LATITUDE-DEPENDENT MANTLE THICKNESS IN UTOPIA PLANITIA ON MARS. P. Król[1], A. Losiak[2], I. Gołębiowska[1] [1]Faculty of Geography and Regional Studies, University of Warsaw (p.krol6@student.uw.edu.pl, i.golebiowska@uw.edu.pl), [2]Institute of Geological Sciences Polish Academy of Sciences (anna.losiak@twarda.pan.pl).

Introduction: Latitude Dependent Mantle (LDM) is a layer composed of sand, dust, and rocks that are cemented by water ice, that covers at least 23% of martian surface [1], and can be seen interacting with various surface features such as impact craters [2] (Fig. 1a). Its origin is not yet agreed upon, but one of the theories connects it to the process of airfall deposition of ice-covered dust grains, which may be related to Mars' obliquity changes [3]. Those changes likely had a significant influence in a global circulation of water [4][5].

Analysis of LDM thickness is important, because it is likely to contain H_2O, which is a crucial resource to analyze in order to study the history of Mars, as well as to sustain manned missions [5]. However, the H_2O content estimates (currently ranging from 10^4 to 10^5 km^3 [6]) cannot be reliable unless the thickness of the deposit is properly determined.

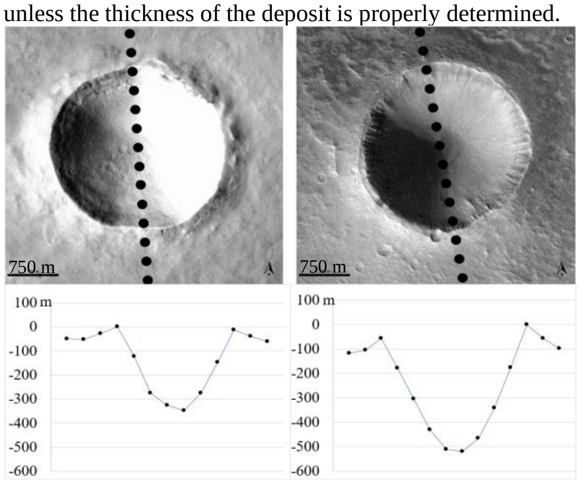

Figure 1: Comparison of two impact craters of a similar diameter (~2,6 km). The one on the left is covered by LDM, while the one on the right is not covered by LDM, and considered relatively "fresh". The cross-sections are drawn from MOLA stamps.

Area of research: LDM thickness was determined at Utopia Planitia – the eastern one of the three major plains, which together form Vastitas Borealis, the biggest plain on Mars located on the north hemisphere. Utopia Planitia is an area covered with LDM overlaying many of its terrain features [5]. Research performed in 2016 by Stuurman et al. [7] proved that water ice exists beneath the surface – at least at the southern section of the research area. In 1979 Viking-2 lander photographed ice on the surface. Most recently, the study area was also a successful landing zone of the Chinese rover Zhurong, which is at the moment (2021) operational.

LDM thickness estimation method was based on comparing the measured depth of the crater filled with LDM with a calculated depth of a similarly-sized crater based on the depth/Diameter ratio for fresh craters [8] measured in Utopia Planitia (Fig 1). The difference between those depths is assumed to be a maximal possible LDM thickness.

To do that, first we analyzed craters in JMars using CTX imagery (~6m/px) to 1) distinguish LDM covered impact craters and the ones not containing it, 2) note other crater properties (LDM degradation or presence of impact melt), as well as to 3) accurately measure the diameter. Later, 4) we plotted individual MOLA shots on the craters to measure their depth; 5) we have selected only the MOLA track coming through the center of the crater. Analyzing single MOLA shoots over measurements on whole-planet DEM were selected to allow accurate measurements of craters <5 km in diameter. It seemed to be important because based on previous studies [7] we expected thickness of LDM to be up to couple hundreds of meters.

Based on this analysis, 6) we created a database of impact craters containing their center coordinates, cross-section showing depth and rim elevation, and additional remarks describing any abnormalities. Records were then divided into two diameter-sorted categories – covered by LDM and not covered by LDM ("fresh"). The fresh craters were measured in order to determine the d/D ratio at Utopia Planitia. 7) We created a map to show the spatial distribution of the LDM in Utopia. We evaluate the total uncertainty of our method to be <100 m.

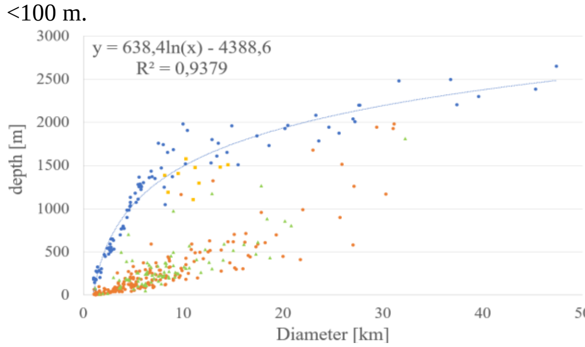

Figure 2: Relation between martian impact craters' depth and Diameter observed in Utopia, along with the equation derived from the gathered data. The difference in depth between fresh (blue) and LDM-filled (orange) craters represents a maximal possible thickness of LDM at this location that is on average up to ~1000 m. Green represents craters containing degraded LDM. Yellow are "fresh" craters with a visible impact melt.

Results: Entire database contains 430 impact craters. For the purpose of mapping 385 were used, as 45 of them were of D < 1 km, which was recognized too small for precise measurements with MOLA data, and resulting in errors.

