Timing, Emplacement, and Distribution of Mare-Fill Units in Oceanus Procellarum, a Large Nearside Lunar Basin*

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Abstract

Although only 17% of the entire lunar surface is covered by basalt and underlying associated magma cooling units, ~60% of the western hemisphere on the lunar nearside contains magmatic complexes emplaced in numerous episodes ranging from approximately 3.75 Ga (billion years ago) to possibly as recently as 0.9 Ga, inferred from crater counts and overlapping relationships between lava-flow units and bright rays associated with Copernican-age craters. Oceanus Procellarum contains the largest continuous extent of lunar basalts on the Moon, and its upper fill is a complex of at least four different flow units, recognized on the basis of albedo and spectral reflectivity. Individually, these flow units are only a few hundreds of meters thick, but may be underlain by 2-4 km thick basin-filling units. Oceanus Procellarum has been interpreted by some authors as the western part of the 2400-km-wide Gargantuan Basin, inferred to have formed from a giant impact ~4.3 Ga. Gargantuan Basin lacks a surrounding mountain rim and underlying mascon, features commonly associated with other nearside lunar basins such as Mare Tranquillitatis, Serenitatis, and Crisium. However, the absence of these features may be due to the Gargantuan Basin having formed so early that the lunar crust may have not been sufficiently rigid to support rim material and excess masses of thick basin-filling units.
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Lick Observatory photograph
Outline

● Oceanus Procellarum
  - Morphology, Crustal Structure, Mare-Fill Units

● Nearsdie Megabasin
  - Basin Configuration and Marginal Structures

● South Pole-Aitken Basin
  - Antipodal Basin Structure

● Significance

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Oceanus Procellarum

Facts and highlights

- Largest mare area
- Poorly developed mascons
- Th, KREEP-rich fill
- 3200-km diameter

Lick Observatory photograph
Mascons and Non-Mascon Basins

Procellarum

A
Imbrium
Serenitatis

B
Crisium
Fecunditatis
Nectaris

C
Grimaldi
Humorum

Sugano and Heki (2004)
Nearside Compositional Units

Most 3.8–2.7 Ga

Modified from Pieters (1978)

- Lava compositional units
- Highlands
- Copernican impact structures
Oceanus Procellarum Compositional Units

Lava compositional units
- Sharp
- Herman
- Telemann
- Repsold

Modified from Whitford and Head (1980)
### Oceanus Procellarum Compositional Units

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sharp</th>
<th>Hermann</th>
<th>Telemann</th>
<th>Repsold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightness</td>
<td>dark</td>
<td>darkish</td>
<td>bright</td>
<td>bright</td>
</tr>
<tr>
<td>Craters</td>
<td>few</td>
<td>intermediate</td>
<td>many</td>
<td>?</td>
</tr>
<tr>
<td>Titanium content %</td>
<td>3-11</td>
<td>1-6</td>
<td>&lt;2</td>
<td>?</td>
</tr>
<tr>
<td>Thickness (meters)</td>
<td>25</td>
<td>150</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>Area (percent)</td>
<td>43</td>
<td>45</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Age (billion years)</td>
<td>2.7±0.7</td>
<td>3.3±0.3</td>
<td>3.6±0.2</td>
<td>3.75?</td>
</tr>
</tbody>
</table>
Procellarum KREEP Terrane

Jolliff, et al. (2000)

Spudis (2005)

Thorium (ppm)

1 12

Jolliff, et al. (2000)
Spudis (2005)
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- **Significance**
Orientale—Multiringed Basin

**USGS Lidar Map**

- **200 km**
- **Basin Rings**
  - **Secondary Craters**
  - **Scours, crater chains, and valleys**

**Lunar Orbiter 4**
Nearside Megabasin–Ring Structures

Western Procellarum Edge

USGS Lidar Map

Whitaker (1981)
Nearsdie Megabasin—Volcanic Domes

Western Procellarum Edge

Mons Rümker
LO-IV-163-H2

Marius Hills
LO-IV-157-H2

USGS Lidar Map
Nearside Megabasin—Wrinkle Ridges

Western Procellarum Edge

Lunar Aeronautical Chart 56
Nearside Megabasin—Radial Graben

Whitaker (1981)

USGS Lidar Map

200 km
Nearside Megabasin–Model

Byrne (2007)

A. Escaping ejecta (hyperbola)
   - Escape velocity
   - 600 km impactor

B. Velocity less than escape
   - Transient crater expands
   - Ejecta passes antipode

C. Velocity falls further
   - Ejecta is concentrated at antipode

D. Ejecta falls between basin rim and antipode
   - Velocity falls further
Nearside Megabasin–Elevation

Clementine Digital Elevation

Byrne (2007)
From Zuber (2004)
Nearside Megabasin–Crustal Thickness

Wieczorek (2007)
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South Pole-Aitken Basin

Collision Model

Modified from Schultz and Crawford (2008)
Mercury: Caloris Basin

Mariner 10 photographs

Antipodal Point

Courtesy Peter Schultz
Antipodal Effects from SPA Basin

Oceanus Procellarum Center

Arcuate and radial graben and ridges

SPA antipode

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

Schultz et al. (2006)
Schultz and Crawford (2008)
Lichtenberg—Possible Young Volcanism

McAlpin et al. (2008)
Clementine UV/VIS

3.47 Ga basalt
Younger basalt

SPA antipode

50 km
Summary

- **Procellarum Basin: Nearside Megabasin**
  - Thin, depressed crust
  - Thorium, KREEP enrichment
  - Elevation profile basin-like
  - Radial graben
  - Aligned volcanogenic features

- **Procellarum: Non-basin attributes**
  - No mascons (isostatic equilibrium)
  - Ring structure incomplete
  - Secondary craters poorly documented

- **South Pole-Aitken Basin:**
  - Antipodal structures in Procellarum area
  - Procellarum volatile-rich deposits—Ina
References


