Atypical Small Crater Morphology in the Shackleton PSR: Indicative of Subsurface Volatile Destabilization?

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Background

- The Shackleton crater is a 21 km diameter crater near the lunar south pole that contains a large Permanently Shadowed Region (PSR) [1-3]
- The temperatures in the PSR are low enough to cold trap volatiles such as water ice
- 2 m/pixel resolution image mosaic [4] from the ShadowCam instrument on the KPLO spacecraft were analyzed and small craters (30-100 m in diameter) showed unusual crater floor morphologies
- We suggest that post impact-induced destabilization of subsurface volatiles may have disturbed the crater floor material as volatiles escaped to space
- The described features are at the transition from the steeply sloped crater wall to the flatter older hummocky crater floor terrain

Methods

- We observe the morphology of the small craters on the Shackleton crater floor in ShadowCam imagery (Figs. 1 and 2)
- We calculate the current thermal environment of the Shackleton crater, using our previous work's thermal model methods and values for the regolith and mega-regolith [5]
- We calculate a subsurface sublimation rate from the saturation vapor pressure and the maximum sublimation rate in a vacuum [6, 7]

Results

- Analysis of ShadowCam imagery has identified seven craters with distinctive morphologies (Figs. 1 and 2)
- Two of the seven described here are found near the crater floor-to-wall transition and near the associated debris apron
- Both craters have Diviner Lunar Radiometer Experiment (DLRE) summer max temperatures of ~95 K and mean temperatures of ~60 K which indicates that water ice would be stable.

Results – Cont.

The primary lighting for the ShadowCam mosaic is 137 to 201 degrees [4] which effectively lights Shackleton's interior wall leading to secondary lighting from the grid west to northwest.

