A European Perspective on ROI for Lunar Volatile Investigations

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The present work was party presented as an appendix to the 'European response to the recent Lunar Exploration and Analysis Group (LEAG) Volatiles Special Action Team (VSAT) report on lunar volatiles' – A report of advisory team under the umbrella of the ESA's Topical Team on Exploitation of Local Planetary Materials (TT-ELPM).

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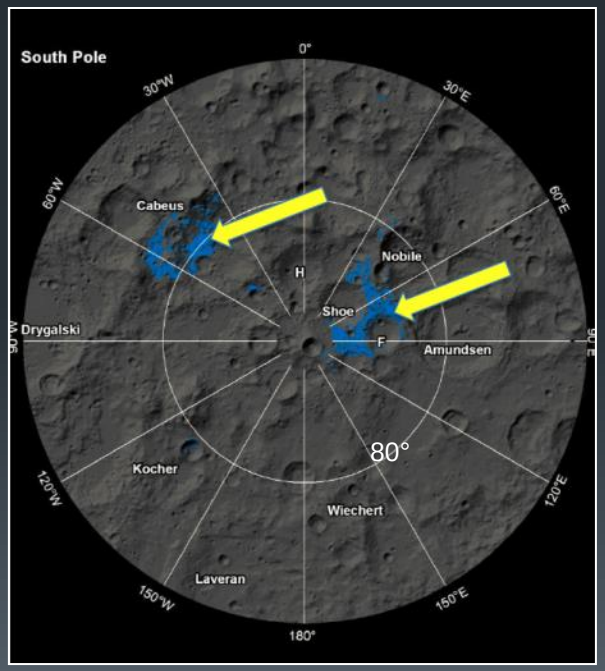
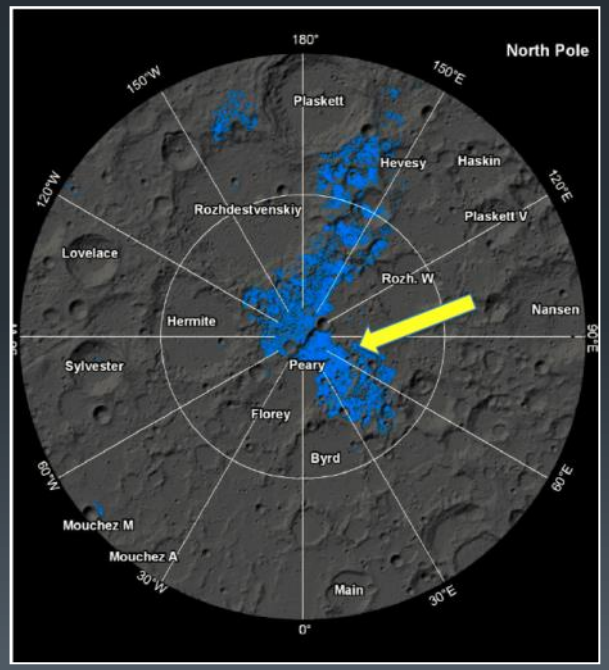
Context

- In December 2014, the LEAG VSAT produced a report in which they highlight three lunar polar areas [Cabeus/Shoemaker/Peary] of significant extent that fulfill the VSAT charter to identify regions “where NASA and international / commercial partners could operate on the lunar surface in a cooperative manner to further understand the size, distribution, form, and resource potential of deposits of water ice and other volatiles.”





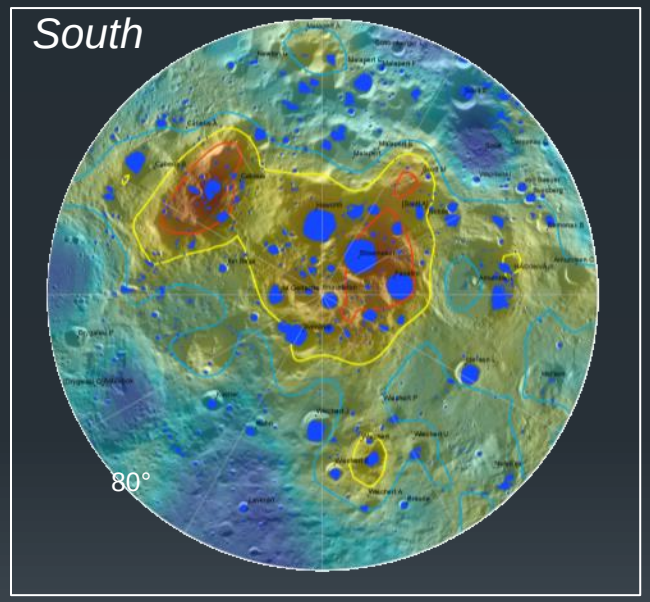
Criterias:

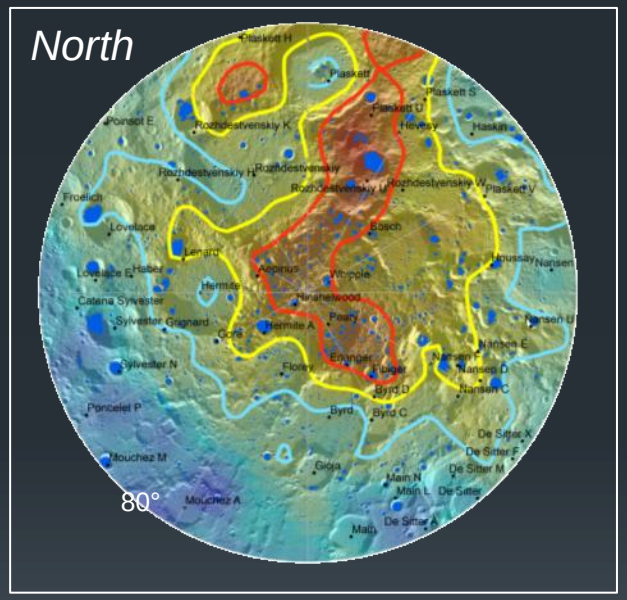
- *Avg, min and max surf T*
- *H concentration*
- *Slope*
- *Lighting conditions*
  - *Duration of illumination*
  - *Permanent shadow*
- *Direct to Earth communication potential*

- In September 2015, ESA’s TT-ELPM provided a review of this report.

Context

- In its reponse, ESA's TT-ELPM agrees with substantial parts of the LEAG VSAT report. However, the team recommended that additional work should be carried out regarding landing sites, taking into account an additional enlarged set of parameters + potential additional science benefits.





