POLAR AND NON-POLAR LAYERS ON MARS: A SINGLE MECHANISM FOR FORMATION? M.A. Mischna[1,2] D.J. McCleese[2,3], M.I. Richardson[2], A.R. Vasavada[1], and R.J. Wilson[4], [1]University of California, Los Angeles, Los Angeles, CA 90095, [2]California Institute of Technology, Pasadena, CA 91125, [3]Jet Propulsion Laboratory, Pasadena, CA 91109, [4]Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08542.

Introduction: The recent discovery of vast quantities of near-subsurface ice in both polar regions of Mars by the Mars Odyssey Gamma Ray Spectrometer (GRS) [1-4] has presented us with an interesting quandary. On one hand, these deposits, found poleward of 60° in both hemispheres, are consistent with thermal models suggesting ice will be best protected in these regions during periods of high obliquity [5-7]. On the other hand, the current paradigm regarding the placement of these deposits, *i.e.*, diffusive deposition of water vapor, appears to be inconsistent with the large volume mixing ratios (~90%) inferred from the GRS data. This incongruity argues that diffusion alone cannot be the primary mechanism for the creation of these reservoirs, and that an alternate, large-scale process should be considered.

Spacecraft Observations: Maps generated by the Mars Odyssey GRS team reveal the presence of massive ice deposits ubiquitously poleward of 60º in both the north and south, well beyond the extent of the observable surface polar layered terrain. We can infer from the GRS data that such deposits may be found only a few to a few tens of centimeters below the surface, and are likely covered by a desiccated surface layer [1].

The GRS results show a distribution of near-surface ice quite similar to the results of [5-7], based on the physical and thermophysical properties of the regolith. One key assumption of these models is the porosity of the soil, which, even for poorly-consolidated regolith, never exceeds ~40%. In other words, the available volume for water vapor within the pore space is limited to 40%. The GRS data, however, yields abundances that are extremely high—as much as 90% by volume, and therefore emplacement via diffusion does not seem wholly consistent with GRS observations.

Further, MGS images of mantled, fretted and otherwise disaggregated, layered terrain are restricted to latitudes just equatorward of these subsurface ice deposits. The suggestion has been made [8] that this distinct "latitude-dependent" morphology is a result of sublimation-driven cementation of the surface material, and hence that these regions, too, must have, at one time, been quite volatile-rich.

Ice Deposition Model: We propose that these observed deposits result from dusty ice sheets formed at the surface, with diffusion into the subsurface being of only secondary importance. Results from a full general circulation model (GCM) [9] support this contention. Whereas presently ice is stable year-round only at the poles (Figure 1a), under periods of higher obliquity, the latitudes of stable, perennial ice change. An increase in obliquity to 35º—approximately that reached at the last obliquity maximum—shifts this zone of stable water ice towards the mid-latitudes, between 50º and 70ºN (Figure 1b). Ice will be deposited in large, localized sheets, predominantly during the wintertime, and in locations of favorable surface properties (*i.e.* high thermal inertia) and favorable atmospheric dynamics. This ice, deposited at a rate of several millimeters to a centimeter per year, will survive through the summer. Over time, ice in such regions may accumulate to potentially significant depths—model results indicate up to several tens of meters may be deposited locally over the course of a single high obliquity excursion.

Increasing obliquity to 45º, which is representative of the high obliquity excursions of 5-10 million years ago, will push this region of stable water ice into the tropics, equatorward of 30º latitude. Under such extreme conditions, the deposition and accumulation of ice is even more substantial, and may, in fact, be limited by the amount of volatiles available for sublimation and transport towards the tropics.

Based upon these model results, it seems possible that the GRS signature we are observing outside the present-day polar deposits is not the present-day diffusion and freezing of water ice in pore space below a preexisting surface, but rather the remnant of a deposited ice sheet(s) during past high obliquity phases, covered by a sublimation lag.

We have developed a simple mechanism to explain the global distribution of water ice by invoking only orbital parameters and the thermophysical conditions of the surface, which is illustrated in Figure 2. The deposition of a layer of dusty ice at a given location will commence once ice at that latitude becomes thermally stable (b). The period of time for which ice will be deposited is clearly dependent on the length of time that obliquity is above some "critical" value, which is different for each latitude. Once Mars' obliquity drops below this "critical" value, ice at lower latitudes is thermally unstable, and will quickly sublime (c), leaving behind the residual lag deposit. For the remainder of the obliquity cycle, ice beneath this lag is quasi-stable and will remain at least until the following obliquity cycle (d). At this point, we argue that one of two processes may occur. If obliquity again rises above the "critical" value, a new layer of ice and dust may form on the new surface. Such behavior may already be seen in the PLD, for which exposed layers of alternating ice and dust are readily apparent. If, however, obliquity does not again rise above the "critical" value, subsequent mechanisms may act to modify the surface and near surface, including the deposition or removal of dust or sand, and other processes responsible for creating the surface morphology observed in these regions. Such behavior may possibly be observed in the latitude-dependent layer.

