ICE FILLED CRATERS IN MARS' NORTH POLAR REGION – IMPLICATIONS FOR SUB-SURFACE VOLATILES

N. Hovius[1] S. J. Conway[2], T. B. Barnie[3] and J.Besserer[4] [1]Dept. of Earth Science, University of Cambridge UK, CB2 3EQ. nhovius@esc.cam.ac.uk [2]Dept. of Earth & Environmental Sciences, Open University, Milton Keynes, UK, MK7 6AA. s.j.conway@open.ac.uk [3]Dept.of Geography, University of Cambridge UK, CB2 3EN. [4]Laboratoire de Planétologie et Géodynamique de Nantes URM-CNRS 6112, Université de Nantes, 2 rue de la Houssinière, BP92208, 44322 Nantes, France.

Introduction: There is much evidence to support the presence of surface water-ice in the North Polar Region, e.g. [1-3], but the subsurface distribution is still unknown. To confirm or reject the past northern basin ocean hypothesis [4] support is needed from the properties of the underlying sediments. As impact craters are a natural probe of the subsurface, we present a systematic study of impact craters above 65°N, to investigate the substrate in this region. We place particular emphasis on 17 craters that show convex-up positive relief in their centres distinct from a central peak, hereafter termed "lumps".

Approach: We performed a crater survey based on Mars Orbiter Laser Altimeter (MOLA) topography. Using watershed analysis we mapped the rims of the craters and extracted the underlying topographic parameters from the MOLA data.

For the craters with lumps we measured any layer-spacing found in THEMIS-VIS, MOC-NA, CTX and HiRISE images and made observations on layer unconformities and sinuosity. The lump asymmetry was calculated from the distribution of aspect from MOLA topography.

We investigated the composition of the lumps in Korolev (206), Louth (503) and 769 using OMEGA and CRISM hyperspectral data. The absorption band at 1.50 µm was used to detect water ice [5], the band at 1.24 µm for coarse-grained ice discrimination and at 2.35 µm for CO_2 frost detection.

Results: There are 1,300 craters with a diameter of >5km in this region, of which 17 contain lumps, as shown in figure 1. These craters are not otherwise distinct from the population. However, the craters with lumps were found to probe to systematically lower local elevations than their neighbours, for a given latitude, as shown in figure 2. Craters without lumps which also probe to depth have fluidized ejecta (e.g. swath 1, 2). In swath 1 these fluidized craters also contain dunefields.

General Description. The craters with lumps fall into three broad groups: 1. those with a smooth ice lump, 2. those with partial dune cover and 3. those with full dune cover. Korolev (206) and Dokka (388) are in group 1, together with 6 other craters. Louth (503), 579 and two other craters fall into group 2 and two craters fall into group 3. The dunes in group 2 are always located at the topographic high.

Structure. The layer-spacing distributions of 503 and 769 are different to those in the north polar basal deposits and the polar layered deposits. The layer-spacing distribution of 579 cannot be differentiated from the polar layered deposits. All layers exhibit high angle unconformities (>70°) and in 503 and 579 have high sinuosity exposed on a low slope. Craters 882, 795 and 515 have not yet been imaged and layers in 544 & 577 have not yet been measured. Layers are not found in 206 & 388 and poor images or dunes obscure possible layers in the other craters.

Asymmetry. The asymmetry of the lumps was compared to wind direction as recorded by dune-slip faces [6]. Proximal to the cap the lumps seem to face the strongest prevailing wind and further away they seem to face away from or orthogonal to the wind.

Composition. Our OMEGA analysis shows the lumps are composed of mainly water ice, found to be of a homogeneous medium-coarse grainsize (<~1mm) compared with the fine seasonal frost cover. A CO_2 frost layer was observed in winter on Louth and crater 769. Neither OMEGA nor CRISM data yield a significant signature for the material making up the dunes in Louth, but it seems to be spectrally similar to areas just outside the crater. OMEGA time series suggest that the lumps are not located in present-day cold traps, as indicated by frost patterns.

Conclusions: The combination of the dissimilarity in the layering distribution and patterns between the lump craters and the cap deposits and their location away from present cold traps, lead us to reject the hypothesis that these lumps were formed by atmospheric condensation: either as a remnant of a previous cap or as independent caps. We therefore suggest the water has a subsurface source, as these craters probe deeper than their neighbours. The few exceptions have fluidized ejecta, suggesting they failed to connect properly to the underlying source and the fluidized craters in swath 1 may contain remnant lumps hidden by dunefields.

We suggest two plausible mechanisms; firstly the water was released on impact and froze out of a declining hydrothermal system [7], secondly the impact event formed a conduit to a periodically overpressurized underlying aquifer [4]. We favour the latter as we do not believe the deposits would survive the intervening time between impact and the present.

We suggest two hypotheses to explain the presence of dunes on the top of the lumps: either the material is sourced from outside the crater and the coarse ice on the lump initiates dune formation, or the material is contained within the lump (coming up with the water from depth) and is released form dunes on degradation of the lump. Without further compositional data we cannot differentiate between these hypotheses.

We attribute the domed shape, with an exterior moat to the water upwelling from a single or clustered fault system, forcing material up, explaining the high sinuosity and occasionally breaking though to create the observed horizontal layers. However we cannot rule out differential insolation [8] or wind ablation [6] and these may have been the erosive processes active during formation, to create the unconformities indicating multiple phases of growth and decay. The exposure of the layers in some of these lumps suggests that they are in a retreating phase.