Lunar Prospector hydrogen maps

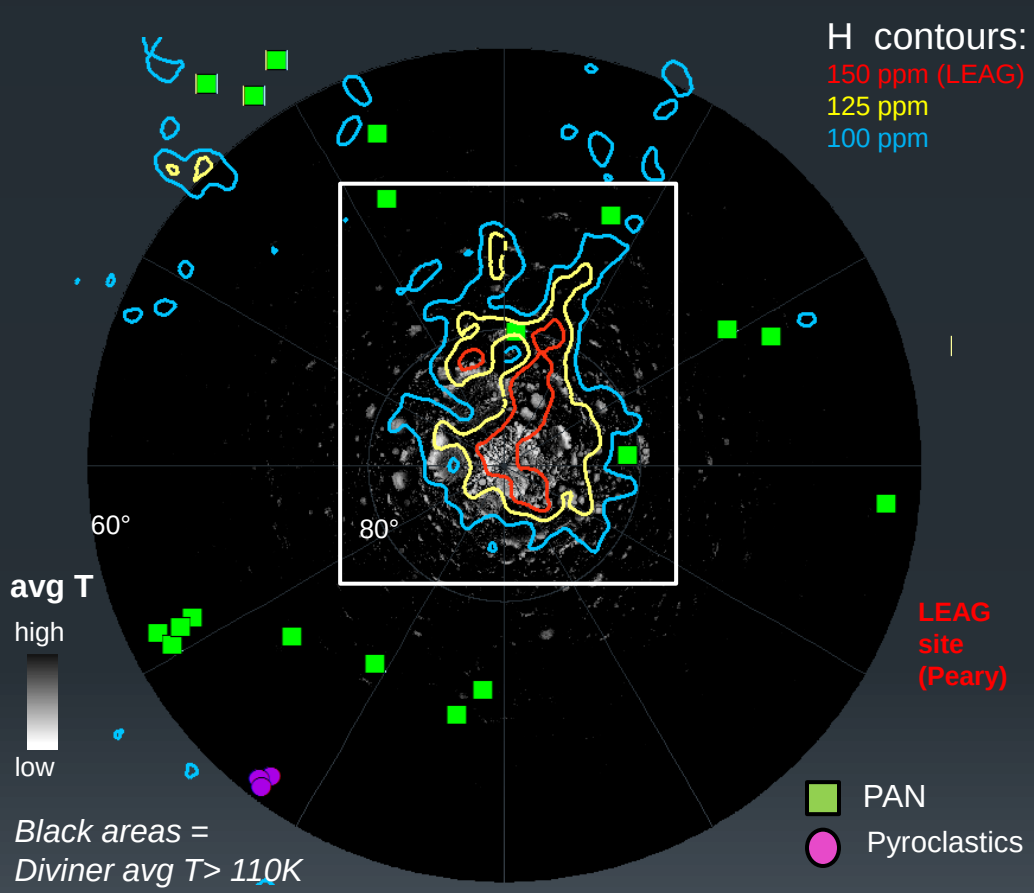
H contours:
150 ppm (LEAG)
125 ppm
100 ppm

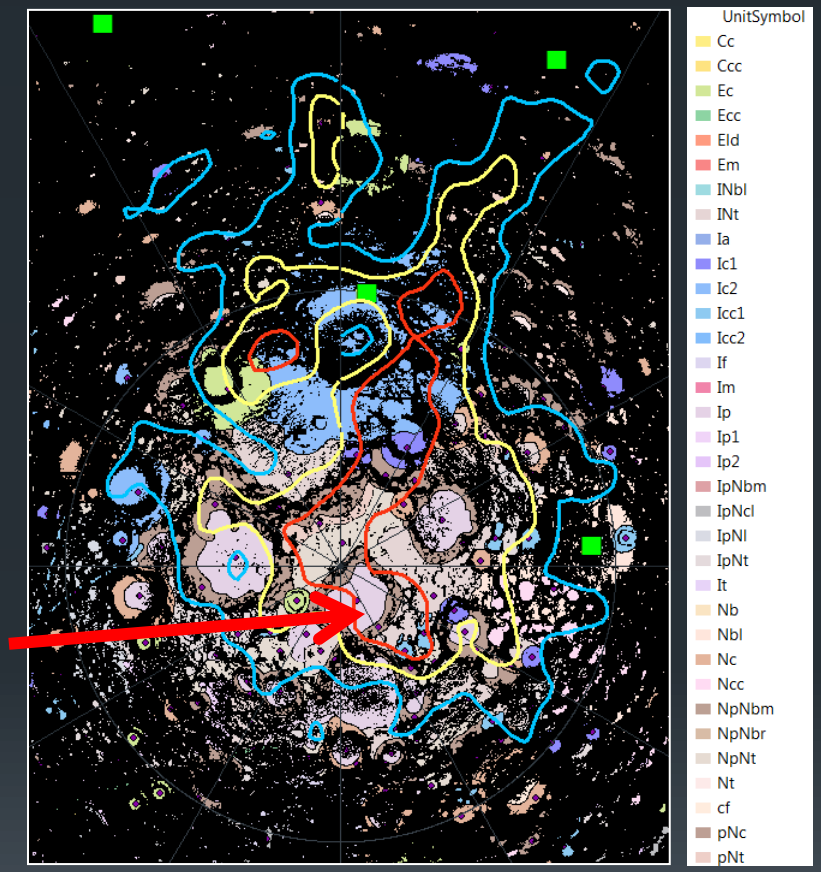
PSR

<u>For example:</u>

- *decreasing the H content threshold to >125 ppm increases the number of available sites in both polar regions,*
- *relaxing the direct-to-Earth and illumination constraints (which are mission dependent) also results in a higher number of potential sites.*

