EVIDENCE FOR RECENT TROPICAL SUBSURFACE ICE ON MARS FROM AGES OF SINGLE-LAYERED EJECTA CRATERS

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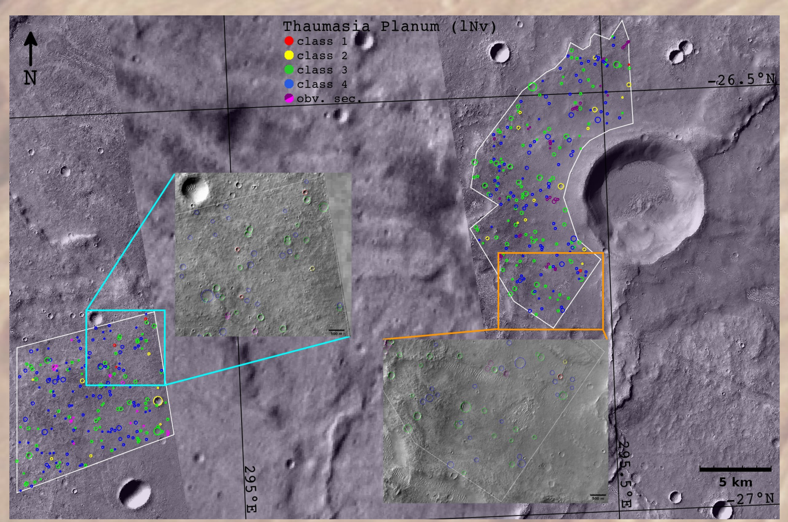
Introduction

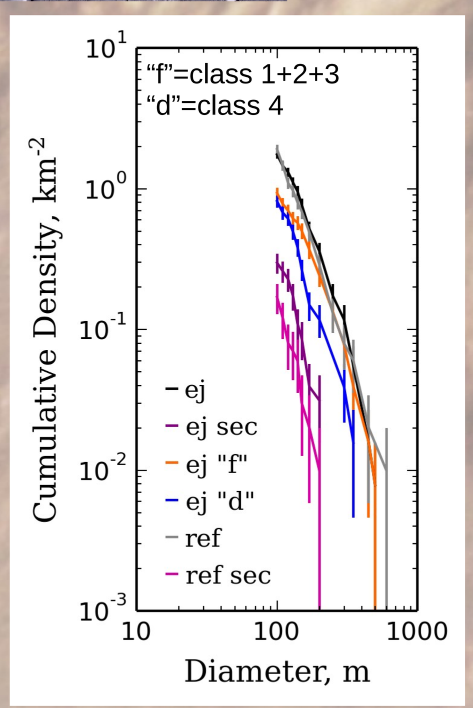
The evolution of subsurface tropical ice on Mars is vital to understanding the history of volatiles and implications for climate and geology. Ice is presently not stable at equatorial latitudes [e.g., 1] and the time-integrated loss is unknown [2, 3]. Layered ejecta craters have long been thought to tap buried ice [e.g., 4] and can sample to greater depths (kms) – necessary at low latitudes – than possible with neutron spectroscopy or even surface-penetrating radar. With the advent of near-global 10-m imaging of Mars, individual craters can be dated from smaller craters superposed on their ejecta blankets [e.g., 5]. We have begun estimating model formation ages of single-layered ejecta (SLE) craters throughout Mars' tropical region. We focus on SLE craters because of their prevalence at these latitudes. Analyzing ages of these craters promises a 4D reconstruction of buried ice on Mars where it is presently unstable at the surface.

