EVIDENCE FROM HRSC MARS EXPRESS FOR A FROZEN SEA CLOSE TO MARS' EQUATOR.

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Introduction: The Cerberus Fossae fissures on Mars are the source of both lava and water floods [1] dated at between 2 &10 million years old. Evidence for resulting lava plains has been identified in eastern Elysium, but seas and lakes from these fissures and previous flooding events were presumed to have evaporated and sublimed away [2]. HRSC images from the ESA Mars Express spacecraft indicate that they may still be there. We have found evidence consistent with a presently-existing frozen body of water, with surface pack-ice, around +5º latitude and 150º east longitude in southern Elysium. It measures about 800 km x 900 km and averages up to 45 m deep: similar in size and depth to the North Sea. It has probably been protected from complete sublimation by a surface sublimation lag formed from suspended sediment exposed by early loss of the surface ice. Its age from crater counts is 5 ±2 Ma.

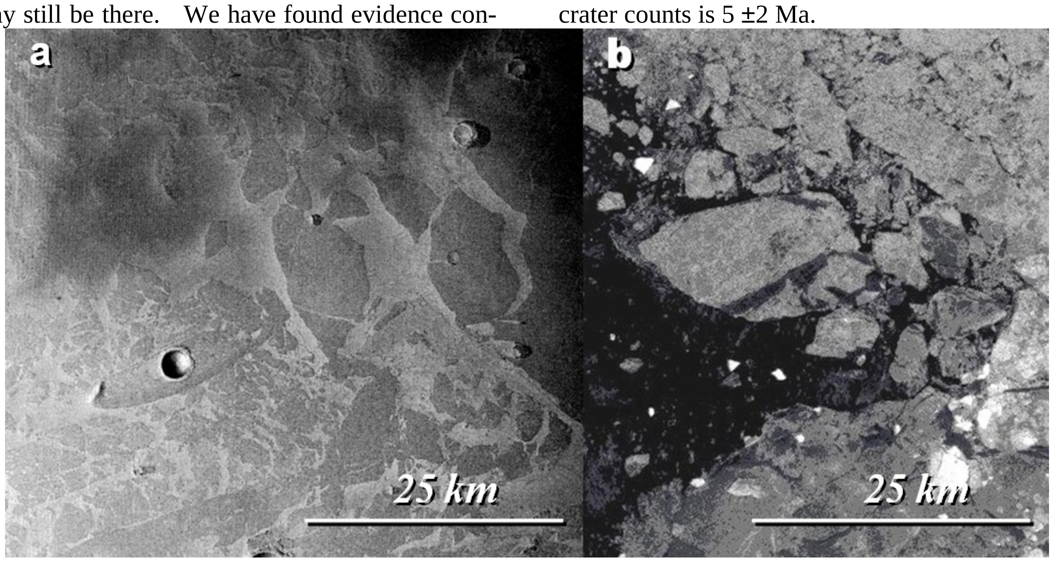

Fig 1. (left) shows extensive fields of large fractured platy features on a horizontal surface, visible near the south end of an HRSC image taken on 2004 Jan. 19, compared with pack-ice in the Antarctic (right). Individual plates are of all sizes from 30 m up to >30 km, with clear signs of break-up, rotation and horizontal drift for distances of several km. The plates show characteristic differences from platy features elsewhere on Mars and in the east of Elysium Planitia. The latter have been interpreted to be rafts of solidified lava floating on the surface of large flood basalts [3], but several observations indicate that this cannot be the case in this area.

Crater-count ages: Surface ages were determined from the size-frequency distribution [4] of 66 impact craters on HRSC images, which suggest a resurfacing event about 5 Ma ago. Counts of 268 craters on MOC images show that the plates are older than the brighter inter-plate areas, by about 1 Ma. Basalt lava flows of 50m depth can remain partially molten at the centre for only about 5 years, so these plates cannot be the result of surges of lava carrying previously solidified crust.

Flood characteristics: A drop in surface level has occurred after flooding of 18 to 85 m (equivalent to about 9% to 16% of the depth prior to flooding) within flooded impact craters (fig. 2). Ponded lava cannot seep into sediments, evaporate or sublime, & thermal contraction would amount to less than 1%.

