

The Berlin Mars near Surface Thermal model (BMST) – Modeling the formation and evolution of sublimation lags on Mars. J. Helbert¹, J. Head², and D. Marchant³ ¹Institute for Planetary Research, German Aerospace Center DLR, (Rutherfordstr. 2, Berlin-Adlershof, Germany, joern.helbert@dlr.de); ²Dept. of Geol. Sci., Brown Univ., Providence, RI 02912 USA; ³ Boston University, Dept. of Earth Sciences, Boston, MA 02215.

Introduction: Morphological studies of Mars show mounting evidence for the widespread existence of near surface ground ice deposits even at low latitudes. The unique images provided by the HRSC camera on Mars Express has provided us with a wealth of morphological detail on these deposits [1]. In the last year we gained completely new insights into ice deposits on Mars with the NASA Phoenix mission for the first time directly studied ice on Mars [2] and the SHARAD instrument on the NASA MRO mission detecting clear evidence for glacial deposits in the equatorial regions of Mars [3, 4].

The open question is whether these deposits are formed in equilibrium with the current Mars atmosphere or whether they could be the remnants of an earlier climate cycle of Mars that would favor the deposition of ice and snow and the formation of debris-covered glaciers [5, 6]. In order to address this issue we use the Berlin Mars near Surface Thermal model (BMST) to estimate the thickness of the sublimation lag on such ancient deposits. A comparison of these values with morphological evidence and the radar data will allow us to gain a deeper insight into the formation and stability of ice deposits on Mars.

This modeling is accompanied by supporting laboratory studies on the detectability of hydration features especially in the mid-infrared range as is, for example, observed by PFS on Mars Express.

The BMST: Over the last six years we have developed the Berlin Mars near Surface Thermal model (BMST) that allows investigation of the detailed evolution of an ice-rich deposit. The main features of the BMST [7,8] are 1) a high vertical resolution (down to the centimeter range), 2) a realistic treatment of the thermal properties of ice-rock mixtures, and 3) a detailed treatment of gas flux within the subsurface. The thermophysical parameters, such as thermal conductivity, and the porosity of the matrix for each layer are recalculated in every time step. All parameters, including water vapor transport, ice distribution and changes in the porosity can be monitored. The model evaluates the diffusion based on the matrix properties (including porosity, pore size and tortuosity) and traces the actual movement of volatiles within the matrix. This dynamic approach allows us to study also the behavior of subsurface ice on a timescale where the soil has not yet reached thermodynamical equilibrium. This approach allows studying “young” ice-related deposits which might form in response to climate variations on short

timescales as well as “old” persistent deposits. There is observational evidence showing multiple climatic cycles on Mars. There are older cycles, in excess of 5-10 Ma, as shown by evidence of glaciation in mid-latitude and equatorial regions [9] and a recent cycle on the order of 100-300 ka as shown for example by the layering in the polar caps [10] and a few million years, as shown by the latitude-dependent mantle interpreted to represent recent “ice ages” [11, 12].

Recent studies: We have performed over recent years several studies assessing the likelihood of the presence of localized ground-ice deposits on Mars. This includes studies for the planned Beagle 2 landing site in Isidis Planitia [13], showing that ground-ice deposits would not be expected within the reach of the MOLE instrument. We have also shown, using the BMST model, that a morphologically identified glacial deposit on the northwestern flanks of Hecates Tholus [7] very likely still contains a stagnant ice core. There are several units on Mars, especially on the flanks of volcanic edifices, which based on morphological evidence, may be glacial deposits and which possibly are still ice-cored [9]. We are working on a more detailed analysis of the deposits on the flank of Arsia Mons, one of the Tharsis volcanoes [14].

Phoenix results: The highly successful NASA Phoenix landed at 68°N in the arctic regions of Mars. We had studied the candidate landing areas for the

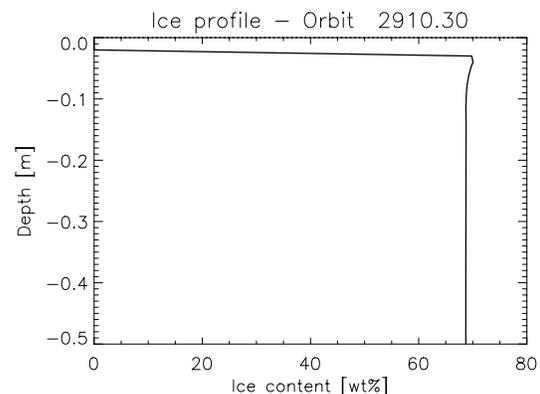


Figure 1 Predicted ice content profile for the Phoenix landing site.

NASA Phoenix mission as a typical example for latitude-dependent mantling [11,12]. Apart from the morphological evidence, the observations by the neutron and gamma-ray spectrometers on Mars Odyssey [15]

have shown that these deposits are very ice-rich below a thin desiccated mantle.

Our models runs had predicted that the top of a persistent ground ice layer could be located just a few centimeters below the surface. Figure 1 shows one of the ice profiles we obtained with the BMST model.