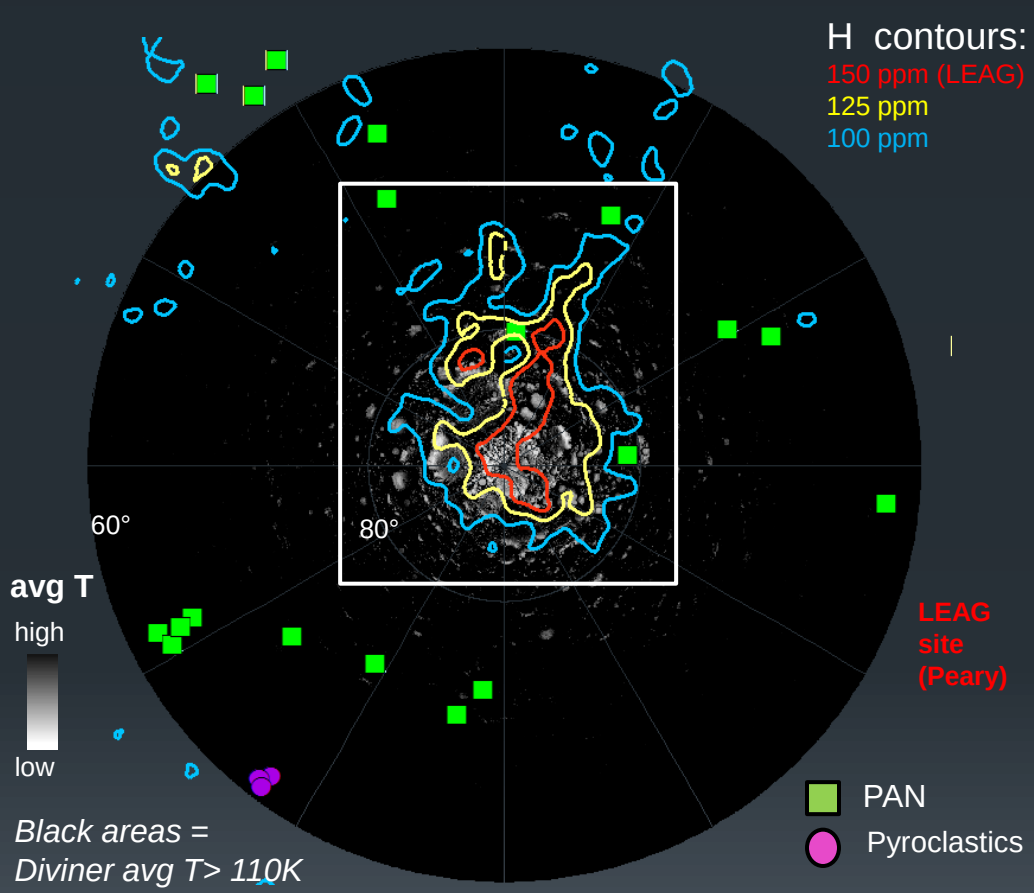
North Pole potential ROI



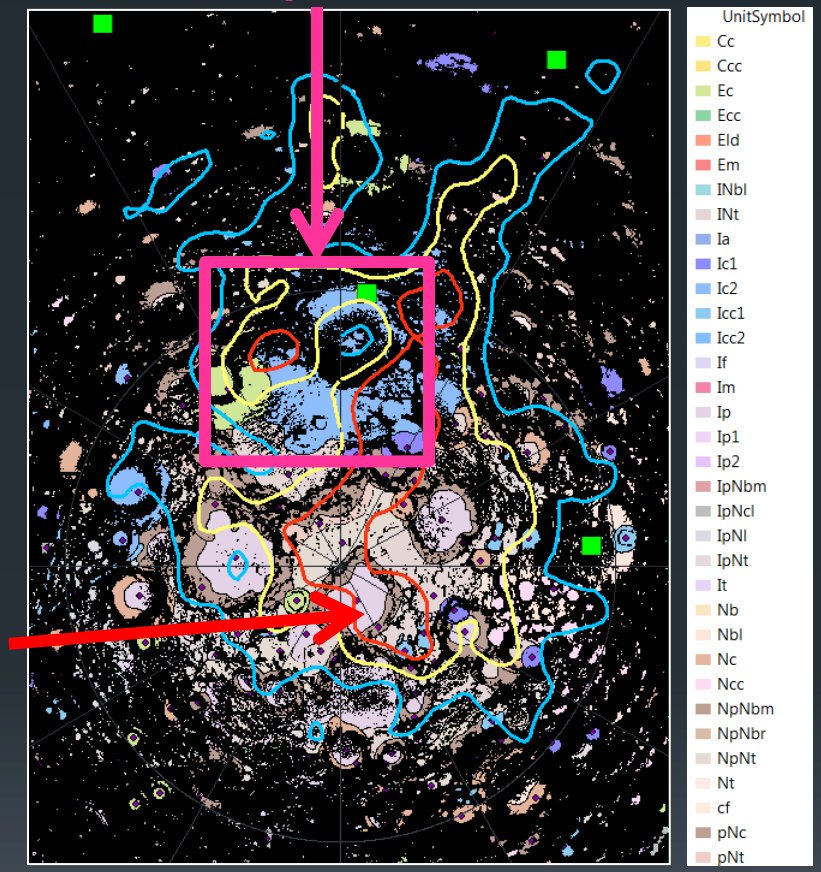


- High H abundance and low average T areas extend below 80° in latitude,
- Additional science benefits are possible at some sites (e.g., sample young geological units, orbital PAN detection…)

North Pole potential ROI



example on next slide



- High H abundance and low average T areas extend below 80° in latitude,
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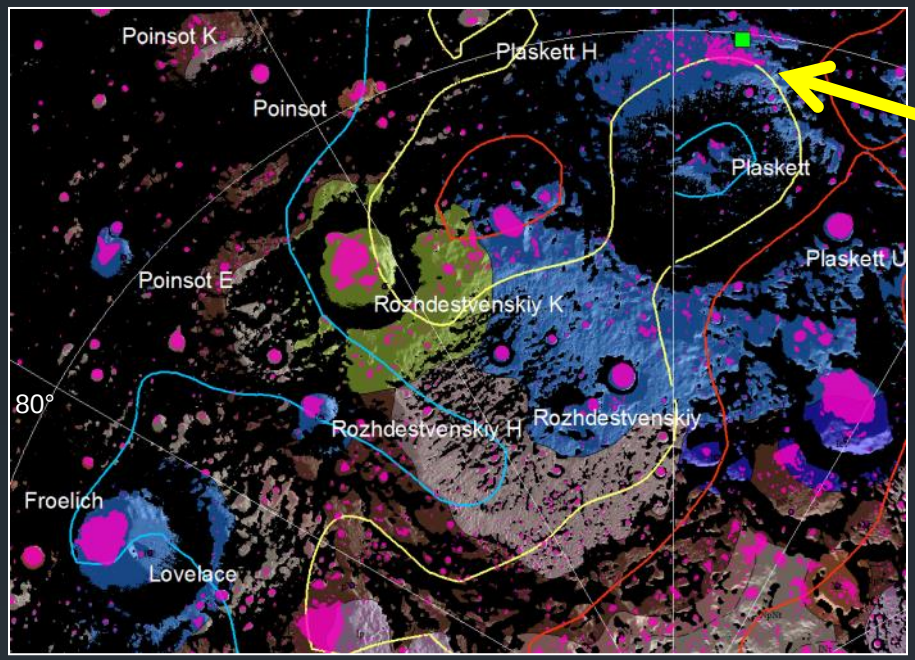
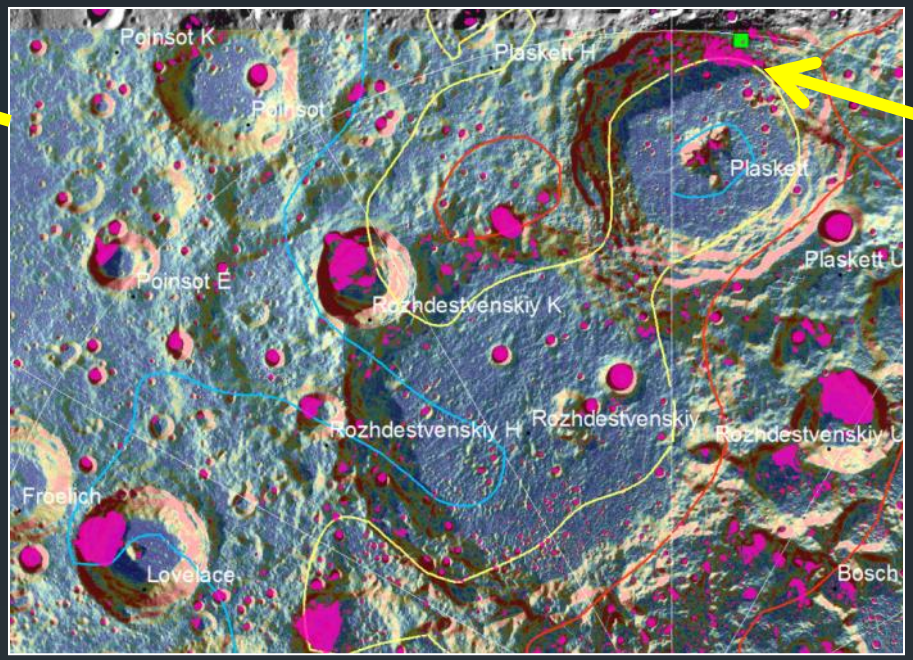
The Plaskett/Rozodestvenskiy region