Fresh craters (blue dots on Fig. 2) as expected follow a roughly logarithmic d/D correlation [8]. There's a visible change in trend angle occurring at about 5 km of diameter, that corresponds to the transition between simple and complex craters in the research area.

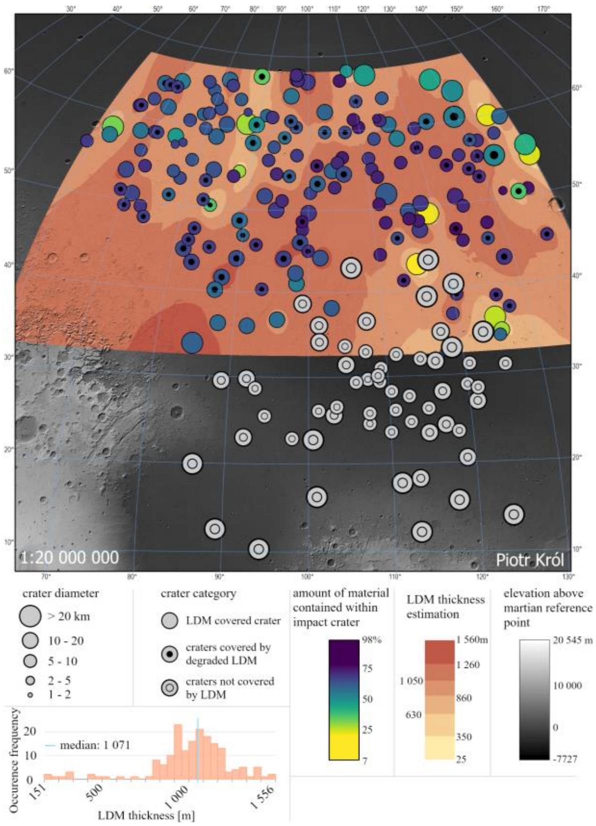

Figure 3: LDM thickness interpolation and % of crater depth being filled out by a material present in Utopia Planitia. Map based on craters with D < 5 km.

Discussion: Our LDM thickness estimation showed, that on average the material filling out LDM is between 600 and 1000 m, but in certain areas of Utopia Planitia, it could be up to 1500 m.

The results obtained in this study significantly exceed previous estimations. They varied from several [1][9] (~10 m locally on ridges [2]), through several dozen (tens of meters at lower latitudes [6]) to hundreds of meters (up to ~170 m locally, as derived from SHARAD data [7]). However, all those methods were focused on estimating minimal thickness of LDM or were the most sensitive to the near-surface zone.

Method limitations: Much higher LDM thickness estimation obtained in this study may also be an effect of the method's limitations.

1) The main limitation of our method is that we are unable to distinguish if the difference in the expected and measured crater depth is caused only by the crater being filled with LDM, or if there is also a contribution from other crater filling materials (impact melt, mass wasting due to crater age, possible lake/ocean deposits). Because of that, our LDM thickness are maximal possible values.
2) The average thickness of the LDM in the craters is higher than on the surrounding planes because craters serve as sediment sinks and they limit erosion inside. Again, this would mean that our estimates represent the upper limit of the LDM thickness.
3) Basing the rim and floor elevation measurement on a single MOLA track significantly increases the uncertainty of the estimation. It would be possible to create complete crater DEMs i.e. from CTX stereopairs, but that would greatly increase time needed for a big scale research. In the current update of this study (only on craters with D > 5 km) we will use a new JMars function "profile viewer" with HRSC MOLA blended DEM 200m v2 as a numeric data source to limit this problem.
4) Different ages of craters also may cause distortions in the results. A low LDM thickness may be caused by the crater being younger than the other craters and thus being exposed to fewer mantling cycles. There are a couple of cases where pairs of similarly sized craters of apparent different age have a different level of filling in. Crater counting dating of those craters may provide us with the ages of different phases of LDM development.
5) Craters with small diameters (<5km) were often filled with material nearly in 100%, and this may have caused artificial lowering of thickness values, especially when present near larger craters. For the purpose of this abstract, we chose to present only the map derived from craters with D > 5 km (Fig. 3).
6) The spatial distribution visible on the map is the effect of interpolation algorithm, that depends on the availability of craters of a certain size in the area. Those results should be interpreted carefully.

Spatial distribution of LDM: Curiously, no direct correlations between latitude, geology, and LDM thickness were observed. Instead, there is a clearly visible belt of high estimation values in the center of the research area, heading from South-West to North-East. This trend may be worth further investigation and verification by further development of the impact craters database.

References: [1] Kreslavsky M. A. and Head J. W. (2002) *Geophysical Research Letters*, Vol. 29, Issue 15. [2] Dickson J. L. et al. (2014) *LPS XXXXV*, Abstract #1680. [3] Laskar J. et al. (2004) *Icarus*, Vol 170, Issue 2, 343 – 364. [4] Balme M. R. et al. (2013) *Progress in Physical Geography* ,Vol. 37, Issue 3, 289 – 324. [5] Kerrigan M. C. (2013) *Electronic Thesis and Dissertation Repository*, 1101. [6] Levy J. S. et al. (2009) *Icarus*, Vol. 206, Issue 1. [7] Stuurman C. M. (2016) *Geophysical Resource Letters*, Vol. 42, Issue 18, 9484 – 9491. [8] Pike R. J. (1974) *Geophysical Research Letters*, Vol. 1, Issue 7. [9] Mustard J. F. (2001) *Nature*, Vol. 412, 411 – 414.