EXOPALEONTOLOGY AT THE PATHFINDER LANDING SITE

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INTRODUCTION. The Mars Pathfinder Mission is a Discovery Class mission that will place a small lander and rover on the surface of Mars in July of 1997. It is primarily a technology demonstration to test the feasability of a direct entry-delivery system, but carries a nominal scientific payload that includes rover-lander and instrumentation for limited mineralogical analysis (1). The nominal landing site was selected by the Pathfinder Team under the leadership of Dr. Matthew Golombek (JPL) based input from 60 participants at a Landing Site Workshop held last Spring at the Lunar Planetary Institute in Houston (1). The mission constraints for the landing site were 0-30^0 N latitude, and below the 0.0 elevation datum. Over 20 landing sites were proposed and a nominal site was selected on southern Chryse Planitia near the terminae of the Ares and Tui outflow channels. In part, the decision to land at this location was based on the opportunity to sample a potentially large number lithologies in a small area (the rover will have a range of a few tens of meters from the lander). The purpose here is to review the general geological context of the landing site and the rationale for Exobiology's recommendation of the Ares site given at the workshop last spring (1). Because Ares and Tui Valles are sourced within terranes that may have originated by thermokarst processes, hydrothermal processes could have operated there for some time. Hydrothermal systems are presently regarded as important sites for a fossil record on Mars (2,3). Models for the formation of the outflow channels suggest that thermal spring sinters and associated aqueous mineral deposits, high priority targets for Mars Exopaleontology (2,3), could have formed in association with thermokarst processes and subsequently been delivered to the landing site in large quantities during the periodic cataclysmic outflows that created the channels.

GEOLOGICAL SETTING OF THE PATHFINDER LANDING SITE. The Ares and Tui outflow channels originate from highly fractured, elongate to circular, collapsed zones called chaotic terranes (4,5). These terranes consist of irregularly broken and jumbled blocks probably formed by the withdrawal of subsurface water (5,6). On a regional scale, the channels are broadly anastomosing networks that include a variety of macro- and mesoscale flow features (7). Catastrophic flooding by water has been invoked to explain many of the features of the large outflow channels on Mars (4), although sources of the water and mechanisms of release are more controversial (8, 9). Features of the martian outflow channels compare favorably with terranes on Earth formed by catastrophic flooding. Analogs for martian terranes include the channeled scablands of eastern Washington, U.S.A. (4). The immense erosive capability of such outflows significantly modifies older features of the landscape, depositing vast quantities of sedimentary material downstream. For example, Komar (10) compared the hydraulic capacity of the outflows that created the Channeled Scablands to turbid flows capable of transporting boulders up to a meter in suspension. Masursky et al. (8) suggested a thermokarst origin for chaos source regions of many martian outflow channels. Outfloods of water would have occurred by the melting of water ice stored in the martian regolith. The favored mechanism is heating by shallow intrusives. It is likely, under this scenario, that epithermal and subaerial hydrothermal systems would have developed and persisted for some time prior to and following major outflow events. Some small channels on the flanks of circular chaos terranes, such as Aram and Hydaspis, possess amphitheater-shaped head reaches with patchy albedos. Such areas are logical sites for ancient subaerial thermal spring systems and their associated deposits.

STRATEGY FOR MARS EXOPALEONTOLOGY. On Earth, microbial fossils are preserved only where contemporaneous mineralization entombs organisms, organic matter and biomolecules before they can be destroyed by oxidation (3). Organic materials carried to the

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martian surface from subsurface oases (see 11) would almost certainly be destroyed by oxidation, if not accompanied by early mineralization. On Earth, high priority geological environments (and associated mineral deposits), where rapid mineralization frequently occurs in the presence of microorganisms, include the following (3): springs (subaerial and subaqueous, thermal and non-thermal) playa lakes (terminal lake basin evaporites), and mineralized paleosols (shallow subsoil hard-pans, including calcretes, ferracretes, silcretes). During crystallization, aqueous minerals also incorporate liquid and volatile phases present in the depositional environment. For stable minerals such as silica or phosphate, primary volatiles may be retained for billions of years and are not only prime targets for fossils and biomolecular compounds, but also for pre-biotic organic compounds, and volatiles of fundamental importance to Exobiology and Mars Science in general.

APPLICATION TO THE PATHFINDER LANDING SITE. As mentioned earlier, the outflows that created the Ares and Tui outflow channels originate from chaotic terranes that may have formed by thermokarst processes (8). Aram Chaos and other semi-circular areas within these terranes may have formed above focused subsurface heat sources, possibly shallow igneous intrusives which interacted with ground ice. Near surface heat sources associated with such features are likely to have sustained hydrothermal activity for some time, depositing thermal spring sinters around vents at the surface, or in the shallow subsurface in association with epithermal systems. Such deposits are likely to have been carried down outflow channels and deposited at the landing site. As noted previously, such aqueous mineral deposits have a high priority for Mars Exopaleontology (3). The high rates of mineralization typically observed in such settings, driven by outgassing and declining tempertaure, provide an important mechanism for entrapping and preserving organisms and their byproducts. If Mars harbors a subsurface microbiota (11), it is likely that organisms were delivered to the surface by such outflows. Where associated mineralization occurred, organisms are likely to have been entrapped and fossilized. In the absence of life, the same aqueous mineral deposits of interest for Exopaleontology are also potential repositories for pre-biotic organic molecules. This is especially important for Exobiology, because the prebiotic chemical record, which has been lost on the Earth by crustal recycling, may still be preserved on Mars.

A key question is whether aqueous mineral deposits are present on the martian surface. Despite the elemental analyses obtained from Viking, mineralogy of the martian surface materials is still debated (12). There is a basic need for future missions to go beyond simple elemental analysis, and include information on mineral structures. This is central to the strategy for Mars Exopaleontology (3). The Mars Global Surveyor aims to map the surface composition of Mars by using infrared and gamma ray spectroscopy (13). Such information is crucial for site selection for future missions with the goal of searching for evidence of ancient martian life. Future landed missions should carry instrumentation capable of the *in situ* identification of a wide variety of aqueous minerals as the basis for evaluating exopaleontological potential, as well as for ground truthing orbital mapping data. Although the Pathfinder camera will have sensitivities for only iron-oxides and iron-bearing silicates (1), it will provide our first opportunity to assess mineralogy and the past activity of mineralizing aqueous systems on Mars. This is of broad interest for Mars Science, and is also a fundamental objective of the Mars Surveyor Program as a whole (13).

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