Black areas = Diviner avg T> 110K, background = geol. map



LOLA 20m slope map (rainbow scale, red = above 20°) overlain on the N pole LROC/WAC mosaic.

PAN

PSR

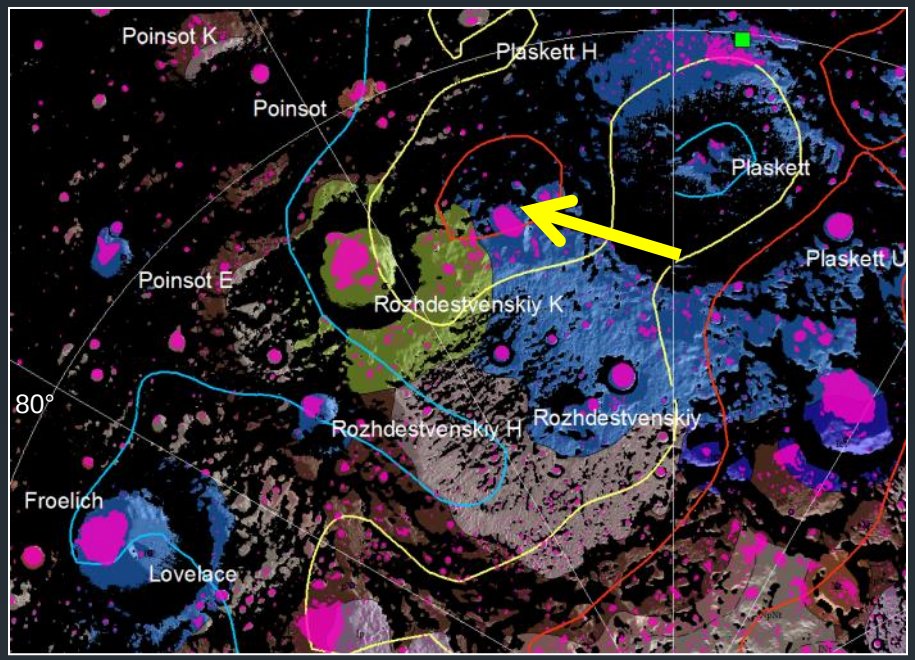
H contours:
150 ppm (LEAG)
125 ppm
100 ppm

slope

Ex 1: S wall of Plaskett crater:

- 125 < H < 150 ppm
- Avg T< 110 K
- Accessible PSR
- Low slopes
- Late Imbrian material
- SELENE PAN detection (Ohtake et al., 2010)
- Exposed central peak 50 km apart
- Illumination > Peary

The Plaskett/Rozodestvenskiy region



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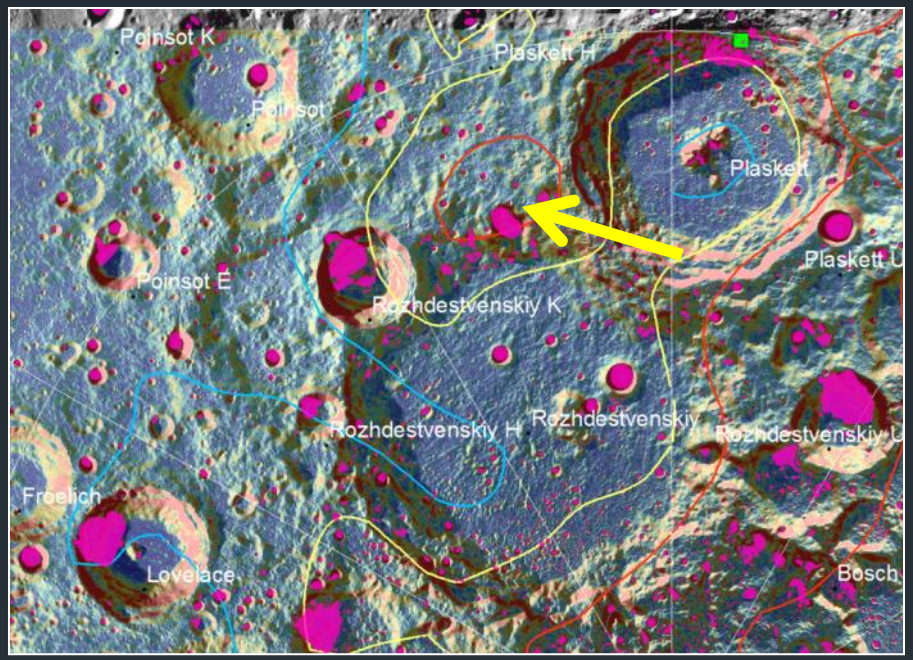


LOLA 20m slope map (rainbow scale, red = above 20°) overlain on the N pole LROC/WAC mosaic.

