Re-examining the Main Asteroid Belt as the Primary Source of Ancient Lunar Craters

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Earth, Atmospheric, & Planetary Sciences

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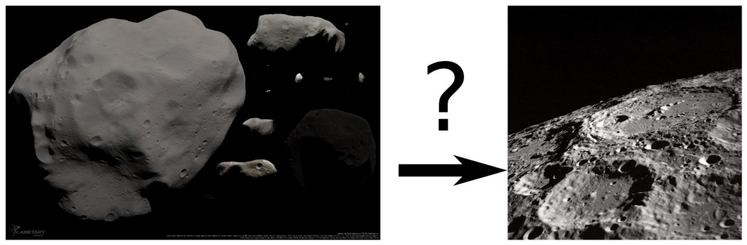
Did the ancient lunar impactors originate in the Main Asteroid Belt?



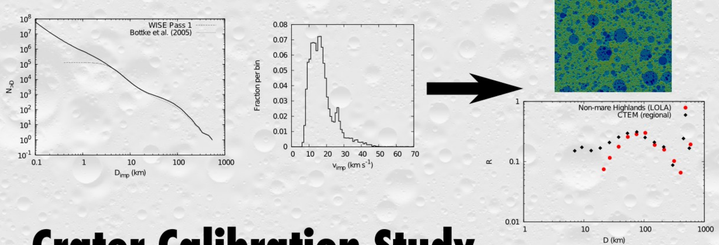
It has been hypothesized that the impactors that created the majority of the observable craters on the ancient lunar highlands were derived from the main asteroid belt in such a way that preserved their size-frequency distribution [Strom et al. (2005) Science 309, 1847].
We dub this the Population 1 Hypothesis.

Alternatively, a destabilized contiguous inner extension of the main asteroid belt produced a bombardment limited to those craters younger than Nectaris basin [Bottke et al. (2012) Nature 485, 78-81].
We dub this the E-belt Hypothesis.

We investigate these hypotheses with a Monte Carlo code called the Cratered Terrain Evolution Model (*CTEM*)

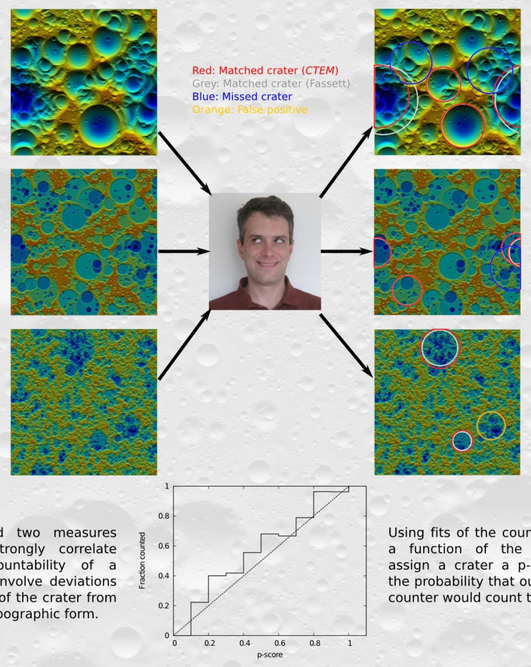
CTEM
Cratered Terrain Evolution Model

CTEM takes as input an impactor SFD, velocity distribution, and a number of target and impactor property parameters. The outputs are a DEM of a terrain modified by impact craters and a crater count.



Crater Calibration Study

160 simulated surfaces were generated, some with large craters in varous states of degradation. The largest three craters on each surface were counted by our human crater counter.



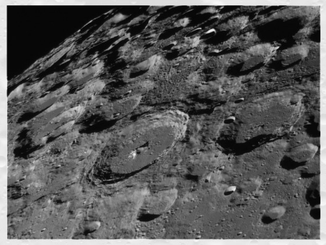
We identified two measures that both strongly correlate with the countability of a crater. Both involve deviations of the shape of the crater from its original topographic form.

Using fits of the count probability as a function of the measures, we assign a crater a p-score, which is the probability that our human crater counter would count the crater.

Tests of the two hypotheses

Two constraints must be simultaneously met

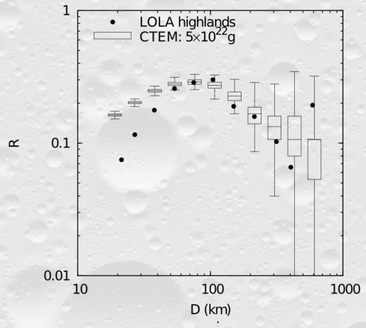
Regional Constraint



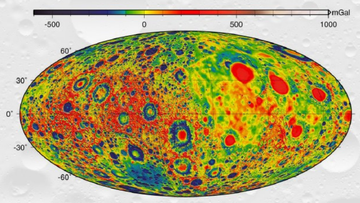
Our simulated surface must match the crater density of the appropriate terrain.

