A MARINE ORIGIN FOR THE MERIDIANI PLANUM LANDING SITE?

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Introduction: The Opportunity instruments have provided compelling evidence that the sulfate-rich chemical and siliciclastic sediments at the Meridiani Planum landing site were deposited in shallow water. The local paleo-environment is most often characterized as a broad, shallow sea or large playa, with surface conditions cycling between wet and dry episodes, interbedding evaporates with eolian fine sediments [e.g., 1,2]. This particular working hypothesis is reasonable, considering the area characterized by the rover's mobility. An alternative, marine origin will be considered here, a working hypothesis that we feel provides a better 'fit' to the local-scale results identified by Opportunity, and the regional-scale characteristics of Meridiani Planum provided by data from orbiting spacecraft, when considered together.

Evidence that a large body of water was the source for the precipitates:

The geochemistry of the sulfates is remarkably uniform over the 700+ meter lateral and ~10 meter vertical sampling by the rover [3-6].

Regional Topography: The landing site is on top of a large, flat-topped hill or mound within the greater Meridiani Planum deposit. On the north and west sides of Meridiani Planum, there is no bounding topography to isolate a lake- or sea-size body of water from the northern plains, and there may never have been.

The hematite spherules [e.g., 6] form a lag that, due to their density, would tend to armor the underlying sulfate-bearing sediments and protect them from eolian deflation. Based on the distribution of the spherules within the underlying sediments, and assuming this distribution is similar to that of now-absent overlying source layers for the spherule lag, there can't have been more than a few meters of material removed from the top of the section. This suggests that the plains surface at the landing site is largely "pristine," and so the regional geomorphology/topography (which has hundreds of meters of total relief) is primary and a direct indication of the process by which the sediments were emplaced. Supporting this notion (to date, at least), no deflation hollows or remnant mesas of once-overlying material have been found in the vicinity of the landing site.

Evidence that all outcrops visited to date are subaqueous sulfate-rich sediment:

Planar crossbeds can indicate either subaerial or subaqueous settings. All those seen by Opportunity are low-angle crossbeds, and so still do not uniquely indicate one setting versus the other. The Burns Cliff "lower unit" in Endurance Crater is the most often-cited example of planar cross-bedding, but close examination of pancam images of this unit show them to include low-angle truncations and lensing of layers within that are most likely indicate subaqueous deposition within that unit as well, separated from the overlying sulfate-rich laminated unit by a discontinuity.

Laminations within Burns Cliff "lower unit" are similar in appearance and scale to laminations within the "upper unit," which, upon close emaniation by Opportunity, is revealed to be finely-laminated sulfate-rich sediment, not eolian sand as previously thought.

The contact between the dark layered material at Burns Cliff with the brighter overlying sulfate is a surface textural change, not a stratigraphic contact between different lithologies. When examined up close, this contact was shown to cut across stratigraphy. The fine laminations that characterize the upper sulfate units, first seen in Eagle Crater, are present in the darker, rougher-textured material below this contact. The dark Burns Cliff "upper unit" appears dark because its surface texture has been modified.

All sulfate outcrops visited thus far are finely-laminated (up to 1-2mm thick laminations) with a remarkably uniform, even rhythmic, appearance. This is easier to explain in a large, long-lived sea or ocean than in a small, ephemeral lake (though it isn't a unique indicator).

Big or Small Hypothesis?

Small. The Meridiani Planum deposit is an eroded sequence laid down in a very large lake or playa, interbedded with eolian sediments. This model implies that the confining topography on the northwest has been eroded away. It does not provide a satisfactory explanation for the uniform stratigraphy and geochemistry over the horizontal distance and vertical section visited by Opportunity to date.

Big. The hummocky mound form of the regional deposit is largely pristine, and indicates evaporite platform deposition (analogous to terrestrial carbonate platforms, but with a sulfate composition) at the margin of a northern plains ocean.

Removal of confining topography on to the northwest is not needed, as platforms commonly form at the margins of ocean-size bodies of water.

The spherule lag implies little erosion of the plains at the landing site has occurred, on the order of a few meters or less, possibly across the entire hematite region as well.

What can be said about the time it took the Meridiani Planum sediments to form?

The very regularly-spaced laminations within the sulfates suggest a rhythmic process. How long did it take for individual laminations to form? Clues to answering that question may lie in the larger-scale features found within the outcrops.

Low-angle, or undulatory crossbeds, with multiple laminations between truncation surfaces suggest sustained current energies and directions between truncation surfaces.

Ripple festoons, again with multiple laminations within sets of ripple forms suggest sustained current and direction for the individual ripple sets.

What are the possibilities? "Known" rhythms, from long to short timescales include Milankovich cycles, Solar cycles, Annual cycles (seasons), and diurnal cycles. The martian moons are too small to have any significant influence at the surface of Mars, so we will ignore them for this discussion. Martian obliquity and orbital eccentricity varies over periods on order of 10^5 to 10^7 year timescales. Solar sunspot cycles occur in 11 and 22 year timescales. It is unlikely that the fine laminations formed over years, due to the requirement of sustained current energies within low angle crossbeds and sets of ripples. Diurnal solar heating and tides are probably the most likely to provide a reasonable timescale fit. Rhythmic changes in weather over seasonal timescales should also probably be considered.

Solar tides in a putative ocean at Mars' distance would have been far smaller than those on Earth, perhaps no more than a few percent. Wind and storm tides would probably be more significant than sun tides. But if the water depth above the sulfate surface was shallow (a meter or two, perhaps) even sun tides could amount to a significant percentage volume change over a broad, shallow platform or shelf, enough to induce currents even under an ice cover.

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