References cited: [1] Jakosky B. M. et al. (2005) *Icarus, 175*, 58-67. [2] Bibring J. P. et al. (2005) *Science, 307*, 1576-1581. [3] Barlow N. G. and Perez C. B. (2003) *JGR.-Planets, 108*. [4] Christensen P. R. (2003) *Nature, 422*, 45-48. [5] Langevin Y. et al. (2005) *Science, 307,* 1581-1584 [6] Tanaka K. L. and Hayward R. K. (2008) *Planet. Dunes Wkshp.* Abstract #1403. [7] Osinski G. R. et al. (2005) *Meteoritics & Planet. Sci. 40*, 1859-1877. [8] Russell P. S. et al. (2004) *LPSC XXXV*, Abstract #2007. [9] Tanaka K. L. et al. (2005) *USGS Scientific Investigations Map 2888*

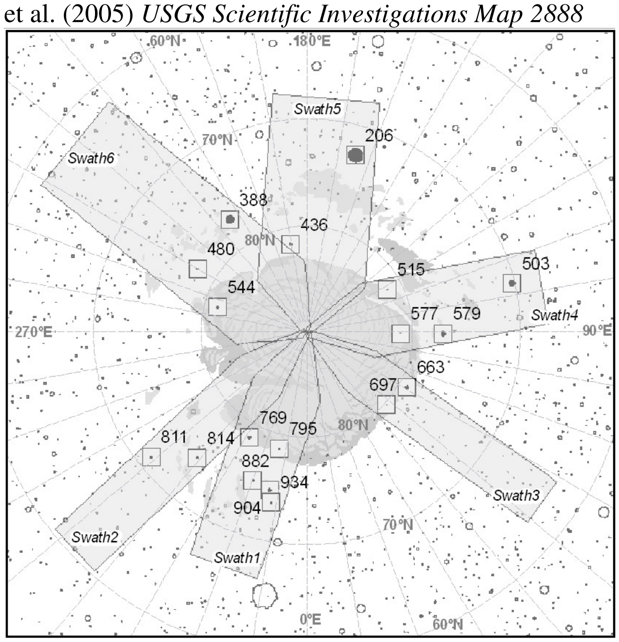

Figure 1: Location map showing; craters in study area, with lump craters labeled and outlined by boxes and locations of the swaths in figure 2. Outline of polar layered and polar ice deposits in grey [9].

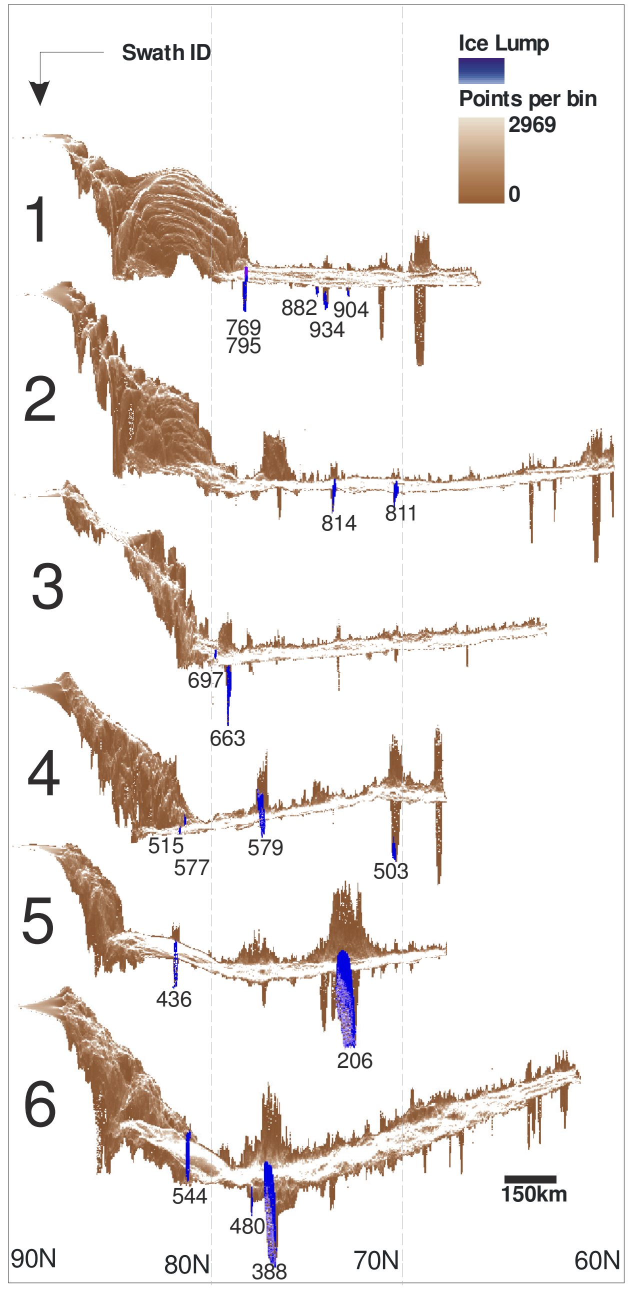

Figure 2: Histogram plots of the elevation within the swaths outlined in figure 1. Blue indicates craters with ice-lumps and the height to which those lumps reach. The vertical scale is exaggerated by ~230.