Lunar Polar H_2O Ice

A Terrain Classification System

Lunar Polar Water Ice: A Terrain Classification System and Optimal Sites for Moon Exploration

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Introduction:

- Water ice is potentially present on the Lunar poles in PSRs [1, 2]
- Considerable interest for understanding the history and distribution of volatiles in the Solar System, role of volatiles in the evolution of the Earth-Moon system, and as a potential resource for human space exploration [3]
- We propose a terrain classification system in order to organize terrain units on the lunar poles for use in future scientific studies and characterizing operational conditions

Classification System Overview

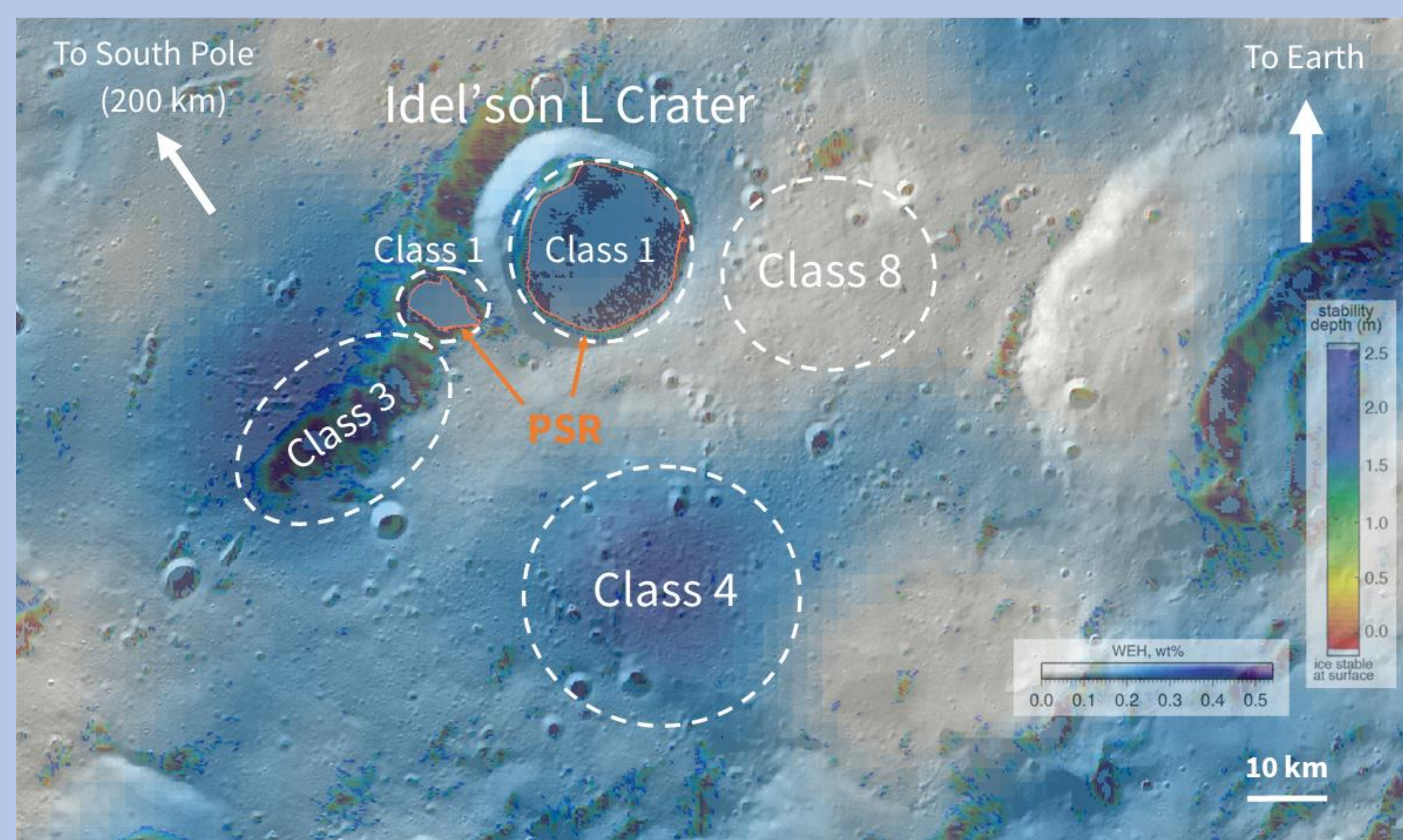
- Classification system distinguishes between eight permutations of three variables:
  - Whether or not there are detections of WEH within top 1 m of regolith
  - Whether terrain is inside or outside a PSR
  - Whether or not thermodynamic stability models predict H_2O ice to be stable within top 1 m of regolith
- System utilizes three main datasets:
  - WEH concentrations derived from LRO LEND data with 10 km resolution [4]
  - Thermodynamic model predicting H_2O ice stability derived from LRO Diviner data [5]
  - PSR locations derived from LRO LOLA data [6]

