SEARCH FOR LIFE IN HIGH LATITUDE GROUND ICE ON MARS

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Introduction: The 2008 Phoenix Mars lander mission sampled ground ice at 68ºN latitude. Mission results, considered along with climate modeling studies, suggest that high latitude ice-rich regolith at low elevations is habitable for life[1]. A lander mission can test the hypothesis that extant life persists in this environment, currently dormant but growing periodically when climate conditions are suitable.

Evidence for Habitable Conditions: The Phoenix lander dug into the subsurface with a robotic arm equipped with a digging scoop to reveal an ice table at average depth of 4.6 cm. Samples were scraped from the dry surface and icy subsurface soils and analyzed. Evidence for liquid water processes was found including 1) beneath dry soil, segregated pure ice was discovered in patches covering 10% of the approximately 1m^2 excavated by the scoop, the other 90% was ice cemented soil consistent with formation by vapor deposition of ice [2]. Segregated ice forms when liquid water films are concentrated during freezing. 2) The soil contained pure calcite mineral, which only forms under aqueous conditions [3]. 3) Varying centrations of highly water soluble perchlorate salts were observed with higher concentrations seen in soil clods suggesting water mobilization [4]. 4) Microscopic imaging identified a population of soil grains showing evidence of solutional weathering [1]. While current climate conditions are too cold to support metabolism in the icy subsurface, climate modeling studies [5] show that variations in solar insolation associated obliquity variations] cause quasiperiodic climate change on Mars. For the past 5 Myr, Mars' obliquity has oscillated on 125kyr timescales about a value of 25° but from 5 Myr to 10 Myr ago, the mean obliquity was ~35° and the maximum obliquity was almost 50°[6]. At these high obliquities, the maximum insolation is up to 2.5 times the present value, and surface temperatures 68 N latitude exceed 273 K up to 100 days per year [5]. At obliquity of 45º temperatures allowing microbial growth persist up to 1 m depth for durations that may allow microbial growth and population rebound [7]. Energy sources are available to support autotrophic surface and chemoautotrophic metabolism in the ground ice. Microscopic images of the surface soil show a population of semitransparent grains that could protect microbes from sterilizing UV radiation[1]. Perchlorate present in the soil at ~0.5% [8] can provide an energy source acting as electron acceptor while organic carbon from exogenous sources, ferrous iron or H_2 produced from water rock interaction can provide electron donors. The largeenergy potential of perchlorates (1.287V) makes them ideal electron acceptors for microbial metabolism and these compounds can be utilized as an energy source by numerous species of microbes that have been isolated from a variety of environments including permafrost [9].

Terrestrial permafrost communities are an example of possible life in the ice-rich regolith. Studies in permafrost have shown that microorganisms can function in ice-soil mixtures at temperatures as low as -20°C, living in the thin films of interfacial water [10]. In addition, it is well established that ground ice preserves living cells, biological material, and organic compounds for long periods of time, and living microorganisms have been preserved under frozen conditions for thousands and sometimes millions of years [11]. If life survives in these areas, growing when conditions allow, biomolecular evidence of life should accumulate in the soils.

Mission Concept: The Mars Icebreaker Life mission [12] plans to land in high latitude ice rich terrain with a payload designed to address the following science goals: (1) search for biomolecular evidence of life; (2) search for organic matter from either exogeneous or endogeneous sources using methods not impacted by the presence of perchlorate; (3) assess the habitability of the ice bearing soils with depth. The mission features a 1-m drill to auger subsurface icy material to the surface where it is delivered to payload instruments that search for biomolecules. By drilling to 1m the habitable zone can be probed to its maximum depth. The Icebreaker payload fits on the same spacecraft/ lander used by Phoenix and can be accomplished within the Discovery mission cost profile.

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