Methods

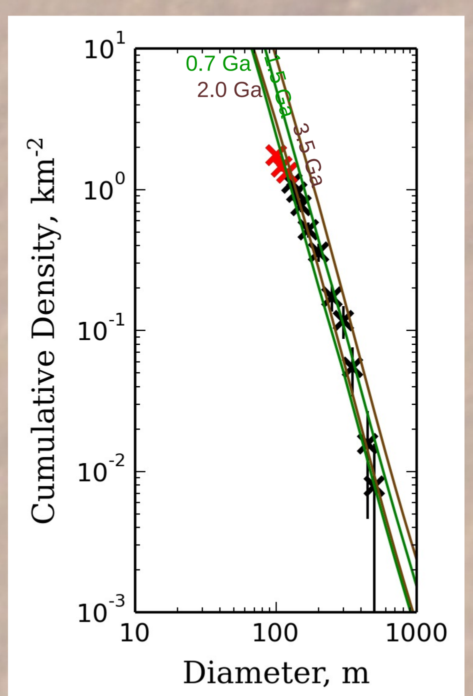
- Selected 206 SLE craters from the Robbins [6] database within ±30º latitude with diameter (D) ≥5 km and MRO CTX coverage
- Measure smaller craters superposed on SLE crater ejecta and in a nearby region on the same geological unit
  - Assign degradation class 1 (freshest) to 4 (most degraded) and identify obvious secondaries in clusters and chains



- Compare SLE (ej) and region (ref) crater size-frequency distributions (SFDs) to assess what diameters were potentially modified by erasure, secondary contamination, or older craters partially buried by ejecta. This example shows possible crater removal for D<130 m indicated by the slight roll-over and increased density of degraded craters ("d"). Low density of obvious secondaries (sec) suggests contamination is minimal. High density of fresh craters ("f") for D>200 m indicates partially buried craters are not likely an issue.



- Estimate model formation age for the SLE crater through fitting the Neukum [7] (brown) and Hartmann [8] (green) production functions to the superposed crater SFD, avoiding affected diameter ranges (shown in red)



References: [1] M. T. Mellon, et al., *JGR* 102, 19357–69, 1997. [2] S. M. Clifford & D. Hillel, *JGR*. 88, 2456–74, 1983. [3] R. E. Grimm & S. L. Painter, *GRL* 36, L24803, doi: 10.1029/2009gl041018, 2009. [4] M. H. Carr, et al., *JGR* 82, 4055–65, 1977. [5] D. Reiss, et al., *MAPS* 41, 1437–52, 2006. [6] S. J. Robbins & B. M. Hynek, *JGR* 117, E05004, doi: 10.1029/2011JE003966, 2012. [7] G. Neukum, et al., *SSR* 96, 55–86, 2001. [8] W. K. Hartmann, *Icarus* 174, 294–320, 2005. [9] H. J. Melosh, *Impact Cratering: A Geologic Process*, 1989. [10] P. Mouginis-Mark, *JGR* 84, 8011-8012, 1979.