PAN

PSR

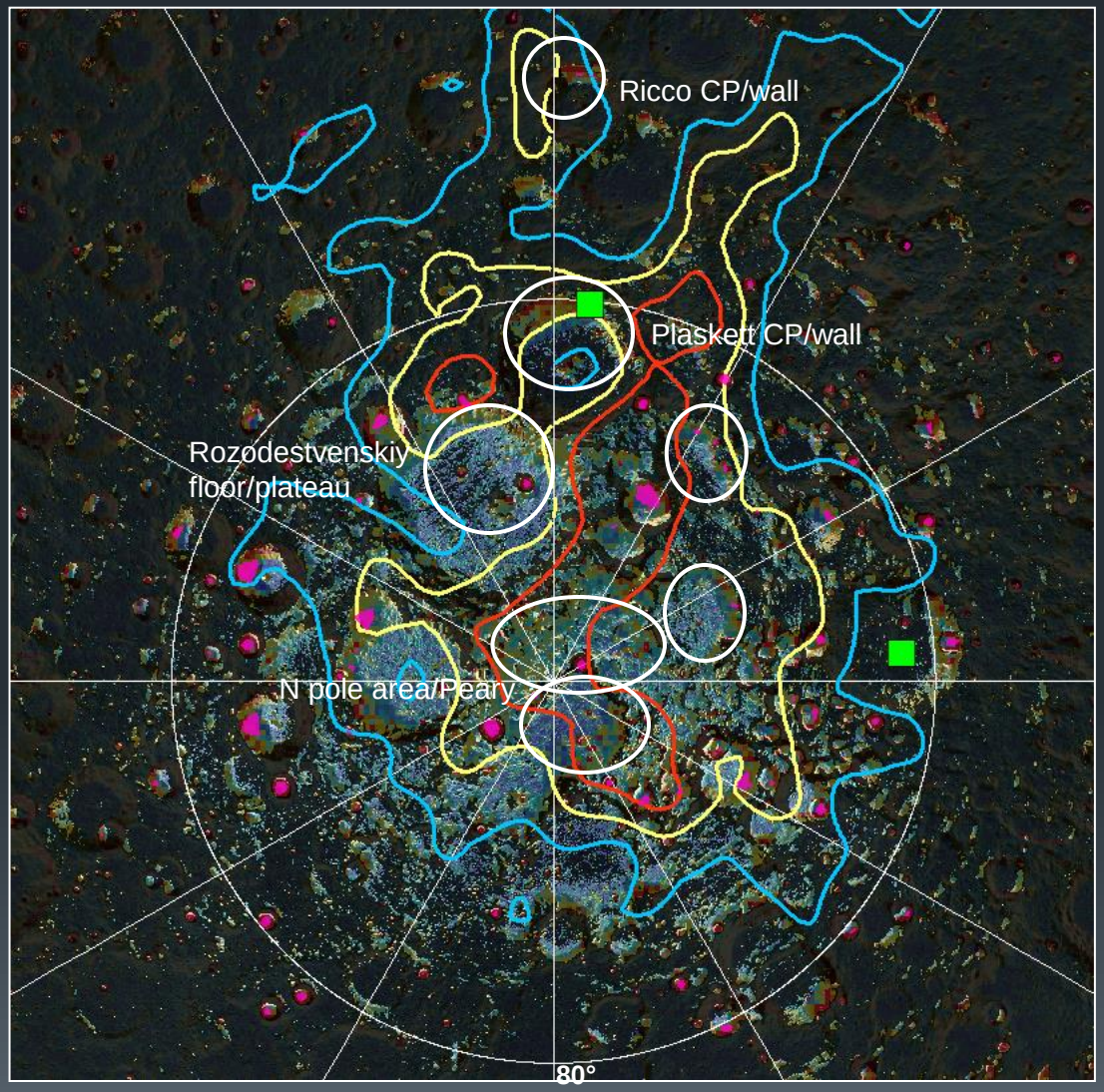
H contours:
150 ppm (LEAG)
125 ppm
100 ppm

slope

Ex 2: plateau SW of Rozodestvenskiy

- 150 ppm < H
- Accessible PSR
- Eratosthenian material
- Earth visibility ~0.2-0.3
- Avg T<110 K et < 54 K in several locations
- Low slopes
- Illumination > Peary ~0,4-0.5

