Searching for sources and sinks of methane on Mars

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Photometric and spectral evidence indicates that liquid saline water seasonally forms by deliquescence in the polar region of Mars and may be linked to methane production.

Determining if life ever existed on another planet is one of the main scientific goals of space exploration. Since liquid water is believed to be a basic requirement for life, an important step in the search for extraterrestrial life is to determine whether it exists on other planets. Mars is the most Earthlike planet in the solar system, and evidence indicates that it had liquid water in the past. Therefore, Mars is an excellent candidate to search for signs of life.

The discovery of physical and thermodynamical evidence for liquid saline water on Mars, and for methane in its atmosphere, have excited the science community by reviving the possibility of extant microbial life on this interesting planet. The discovery of liquid water was initially debated by a few scientists from the Phoenix mission, even after perchlorate salts were discovered, because the thermal- and electrical-conductivity probe produced inconsistent results. However, new evidence supporting the discovery of liquid water has been accumulating. This implies that Phoenix was the first spacecraft to detect and photograph liquid water beyond Earth.

Current measurements suggest that the concentration of methane in the Martian atmosphere varies significantly in both time and space. However, this is not consistent with what is currently known about the planet, because it implies the presence of puzzlingly large sources and sinks of this biologically interesting gas. Geothermal as well as bio- and geochemical aqueous processes in the shallow subsurface are potential sources of methane and other trace gases. Electrical activity in dust storms is a potential methane sink because it is likely to produce nonequilibrium trace gases, such as oxidants, capable of destroying it.

Previously, we showed thermodynamic and photographic evidence that the Phoenix lander found liquid saline water in the Martian Arctic. Now we show quantitative photometric evidence that Phoenix found liquid water, and that deliquescence (melting into a liquid aqueous solution) causes liquid water to sporadically flow in the polar region of Mars. This discovery supports our hypothesis that freeze/thaw cycles lead to seasonal formation of liquid saline water where ice and salts exist near the surface. It suggests that water forms sporadically on the Martian surface and is common in its shallow subsurface. This has important implications for the geochemistry and habitability of Mars. In particular, it is consistent with the idea that either bio- or geochemical aqueous processes in the shallow subsurface are potential sources of methane.

We have proved experimentally that sodium perchlorate, a salt found in significant amounts in the Martian soil by the Phoenix lander, grows by deliquescence while absorbing water from the atmosphere under the environmental conditions of the

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Figure 2. Spheroids on a strut of the Phoenix lander. (A1–A3) Previously reported raw versions of images of spheroids on Martian days (sols) 8 (A1), 31 (A2), and 44 (A3). (B1–B3) New photometric analyses of images A1–A3. These albedo or photometric images show isolines at 0.1 in white and 0.3 in black. The color code used in Figure 1 applies. The white isolines enclose areas of low albedo associated with growth and movement of spheroids, an indication of growth by deliquescence. None of the spheroids have an albedo low enough to correspond to frost. The albedo values indicate the presence of either the liquid phase or refrozen liquid (albedo \(\approx 0.45\)).

Phoenix landing site. We analyzed images of brines from laboratory experiments under Martian conditions and from spheroids found on the Phoenix lander by finding the brightest pixels, indicating ice, and the darkest pixels on shadows, indicating a reflected radiance of around zero, and adjusting the reflectance of each pixel using an innovative technique. The resulting images are referred to as reflectance-adjusted images, or simply albedo images.

Figure 1(A) shows an image of a sample of sodium perchlorate brine in the laboratory at 700 Pa and 225 K, the environmental conditions at the Phoenix landing site. The bright area inside the sample holder is a mixture of ice and frozen brine, the dark area is liquid brine, and the bright area outside the sample holder is frost. Figure 1(B) shows the results of new calculations of the approximate albedo of each pixel, with isolines at 0.1 in white and 0.3 in black. This photometric analysis indicates that frost and frozen brines have high albedos, and that areas with liquid brines have an albedo lower than 0.3.

Figure 2 shows that an area of the Phoenix strut where a spheroid appears to liquefy before dripping has a low albedo value characteristic of liquid brines. The albedos of other areas where spheroids grow are similarly low, supporting the idea that they grow by deliquescence. Moreover, the low albedos at the edges of some of the spheroids also indicate the presence of the liquid phase, because ice strongly scatters light and would have uniform albedo when illuminated by diffuse light, but liquid would not, because it enhances forward scattering. Therefore, the new quantitative photometric analysis reported here adds to the physical and thermodynamical evidence that the Phoenix lander discovered liquid saline water on Mars.

We will soon present this new photometric evidence and a spectral proof that liquid water forms seasonally in the Martian polar region. The spectral data clearly shows that deliquescence causes the formation of pond- and flowlike features in the polar region. These results have important implications for the search for extraterrestrial life, because a diverse array of microorganisms thrives in brines.

We are conducting two types of research to follow up on the discoveries reported here, including laboratory studies of the formation of brine layers in the shallow subsurface and their implications for life, as well as a search for evidence of brines in the Martian subsurface and their relationship with sources and sinks of trace gases. In particular, the proposed Trace Gas Microwave Radiometer is an instrument designed to search for evidence of processes that produce and destroy trace gases in locations hidden from other instruments.

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References


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