller et al. (2021) *Science* 372. [19] L.G. Evans et al. (2006) *JGR-Planets* 111. [20] S. Karunatillake et al (2007) *JGR-Planets* 112.