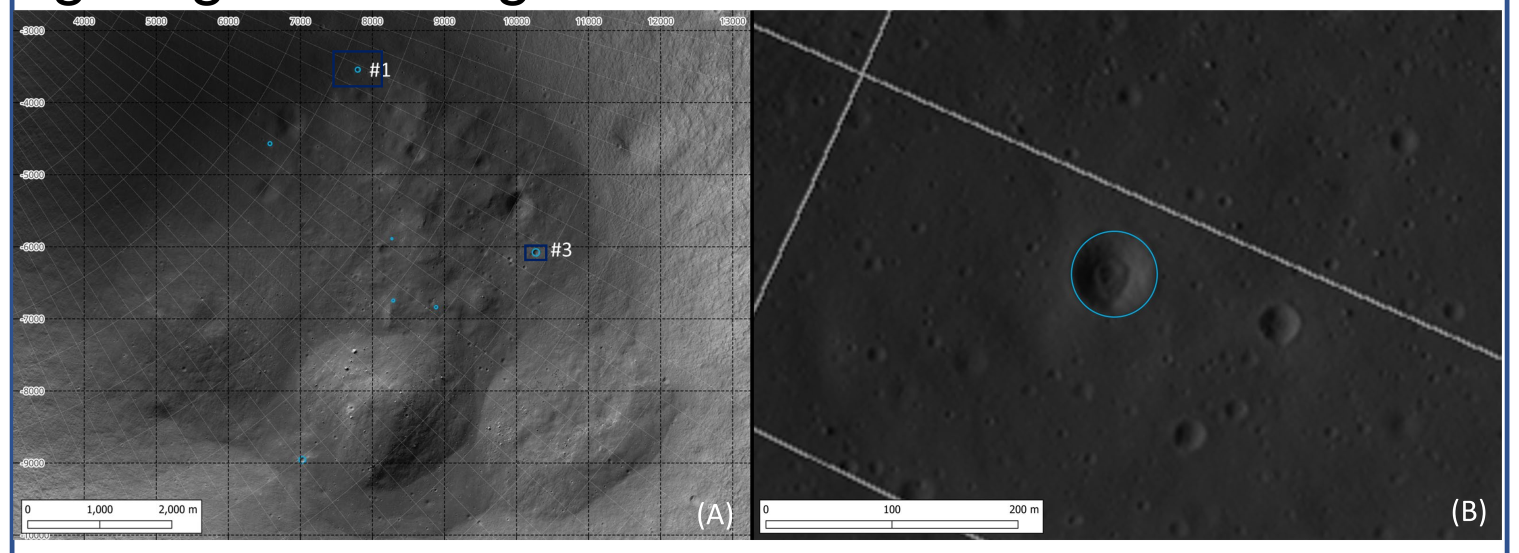

Fig. 1. (A) The location of the seven small craters with unusual morphologies (blue circles). Two of these craters, labeled #1 and #3, are near the Shackleton crater wall-to-floor transition. (B) Small crater #1 has an unusual floor morphology with an apparent central pit with an elevated moat and ring.

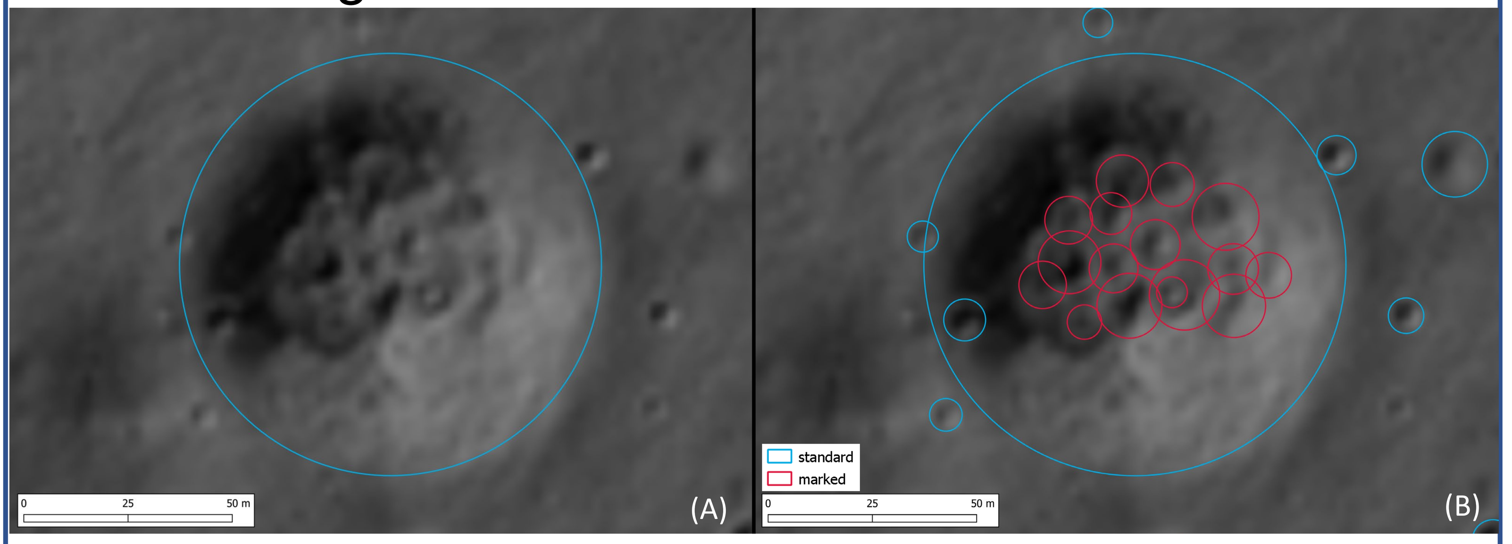

Fig. 2. (A) The small crater #3 shows an unusual floor morphology with apparent overlapping ring shapes. Crater #3 is 98 m in diameter. (B) The overlapping raised rings apparent in the crater floor are digitized (red). The individual elevated rings have 10-12 m diameters around pits 4-5 m in diameter.