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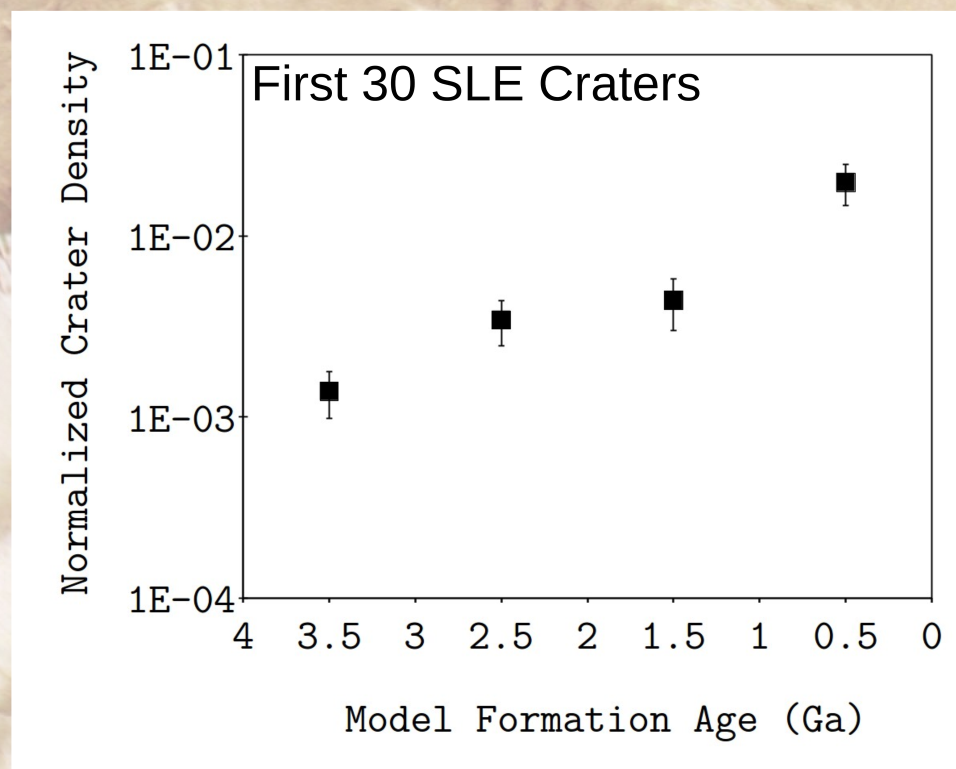
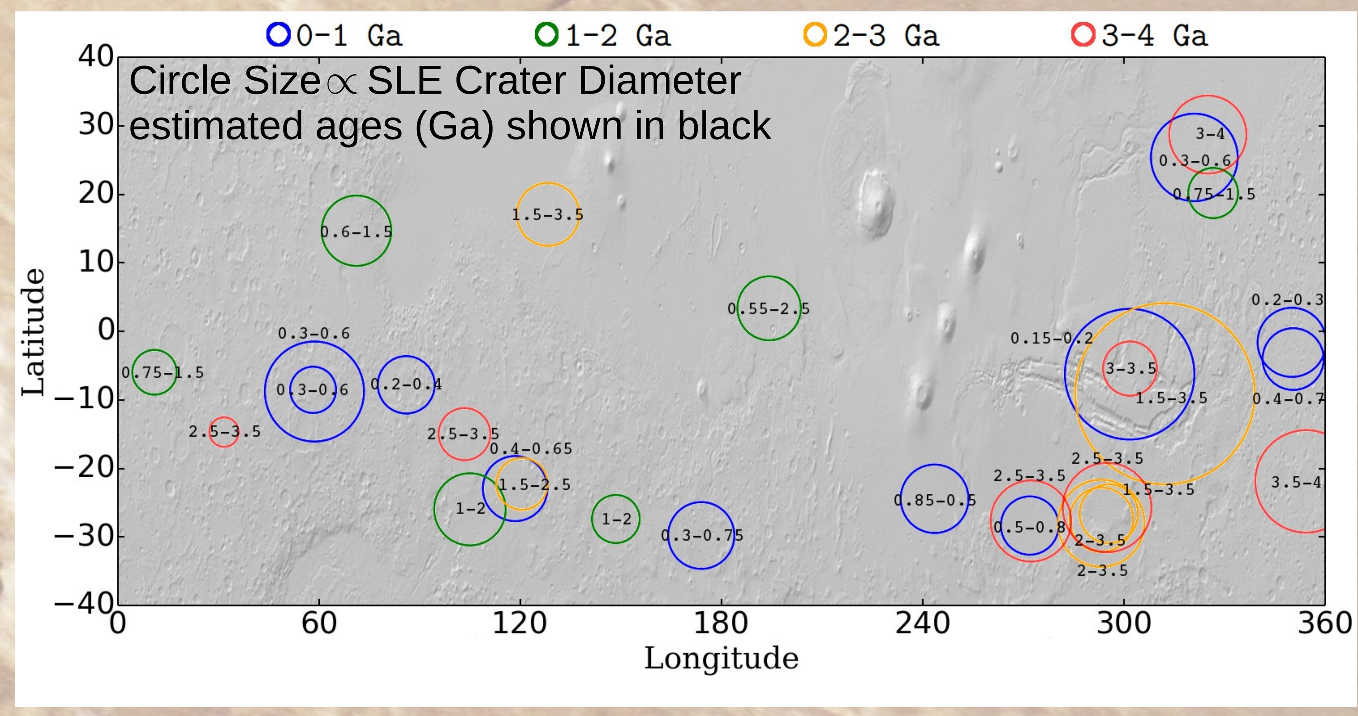
