Mars Subsurface Hydrology in 4D and Implications for Extant Life

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Summary: Liquid groundwater on modern Mars might be an essential requirement for extant life on Mars. However, to this date, we do not know whether there is water in the Martian shallow or deep subsurface. Here, we show how groundwater levels might have evolved over the last 4.5 Ga inside the Martian subsurface as a function of location, depth and time using numerical geodynamical evolution models. We also discuss the techniques that can be applied to searching for liquid water on modern-day Mars.

The Martian subsurface has had and still has the potential to enable environments with stable groundwater. The possibility of such underground waters has gained more interest since the announcement of a possible subsurface lake beneath the South Polar Layered Deposits on Mars with MARSIS [1]. The temperature at the base of these polar deposits at 1.5 km has been estimated to be ~205 K, which would require large amounts of dissolved salts (likely Ca- or Mg-perchlorates) to sufficiently reduce the freezing point of water.

Due to attenuation, MARSIS and SHARAD have generally great difficulties to detect groundwater beneath a depth of a few hundred meters, particularly at an aquifer horizontal scale of less than a few tens of km and away from the polar caps. Since initial estimates of the groundwater table are generally far beyond a depth of 1 km [2], Martian groundwater might be much more widespread but has so far not just remained undetected but was rather undetectable.

In the first part of this talk, we show evolving water table results produced with 4D (*three in space and one in time*) interior models of Mars that self-consistently compute the subsurface thermal profile, groundwater stability depth, porosity, and permeability as a function of location and planet age across the last 4.5 billion years. The two models used are (**A**) a 3D spherical full mantle convection [3] and (**B**) a parameterized thermal evolution model both coupled to a 3D crustal model that is compatible with today's gravity and topography data. The spherical full mantle convection model explicitly considers both lateral variations of the crustal and mantle heat flow contributions, which can lead to regional perturbations that can shift the groundwater table closer to the surface. The advantage of the parameterized model on the other hand is the inclusion of various uncertainties in initial conditions, rheology, subsurface rock composition, thermal properties of crust and mantle, radiogenic heart source distribution, and groundwater chemistry (variable amounts of Ca- and Mg-perchlorates and chlorides as well as sulfates). We show how groundwater levels vary as a function of location on Mars today and across time, and discuss implications for potential aquifers beneath the polar ice caps and the implications for the potential for extant life on Mars.

In the second part of this talk, we will describe how we can use a variety of techniques to sound for liquid water in the Martian subsurface [3]. We will especially highlight the ability of transient electromagnetic sounding (TEM) to detect deep groundwater at depths of kilometers with modest payload power and mass—laying out the technology that could help us finally answer the question whether there is still liquid water in the Martian subsurface today—with potentially profound implications for the existence of and search for extant life on Mars.

References: [1] Orosei et al., Science 2018. [2] Clifford et al., JGR, 2010. [3] Plesa et al., JGR, 2016. [3] Stamenković et al. (2019), Nature Astronomy 3, https://www.nature.com/articles/s41550-018-0676-9.

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