The Variability of Crater Identification Among Expert and Community Crater Analysts

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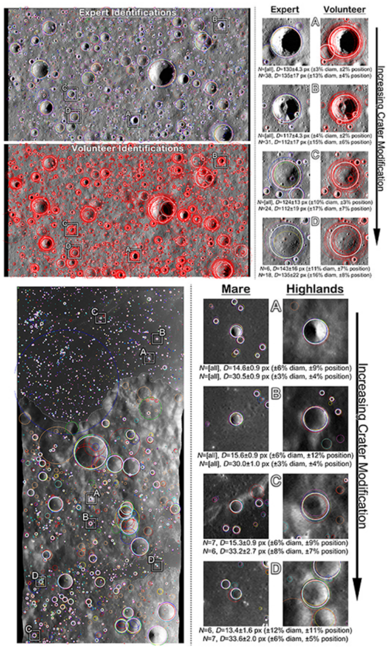
Abstract

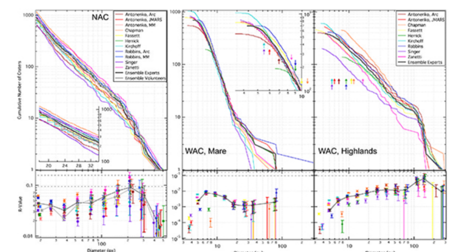
Statistical studies of impact crater populations have been used to model ages of planetary surfaces for several decades [1], but this assumes that crater counts are approximately invariant and a "correct" population will be identified if the analyst is skilled and diligent. However, the reality is that crater identification is generally subjective, so variability between analysts, or even day-to-day for a single analyst, is expected [*e.g.*, 2-3]. This study was undertaken as the first of its kind to quantify the variability within an expert analyst population using different techniques, and between experts and minimally trained volunteers.

Examining the Markings



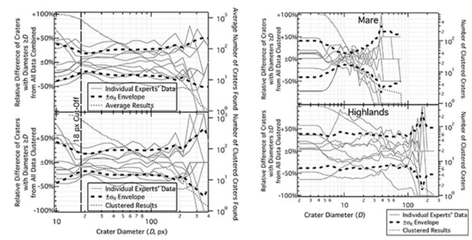
All crater identifications on the NAC (top) and WAC (bottom) images by experts (each expert is a different color), volunteers (NAC only), and the output from the clustering code (overlaid white circles). The small side boxes illustrate how we varied on the different terrains as a function of crater preservation state, showing that there was generally a larger uncertainty as preservation state decreased, but that volunteers were generally invariant except in the number who identified the crater.

Size-Frequency Analysis



This shows cumulative size-frequency diagrams (top) and R-plots (bottom) for all individual researchers, the clustered results, and the volunteers (NAC only). The NAC data were limited to ≥18 px in diameter, while the WAC were left to researcher discretion and the small arrows indicate the diameter to which they estimated completeness. The ensemble and expert NAC data overlap very well.

All experts were complete for ≥18 px in the NAC image (no change in slope) by trying to be complete to smaller diameters. The WAC image shows we were very good at replicating each others' results for the mare, but not the highlands (possibly due to high sun) Also, the diameter at which a researcher estimated completeness was too liberal in several cases.



These figures show the relative difference for each expert (thin grey lines), as a function of diameter, from the ensemble population and show the ±1σ envelopes of the deviation at each diameter bin.

The 1σ envelope for the NAC averages ±25%, while the mare gets as low as ±15% and the highlands show 35-45%.

Methods

Images:

Lunar Reconnaissance Orbiter Wide-Angle Camera (WAC) and Narrow-Angle Camera (NAC) images M119455712M and M146959973L were processed in ISIS software via standard radiometric techniques and georectified to the Moon by Robbins. These were then placed on a server from which the other analysts retrieved them.

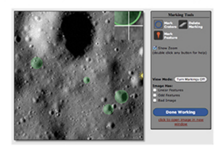
Researcher Methods:

There were 8 professional crater analysts who gathered 11 datasets for the NAC and 9 for the WAC (Antonenko and Robbins used multiple interfaces). Seven different techniques used to identify and measure craters, the concept being to "study crater analysts in their natural habitats."

These were: ArcMap software employing rim-tracing (Robbins), CraterTools (Fassett, Zanetti) [5], Crater Helper Tools (Antonenko, Herrick) [6], or chord-drawing (Singer); JMARS's crater-measuring tool (Antonenko, Kirchoff); SAO Image with custom PERL scripts (Chapman); or the Moon Mappers interface (Antonenko, Robbins; for the NAC image only).

Volunteer Citizen Scientist Method:

Volunteers used the CosmoQuest Moon Mappers online interface (cosmoquest.org) [7], an online portal that presents basic crater identification tools and a 450×450-px sub-image. There are no image manipulation tools provided (*e.g.*, zoom in or out, brightness / contrast / gamma adjustment). The interface requires the volunteer to click on the center of a crater, hold the mouse down, and drag until the rim is reached. It will save the crater if the diameter is ≥18 px.



Data Reduction:

A modified DBSCAN [8] code was developed to cluster crater measurements based on diameter-scaled proximity of crater centers and the crater diameter. This algorithm works by taking each crater and searching within a pre-defined scaled location offset and diameter difference (*e.g.*, 10 px offset of a 20-px-diameter crater is relatively large, but that 10 px offset for a 200-px-diameter crater is negligible). Other craters within this distance were considered members of the cluster

A crater was included in the final expert dataset if ≥half of the experts identified it (though in other applications, a different threshold may be appropriate). The threshold for volunteers was set such that at least 60% needed to identify the feature (this gave the best comparison with expert data).

CosmoQuest: http://cosmoquest.org

Conclusions

- Variability in crater counts is ~15-45% but can be different by as much as a factor of 2-3.
- When using these to estimate ages, they vary from 1.5±0.7 to 3.2±0.8 Gyr (NAC), 1.3±0.4 to 2.2±0.5 (WAC, mare), and 3.4±0.1 to 3.8±0.0 (WAC, highlands).
- Volunteers, as an ensemble, can produce crater population statistics as good as experts: NAC expert age is 2.71 Ga, volunteer 2.72 Ga.
- Standard Poisson uncertainties are a *minimum* uncertainty measure because they do not factor in the single analyst's threshold of detection and the larger variations expected among other experts.

References & Acknowledgements

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Find our work online: http://dx.doi.org/10.1016/j.icarus.2014.02.022 || http://youtu.be/NRS5FC-34ss || http://youtu.be/fGQF2-G4jNw

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Movie Description of Detailed Results: http://youtu.be/NRS5FC-34ss

Movie for the General Public: http://youtu.be/fGQF2-G4jNw