It should be noted that the profile shows a highly desiccated upper layer on top of an ice-enriched layer that caps a ground ice deposit. This profile shows a good agreement with the findings by the Phoenix mission: a layer of almost pure ice covered by a dry soil layer (Fig. 2). Especially the prediction of a dry top layer is interesting, as a formation by diffusion from the atmosphere would most likely lead to an increased humidity in the top layer.

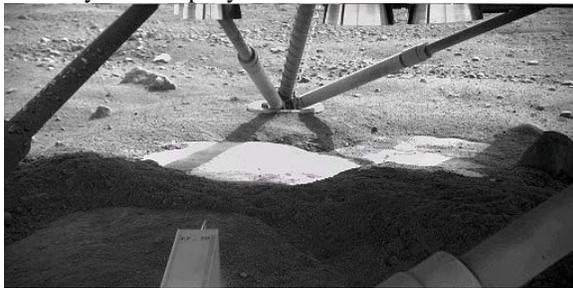


Figure 2 Ice deposit under the Phoenix lander (NASA/JPL Caltech/University of Arizona/Max Planck Institute)

Equatorial deposits: We have in the past studied the possibility of mid-latitude to equatorial ice deposits, especially addressing the modification of the dichotomy boundary by glacial and periglacial processes. Typical examples of morphological structures associated with this modification are northern mid-latitude lineated valley fill and lobate debris aprons [16].

Recently the SHARAD instrument on MRO has gathered compelling evidence for the existence of extensive buried glacial ice in ancient debris-covered glaciers in both eastern Hellas [3] and in valleys and deposits around basal massifs at the dichotomy boundary in the northern hemisphere [4]. These deposits consist of almost pure ice covered by an ice free debris layer.

In the current Mars climate surface ice would be unstable at these latitudes. So the formation of the debris-covered glacier must date back to a different climate period on Mars favoring ice deposition in equatorial and mid-latitude regions [5,6].

Applying the same technique as done previously for the Hecates Tholus deposit [7] we are working on estimates for the maximum thickness of the sublimation till covering the glacial deposit. The BMST is based on the idea that ice deposits are under current conditions not stable and that sublimation will occur.

As a dynamical model we can follow the sublimation of the ice and derive a maximum velocity for the downward migration of the ice table. We call this number the burial gradient. With this gradient and the age of the deposit derived from crater counts we can give a strict upper limit for the thickness of the sublimation lag. Figure 3 shows the evolution of the burial gradient for a test run with the BMST in the Hellas region. We get a final burial gradient of approx. $2 \cdot 10^{-7}$ m/a. Extrapolating this number linearly we can conclude that the sublimation lag can not be thicker than approx. 60m if we assume an age of 300Ma.

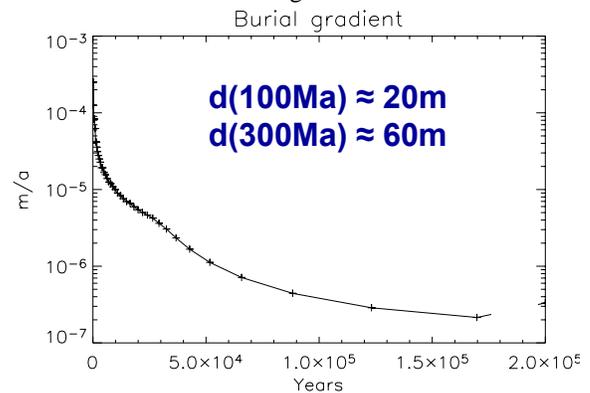


Figure 3 Upper limit for burial depth of a debris-covered glacial deposit in eastern Hellas

Conclusions: Evidence is mounting now for the existence of vast deposits of subsurface ice also in the mid-latitude and equatorial regions of Mars. Our modeling combined with the morphological evidence lead us to the conclusion that we are seeing here the remnants of ancient Martian “ice ages” rather than recent superficial deposits of ice in equilibrium with the atmosphere and produced by vapor diffusion.

References: [1] Head, J. W., et al. (2005) *Nature*, 434, 346-351. [2] Smith, P. H. and the Phoenix Team (2008) *Eos Trans. AGU*, 89(53), #P13F-01. [3] Holt, J. et al. 2008 *Science*, 322, 5905. [4] J. Plaut et al., *GRL* 35, 36379, 2008; [5] Forget, F. et al. (2006) *Science*, 311, 5759 [6] J-B Madeleine et al, *LPSC* 38 1778, 2007; [7] Helbert, J., et al. (2005) *GRL*, 32, L1720 [8] Helbert J. and Benkhoff, J. (2003) *J. Geophys. Res.*, 108 (E12), 8087 [9] Head, J. W., et al. (2005) *Nature*, 434, 346-351 [10] Milkovich S. et al. (2004) *JGR* [11] J. Head et al., *Nature* 426, 797, 2003; [12] Kostama, V.-P et al. (2006) *GRL* 33, 11. [13] Helbert, J. et al. (2006) *AdSpR* 38, p. 709-712. [14] Helbert, J., et al. (2006) *LPSC XXXVII*, #1371. [15] Boynton, W. et al. (2002) *Science*, 296, 81-85. [16] Head et al. (2006) *GRL* 33, L08S03.

Acknowledgment: This work was funded by the German Research Foundation (DFG).