North Pole potential ROI: summary

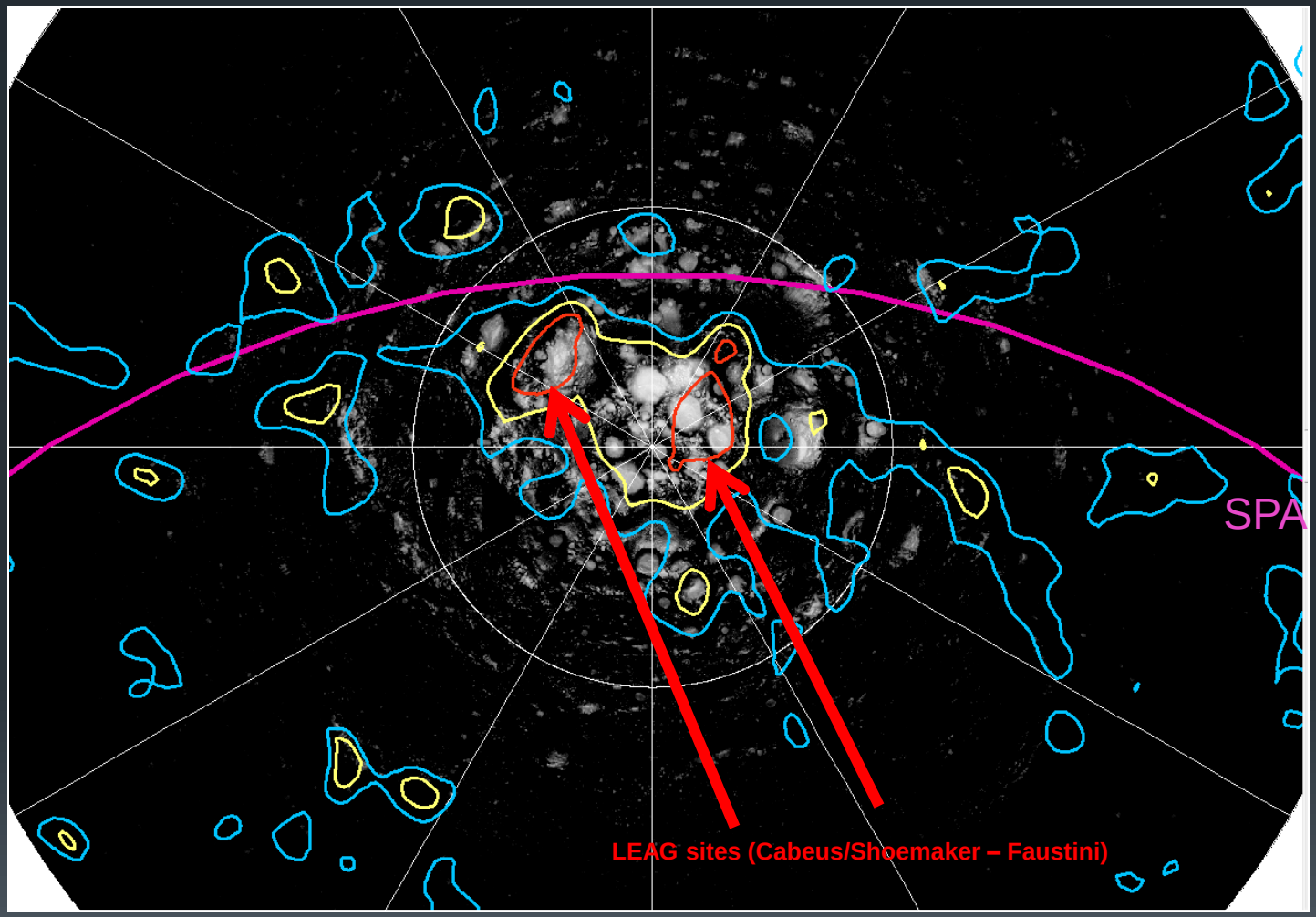


PAN H contours: 150 ppm (LEAG), 125 ppm, 100 ppm PSR slope

Background: LOLA slope map/WAC mosaic. Blackened= avg T>110K

- ROI (H-rich regions) extend beyond 80° in latitude,
- Lowering H to > 125 ppm or relaxing the direct-to-Earth communication constraint significantly increases the number of potential ROI (most ROI are located on the farside),
- Additional science benefits are possible at many of those ROI sites (e.g., sampling of young geological units).

South Pole potential ROI



Black areas =
Diviner avg T> 110K

avg T

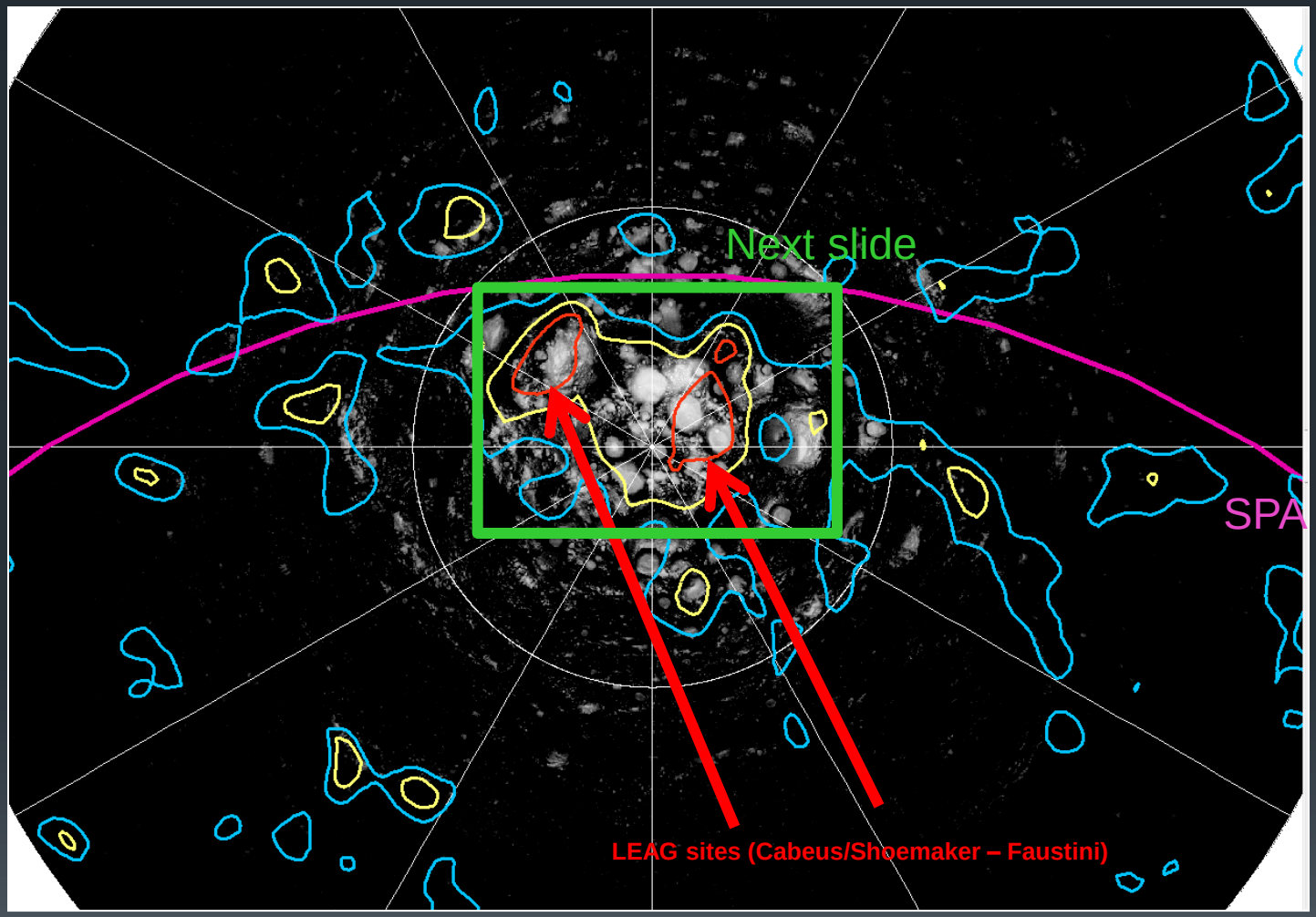
+

-

H contours:
150 ppm (LEAG)
125 ppm
100 ppm

- Reducing H to > 125 ppm increases number of potential ROI (e.g., Admunsen crater)
- Relaxing direct-to-Earth communication/illumination constraints does not increase much the number of potential ROI (nearside).