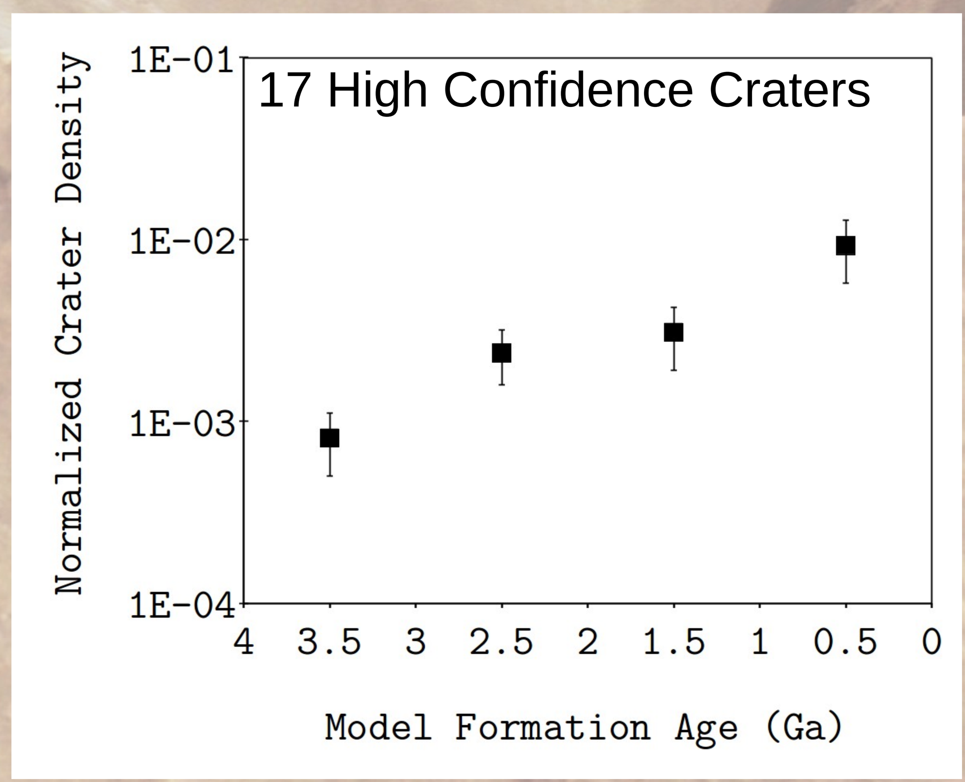
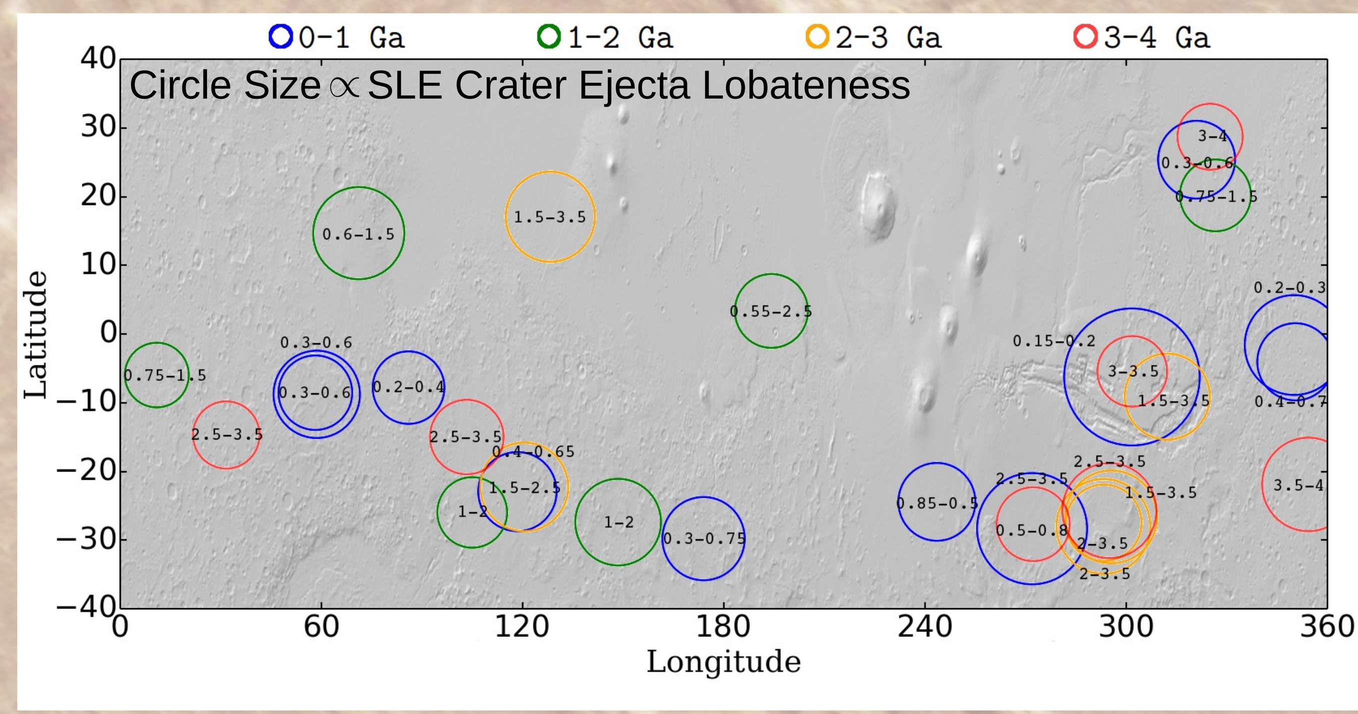
Preliminary Results









