SEDIMENTARY MOUNDS ON MARS: TRACING PRESENT-DAY FORMATION PROCESSES INTO THE PAST.

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Introduction: High resolution photography and spectroscopy of the martian surface (MOC, HiRISE) from orbit has revolutionized our view of Mars with one and revealed spectacular views of finely layered sedimentary materials throughout the globe [1]. Some of these sedimentary deposits are 'mound' shaped and lie inside of craters (Fig 1). Crater mound deposits are found throughout the equatorial region, as well as ice-rich deposits found in craters in the north and south polar region [2-4]. Despite their wide geographical extent and varying volatile content, the 'mound' deposits have a large number of geomorphic and structural similarities that suggest they formed via equivalent processes. Thus, modern depositional processes of ice and dust can serve as an invaluable analog for interpreting the genesis of ancient sedimentary mound deposits.

'Mound' Characteristics: Sedimentary 'mounds' on Mars are defined by a number of unique identifying factors that are shared by many examples regardless of geographical location or volatile content.

Topographic Profile. 'Mound' deposits are most clearly defined by their distinctive shape within craters on the martian surface. They are typically defined by 'moats' between the crater walls and the deposit which creates a distinctive topographic profile where deposits accumulate in a central mound yet do not completely fill their basin [2, 5].

Fine scale layering. The mound deposits typically contain fine (meter to 10s of meters) layering that is rarely flat lying [1, 4]. The layering often shows periodic or cyclic patterns indicating some control from orbital dynamic cycles [6, 7]. However, in many cases the layering is disrupted by faulting or discontinuities which truncate layers and disrupt the long term record. In the volatile-rich polar deposits, this layering is also observable via radar sounding [4].

Deposit Thickness and Character. Mounds can have very substantial thicknesses that can approach the depth of the basin in which they are found, though these deposits rarely exist above the level of the surrounding basin rim [5]. These deposits also have clear geomorphological and spectroscopic differences from the basin wall rocks indicating that the sediments were not derived from basin erosion or mass wasting processes and sediments are typically very fine grained and poorly cemented [3, 8].

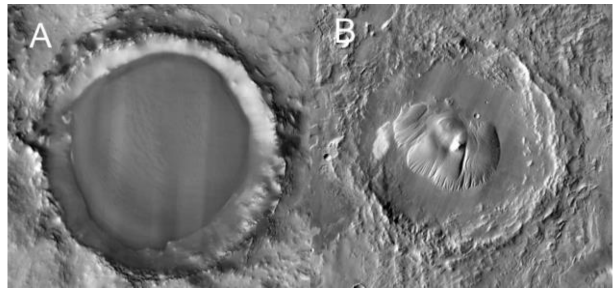


Figure 1. THEMIS Daytime Infrared Image of (A) Korolev Crater and (B) Nicholson Crater on Mars. Image credit: ASU/NASA/JPL.

Structure. Mound deposits commonly show draping relationships with bedding frequently parallel or subparallel to the underlying topography. Although this can frequently be disrupted by erosion, mass wasting, or faulting [4, 6].

Other Characteristics: There are several other important characterstics observed in 'mound' deposits that are latitude and age dependent:

Volatile Content: High latitude modern mound deposits contain much higher contents of ice, typically > 90% [8]. Low latitude mound deposits are ice-free and contain an unquantified level of hydrated minerals.

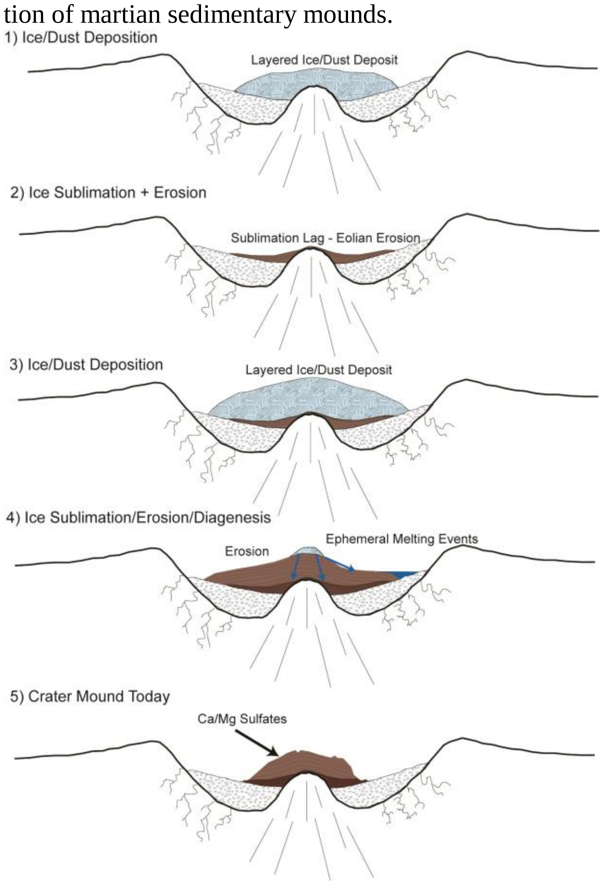
Mineralogy: Low latitude mounds can contain (spectroscopically detectable) sulfate minerals and sometimes clay minerals [9]. These minerals have not been spectrally identified in the high latitude mound deposits although sulfates have been observed to be eroding out of the north polar layered deposits in places [10].

