Giant Impact Basins of the Solar System*

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Abstract

Mars, Mercury, the Moon, and many satellites of gas giants Jupiter, Saturn, and Uranus, are scarred with giant impact basins that record collisions from asteroids during the early history of the solar system. Giant impact basins, typically hundreds to thousands of kilometers in diameter, are associated with distinctive morphological features, including multiple concentric rings, radially distributed scour valleys, fractures and radial graben, crater chains, and large (>20 km in diameter) secondary craters. Impacts that formed giant basins commonly resulted in deep excavation and fracturing of planetary crusts, forming conduits for later upward migration of magma plumes and subsequent basin infilling with lava. For example, most giant nearside lunar basins that formed between 3.8 and 4.3 billion years ago are partly filled with basalt. The Serenitatis Basin contains a succession of layered extrusive units that are collectively 2 to 4 km thick, 750 km in diameter, and 300,000 to 500,000 km in volume. Some giant impact basins are also associated with antipodal features caused by propagation of compressive waves through the planetary interior. These features include hilly, lineated, and jumbled terrain, as observed in areas antipodal to the Caloris Basin on Mercury. Swirled terrain and remnant paleomagnetism are observed on the Moon in areas antipodal to the Imbrium Basin. In addition, some recent features on the Moon, such as Ina, antipodal to the South Pole-Aitken Basin, are inferred to have been caused by degassing of volatiles (important materials for sustaining human settlement) in areas of weak and fractured crust.
Giant Impact Basins of the Solar System

William A. Ambrose
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Bureau of Economic Geology

Lunar Orbiter photograph
Outline

Early Solar System Bombardment
- Origin and Significance
- Giant Impact Basins on the Moon

Inner Solar System
- Mercury and Mars

Outer Solar System
- Callisto, Mimas, Miranda

Significance
- Planetary Structure and Volatiles

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Lunar Impact Origin

- Density differences
- Volatile depletion
- Isotopic similarities
- Lunar orbit inclined $5^\circ$
Hadean Eon: 3.8–4.56 Ga

- Early bombardment phase
- Saturation cratering to at least 4.2 Ga
- Earth crustal formation
- Crust-mantle differentiation
- 3.8 Ga: end of late bombardment phase
Late Heavy Bombardment
4.0 - 3.8 Ga

William Hartmann
Late Heavy Bombardment

Hadean Saturation cratering

- Nectaris (3.90 Ga)
- Imbrium (3.85 Ga)
- Orientale (3.82 Ga?)

Pre-Nectarian

Nectarian

Imbrian

Pre-Nectarian

Haskin, Cohen et al.
Clementine: Lunar Topography

Near side

Far side

Orientale Basin

South Pole–Aitken Basin

Relief: kilometers
Lunar Orbiter 4

Orientale Basin

900 km

Mantle

Rings

Mare basalts

Impact melts

Ejecta

Modified from Wood (2003)
Orientale Basin

USGS lidar map

Lunar Orbiter 4

200 km

Basin rings

Secondary crater

Scours, crater chains, and valleys
Crisium Basin

USGS lidar map

Grazing impact ejecta

Gault and Wedekind (1978)

200 km

Basin rings

Secondary crater

Scours, crater chains, and valleys
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Mercury: Caloris Basin

Mariner 10 photographs

Antipodal point

Courtesy Peter Schultz

650 km

~ 50 km
Martian Topography

Borealis Basin

Tharsis Bulge

Hellas Basin
Hellas Basin

~3.9-Ga impact

>2,200 km across

> 8 km deep

3.9 – 3.0 Ga basin fill

Elevation (km)

Distance (km)
Borealis Basin

MOLA data

2,000 km
Borealis Basin

North Polar View

- North pole 6 km lower than south pole
- ~7,700 km diameter
- Remnant rim massifs identified
- Basin possibly filled with Noachian seas

Wilhelms and Squyres (1984)
Martian Polar Basins

Chryse Basin
(Schultz et al., 1982)

Tharsis Basin
(Schultz & Glicken, 1979)

Isidis Basin
(Tanaka, 1986)

Utopia Basin
(McGill, 1989)

Elysium Basin
(Schultz, 1984)

MOLA data
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Callisto—Valhalla

750 km
Callisto-Valhalla Antipode
Mimas

- Inner moon of Saturn
- Herschel crater
  130 km wide
  10 km deep
- Central peak 6 km high
- Fractures on opposite side
Miranda

Voyager 2 photograph
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South Pole–Aitken Basin

Laser altimetry

Collision model

Modified from Schultz and Crawford (2008)
Ina–Recent Volatile–Rich Deposits

Schultz et al. (2006)
Schultz and Crawford (2008)
Summary

Early Solar System Bombardment

- Early Bombardment: 4.0 – 4.6 Ga
- Late Heavy Bombardment: 3.8 – 4.0 Ga
- Steadily Declining Impact Flux

Solar System Distribution

- Moon
- Mercury and Mars
- Outer Solar System

Significance:

- Crustal Structure and Volatile Distribution
- Earth Hadean
References