Where the plates have encountered craters and islands, these have acted in a similar manner to ice-breakers as the plates drifted past them, leaving straight or curved leads downstream of uniform width (L, fig. 2). These are not found within lava rafts. These lanes are still very smooth at the 10 metre scale, as are similar features in pack-ice on Earth. Also, the plates attain sizes one to two orders of magnitude greater than the largest known terrestrial basalt rafts. Both these observations, together with the very horizontal surface (<5 m height variation over more than 60 km, i.e.<0º.005, corresponding to terrestrial tidal sea surface slopes in some estuarine situations) imply an extremely mobile fluid, with similar characteristics to water.

Other characteristics also resemble pack-ice.

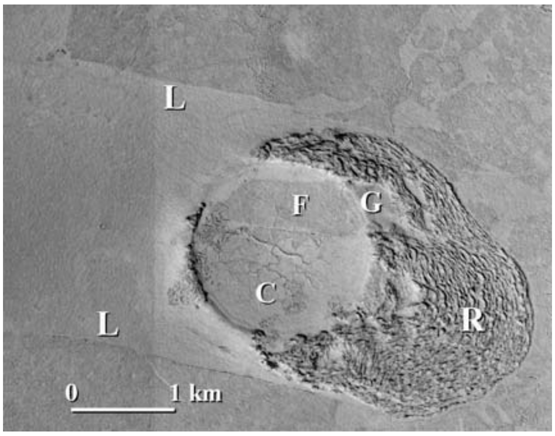

Fig. 2 is a MOC image showing pressure ridges R with wavelengths between 10 and 70 m within the rubble pile on the upstream side (right). Caused by plate drift, these appear to have extended outward from the crater edge as the liquid level dropped and the frozen surface was grounded progressively further down the outer slopes of the crater. They are strikingly similar to rubble piles of sea ice that form around islands in the Arctic and Antarctic. The sagging and consequent surface cracking **C** within the crater itself as the level dropped are also visible. One plate **F** has drifted into the crater when the level was higher through the gap in the rim **G**, but then become grounded in its present position as the surface lowered, draping it over the NE rim.

Pack-ice: We interpret the structures and textures to be due to pack-ice formed as a moving and fracturing thermal boundary layer on top of ponded aqueous floodwater which later froze. Reasonable estimates of the depth can be made by using the rim height to diameter ratios of partially submerged impact craters, assuming these are fresh. 14 crater rims have been identified from their traces partially above or just below the ice, yielding initial water depths of between 31 and 53 m, with an average at 45 m. MOLA profiles across three flooded craters indicate that low parts of the rim are still 0 to 30 m above the mean ice level, suggesting that evaporation, sublimation and seepage sagging may have lowered the ice thickness to a present mean value of around 30 m ice depth.

Ice is unstable at the surface of Mars at the present time due to sublimation in the 6 mbar atmosphere, but it is thought that huge volumes of volcanic ash were also erupted from Cerberus Fossae [3] which if contemporaneous with water emission would have formed a substantial protective layer on the ice. Depending on the porosity and thermal properties of this layer, the subsequent lowering of the floe surfaces could be very slow. Subliming water vapour migrating through the pores will over time help to sinter and chemically bind the particles to form a stronger sublimation lag.

We suggest the following sequence of events: firstly, pack-ice formation with a volcanic ash covering, secondly, remobilisation, break-up and drift of pack-ice, and cessation of volcanic activity, thirdly, freezing of entire body of water, and finally, the sublimation of the unprotected ice between the ash-covered ice-floes, gradually exposing the suspended sediment at the surface to form a protective layer with a younger age than the floes.

The question remains as to whether the frozen body of water is still there, or whether the visible floes are preserved in a sublimation residue draped over the substrate. Two observations suggest that it is still there:

1. Submerged craters are too shallow, suggesting that most of the ice is still within the craters.

2. The surface is too horizontal. Ice depth estimates above indicate that the "sea bottom" varies in altitude by 55 m. Had the ice been lost, this should have resulted in greater height variation.

Micro-organisms found within deep-sea hydrothermal vent communities are common ancestors to many forms of life on Earth, and a Martian aquifer having intermittent contact with the surface might provide an opportunity not only for troglodytic life to develop, but to be disgorged on to the surface, and the frozen sea described here would be a prime candidate area for the preservation and discovery of its remains.

References: [1] Berman, D. C. & Hartmann, W. K. (2002). *Icarus 159*, 1-17. [2] Carr, M.H. & Head III, J.W. (2003). *JGR 108*, No. E5, 5042. [3] Keszthelyi, L., McEwen, A.S. & Thordarson, T. J. (2000) *JGR 105*, E6, 15,027-15,049. [4] Hartmann, W.K. & Neukum, G. (2001). *Space Sci. Rev. 96*, 165-194.