GEOLOGY AND LANDING SITES OF THE ELYSIUM BASIN-TERRA CIMMERIA REGION, MARS.

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Introduction: Of key importance to future Mars missions is the search for evidence of past or present life. Potential sites for the 2001 lander are limited to low latitudes and elevations <2.5 km because of engineering constraints. We have identified landing sites that hold high priority for astrobiology that fall within these constraints. Three of the potential sites are in the Elysium Basin-Terra Cimmeria region, an area that has experienced a prolonged and complex hydrologic history. We recommend these sites be targeted early for high resolution orbital imaging and spectral mapping.

Astrobiology in Mars Missions: The search for life on Mars, whether it be extant or extinct, began systematically with the Viking missions of the 1970s [1]. While results of the biology experiments from the two Viking Landers have been widely interpreted as being due to inorganic processes [1], the Orbiters revealed that early Mars was more Earth-like and that liquid water played an important role in shaping the early Martian surface [2] making conditions favorable for exopaleontology [3-7].

The Mars 2001 Lander does not as yet have a landing site identified. However, in keeping with the objectives of the NASA's Astrobiology Institute (NAI), a site with a clear potential for astrobiology must be a top priority. Such a site should include a region with a definite hydrological history. This includes locales with valley networks, outflow channels, lacustrine basins, or outflow plains. Hydrothermal deposits are also important targets and may be associated with identifiable features such as volcanic constructs, pyroclastic flows, chaotic terrains formed by magma-ground ice interaction, and impact sites. Although hydrothermal deposits have not yet been discovered, it is hoped that new high resolution imaging from the Mars Observer Camera (MOC) and compositional information from the Thermal Emission Spectrometer (TES) might help locate such features.

Mars 2001 Site Selection Constraints: Several important engineering constraints have been imposed on possible landing sites for the 2001 mission. Latitudes are presently restricted to 3°N to 12°S, to ensure maximum solar power for the longest time. The elevation must be below +2.5 km but above -3 km. In addition, surfaces must have rock abundances (estimated from IRTM data [8, 9]) of 5-10% coverage to provide high probability for a safe landing. In addition, dust coverage at the site needs to be at a minimum so that the lander is not in danger of sinking into the regolith and that local rocks are not buried. Finally, it is preferable that sites under consideration have been (or will be) imaged at high resolution (<50 m/pixel) either by Viking or by MOC to improve our assessment of potential engineering safety hazards (e.g., boulders, steep slopes, etc.).

Geology and Potential Sites of the Elysium basin / Terra Cimmeria region: As part of an extended reconnaissance of the equatorial region of Mars to find sites that have the highest priority for exopaleontology [10], the geology of the southern Elysium basin and north Terra Cimmeria has been mapped at 1:2M scale [11]. The area covered ranges from 5°S to 23°S and 170°W to 200°W, and includes Gusev crater, north Ma'adim Vallis, and Apollinaris Patera. This area is scientifically interesting and astrobiologically significant as it has been shown to have had a varied and prolonged hydrologic history with its valley networks, multiple outflow channels, and evidence of cryospheric melting near Apollinaris Patera.

In developing a detailed geologic framework for potential landing sites within Elysium Basin/Terra Cimmeria, we utilized the highest resolution data available, including both Viking Orbiter and MOC images. Our visible range mapping will be combined with spectral (and eventually mineralogical) data obtained from the Thermal Emission Spectrometer as they become available from the MGS '96 mission. Data from the Thermal Emission Imaging System (THEMIS) instrument, to be obtained during the 2001 orbital opportunity, may also provide important mineralogical data needed to refine site priorities.

In our investigation, we targeted specific sites that meet criteria relevant for exopaleontology. The types of sites are (in order of priority): hydrothermal, lacustrine, and grab-bag. The chaotic terrain west of Apollinaris Patera and Reuyl crater are potential hydrothermal regions, Reuyl is also a likely lacustrine environment, and the mouth of a valley network in north Memnonia Terra is a grab-bag site. Characteristics of these sites are listed in Table 1.

The disrupted, blocky regions west of Apollinaris Patera appear to have formed where ground water erupted from a subsurface aquifer adjacent to the volcano [12]. Such outflows could have resulted from pressure increases that occurred during periodic subsurface geothermal heating. Because Apollinaris was active throughout most of the Hesperian period [13], it is possible that magma-ground ice interaction formed the chaos and may have sustained hydrothermal activity in the area. On Earth, hydrothermal deposits have been shown to be excellent repositories for a microbial fossil record [4, 14]. For example, fossil biosignatures can often be captured and preserved in silica, carbonate and Fe-oxide sinters [15-18]. We have identified a smooth depression within the chaos as a potential landing site (11.1°S, 188.5°W). VO image coverage includes the series (596A35-36; 635A57) at ~225 m/pixel resolution, and (372B01-26) at ~35 m/pixel resolution, although rock abundance models suggest that surface dust might be too deep.