- SLE crater density with time normalized to Neukum impact flux [7]
- Expected trends: flat if subsurface ice stable; negative-sloped if ice decreasing
- Find positive slope & several ages <1 Ga for first 30 craters (top)
- Potential causes: (1) some ages are resurfacing ages; (2) SLE crater ejecta destroyed faster; (3) ice recently cold-trapped at shallower levels due to vapor diffusion
- Analyze a subset of SLE craters with little evidence for resurfacing (17), such that ages have "high confidence" of being formation ages (bottom)
- Trend flatter, but still positive => resurfacing partly the answer, but other causes plausible & ice is preserved at tropical latitudes

- Top: Diameter is a proxy for max depth to ice: d_{ice}=(0.05-0.07)D [9]
- Bottom: Lobateness is a proxy for ice abundance: higher lobateness = higher abundance [10]
- For the first 30 craters:
  - No clear trend for location or depth to ice with time
  - Craters with largest lobateness are all <1 Ga and within 0 to -30ºN and 270 to 360ºE => ice abundance may have increased toward the present in this region
- Trends similar for the "high confidence" age subset (not shown)
- Trends for Hartmann flux [8] similar (not shown); however, ages younger by a factor of 2

Conclusions

- We have discovered young SLE craters (< 1 Ga) at tropical latitudes on Mars indicating the presence of subsurface ice at < 1 km depth.
- More young SLE craters are found than predicted from impact rates. This could be due to resurfacing of superposed craters or entire ejecta blankets. Alternatively, ice could have migrated to shallower depths due to cold-trapping.
- Young SLE craters with high lobateness indicate subsurface ice abundance may have increased regionally toward the present.
- Continue to analyze the rest of the 206 selected SLE craters to tighten constraints.

Background Image: 20-km SLE crater located in Hephaestus Fossae (21ºN,237ºW); Mars Express HRSC ESA/DLR/FU