Additional Parameters and Subclasses:

- Proposed classification system can be expanded into more classes and subclasses
  - Classes 3 & 4, located outside the PSRs with concentrations of WEH, have wide ranging illumination conditions. Given the full lunation duration of 29.5 Earth days, subclasses of terrains with different fractional amounts of insolation time could be distinguishable. For longer insolation durations, H_2O ice stability depth would increase, but solar powered missions might operate at lower risk in such areas.

Classification of H_2O Ice Deposits

	1	2	3	4	5	6	7	8
WEH detected w/in top 1 m [4]	Y	Y	Y	Y	N	N	N	N
Located w/in a PSR [6]	Y	Y	N	N	Y	Y	N	N
Predicted stable w/in top 2.5 m [5]	Y	N	Y	N	Y	N	Y	N

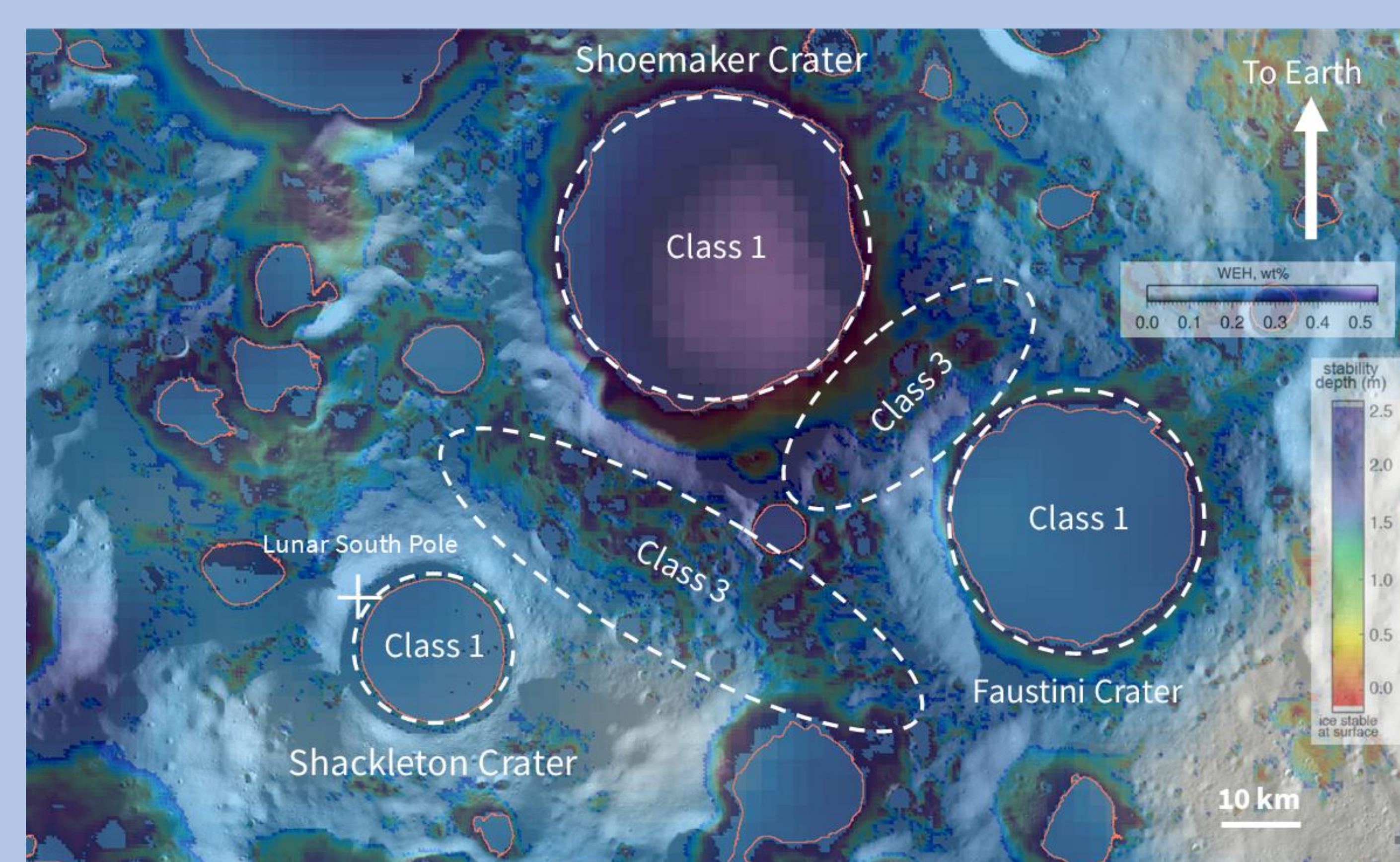


Case Study #1

- Region Surrounding Idel'son L Crater
  - Centered at 84.2°S, 115.8°S, just behind lunar limb
  - Occasionally in view of Earth due to libration
  - Presents examples of Class 3 and 4 terrains optimal for early exploration

Case Study #2

- Region Surrounding the Lunar South Pole
  - Large Class 1 and 4 regions within and surrounding Shoemaker Crater
  - Class 1 site within NASA Artemis target Shackleton Crater



Conclusions

- Allows the complex relationship between H detection, PSRs, and modeled H_2O ice stability to be organized and mapped
- Aids in understanding the origin, age, and 3D distribution of H_2O ice at the lunar poles
- Supports optimal site selection for future robotic and human exploration
- The spatial scale of terrain class occurrence dictates future missions should explore wide ranges (>100km) to encounter a broad sampling. Mission concepts such as JPL's highly mobile GlobeTrotter soft hopper could meet such requirements [10]