For the Population 1 hypothesis, a CTEM simulation must match the observed number of 90.5-128 km craters on the lunar highlands.

For the E-belt hypothesis, a CTEM simulation must match the observed N(20) or N(64) of Nectaris.



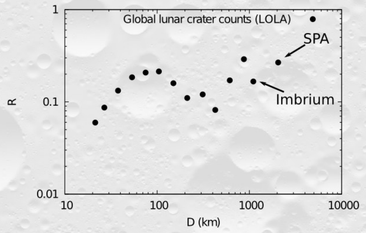
Global Constraint



The global constraint is based on the observed number of the largest basins.

For the Population 1 hypothesis, a CTEM simulation must produce no more than 1 basin larger than 1200 km.

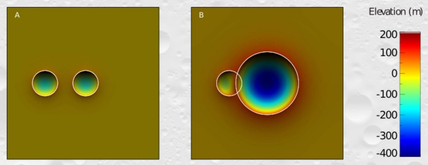
For the E-belt hypothsis, a CTEM simulation must produce none larger than 1200 km



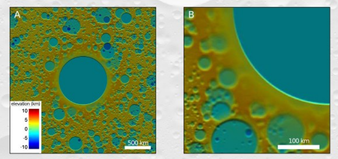
For every case, we run 100—1000 simulations. This allows us to characterize the statistical variations directly, rather than relying on the assumption that the errors are governed by Poisson statistics.

Modes of Crater Degradation

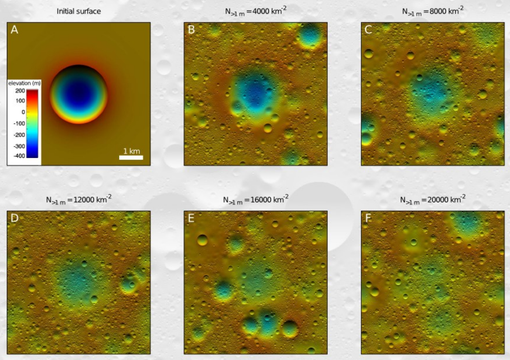
Cookie Cutting

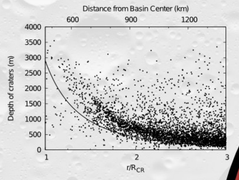


Ejecta Burial

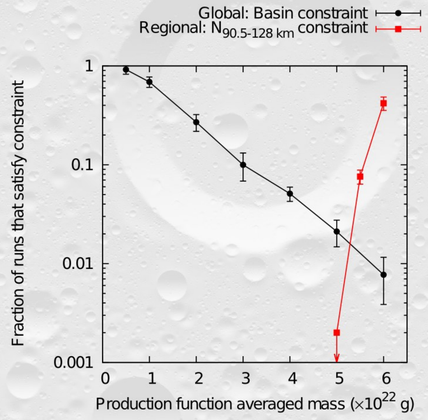


Sandblasting



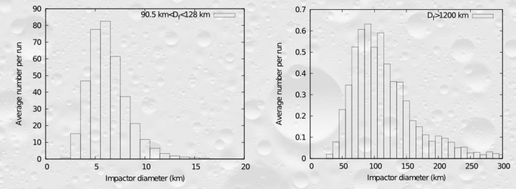


Population 1 Hypothesis Result



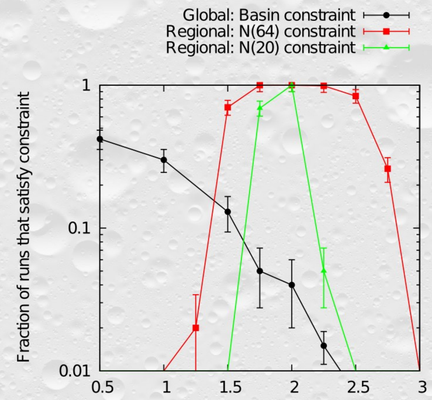
Our results indicate a very low probability in matching both of these constraints with an impactor population resembling the modern main asteroid belt.

The modern main asteroid belt SFD is therefore a poor model for producing the observed lunar highlands crater population



The ratio of ~100 km craters to megabains is about 6x higher on the lunar highlands than the corresponding impactor sizes in the main belt.

E-belt Hypothesis Result



The E-belt Hypothesis is slightly less problematic than the Population 1 Hypothesis. Still, less than ~10% of runs match both constraints simultaneously

The Main Belt would have produced either more megabasins or fewer ~100 KM craters than are observed.

On the right is a "typical" outcome of a *CTEM* global lunar simulation using a main belt impactor SFD. The total cratering level was chosen to match the regional D_f = 90.5-128 km constraint (Population 1 Hypothesis).

In this run, 6 basins larger than Imbrium were produced.