In addition to a hydrothermal site, ponding of water in the Reuyl crater basin (9.9°S, 192.8°W) may have deposited lacustrine shales. Drying up of such a lake could have left behind evaporites (e.g., halite, gypsum, and carbonate), which are also important targets for a potential Martian fossil record. Reuyl crater is a large (~100 km diameter) relatively young impact crater which possesses an anomalously large central peak and floor deposits of high albedo. Impact into an ice-rich lithosphere could have produced hydrothermal systems within the crater adjacent to the central peak with outflows ponding to form a lake (possibly ice-covered). Evaporation of an ice-covered lake would have left aqueous minerals (hydrothermal deposits, evaporites, etc.) on the crater floor, perhaps accounting for the high albedo observed near the central peak. If biota were present, they could have been preserved within these deposits. Although we consider this an interesting and important target, there is presently a lack of high resolution orbital coverage (see VO 596A31-34), making it an ideal candidate for high resolution MOC imaging.

A small valley network system in northern Memnonia (11.2°S, 178.2°W) is the site of a possible lacustrine environment where ancient materials were transported from the highlands and deposited in a shallow basin in the lowland transition zone (see 437S07-09; 438S02-25; ~70 m/pixel). Because the valley cuts into ancient surfaces and materials were fluvially deposited on Hesperian plains, the period of activity is suggested to be Late Hesperian, when most other hydrologic activity was occurring in the area. A landing site near the mouth of the valley network could provide access to a variety of different rock types derived from the adjacent highlands making this a “grab bag” site. In addition, more basinal sediments could provide access to fine-grained detridal material (shale) which are good targets for preserved organic matter.

Unfortunately, with the further constriction of the latitudinal constraints, several other high-priority sites have been discarded. One such site is at the mouth of Ma’adim Vallis where it debauches into Gusev crater (16.2°S, 184.0°W), a possible former lacustrine environment. This channel had been active throughout the Hesperian period and into the Amazonian [19]. Sediments from the oldest highland units were incised and the material was transported down the channel in a series of events and emplaced in overlapping deposits on the crater floor. These materials should have a wide range of ages, be fairly well sorted in the delta, and might have preserved fossils in possible shales. Similar sites are at the mouths of Al-Qahira Vallis (15.5°S, 195.2°W) and Durius Vallis (15.7°S, 188.2°W).

Conclusions: The discovery of evidence for past life is a main driving forced behind the current Mars missions. Because the Mars 2001 Lander is limited with respect to its possible landing sites by a very restrictive set of engineering constraints, only a few high priority targets have been identified to date. A geologic map of the Elysium Basin-Terra Cimmeria region was produced to better understand the nature of potential landing sites in a terrain of prolonged and varied hydrothermal activity. The chaos and channels adjacent to Apollinaris Patera provide access to a potential hydrothermal area, where groundwater-magma interaction might have provided an environment suitable for sustaining and preserving life. Reuyl crater is a potential lacustrine environment where evaporite deposits might have accumulated. Hydrothermal activity may have occurred near the central peak. Sediments at the mouth of a valley network system in north Memnonia could provide a grab-bag of rock materials transported from the southern highlands. However, images of these sites are either not available at preferred resolution or are of marginal image quality. Because of this, we recommend that a high priority be assigned to targeting the chaos west of Apollinaris Patera, Reuyl crater, and the valley network in north Memnonia for high resolution MOC imaging and for mineralogical mapping by TES.

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TABLE 1. Landing site characteristics.

	APOLLINARIS CHAOS	REUYL CRATER	MEMNONIA VALLEY
Center Lat.	11.1°S	9.9°S	11.2°S
Center Long.	188.5°W	192.8°W	178.2°W
Lat. Range	10°-12°S	9°-11°S	10°-12°S
Long. Range	187.5-189.5°W	192°-194°W	177°-179°W
Elevation*	+1 to +2 km	-1 to 0 km	+1 to +2 km
Landing Ellipse	10 x 20 km	10 x 20 km	10 x 20 km
Slope	low	low	low
Rock Abundance	0-5%	0-5%	0-5%
Unconsolidated Material** [+]	dusty some mantling	moderate dust low mantling	dusty low mantling
Site Type	hydrothermal lacustrine outflow lowlands	hydrothermal lacustrine	valley network grab-bag lacustrine
Image coverage (m/pixel)	596A35-36; 635A57; 372B01-26 ~225; 255; 35	596A31-34 ~225	437S07-09; 438S02-05 ~62-66

* USGS 1:15M Topographic Map, I-2160, 1991
** Based on composite maps from http://mars.jpl.nasa.gov/2001/landingsite/EngConstr.html
[+] Based on VO image observation