

MARTIAN GULLIES AND THE STABILITY OF WATER IN THE MARTIAN ENVIRONMENT.

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Introduction: The discovery of high concentrations of hydrogen at near surface levels of Mars' polar regions by the Gamma Ray Spectrometer on the Mars Odyssey spacecraft [1] has once again sparked the debate as to the existence of liquid water on the Martian surface. Surface features observed in the recent Mars Global Surveyor and Odyssey missions have given great insight into the possibility of liquid water being present on Mars throughout the planet's history as well as the possibility that near surface liquid water may still exist today. Martian gullies are similar in size, shape, and appearance to gullies on Earth carved by liquid water [2]. Also, there is substantial evidence that the relative age of Martian gullies is quite young, namely lack of impact craters on gully surfaces and the superposition of the gullies on otherwise geologically young features [2].

Martian meteorites contain carbonate deposits at levels of several per cent in ALH84001 as well as trace amounts of carbonates and the mineral iddingsite in several other meteorites [3]. Detailed microstratigraphy shows that these deposits were present in the rocks while on the martian surface, providing direct evidence that liquid water circulated through the martian crust [3]. Indirect geochemical evidence for liquid water in the crust comes from measurements of various isotope ratios in weathering products, notably enhanced D/H, ¹³C/¹²C, ¹⁵N/¹⁴N, and ³⁸Ar/³⁶Ar ratios [4].

Despite this evidence it is still counterintuitive that liquid water exists on the surface of Mars. Liquid water should not exist an equilibrium phase due to the low mean annual pressures and temperatures. The minimum requirements for the existence of liquid water are pressures and temperatures above the triple point, but below the boiling point. A general circulation model of martian climate indicates that there are regions on the Martian surface that are favorable for the existence of liquid water, specifically the Amazonis, Chryse and Elysium Planitia, in the Hellas Basin, and the Argyre Basin [5]. The locations of these regions are poorly correlated with the location of the martian gullies discovered by the Odyssey mission [5]. If the water that forms the Martian gullies contains significant concentrations of water-soluble salts then the melting point will be lowered and the equilibrium vapor pressure of the solution will be reduced. Salts are believed to be a significant component of martian soil, at least at some localities, based on Viking data [6].

Here we investigate the ability of liquid water to remain stable and form surface features in the martian environment. The behavior of water on the martian surface has been explored in some depth [*e.g.*, 7], but the influence of regolith on water behavior has been given limited study. In our experiments, we document the behavior of various water volume fractions in a martian soil simulant under martian conditions by spectroscopy and visual analysis. Spectroscopy was utilized to ascertain the level of activity occurring on the surface of the test bed.

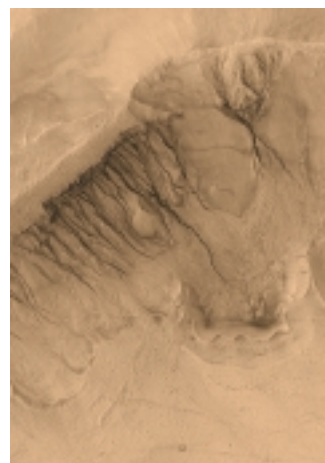


Fig. 1. Martian gullies in crater in Newton Basin located near 42.4°S, 158.2°W. (www.msss.com)

Experimentation: The Andromeda planetary environmental chamber was used as a test bed for our experiments. The chamber is designed to allow simulation of a variety of asteroidal and planetary environments, including the near surface (~1 meter depth) [8].

Experiments were conducted using Hawaiian volcanic tephra, taken from the same site as JSC-1 martian soil simulant [9]. Our simulant was baked in an oven at a temperature of 110° for 24 hours to remove adsorbed water. Mixtures of 1000 ml of simulant and distilled water in volume fractions of 5%-50% water content were produced and placed inside a dish for a total depth of approximately 8 centimeters. The volume content of water was increased in each successive mixture by intervals of 5%. Each of these mixtures was placed in the Andromeda Chamber, which for these experiments was equipped with a solar simulator with UV filter, a spectrometer, and a wireless camera system. The Andromeda Chamber was then pumped

down to a pressure of 6 millibars (martian surface pressure) at a nonlinear rate. During the vacuum process, reflectance spectra were obtained at atmospheric pressures of 760 millibars, 100 millibars, and 6 millibars. Once a martian pressure of 6 millibars was achieved the system was kept at this pressure for 60 minutes. The behavior of these mixtures was monitored through a wireless camera system throughout experimentation.

Results: Analysis of the experiments conducted consisted of spectroscopic and visual observations. Spectroscopy was utilized to determine changes in reflectance intensity and spectra as a function of time and atmospheric pressure, and visual analysis was utilized in order to document any features formed on the surface of the test bed.

The reflected light intensity decreased as the water volume percentage range was increased between 10%-15%, and increased steadily as the water volume percentages was increased to 40%, at which level the mixture behaved as a liquid and exhibited significant vaporization during atmospheric pressure reduction.

While monitoring the surface of the mixture during reduction in atmospheric pressure, we noted the formation of surface features on the scale of centimeters, notably geysers which appeared suddenly and decreased in activity over time. The most prominent and abundant surface features were formed between the water volume percentages of 15%-25%. Less prominent features were also formed in mixtures with a water volume percentage of 30% and 35%. It was observed that mixtures with either a very small amount of water, 5% and 10%, or a large amount, 40%-50%, did not produce any observable surface features. At the end of the experiment the location of geysers was marked by small craters or depressions.

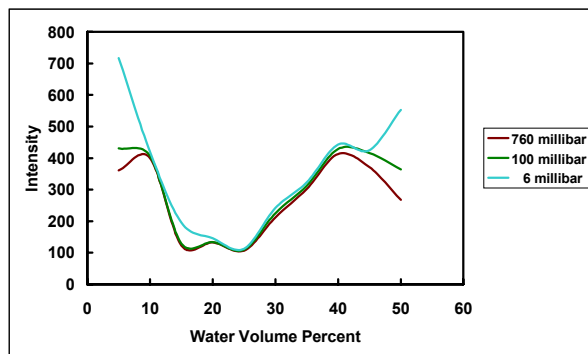


Fig. 2. Relative reflected light intensity versus water volume percentage.

Conclusions: There is a distinct pattern in the spectra of mixtures and resultant formation of observable surface features. Mixtures that exhibited the most observable surface features exhibited the lowest intensity measurements in their spectra. Mixtures that exhibited the least observable surface features exhibited the greatest intensity measurements in their spectra.

The observed trends in spectral reflectivity (Fig. 2) are best interpreted in the context of the visual observations. We suggest that, for intermediate water volume percentages (15-30%), the geysers produce limited grain-size separation of the regolith, with finer-grained material being preferentially carried to and deposited on the surface. The fine-grained material includes a larger proportion of weathering products, mostly clays, than the bulk simulant, and thus the surface takes on the reflectance properties of the weathering products. These tend to be more red, and darker than the bulk tephra. For mixtures with water volume percentages <15%, geysers are not sufficiently abundant to result in widespread formation of a surface layer of fine-grained material. For water volume percentages >30%, the entire simulant behaves as a fluid, and grain-size separation, if it occurs, is largely destroyed by convection of the regolith.

We find that liquid water, or even ice, if existing in small quantities at near surface levels can be a primary agent in the formation of surface feature formations. The intermediate water volume percentages that produced the most numerous surface features are similar to those suggested for shallow regolith aquifers by Odyssey [1]. Smaller and larger water volume percentages would probably leave little large-scale evidence on the surface.

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