A MODEL FOR THE HYDROGEOLOGICAL EVOLUTION OF MARS AND RELATED PRIME CANDIDATE SITES FOR THE ASTROBIOLOGICAL EXPLORATION

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Different-sized bodies of water have been proposed to have occurred episodically in the lowlands of Mars throughout the planet's history [1], largely related to major stages of development of Tharsis [1,2]. These water bodies range from large oceans in the Noachian-Early Hesperian, to a minor sea in the Late Hesperian, and dispersed lakes during the Amazonian. Assuming that the search for life is directly linked to the search for water, the possible biological history of Mars must have been largely influenced by the endogenetically-driven hydrogeological cycles. In consequence, terrestrial biological and environmental analogues can now be placed in context with the model proposed, so contributing to draw a general approach for the history of life on Mars.

If the search for extant/fossil life or biomarkers on Mars is fully successful, our analysis would suggest that records of microbial activity will be reflective of the inundation phases and varying aqueous surface and subterranean environments, similar to what is observed on Earth. Subsurface water in subterranean cavernous environments may have remained stable over relatively long geologic periods, so that radiation and adaptation to complex subsurface environments may have taken place. This analysis unfolds three prime candidate sites for the astrobiological exploration of Mars, each one corresponding to a major inundation phase of the global hydrological model:

1. Noachian to Early Hesperian: Meridiani Planum, based on (a) the geologic setting of the region [1]; and (b) the comparative analyses of hematite locations on Earth and Mars [3], which suggest an aqueous-hydrothermal or ambient fluid flow origin [4], with diagenetic formation of hematite concretions from groundwater flow[5,6], well according with the latest results of the *MER Opportunity*.
2. Late Hesperian to Early Amazonian: Mangala Valles, where diminishing martian episodic hydrologic events over geologic time are clearly recorded [7], particularly representing a later pulse of Tharsis-driven hydrologic activity.
3. Amazonian: Orcus Patera, a volcanic caldera or impact crater where ponded bodies of water [8,9] may have existed during almost contemporary times.

To propose these prime candidate sites, here we perform a comprehensive analysis of the evolution of water on Mars, including:

1. Evolution of the proposed shorelines, taking into account (1) local and/or temporal changes in the effective elastic thickness of the martian lithosphere [10]; (2) possible local variations of the thermal structure of the lithosphere producing differential thermal isostasy [11,12]; (3) the emplacement of lava flows [13] and/or deposition of sediment [14] in the putative northern ocean basin region, such as recorded for the Early and the Late Hesperian, respectively; (4) water transfer between different regions [15,16]; and (5) degradation of basins boundaries related to endogenic or exogenic activity [17].
2. A volumetric approximation to the plains-filling proposed oceans, considering the lithosphere rebound due to water unloading associated with the disappearance of an ocean [16,18].
3. Geochemistry of the Noachian oceans and derived mineralogies. The Noachian oceans, and possibly also any subsequent liquid water-mass on Mars [1], were enriched in iron hydroxides and magnesium sulphate salts, as revealed by the MER Opportunity after analyses on the sediments deposited at Meridiani Planum [19]. The CO_2, SO_2, and water generated from the volcanism and flood outbursts would have produced the acidic conditions to generate extensive sulfate salt emplacement on the martian surface. Aqueous thermodynamic calculations considering a CO_2-dominated atmosphere and a steady supply of iron and sulphate to seawater, which respectively raised concentrations up to 0.8 mM and 13.5 mM, result in acidic oceanic waters with $pH<6.2$, thus suggesting paleoenvironmental surface and near-surface conditions at least moderately acidic [20]. This precluded carbonate formation by oceanic sedimentation as a widespread global phenomena [21].
4. Ultimate water evolution on Mars and the possible fate of the ancient oceans, including escape to space and infiltration into the ground to form groundwater and permafrost.

References
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