BOULDER DISTRIBUTIONS AROUND YOUNG LUNAR IMPACT CRATERS: CASE STUDY OF SOUTH RAY CRATER

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Abstract #1146

Introduction

Boulder distributions around lunar impact craters are a powerful tool for understanding the rate at which rock becomes regolith [1-4] and the distance to which craters of different sizes distribute boulders [5,6].

- Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) images (0.5 -1 m/pixel) [7] are used to count and measure boulder distributions.
  - We demonstrate this using a NAC boulder count around South Ray, a 700 m diameter, 2 Ma-old [8] impact crater in the Descartes Highlands, near the Apollo 16 landing site (9.15° S, 15.38° E).

Methods

- Boulders are measured as ellipses using Crater Helper Tools in ArcMap (Fig. 1).
  - The smallest boulders that we identify with confidence are ~1-2 m.
- The distance of each boulder from the crater center is determined using the haversine formula [9].
- We omit boulders inside the rim because steep slopes inside rims refresh the rock population as crater walls degrade.

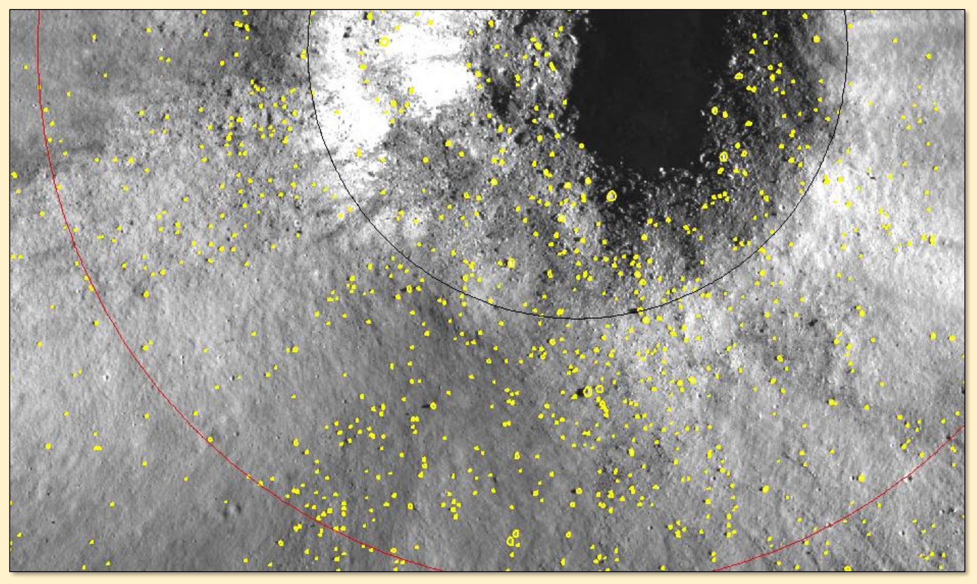

Fig. 1. Boulders (yellow ellipses) near the rim of South Ray (black circle). Elongated shadows are visible to the left of boulders.

