THE ORIGIN AND EVOLUTION OF ICE DOMES IN THE NORTH POLAR REGION OF MARS. S. J. Conway[1], N. Hovius[2], T. D. Barnie[3], J. Besserer[1], S. Le Mouélic[1] and N. Reed[2], [1]LPGN, CNRS/Univ. Nantes, 44322 Nantes, France, susan.conway@univ-nantes.fr [2]Dept. of Earth Science, University of Cambridge UK, CB2 3EQ. [3]Dept.of Geography, University of Cambridge UK, CB2 3EN.

Introduction: We have identified 12 craters in the north polar region of Mars that contain domes of ice and 6 additional craters that contain domes which could have ice beneath a cover of dunes (Fig. 1). These domes are located both adjacent to the polar cap deposits and up to ~600 km away. The two largest domes, in Korolev and Dokka craters, are located at distances of 623 and 301 km respectively. These domes are assumed to be remnants of a previously more extensive cap [1,2]. We test this hypothesis and also explore three other possibilities: that the domes are formed by (1) post-impact hydrothermal activity, (2) upwelling of water from a deep aquifer, or (3) formed separately from the polar ice cap.

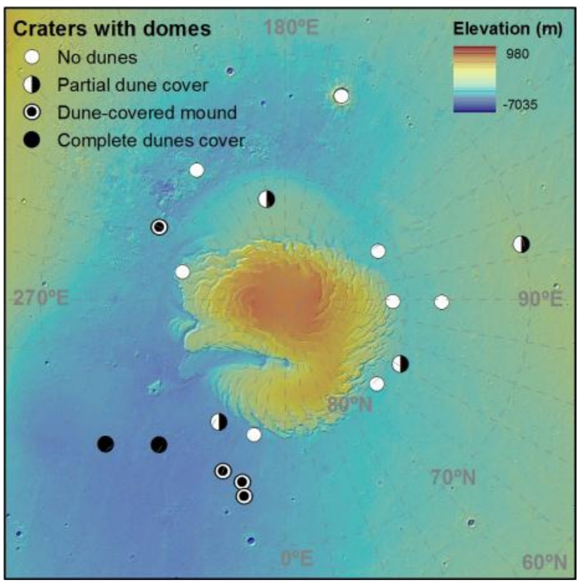

Fig. 1. MOLA map of craters containing domes.

Approach: We performed a survey of all craters > 65°N and gathered their spatial and geometric statistics using MOLA topographic data. For the craters containing domes we estimated the volume and asymmetry of the domes, by fitting a power-law curve to the average interior wall-profile of the crater. We used CRISM and OMEGA spectral data to verify the domes' composition. To ascertain the geological structure of the domes we used HiRISE and CTX image data in conjunction with MOLA topographic data to map and interpret visible layering. The internal structure was assessed using SHARAD radar data.

Results: The volume of the domes ranges between 0.8 and 3900 km^3. The total volume of ice is approximately 5700 km^3, ~1% of the volume of the polar layered deposits [3]. The greatest thickness of ice is within Korolev, ~1.8 km, which is equivalent to the thickness of the polar layered deposits [3]. Unlike for the South Polar Region [4], we found no decrease in dome volume with distance from the polar cap. In terms of depth-diameter measurements the craters are similar to those in the North Polar Region, but tend to be shallower (even considering the ice-infill). However, the craters containing domes are always the deepest penetrating for their local area, i.e. are either the largest, or are smaller craters located on lower local topography.

The domes always have a component of north-south asymmetry, with south-facing slopes shallower and broader, and north-facing slopes steeper and shorter (Fig. 2). The east-west asymmetry is almost always present and particularly marked near to the cap, with the center of mass of the domes always displaced to the west. The pattern is more complex further from the cap. The domes almost always have an external moat, as in Fig. 2.

The spectral data revealed that the composition of the exposed domes was predominantly water ice, with a small percentage of CO_2 ice and dust, very similar to the polar layered deposits (PLD) [5].

Layers were measured on six domes. In general the layers are regularly spaced and packets of layers are separated by relatively frequent angular unconformities. The layers dip towards the outer-edges of the domes, having a similar steepness to the current topography (Fig. 3). This general layering structure was also found internally in radar data for Korolev and Dokka. In terms of layer-spacing the domes are not distinguishable from the PLD, or the basal unit (BU) deposits. The frequency of unconformable contacts is greater than in the PLD, but similar to the BU. The dip of the layers is greater than the PLD, but not the BU.

Discussion: The overall shape and asymmetry of the domes can be explained solely as a consequence of ablation processes and therefore is not a useful indicator of dome-forming processes. The north-south asymmetry and presence of a moat can be attributed to radiation, as found by [6]. The east-west asymmetry follows the principle wind directions in the polar region (E-W near the cap and complex further away [7,8]).

Unconformable contacts indicate multiple episodes of dome-building and retreat, which suggests that the domes cannot have been built in a single 'event' by impact-induced hydrothermal activity. Although the craters containing domes are those that penetrate to the deepest local depths, consistent with the upwelling of water from an aquifer, this mechanism would be expected to create more chaotic internal stratigraphy, with more 'dirty' ice. For the 8 domes closest to the cap we cannot rule out their formation as a part of the polar cap. For the rest, remnants of a more extensive cap would be expected to decrease in volume with distance from the cap, which is not the case. The large depth of ice contained in some of the craters and their layering structure is also hard to reconcile with this theory.