Discussion: The advantage of the layering mechanism discussed above is its simplicity. A single mechanism for ice distribution can be used to explain both layered volatile and layered sedimentary deposits presently observed in both the polar and non-polar regions of Mars [10]. This argument is consistent with the observed latitudinal distribution of the dissected terrain being the result of mid-latitude ice deposition at a once higher (~35°) obliquity. It requires no *ad hoc* assumptions about the properties of the surface, or the presence of liquid water. Indeed, the only assumption we must make (which is well grounded) is that dust must be present along with the water ice during deposition.

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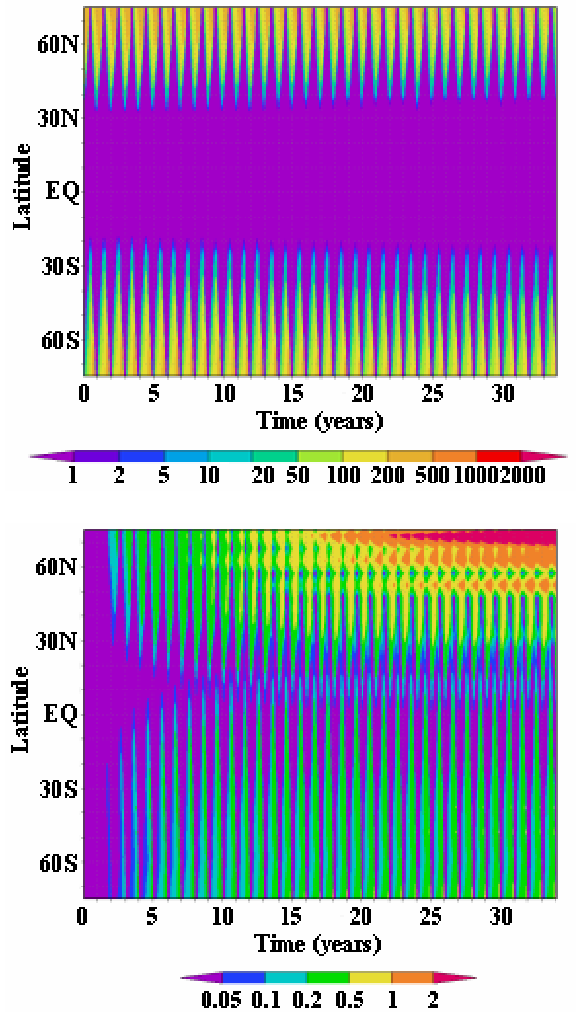

Figure 1: **(a)** Zonally-averaged surface ice (±75° latitude) at 25° obliquity run for 34 simulated martian years. Ice abundance is in µm. **(b)** Same as (a) but for 35° obliquity. Ice abundance is in cm. Surface ice predominantly located in high mid-latitudes, between 50°-70°N latitude.

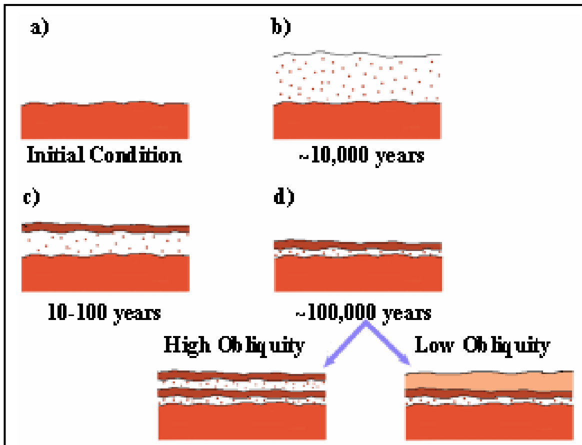

Figure 2: Timeline of surface layering mechanism over obliquity timescales (indicated times are phase durations, not accumulated time during process). **a)** initial exposed regolith **b)** becomes site for residual ice deposition due to variation in astronomical elements. Accumulation goes on for ~10^4 years before **c)** elements change again, area becomes unstable for water ice and net sublimation occurs. However, dust in ice accumulates during sublimation, and generates an isolating lag within 10^1-10^2 years that can **d)** greatly reduce ice loss over an astronomical cycle. The cycle can continue, developing layers, or area may become buried in unconsolidated dust.