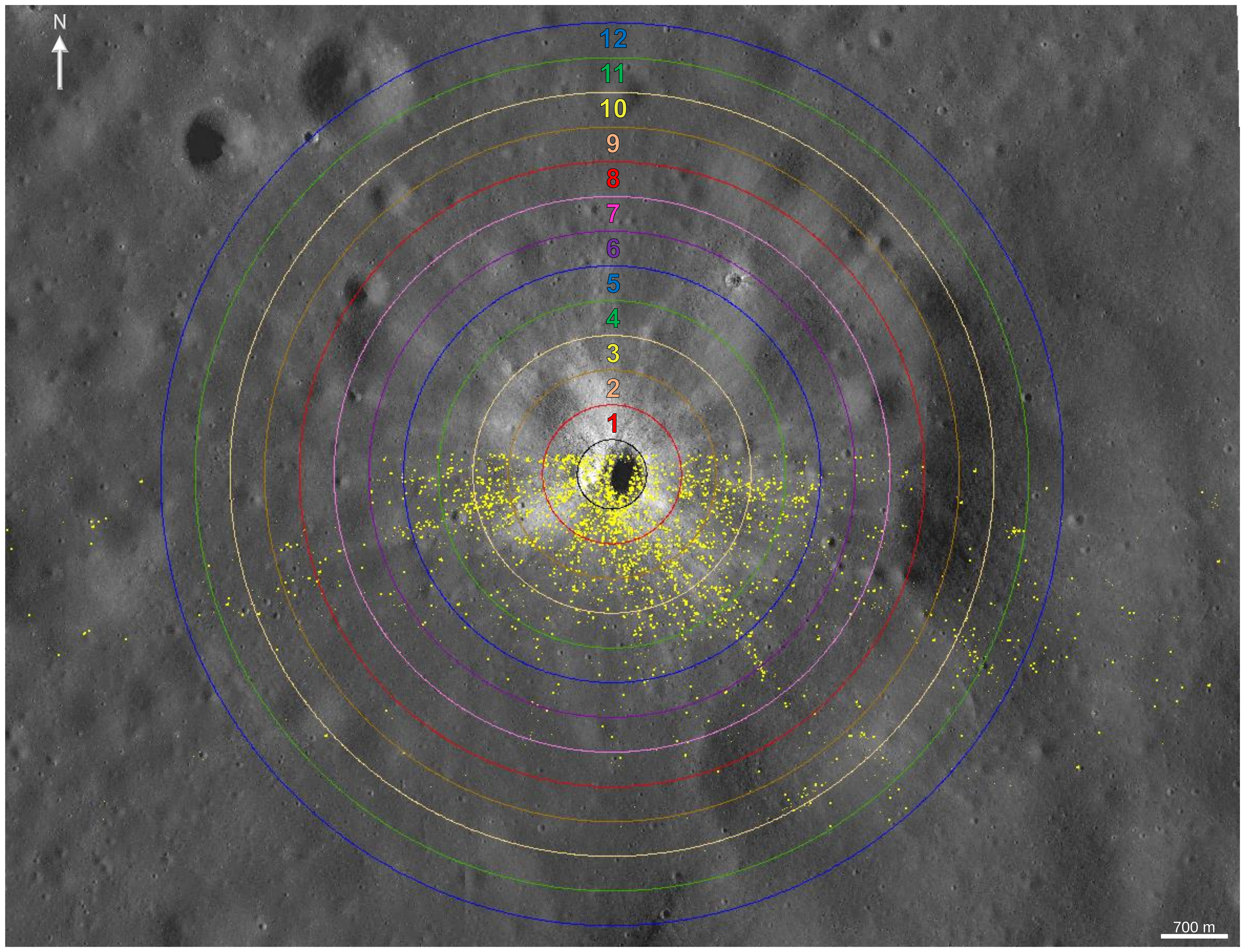

Fig. 2. Boulder counts centered at South Ray crater. Colored circles and numbers indicate distances from the rim (black circle) in crater radii. The count only includes boulders in the southern half because the northern half is likely contaminated with boulders from nearby North Ray crater. We assume the distribution is similar for the northern portion. NACs M181065865L and M1108182629.

Diviner Rock Abundance

- NAC boulder distributions can be used to validate Diviner rock abundance (DRA) [5], which measures the cumulative areal fraction (CAF) of the surface covered in boulders > 1 m [14].
- DRA values can be used to extend NAC boulder count trends to smaller boulder sizes [15].
- Our LROC NAC count closely matches the DRA value (Fig. 5), within error, at South Ray.

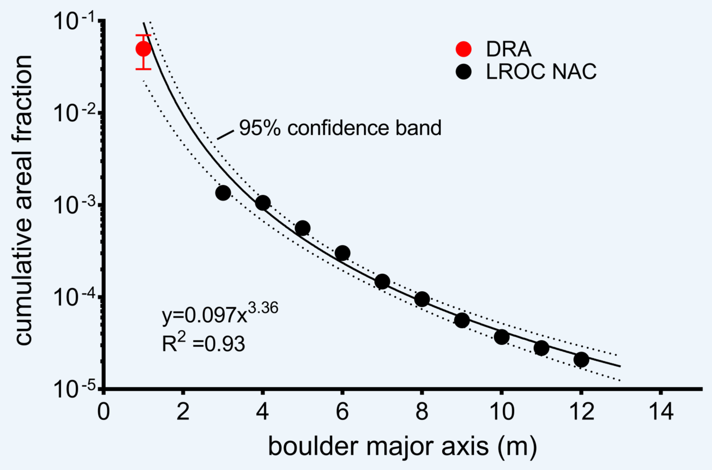

Fig. 5. Comparing NAC boulder distributions with DRA. CAF is calculated by dividing the area of NAC-measured boulders (binned by size) by the count area. The data point at 2 m is excluded because it is part of the roll-off due to the limit of resolution.

Conclusions

- We have demonstrated, using South Ray, the utility of boulder distributions. Combining SRDs, SFDs, and RFDs across craters of various ages will allow us to test models of boulder breakdown rates, with long-term implications for understanding the Moon's regolith production rate**.**
- Our boulder distributions reveal that:
  - South Ray ejected boulders out to at least 18 crater radii.
  - the maximum boulder size for this 700 m diameter crater is ~14 m.
  - the SFD exponent (-5.5) is steep, indicating the ratio of small to large boulders is higher than for older craters.
- The ability to predict boulder size distributions as a function of distance from a crater is particularly useful in assessing potential boulder hazards for future missions.