The presence of layers that drape topography argues for atmospheric deposition separate from the polar cap. Present-day exposures of layers at the surface and radar data showing that these domes are layered throughout, suggests these domes are both building and eroding at present-day.

Once sufficient ice has been deposited the domes form natural cold-traps throughout the year, as shown by [9,10]. We propose that the fact that their host craters penetrate to the deepest depths can explain the initiation of dome-building in these particular craters. These craters would form both traps for water-vapor laden katabatic winds coming of the cap [11] and are more likely to form temperature inversions.

Conclusions: We surmise that the majority of the domes were formed by atmospheric deposition of water ice separate from the polar cap. The host craters are cold traps for water vapor, because their bases are located at low local elevations. Their present-day shape is controlled by ablation by wind and radiation. These domes provide important constraints for understanding past and present water cycles in the region.

References: [1] Garvin J. B. et al. (2000) *Icarus, 144*, 329-352. [2] Tanaka K. L. et al. (2008) *Icarus*, *196*, 318-358. [3] Selvans M. M. et al. (2010) *JGR*., *115*, doi:10.1029/2009JE003537. [4] Russell P. S. et al. (2003) *6th Int. Conf. on Mars*, Abstract #3256. [5] Langevin Y. et al. (2005) *Science*, *307*, 1581-1584. [6] Russell P. S. et al. (2004) *LPSC XXXV*, Abstract #2007. [7] Howard A. D. (2000) *Icarus*, *144*, 267-288. [8] Tanaka K. L. and Hayward R. K. (2008) *Planetary Dunes Workshop*, Abstract #1403. [9] Armstrong J. C. et al. (2005) *Icarus*, *174*, 360-372. [10] Kuti A. (2009) *LPSC XL*, Abstract #1006. [11] Pankine A. A. et al. (2009) *Icarus, 204*, 87-102.

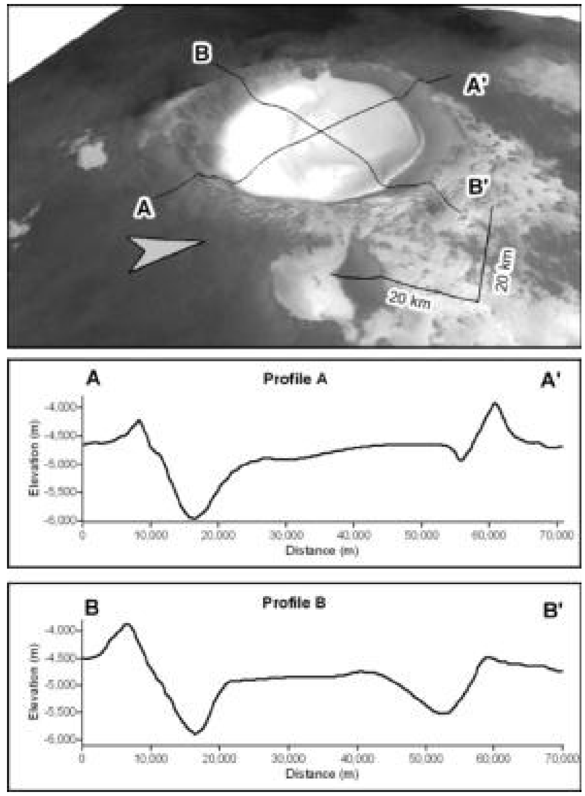

Fig. 2. Dokka crater. Top: perspective view of a subset of HRSC image H1177_0000 draped over MOLA topography. Arrow points to North. Bottom: Profiles A and B generated from MOLA topography as marked on top part of figure – note the exaggeration of the vertical scale (same in A and B). Credit for HRSC images ESA/DLR/FU Berlin (G. Neukum).

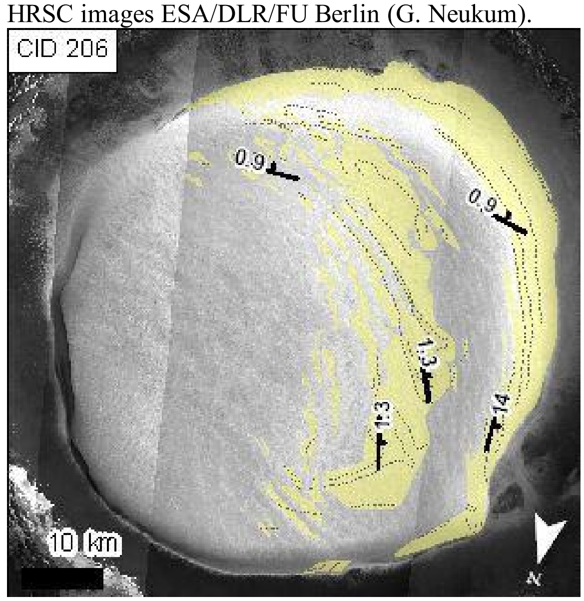

Fig. 3. Dips and exposures of layers in Korolev crater. CTX Images, P20_008831_2529, P21_009042_2528, P21_009332_2529, P22_009477_2530, P22_009754_2529.