Crater Counting Chronologies

- Planetary radius determines the duration over which radioactive decay can maintain geological activity.

Crater density on a surface is a proxy for “age” presuming you know the local impact rate as a function of time.
Highlands vs. Maria / “Old” vs. “Young”

“age” = time since last resurfacing
Lunar Elevations

Blue = low    Red = high
Cratering Isochrons

- The degree to which a surface is cratered depends on...
  - you tell me...
A Natural Evolution of Cratering Rate
Figure 10-6. The diameter of an impact crater as a function of meteorite size for three different impact velocities. Scale at right gives the estimated energy required to make each crater. Documented craters on Earth and the moon are shown. The assumed meteorite density is 3 g/cm³. (Crater energy and diameter data from Baldwin, 1963; Wasson, 1974, p. 145; Voritman, 1977)

\[
D = 0.7 \left( \frac{g_{\text{earth}}}{g_{\text{local}}} \right)^{1/6} \left( K.E. \frac{\rho_{\text{impactor}}}{\rho_{\text{target}}} \right)^{1/3.4}
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Cratering Mechanics

http://www.astro.virginia.edu/class/skrutskie/images/SLOW_M_1.MOV
http://www.youtube.com/watch?v=QfDoQwlAaXg
http://video.mit.edu/watch/milk-drop-to-splash-3105/
Cratering Mechanics
Cratering Mechanics
Ejecta
Secondary Craters
Complex Craters
Multi-ring Basins

Mare Orientale – Earth's Moon

Valhalla Basin – Jupiter's Moon Callisto
Saturation
Crater Counts vs. Size vs. Surface “Age”

- Craters accumulate over time on a “fresh” surface.
- Eventually the crater density saturates.
- Large impacts can also produce large numbers of secondary craters.

\[ \text{NO. CRATERS/KM}^2 \]

- Lunar Highlands
- Lunar Maria
Scaling to other Worlds (isn't easy)

- We have the advantage of being able to radiometrically date lunar samples – thus providing an absolute age scale for the lunar crater isochrons.

- We don't know how the cratering rate varies throughout the solar system, so other cratering chronologies are relative.
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Vesta Crater Counts

Isochrones indicate K/Ar-Ar Ages of HED Meteorites with High Probabilities

- Vesta_HRT, area=2.93x10^1 km^2
- Vesta_large_craters, area=6.41x10^3 km^2
- Vesta_Rhea-Silvia_landslides_average, area=6.87x10^1 km^2
- Vesta_Rhea-Silvia_all_craters, area=3.31x10^5 km^2
- Vesta_HCT_NE, area=0.77x10^5 km^2

Cumulative Crater Frequency (km^-2)

2.49^{+0.25}_{-0.26} Ga

Diameter (km)
Timeline of Martian Volcanism

• A crater-count study on Mars dates the calderas on 20 major volcanoes.

• High-resolution images from the Context Camera (CTX), onboard NASA’s Mars Reconnaissance Orbiter, allow a larger range of crater sizes than were ever used before.

• The timing of the last major summit eruptions correlates well with the crystallization ages (~165-170 million years) of the youngest basaltic Martian meteorites.
Timeline of Martian Volcanism – Olympus Mons

Six calderas on Olympus Mons show ages ranging from about 140 - 420 million years.
Three calderas on Elysium Mons show ages around 3 billion years.
Timeline of Martian Volcanism and Meteorites

• After Apollinaris Mons shut off, major volcanism ended throughout the highlands and Syrtis Major, then in the smaller Elysium volcanoes, and finally in the largest of the Tharsis volcanoes.

• Martian meteorites a few 100 million years old likely came from the younger flows of the Tharsis Montes.
Late Heavy Bombardment and the “Lunar Cataclysm”

Lunar Impact Basin Chronology
Results of the "Nice" Model

Uranus
Neptune

Cumulative lunar impact mass (g)

Time (yr)