WEATHERING AND EROSION OF THE POLAR LAYERED DEPOSITS ON MARS; K. E. Herkenhoff, Jet Propulsion Laboratory 183-501, Pasadena, CA 91109

The Martian polar layered deposits are widely believed to be composed of water ice and silicates, but the relative amount of each component is unknown. The "conventional wisdom" among Mars researchers is that the deposits were formed by periodic variations in the deposition of dust and ice caused by climate changes over the last 10 to 100 million years [1]. It is assumed here that water ice is an important constituent of the layered deposits, that the deposits were formed by eolian processes, and that the origin and evolution of the north and south polar deposits were similar.

Calculations of the stability of water ice in the polar regions of Mars [2,3] indicate that ice should not currently be present at the surface of the layered deposits. The present water ice sublimation rate is high enough to erode the entire thickness of the deposits in about a million years. This result suggests that sublimation of water ice from the layered deposits results in concentration of non-volatile material at the surface of the deposits. Such a surface layer would insulate underlying water ice from further sublimation, stabilizing the layered deposits against rapid erosion.

The color and albedo of the layered deposits suggests that bright, red dust is the major non-volatile component of the deposits. However, the differences in albedo and color between mantling dust and exposures of layered deposits in the south polar region [4] and the association of dark dust material with the north polar layered deposits [5] indicates that there is at least a minor component of dark material in the deposits. The dark material may be either sand or dust; each possibility is examined below. The dark material must either be intimately mixed with the bright dust in the layered deposits or occur in layers or lenses less than a few meters in size, or they would be visible in high-resolution Viking Orbiter images.

The presence of small amounts of dark sand in the layered deposits can account for the dark dunes that appear to have sources in the north polar deposits [5]. Poleward circulation during the summer is then required to transport sand into the layered deposits. The most significant problem with this hypothesis is the eolian codeposition of sand and dust in the polar regions. It is unlikely that sand can be carried in suspension by even a much denser Martian atmosphere, so that sand must be transported by saltation [5]. Saltating sand would eject dust into suspension, hindering codeposition of sand and dust. Although small amounts of sand may have saltated over frozen, cemented dust toward the poles, the difficulties with this scenario prompt consideration of alternative hypotheses. A theory for layered deposit formation and evolution involving only dust (bright and dark) and ice is proposed below.

How can dark dust in the layered deposits form the dunes observed in the polar regions? Sublimation of dust/ice mixtures has been shown to result in the formation of filamentary sublimation residue (FSR) particles about 100 microns in size [6]. Such particles can saltate along the Martian surface, and may therefore create dunes [7]. In order to form saltating material by this mechanism that is at least 3 times darker (in red light) than the bright dust that mantles much of Mars, dark dust grains must preferentially form FSR particles. Magnetic dust grains would be expected to form FSR more easily than non-magnetic dust, and are probably much darker. Experimental formation of FSR with magnetic material has not been attempted, and should be the subject of future research.

There is direct evidence for 1-7% magnetic material in the surface fines at the Viking lander sites [8]. In addition, analysis of Viking lander sky brightness data indicates that suspended dust over the landing sites contains about 1% opaque phase, perhaps of the same composition as the magnetic material on the surface [8,9]. Within the uncertainties of these measurements, the percentages of magnetic material given above are identical to the volume of dark dune deposits in the polar regions expressed as a percentage of eroded layered deposits (Table 1). This comparison indicates that the presence of magnetic material in the layered deposits is likely, and that formation of sand dunes from dark FSR particles is plausible.
In summary, weathering of the layered deposits by sublimation of water ice can account for the geologic relationships observed in the polar regions. The non-volatile component of the layered deposits appears to consist mainly of bright red dust, with small amounts of dark dust or sand. Dark dust, perhaps similar to the magnetic material found at the Viking Lander sites, may preferentially form filamentary residue particles upon weathering of the deposits. Once eroded, these particles may saltate to form the dark dunes found in both polar regions. Eventual destruction of the particles could allow recycling of the dark dust into the layered deposits via atmospheric suspension. This scenario for the origin and evolution of the layered deposits is consistent with the available data.

REFERENCES


Table 1

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Fraction</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Magnetic material in surface fines</td>
<td>1-7 %</td>
<td>[8]</td>
</tr>
<tr>
<td>Opaque phase in atmospheric dust</td>
<td>1 %</td>
<td>[9]</td>
</tr>
<tr>
<td>Volume of dark dunes/volume of eroded polar deposits</td>
<td>1-10 %</td>
<td>[10]</td>
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