South Pole potential ROI



Black areas =
Diviner avg T> 110K

avg T

+

-

H contours:
150 ppm (LEAG)
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100 ppm

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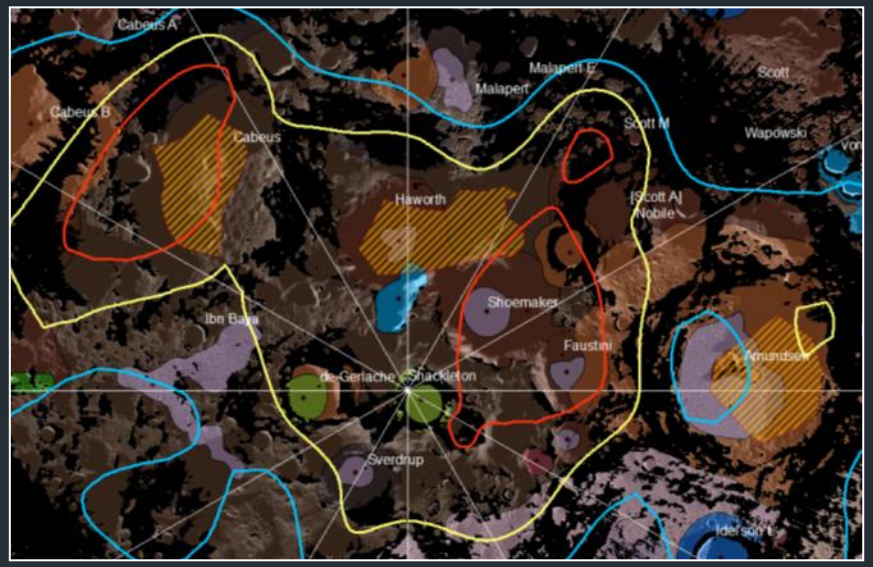
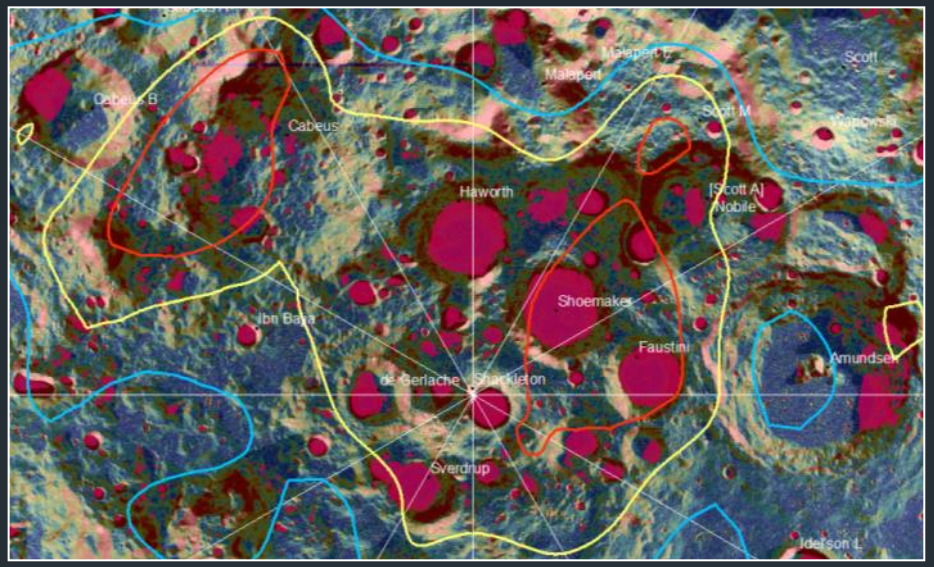
The South Pole region



Black areas = Diviner avg T> 110K, background = geol. map
Diviner avg T< 54 K



LOLA 20m slope map (rainbow scale, red = above 20°) overlain on the N pole LROC/WAC mosaic.

slope

PSR

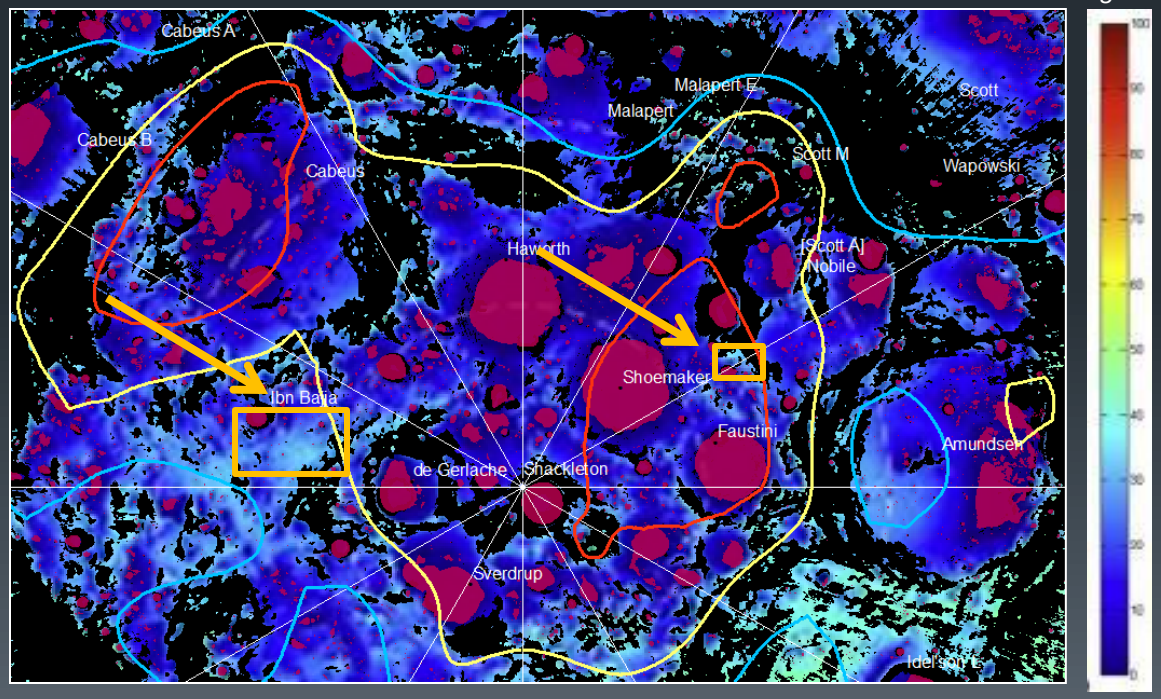
H contours:
150 ppm (LEAG)
125 ppm
100 ppm

- A large area around the SP with H >125 ppm and avg T< 110 K,
- Slopes can be high / accessibilty to PSR is more limited,
- 3 wide areas with T< 54 K: Amundsen, S Cabeus, Haworth,
- Good Earth visibility at most sites (nearside),
- Limited illumination.

Specific landing site/ROI selection is highly dependent on the mission objectives and requirements.

