A COMPARISON OF THE MARTIAN MEDUSAE FOSSAE FORMATION WITH TERRESTRIAL CARBONATE PLATFORMS. T. J. Parker, University of Southern California, Dept. of Geological Sciences, Los Angeles, 90089-0741.

Models of the evolution of the terrestrial planets' atmospheres developed over the last 20 years predict that Mars should have outgassed between several hundred millibars to as much as 20 bars of CO_2 over geologic time (1-4), though in the last few years the minimum value has been upgraded to as much as a few bars. Many investigators believe that the best way to eliminate the CO_2 is through the formation of carbonate minerals in the presence of liquid water (5-8). Past epochs of liquid water on Mars are evident in the form of abundant ancient fluvial channels, thick stratified sequences of probably lake deposits in Valles Marineris (9) and possible shorelines along the perifery of the northern lowland plains (10) defining an ocean that may have occupied the planet's northern lowland plains as recently as early Amazonian time.

The search for carbonates on Mars can be approached in two ways. First, the spectral signature of carbonate minerals might be found (11, 12). Second, a search for morphology characteristic of (or at least consistent with) carbonate deposits is another valid approach (8). Here, I have taken the latter approach by looking for morphologies and associations that might be best explained via a carbonate interpretation. Because the best Viking Orbiter images of Mars are on the order of 10-100m/pixel and the average resolution for the planet is closer to 200m/pixel, it makes sense to focus on comparisons with terrestrial morphologies at similar scales. These include the regional distribution and overall plan form of a deposit (to the extent that it can be considered as characteristic) and local-scale features such as shoals and sand waves (that are demonstrably marine or lacustrine rather than eolian). The Medusae Fossae Formation (MFF) exhibits many aspects that I feel can be best explained if it is interpreted as a system of carbonate platform deposits laid down in an ocean . This deposit has been interpreted as either a large, wind-blown volcanic ash deposit (13), other wind-blown material trapped along the escarpment between highlands and lowlands (14, 15), or ancient polar layered deposits (16). Its radar signature (as described by 17), is quite dark, while the south polar layered terrains appear bright. Synthetic aperature radar images of young terrestrial ash deposits in the Andes also appear relatively bright. The radar signature appears to require a uniformly fine-grained material (on the order of dust-size to fine sand-size material) at least several meters thick, in order not to reflect the radar or transmit reflections off the underlying terrain. Accumulation of tens to thousands of meters of unwelded, friable ash blankets would seem to require a large number of discrete, thin deposits. The radar signature, therefore, seems inconsistent with the first and third interpretations. This requirement may be met by infering uncemented sand or loess, thereby lending support to the suggestion that they may be eolian deposits. It might also be met by inferring chemically precipitated, largely uncemented carbonates.

A number of regional-scale characteristics of the formation should be noted: (i) It consists of many large, elongate deposits that exhibit a pronounced northwest-southeast orientation. The deposit east of the crater Nicholson (centered at 0° lat., 159° lon.) is a good example of a largely "unmodified" deposit (with only incipient yardang development) that is so oriented. (ii) For the most part, yardang development also shows a northwest-southeast orientation with some variation (although locally they may even be oriented perpendicular to this trend). This suggests that prevailing winds may have been responsible for the orientations of both the local and regional-scale development of the formation as a whole (both its initial deposition and subsequent erosion). (iii) Two of the relatively unmodified deposits exhibit very-large ripple-like structures, with wavelengths on the order of a few tens of kilometers, that are typically oriented southwest-northeast, perpendicular to the orientation of the overall deposit (at 4°N lat., 160° lon., and at 2°S lat., 183° lon.). The scale of these structures is much too large to compare with either dunes or sand waves. Terrestrial marine shoals (18) appear similar and may be comparable in size. Alternatively, the martian polar deposits exhibit troughs with spacing comparable to that of the MFF. This led Schultz and Lutz-Garihan (16) to suggest that the MFF may be an old polar deposit that formed at a time when Mars' axis was oriented 90° away from its present position relative to the lithosphere. However, the modern polar troughs are distributed in a spiral pattern in a more or less circular deposit, whereas the MFF structures are not. (iv) Where the lowland/upland boundary south of the MFF is not expressed as an escarpment, the cratered terrain appears to exhibit a gradual smoothing from south to north over as little as a few kilometers to several tens of kilometers. This may have been caused by repeated transgressions of an ancient ocean.

A number of local-scale characteristics of the formation should also be noted: (i) Despite observations to the contrary (13, 19, 20), I feel that there is evidence of layering within the formation. (ii) In many places along its northern boundary, the formation exhibits karst-like erosional pitting (17). This morphology, too, might be explained by a late, but less extensive marine transgression with dissolution of previously deposited carbonates (8). (iii) Although eolian erosion is abundantly evident throughout the region, eolian deposits (other than perhaps the formation itself), such as dune fields, are rare. However, in places where the upper member of the formation appears least eroded and is covered by high resolution images, well-defined, long-wavelength large ripple trains can be observed (e.g., 9°S lat., 175.5° lon.). Their confinement to the surface of the formation, not in the surrounding terrain, suggests that they are primary features that formed at the time the formation itself was emplaced. These ripples have wavelengths on the order of tens to hundreds of meters, comparable to terrestrial dunes and sand waves. Known eolian dunes elsewhere on Mars exhibit high contrasts between their sunward and antisunward (not necessarily shadowed) sides. The comparatively subtle shading across the MFF ripples suggests that their amplitudes are quite low. Sand waves (formed under water) have much higher wavelength to amplitude ratios than do dunes (18). Sand waves in the Bahamas (18) appear similar, both morphologically and in scale, to the MFF ripples.

It is suggested that the MFF might best be interpreted as a system of ancient carbonate platform deposits. The best modern terrestrial analogs would be oolitic deposits, such as found over large regions of the Bahama Banks. To fit the observed morphologies and radar signature, a process akin to inorganic oolite precipitation and transport (18, 22), with little cementation, is proposed. An oolitic grain size is necessary both to provide the "stealth" radar signature and to allow the development of wave-like bedforms. A largely uncemented state is also needed to explain the radar signature, requiring relatively rapid deposition and little to no subsequent cementation or diagenesis. This requirement probably can be met because ocean transgressions on Mars were likely short-lived (on a geologic time scale), and separated by long periods with temperatures below freezing (preventing dissolution and cementation through rain or groundwater migration within the deposit). Also, carbonate precipitation would have taken place fairly rapidly when liquid water was present, because of the planet's high atmospheric CO_2 content.

Carbonate platforms would require a relatively warm martian paleoenvironment, at least epocally until as recently as early Amazonian time. Pollack et. al. (7) developed a model with which they calculated the longevity of an early warm and wet paleoenvironment on Mars. They concluded that Mars would have maintained enough of a greenhouse effect for up to a billion years or so if CO_2 was continually being recycled through deep burial, leading to thermal decomposition of carbonates, and expulsion to the atmosphere through intense, global-scale volcanism. More recently, the contribution of large meteorite impact excavation of buried volatiles has been discussed (23). Prior to the heavy meteorite bombardment period, it may have been possible to continuosly recycle CO_2 by these processes. After the heavy bombardment ended, however, declining rates of volcanic thermal decomposition of carbonates would have been unable to keep pace with the rate of formation of new carbonates whenever liquid water was present, with the result that the planet's atmospheric greenhouse dwindled, global temperatures dropped (modulated by Milankovich cycles), and standing bodies of water became more ephemeral and finally ceased to form.

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