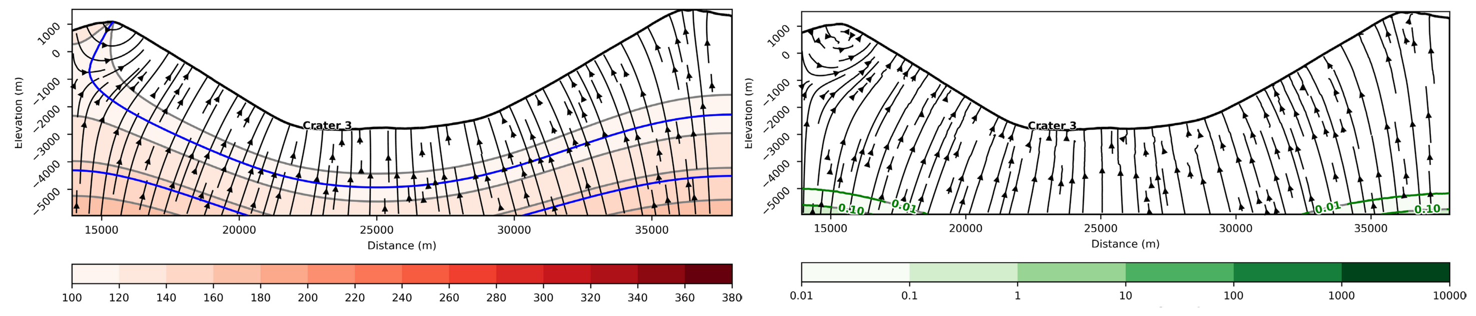

Fig. 3. (A) A thermal model with heat flow of 6 mW/m [8] across the Shackleton PSR bisecting Crater #3 shows that the current volatile stability zone is thick and could potentially maintain buried ice. (B) The thermal model converted to depth-dependent sublimation potential indicates very low subsurface sublimation rates.

In addition to mosaic data above, the craters #1 and #3 appear similar in multiple lighting directions of individual map projected ShadowCam images.

Discussion

We consider several causes for the observed atypical crater floor morphologies.

1. imaging artifacts or multipath lighting (unlikely given the typical appearance of adjacent smaller craters)
2. subsequent impacts and sidewall collapse (unlikely given the high spatial density of pits and ridges on #3 crater's floor)
3. subsurface ice or volatile vaporization post -impact (consistent with the current observations)

If the final option, gas escape was likely influenced by thermal dispersion, overburden removal, and radial fracturing from the impact. These would facilitate the migration and focusing of gases from released volatiles.

Potentially analogous fluid escape features are to Earth's seabed pockmarks (Fig. 4).

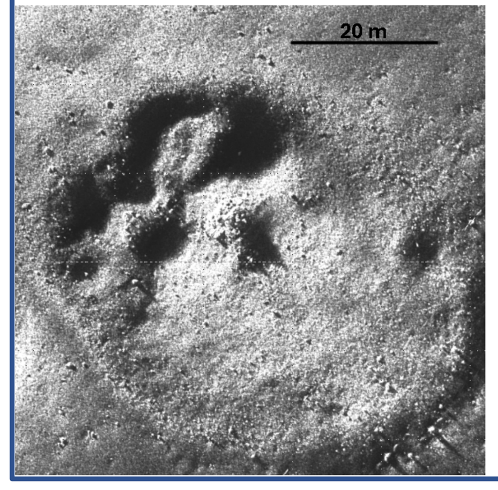

Fig. 4. Sidescan sonar image of an irregular seabed pockmark ~45 m in diameter with smaller pockmarks or ridges from gas seepage disturbing the sediment on the floor of the larger depression [9].

Conclusion

- The Shackleton PSR floor contains small craters with atypical floor morphologies including overlapping pits and rings
- These features may indicate volatile release and a patchy subsurface volatile distribution
- This may indicate the existence of volatiles 10s of meters below the surface at the time craters #1 and #3 formed from impacts [10, 11]
- These craters would be locations for sampling and geophysical measurements to better understanding volatiles in regolith and assess the prospects for extracting lunar volatiles

References

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