Boulder Distributions

Size-Range Distributions (SRDs)

- SRDs inform how the distribution of boulder sizes varies with distance from the crater.
- South Ray has boulders out to at least 18 crater radii (Fig. 3). The largest boulders (>6 m) are closer to the rim and smaller boulders are at all distances.
- Large boulders are present out to farther distances than for older craters (*e.g.*, Cone [5]), supporting the idea that larger boulders degrade more quickly [3,10].
- Quantile regression fits to SRDs can be used to constrain the maximum boulder size at any given distance from a crater:

$$d_{max} = aR^{-b}$$

where d_{max} is the maximum boulder diameter at a range R.

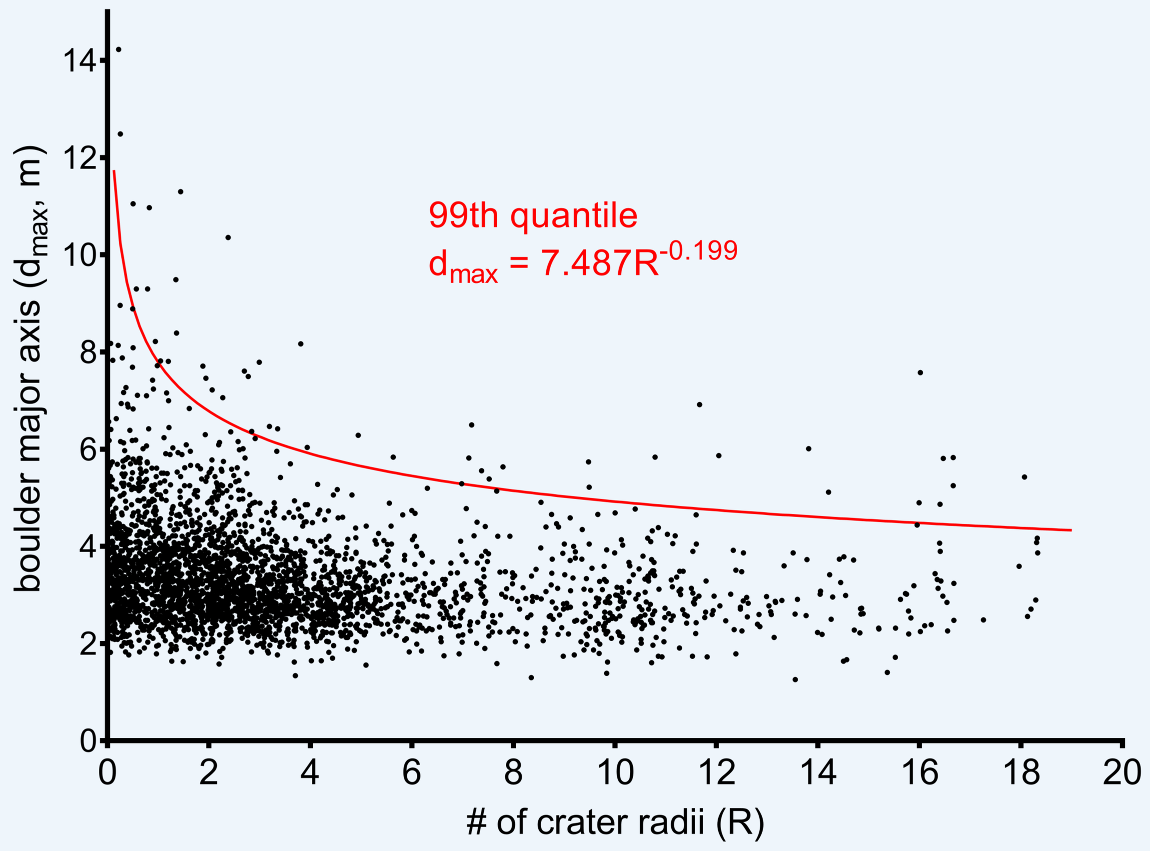

Fig. 3. Size-range distribution for South Ray crater. Red curve is the 99th quantile (typical size below which 99% of the boulders fall).

Range-Frequency Distributions (RFDs) & Size-Frequency Distributions (SFDs)

- RFDs show the areal density of boulders as a function of distance and show the maximum distance that ejecta blocks are transported.
- At South Ray, the areal density of boulders decreases with increasing distance from the crater rim (Fig 4).
- SFDs are created by plotting the diameter of boulders against their cumulative frequency per count area.
- SFDs reveal the quantity of boulders at each observed size distributed around the crater (Fig. 4).
- Both SFDs and RFDs are fit with a power-law, consistent with other studies [1 ,11-14].

