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Evidence for the Widespread Occurrence of Massive Ground Ice in the Northern Plains of Mars: A Potential Relic of a Former Ocean?

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The possibility that a large ocean once occupied the northern plains of Mars has been proposed based on the interpretive identification of various landforms, including sedimentary deposits, outwash plains and shorelines – the latter based largely on the work of Parker et al., who identified evidence of a series of nested levels, which they interpreted as shorelines, located along the highland/lowland boundary. The combination of high-resolution orbiter images with MOLA gridded topography has enabled the compilation of regional and global maps of the proposed shorelines. The highest and oldest of these was called the 'Arabian Level' and is believed to date back to the Late Noachian. In high-resolution MOC, HiRISE and HRSC images, the Arabian Level exhibits evidence of terracing (potentially indicative of wave-cut erosion); however, the topographically lower, younger 'shorelines' do not. The interior plains encompassed by these lower levels include vast expanses of cold-climate landforms, such as polygonal ground and scalloped depressions, a relationship that is consistent with either an initially warm, but progressively cooling, aqueous environment – or initial conditions that were cold from the outset. In either case, the flow-front-like morphologies associated with the lower levels may have resulted from ice-shoving due to short-lived transgressive events caused by later episodes of outflow channel activity around the northern plains.

Persuasive new support for the ocean hypothesis comes from surface permittivities derived from the global observations of the MARSIS orbital radar sounding investigation on Mars Express. These permittivities, which are a measure of how strongly a radar pulse is reflected from the Martian surface, are unexpectedly low throughout the northern plains, consistent with the occurrence of thick deposits (at least $\sim$60-80 m) of either highly-porous or ice-rich sediment. Further insight into the origin of these low permittivities is provided by their close agreement with the geographic distribution of multilobate fluidized ejecta craters, and other cold-climate landforms, within the region interior to the proposed ocean shorelines – providing persuasive evidence of an association with ground ice, most plausibly related to a surviving remnant of a former ocean and/or the frozen discharge of the outflow channels.

The survival of a frozen relic of an ancient ocean is an expected consequence of its response to the onset of a cold early climate, and subsequent burial by volcanics and eolian and fluvial sediments, that may have preserved a remnant of this ice to the present day. While sublimation may have depleted some of the initial inventory of ice, replenishment by later episodes of outflow channel activity, continued mantling by volcanism and sediments, combined with the potential geothermal redistribution of ground ice from depth, is expected to have led to the development of a complex stratigraphy of massive ground ice, frozen sediments, and volcanics, throughout the northern plains. The distribution and correlation of cold-climate landforms, high mobility fluidized ejecta craters, and the low surface permittivities inferred from the MARSIS data, are all consistent with this interpretation. We are continuing our investigation of these and other relationships to test and better constrain these results.