Assessing Habitability: Lessons from the Phoenix Mission

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The Phoenix mission's key objective was to search for a habitable zone[1]. The Phoenix lander carried a robotic arm with digging scoop to collect soil and icy material for analysis with an instrument payload that included volatile mineral and organic analysis[2] (3) and soil ionic chemistry analysis[3] (4). Results from Phoenix along with theoretical modeling and other previous mission results were used[4] to evaluate the habitability of the landing site by considering four factors that characterize the environments' ability to support life as we know it: the presence of liquid water, the presence of an energy source to support metabolism, the presence of nutrients containing the fundamental building blocks of life, and the absence of environmental conditions that are toxic to or preclude life. Phoenix observational evidence for the presence of liquid water (past or present) includes clean segregated ice, chemical etching of soil grains, calcite minerals in the soil and variable concentrations of soluble salts[5]. The maximum surface temperature measured was 260K[6] so unfrozen water can form only in adsorbed films or saline brines but warmer climates occur cyclically on geologically short time scales due to variations in orbital parameters. During high obliquity periods, temperatures allowing metabolism extend nearly a meter into the subsurface[7]. Phoenix discovered ~1%w/w perchlorate salt in the soil[3], a chemical energy source utilized by a wide range of microbes. Nutrient sources including C, H, N, O, P and S compounds are supplied by known atmospheric sources or global dust. Environmental conditions are within growth tolerance for terrestrial microbes. Summer daytime temperatures are sufficient for metabolic activity, the pH is 7.8 and is well buffered and the projected water activity of a wet soil will allow growth. In summary, martian permafrost in the north polar region is a viable location for modern life.

Stoker et al.[4] presented a formalism for comparing the habitability of various regions visited to date on Mars that involved computing a habitability probability, defined as the product of probabilities for the presence of liquid water (P_{lw}), energy (P_e), nutrients (P_{ch}), and a benign environment (P_b). Using this formalism, they argued that the Phoenix site was the most habitable of any site visited to date by landed missions and warranted a follow up mission to search for modern evidence of life. This paper will review that conclusion in view of more recent information from the Mars Exploration Rovers and Mars Science Lander missions.

[1]Smith, P. E. *et al*. (2009), Water at the Phoenix landing site, *Science,* 325, 58-61. [2]Boynton, W. V. *et al*. (2009), Evidence for Calcium Carbonate at the Mars Phoenix Landing Site, *Science*, *325*, 61-64. [3]Hecht, M. *et al.* (2009), Soluble chemistry of martian soil: Findings from the Phoenix Mars Lander, *Science,* 324, 64-67. [4]Stoker C.R. *et al.* (2010), The habitability of the Phoenix landing site, *J. Geophys. Res.,* 115, doi:10.1029/2009JE003421. [5]Cull, S. *et al.* (2010), Compositions of subsurface ices at the Mars Phoenix landing site, Geophys. Res. Lett. 37, doi:1029/2010GL0453269. [6]Zent, A. P. *et al.* (2010), Initial Results from the Thermal and Electrical Conductivity Probe (TECP) on Phoenix, *J. Geophys. Res.,* 115, doi:10.1029/2009JE003420. [7]Zent, A. P. *et al.* (2008), A historical search for habitable ice at the Phoenix landing site, *Icarus, 196,* 385-408.