South Pole potential ROI for ESA's Prospect Rover

- <u>Mission objective:</u> Determine the distribution of water and other volatiles on a local scale.
- <u>Requirements:</u> Mobile range of 50 km, illumination fraction >0.25, direct-to-Earth communication, etc…

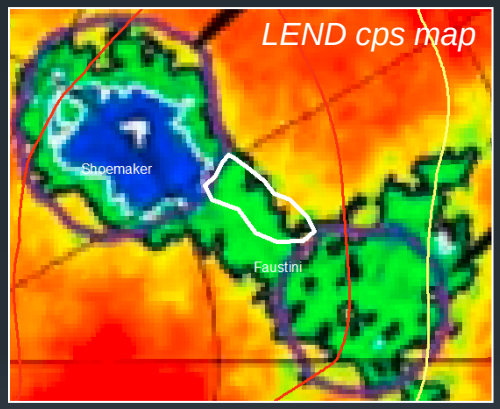


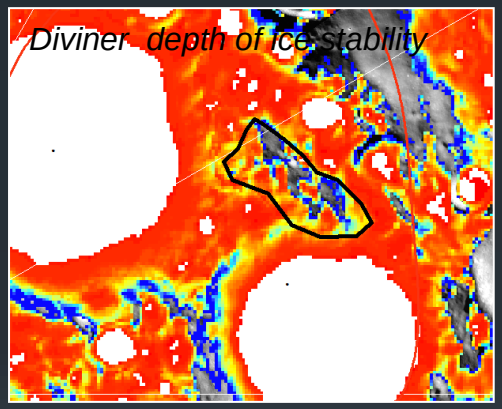
Black areas = Diviner avg T> 110K and/or slope >20°
Background = avg illumination over a 18.6 yrs cycle (Mazarico et al., 2011)

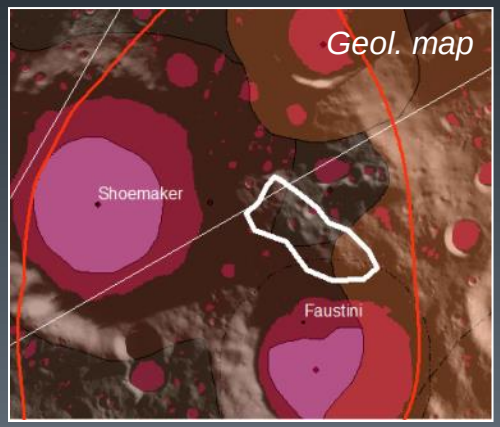
- Illumination conditions are the main driver for the site selection here
- At least 2 potential ROIs:
  1. Topographic high between Shoemaker/Faustini
  2. Imbrian plain south of Ibn Bajja

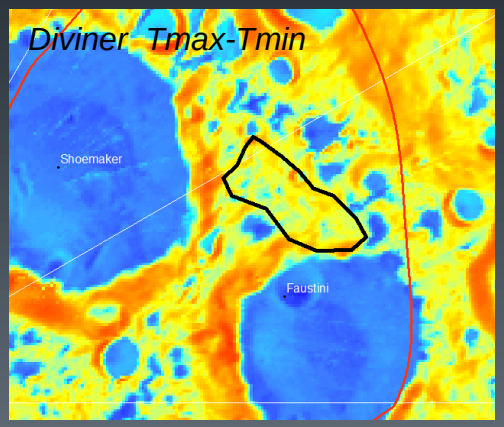
ESA's test site 1

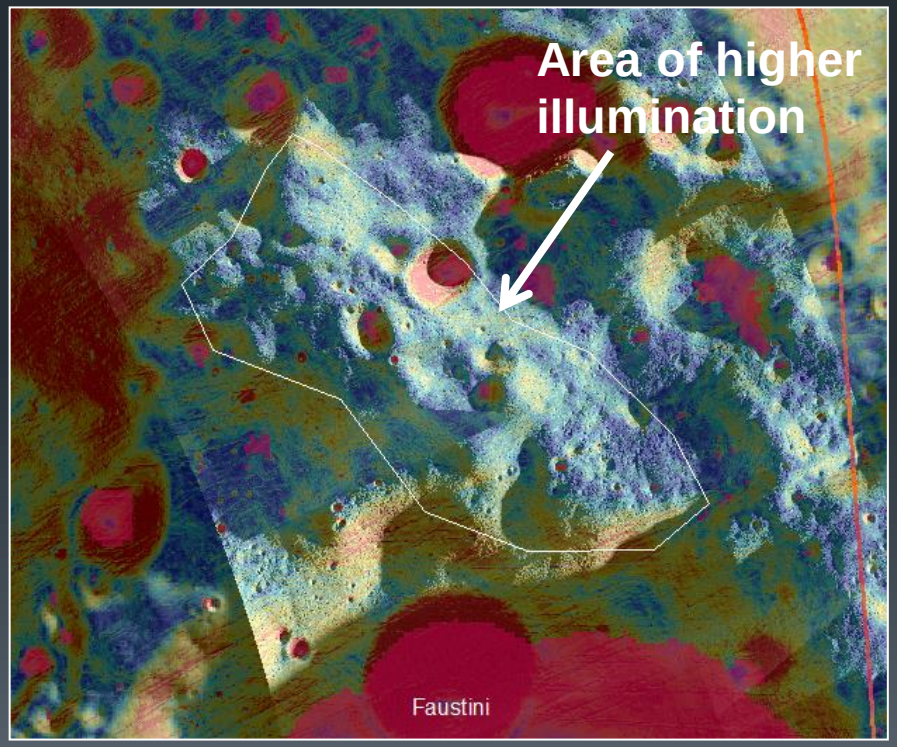
- In addition to fullfilling scientific constraints + mission requirements, site is:
  - located at a geologic triple point
  - located at the limit of LEND H detection
  - located within an area where various ice stability depths are predicted/ Diviner Temperature is spatially variable.











LOLA 20m slope (red= >20°) / LROC NAC 1m polar mosaic

slope

Datasets and Credits

- Hydrogen content (Lunar Prospector, PDS)
- Bolometric Temperature, avg, min, max (Diviner, PDS) + courtesy of the Diviner team/ P. Williams
- PSR (LOLA, MIT) *Mazarico et al., 2011*
- Slope (LOLA, PDS + ArcGIS; LPI Lunar Interns)
- Illumination (LOLA, MIT). *Various alternative maps are available (LAMP, WAC… cf. Bussey et al., Nova et al., …). We used here the maps of Mazarico et al., 2011*
- Earth visibility (LOLA, MIT) *Mazarico et al., 2011*
- Geologic maps (USGS, Renovation 2013) *Fortezzo and Hare, 2013*

LEAG and ESA TT-ELPM reports available at:
http://lunarvolatiles.nasa.gov/knowledge-capabilities/lunar-volatiles-knowledge/

See also the work of the LPI interns Concept 4 team /CLSE Global Lunar Landing Site Study:
http://www.lpi.usra.edu/exploration/CLSE-landing-site-study/

Many thanks to all the instrument teams for making their data available!

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