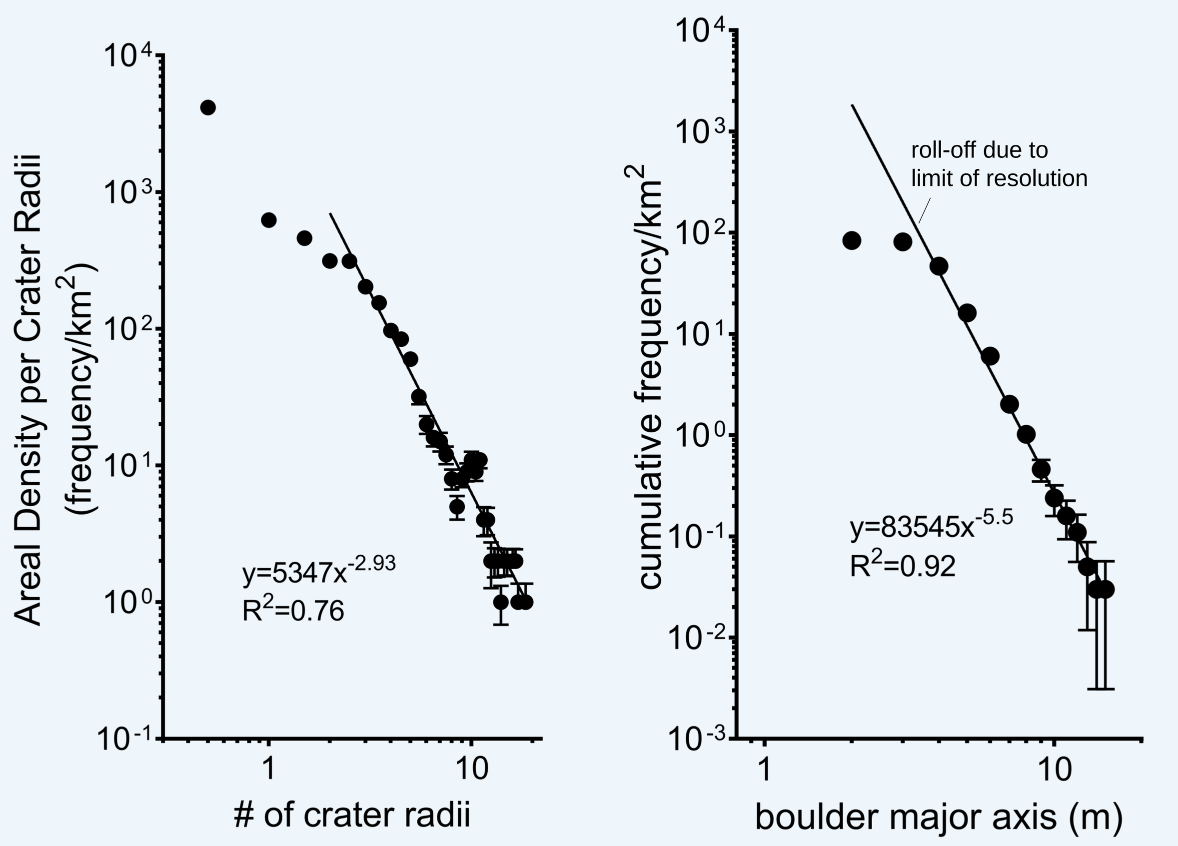

Fig. 4. (Left) Range-Frequency distribution and (Right) Size-Frequency distribution for South Ray crater.

Acknowledgements & References

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References: [1] Basilevsky et al. (2013), *PSS, 89,* 118–126. [2] Basilevsky et al. (2015), *PSS, 117,* 312-328. [3] Ghent et al. (2014) *Geology, 42,* 1059–1062. [4] Mazrouei and Ghent (2017), *48th LPSC,* Abstract #2507. [5] Watkins et al. (2017), *48th LPSC,* Abstract #1245. [6] Watkins et al., *this meeting, Abstract #1201.* [7] Robinson et al. (2010) *Space Sci. Rev. 150,* 81–124. [8] Arvidson et al. (1975) *Moon, 13*, 259–276. [9] Inman (1835) *Navigation and Nautical Astronomy 3rd Ed.* [10] Housen and Holsapple (1999), *Icarus, 142,* 21-33. [11] Bart and Melosh (2010) *Icarus, 209,* 337–357. [12] Shoemaker et al. (1969), *Surv. Proj. Final Report II,* 21-136. [13] Cintala and McBride (1995) *NASA TM-104804.* [14] Bandfield et al. (2011) *JGR 116.* [17] Elder et al. (2016) *AGU Fall Mtg,* Abstract #P24A-04.

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