**ICE AND LAYERING ON EARLY AND MODERN MARS.** N. Hoffman, WNS GeoScience, 22 Marlow Place, Eltham VIC 3095, Australia (nhoffman@vic.bigpond.net.au).

**Introduction:** The ubiquitous layering of the equatorial regions of Mars [1] is an enigma requiring explanation. How have such thick deposits of layered material accumulated, and what is their composition? Both sedimentary and volcanic explanations have been proposed, but there seems to be little evidence for the global volumes of liquid required for such extensive sedimentation, nor for the many volcanic vents or fissures.

Layering is clearly penecontemporaneous with the entire Noachian and early Hesperian cratering record, since craters both large and small cut into layering and are themselves filled by layered deposits as revealed by smaller later-stage craters and by cross-cutting erosive canyons and tectonic zones. Curiously, the layering also exists inside closed craters and there is little evidence for erosive degradation of the crater rims. It is as if the layered material fell out of the sky. Indeed, an ignimbrite origin is one possibility, except that source vents and calderas of sufficient magnitude are absent.

**Analogue and Model:** The Martian poles today are trapped in an icy deep freeze and evolve by the addition of layers of dust and ice during annual and longer-term climatic cycles. The most characteristic aspect of Polar terrains is their layering. Similarly, the early Mars was a global iceworld according to the White Mars paradigm and temperatures of equatorial Mars in the Noachian would have been similar to modern polar temperatures.

As discussed in other contributions in this series, the early atmosphere of Mars was unstably supported by major impact events and repeatedly collapsed to form a new global veneer of volatile ices. Each impact caused local vaporisation of volatile ices and atmospheric regeneration, and emplaced a ballistic layer of rock and refractory ices on the surrounding region. Major impacts would have laid down global layers whilst smaller impacts would have led to regional or local additions.

Large impact events would vaporise significant volumes of icy regolith, leading to outgassing into a local or more extensive “bubble” atmosphere. This atmosphere would persist so long as enough large impact sites were hot enough, but as they cooled the atmosphere would collapse in a global snowfall and ice layer. Each impact would spray out extensive ejecta sheets of rocky debris and refractory ices, then these would be buried with a volatile-rich layer by subsequent atmospheric collapse.

In any one area, an alternation of icy and rocky layers would accumulate, largely by airfall, draping and infilling prior topography (craters). Thus craters would fill with layered sequences, even if they had no entrance or exit for sediments. Thick layered sequences would accumulate over Mars’ plains, interrupted only by local impacts which would create their own crater and spread the excavated material in another layer outside.

With the progressive slowdown of the grand cosmic bombardment, and the reduction in impactor size, the surface would evolve through a long-term zero-sum process to the Mid-Hesperian state of a layered regolith with craters formed in layered material and filled in their turn by more layered material. Wherever one cuts into the surface of Mars, the result will be horizontally layered unless it is in the immediate rim of a crater where overturning of prior layers would be expected or inside large craters where a more extensive impact melt or welding would be expected, along with central uplifts or rings.

Thus we explain the layering of Mars as an inevitable consequence of large-scale cratering on a planet surfaced with ice and rock. The Moon is not layered, due to its lack of volatiles and atmosphere. The layering on Mars tells us that it did have a significant volatile budget, much of which is still sequestered in the layering, especially water which on Mars is a relatively refractory ice, compared to solid $CO_2$ or $CO_2$ clathrate. In the context of early Mars, water ice was a refractory component of the regolith and $CO_2$ the active volatile which ephemerally melted under favourable high pressure, lower temperature cycles.

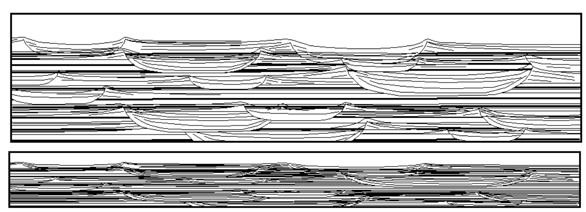

*Figure 1:* Cross-section of the accumulated layers on Mars resulting from repeated impact sheets and atmospheric freeze-out. Top, at vertical exaggeration of 2.5:1. Bottom, at true scale. Note how little departure there is from strict horizontality due to the wide aspect ratio of craters.

**References:** [1] McEwen A. S. et al. (1999) Nature 397, 584-586.