Future Terrain Classification System Evolution

- Additional datasets/criteria could be incorporated into future versions of the classification system
  - UV/IR Reflectance [7-9]
  - Solar Illumination Duration
  - Radar and Polarization
  - Terrain Roughness
  - Slopes
  - Direct-to-Earth Comms Visibility

Optimal Terrain for Early Exploration

H_2O ice deposits in the lunar polar regions do not map identically with the PSRs. Class 3 and 4 Terrains encompass the areas presenting H detections within the top 1 m of the regolith *and* are non-PSRs. Although Class 3 and 4 Terrains include areas remaining shadowed for substantial fractions of a lunation, some sites receive so much solar illumination that H_2O ice is disallowed by the Diviner model down to depths of more than ~1 m and yet LRO LEND detects H within the top 1 m. This discrepancy between observed distribution of H_2O ice and model "predictions" may be due to imperfections in the model and/or the possibility that some of the H_2O ice detected is relict, representing thermodynamic stability conditions that were different in the past [5]. Although WEH concentrations in Classes 3 and 4 are generally lower than in Class 1, Classes 3 and 4 cover substantial areas and represent a significant fraction of the H_2O ice within the top 1 m of the regolith at the lunar poles. Because non-PSRs may present exploration conditions that are less constrained (more forgiving temperature and power-wise) than PSRs, Class 3 and 4 terrain may offer optimal opportunities for early phases of near-surface H_2O ice exploration on the Moon.

Acknowledgments

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