PALEOLAKE DEPOSITS IN CENTRAL VALLES MARINERIS: A UNIQUE OPPORTUNITY FOR 2001. Bruce Murray, California Institute of Technology.

Introduction

Paleolake deposits have been mapped in Central Valles Marineris since Mariner 9 and Viking (McCauley, 1978; Nedell et al., 1988;Witbeck et al., 1991). Accordingly, the region has been proposed as a priority target for landed payloads intended to detect diagnostic mineral evidence of a permanent lake environment, and, especially, biogenic signatures that could have survived from such promising candidate Martian habitats. (eg, Murray, et al, 1996; Yen, et al, 1999, Murray, et al, 1999). Just-released MOLA data strongly buttress the hydrological case for long-duration ice-covered lakes there during Hesperian times at least. And terrestrial discoveries within the last decade have extended the known subsurface distribution and seemingly ancient character of terrestrial chemotrophic microbes. These results, combined with the ground-water biogenic signature inferred by some from the Allen Hills meteorite, have strengthened significantly the scientific case for Central Valles Marineris.

Until now, the difficulty has been the absence of a technical means within the Surveyor or New Millenium DS-2 capabilities for landing upon outcrops of interior layered deposits. Now the improved 2001 lander design brings exposures of interior paleolake deposits within the Surveyor program targeting capability for the first time. It is my purpose to argue here that several candidate paleolake deposits within the Central Vallis Marineris should be included as candidate landing sites pending definitive high-resolution MGS and Surveyor '98 observations.

Geological Setting and Biological Potential.

Carr (1996) suggested that ground water flowed from the Tharsis uplands into the deep canyons of Valles Marineris before debouching onto Chryse Planitia in the northern plains. Such a flow may have persisted for billions of years, and is generally inferred to have maintained deep lakes beneath which lacustrine sediments accumulated. Remnants of these Hesperian Age lake deposits survive today as conspicuous layered strata in Central Valles Marineris. Just published MOLA data (Smith, et al, 1999) confirm in detail this topographic trend and, most importantly, prove that deep, permanent lakes did indeed exist, especially in Central and Western Valles Marineris. Because the canyons in the Valles Marineris are deeper than the probable ground water table at that period, large portions of the canyons would have filled with water and formed ice-covered lakes.

Research in the dry valleys of Antarctica suggests the possibility that even though the surface of Mars was too cold to be habitable, early life might have survived in highly specialized environments under relatively thin layers of ice in perennially ice-covered lakes (McKay 1985, McKay and Davis 1991). The Valles Marineris ice-covered lakes not only might have contained martian chemotrophs from the incoming ground water, but also offered habitat for any martian phototrophs under the relatively thin ice, as is the case in now in Antarctica. It is even possible that traces of biogenic organic material might still be preserved below the surface oxidant layer in the cold, stable lacustrine strata within Valles Marineris.

Where in Central Valles Marineris?

Witbeck et al., 1991, mapped at 1:2M scale the geology of part of central Valles Marineris based on Viking data. They show large patches (10's of km) of layered deposits (unit Hvl, bluish green unit color on their map) within the deep, broad Hebes, Ophir, Candor, and Melas Chasmata. (More detailed studies have been compiled recently by Tanaka, and by Lucchitta.) These layered deposits form the oldest interior materials; in turn, they are embayed or partly buried by several varieties of unlayered floor deposits and landslide materials.

Candor Mensa (6.5 S, 73.5 W) for example, forms a 50-70 km elongate mesa about 4 to 5 km above the floor (but still apparently below the ancient lake level). The surface is a flat plateau which might facilitate access to surface exposures of the youngest lake strata. The highest resolution of Viking images of this feature ranges from about 60 to 90 meters per pixel, permitting only very thick layers to be measured; Even so, Nedell et al. (1987) found layers varying in albedo and competence that were 100-200 m thick. Extensive MOC and MARCI imagery of this feature could indicate whether indeed ancient layering can be sampled there, as well as the presence of any small-scale roughness of significance to the 2001 lander safety.

Smaller and lower mounds of this same unit (but still relatively flat-topped over an area seemingly within the targeting capability of the 2001 lander) occur at 9.7 S, 75.3 W, and at 11 S, 73.5 W. As with Candor Mensa, MOC and MARCI imagery should clarify their landing safety and the likelihood of bedrock exposures. These might provide access to somewhat older portions of the same Hesperian lake deposits, and also may exhibit an erosional surface at the landing site. Unlike the younger units that comprise the lowest elevations of Valles Marineris, none of the three Hesperian exposures proposed here appears to be mantled with eolian deposits.

Another benefit of all three sites is that distant cliff exposures of older crustal material (mapped as HNu by Witbeck, et al) may be visible in the distance. MOC discovered that this older crustal unit, which comprises the main walls of Valles Marineris, is comprised of thick and horizontally very extensive layers, not the megabreccia many had inferred by analogy with the Moon. Thus the 2001 multi-spectral imaging and miniTES instruments may be able to determine if these older deposits are of likely igneous (pyroxene, feldspar) or sedimentary (carbonate, sulfate, phosphate or hydrated minerals) origin.

The same two instruments would be able to study the surface exposures adjacent to the lander itself, looking for paleolake mineral signatures and diagnostic morphology. The rover camera and traction observations could add close-up imaging and textural and induration information as well. Anomalously high abundances of Na, S, P, Ca, or Cl detected by the APXS would be suggestive of lake-deposited origins.

The robotic arm would be able to image within a trench, possibly acquiring diagnostic sedimentary information in-situ. Samples collected by the arm for analysis by the Mossbauer Spectrometer and by MECA could further aid the interpretation of origin.

Altogether, it is reasonable to suppose that the 2001 lander located at sites such are proposed here could:

1. Determine if bedrock, or debris derived from bedrock, can be sampled at that site.
2. Determine whether or not that bedrock carries a mineralogical and/or textural signature consistent with deposition from a permanent lake.
3. Determine the requirements for the design of a follow-up Surveyor mission capable of searching effectively for a biogenic signature in those ancient strata (eg, a drill). (If relatively unaltered lacustrine samples are indeed accessible). That follow-up conceivably could be a sample return mission; Alternatively, in-situ collection and analysis might be deemed more cost-effective.
4. Provide excellent panoramic and spectral coverage of surrounding elevated areas, including diagnostic spectral information regarding the igneous vs. sedimentary origin of the older (HNu) crustal unit.
5. Provide a most compelling site for public education and interest because of the biogenic implications of the site as well as its dramatic location.

Why 2001?

Each new Mars lander faces a tough challenge. It must attempt to do something of critical scientific importance and of compelling public interest, and yet at modest cost! Pathfinder took the risk of landing on a rough, bouldery terrain to discover and describe a remarkably well-preserved surface evidently dating from the last catastrophic flood there. The '98 MVACS is pushing the engineering latitude limits to about 75 S in order to collect critical information about the polar layered terrains and the underlying processes of Martian climatic fluctuations. DS-2 hopes to demonstrate an inexpensive way to probe the soil or emplace network instruments over much of Mars.

What is the fundamental aspect of Mars that the 2001 lander will attack? How will it justify its existence in the increasingly cost-constrained Mars program environment? What will attract broad and sustained public interest?

2001 must aim for major accomplishment on its own, as well as to provide an essential legacy for later Mars missions. That will likely require require accepting some landing risk. I believe the Hesperian lake strata offer a unique and especially promising objective for 2001.

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