Slumping/Mass Wasting. Low latitude mound deposits are sometimes marked by extensive slumping and mass wasting processes including landslides, faulting, and other deformation. These features are not typically found in the higher latitude deposits.

Discussion: The similarities between the sedimentary mounds found at high latitudes and low latitudes are striking and several of the differences between these two groups of landforms can be attributed to the mounds having different ages and being at different stages of evolution. The ice-rich high latitude mounds are younger and in the process of accumulating sediment while the older low latitude mounds are being slowly eroded.

We propose a sequence of mound development similar to previous workers [3, 11, 12] outlined in Figure 2. High obliquity events would allow for dust/ice deposition inside of select craters. This would create cycles of deposition and removal during periods of lower obliquity injecting a rhythmic signal into the layering. Repeated cycles of deposition (Fig. 2 steps 1-3) would build the mounds inside the crater but deposition would not occur in the moat near the crater walls as seen in the modern examples (Fig. 1). Net deposition would eventually cease due to the removal of the sediment supply or change in the obliquity cycle. Under lower obliquity conditions ice would be removed through sublimation and/or melting. Eolian erosion would then sculpt the mound into the present day.

Figure 2. Sketch model for the formation and evolution of martian sedimentary mounds.



Sediment/Volatile supply: One major difference between high and low-latitude crater mounds is clearly the ice/dust ratio within the deposits. Sediment supply on Mars includes impact-generated dust, volcanic production of ash, and clastic material mobilized by erosion. Due to much lower rates of impact, volcanism, and erosion in the Amazonian, it is expected that modern high latitude mounds would contain much higher ice/sediment ratios. On the other hand, sediment supply in the Hesperian may have peaked with substantial volcanism occurring at that time [13].

Likewise the supply of atmospheric sulfur in the modern age is extremely small due to substantially lower levels of volcanism. Therefore, modern high latitude crater mounds should be sulfate-poor, and perhaps more poorly cemented. Punctuated sulfur production through martian history [13, 14] could result in mound deposits that could be sulfur poor and others that are sulfur rich, depending on whether they formed during a period in which there was a large amount of sulfur production.

Sulfate minerals associated with the low latitude ancient crater mounds are not necessarily evidence for water-rich, warmer environments. It has now been shown by laboratory experiments [15] and observations of sulfates in the polar regions [10] that sulfate formation can occur under cold, water-limited conditions (Fig. 3).

Conclusion: Based on the numerous and compelling similarities between modern and older mound deposits on Mars, it is likely that present day processes may provide crucial insight into the past. This uniformitarian vision of martian geologic history does not require massive floods or global changes to explain the sedimentary rocks we see preserved today.

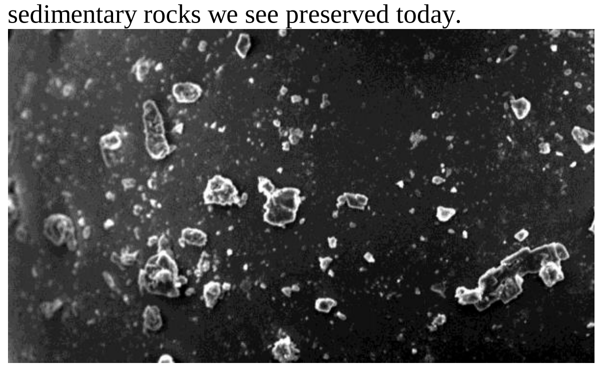


Figure 3. Sulfate weathering products produced during olivine weathering experiments at -40° C. Experimental duration was 2 weeks. All particles in field of view are sulfate minerals.

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