Geologic and Geomorphologic Interpretation of the Mare Orientale Impact Basin Region of Earth's Moon

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Abstract

The Mare Orientale impact basin is a multi-ring impact structure located in the Southern equatorial region of Earth's Moon and covers 2.48 million square kilometers of the lunar surface. The rocks in the area are composed of basaltic lava flows and basement rock displaced by impact events that range in age from 4.5 to 1 Ga. In order to interpret the geology of the area, multiple datasets were compiled in ArcMap and ArcGIS Pro. The topography of the region was constructed by the combination of two high-resolution lunar digital elevation model from the NASA Goddard Space Flight Center. Analyses of the Unified Geologic Map of the Moon from the United States Geological Survey Astrogeology Science Center provided data used to determine lithology and ages of the geologic formations in the area. These data allowed for a more informed cartography based on age relationships and morphology. The union of the topography and Unified Geologic Map of the Moon were used to construct hypothesized geologic cross-sections of the multi-ringed impact basin. The asymmetric ejecta blanket boundaries provided the key to understanding the subsurface structure of the basin, as well as the hypothesized trajectory of the meteorite that created the Mare Orientale impact basin.

Methods

Elevation data was analyzed from a high-resolution digital elevation model (DEM) from the NASA Goddard Space Flight Center. The DEM was created with data taken remotely using the SELENE Terrain Camera on the Lunar Orbiter Laser Altimeter. The DEM that underlays the geologic map was created by the combination of two tiles from NASA's dataset. Analyses of the Unified Geologic Map of the Moon, shown on the right in Figure 1, from the USGS Astrogeology Science Center provided data required to determine the lithology and ages of geologic formations. Adjustments to cartography provided a better visual display of the age of the geologic units.

Figure 1. Three-dimensional projection of The Unified Geologic Map of the Moon (USGS).

Geologic Map

Map Explanation

0 250 km

Geologic Units

- Cc, Copernican Crater
- Ec, Eratosthenian Crater
- Ec, Eratosthenian Mare
- INt, Imbrian-Nectarian Mare
- Ib, Imbrian Basin
- Ic, Imbrian Crater
- Ic1, Imbrian Crater, Lower
- Ic2, Imbrian Crater, Upper
- Id, Imbrian Dome
- Im2, Imbrian Mare, Upper
- Iohi, Orientale Hevelius Fm, Inner
- Ioho, Orientale Hevelius Fm, Outer
- Ios, Orientale Hevelius Fm, Crater
- Iom, Orientale Maunder Fm
- Iork, Orientale Montes-Rook, Knobby
- Iorm, Orientale Montes-Rook, Massif
- Ip, Imbrian Plains
- It, Imbrian Terra
- Itd, Imbrian Terra Domes
- Nb, Nectarian Basin
- Nb, Nectarian Basin, Lower
- Nbm, Nectarian Basin Mare
- Nc, Nectarian Crater
- Nt, Nectarian Terra
- pNc, pre-Nectarian Crater
- Hypothetical Trajectory, A-A'
- B-B'

Figure 4. Geologic map of the study area expanding from the equator to 30° South and from 225° East to 315°

In order to create Figure 4, the Unified Geologic Map of the Moon was compiled in ArcMap and cut to the size of NASA's digital elevation model. The cartography of the Unified Geologic Map of the Moon is relatively simple and lacks age color correlations. Figure 4 has revised cartography with age color correlations. The lithology of the 25 geologic units are defined in the data associated with the Unified Geologic Map of the Moon. The generalized ages of the geologic units span 4.5 Ga. A hypothesized trajectory for the asteroid that created the basin is included in the geologic map, as well as two cross-section lines.

Location

The study area is located in the Southern equatorial region of Earth's moon. This area spans from the equator to 30° South and from 225° East to 315° East. The total area is 2.48 million square kilometers of the Eastern Mare Orientale Impact Basin Region. Figure 3 (shown to the right) is a size comparison of the area and the United States. The rocks are composed of extrusive mafic igneous rocks that have been deformed by impact events.

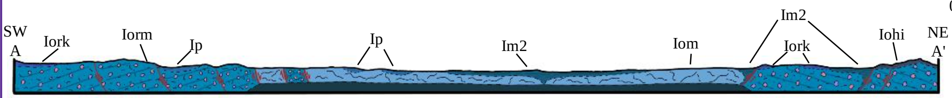
Map Explanation

Area of Interest

Figures 2 and 3. Figure 2 (left) shows the location of the study area (shown in red) on a 3D projection of Earth's moon (NASA) to the West of Earth's view. Figure 3 (right) compares the size of the study area with the United States.

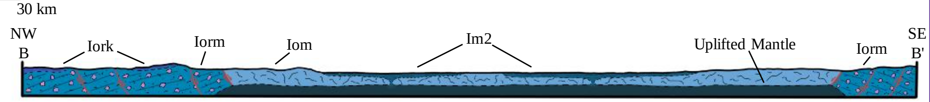
Hypothesized Cross-Section

Figure 5. Hypothetical geologic cross-section running parallel to the hypothetical trajectory of the asteroid.



30 km
V.E.=1x
0
30 km

Figure 6. Hypothetical geologic cross-section running perpendicular to the hypothetical trajectory of the asteroid.



Explanation

- Iorm, Orientale Montes-Rook, Massif
- Iom, Orientale Maunder Fm
- Iohi, Orientale Hevelius Fm, Inner
- Iork, Orientale Montes-Rook, Knobby
- Ip, Imbrian Plains
- Im2, Imbrian Mare, Upper
- Lunar Mantle
- Fault

Hypothetical cross-sections (Figures 5 and 6) were created to visually convey the complex spatial distribution of impact melt, ejecta blankets, and lava flows of a multi-ringed basin that is untouched by geologic processes that would alter such on Earth. The Mare Orientale impact basin is constructed of eight units. The first unit to form was the Montes-Rook Formation Massif Facies (Iorm) from the mechanical uplifting of the basement rock. The impact also created the Maunder Formation as impact melt. The event also expelled ejecta blankets that are distinguished in the Montes-Rook Formation Knobby Facies, the inner and outer facies of the Hevelius Formation, and the Imbrian Plains. The instant cooling produced heavily fractured areas that created the multiple rings of the basin. The faults allowed access for basaltic lava flows which are easily seen as dark smooth areas contrasting with the light chaotic material of ejecta. The cross-section lines were chosen as being parallel and perpendicular to the trajectory in order to best visually show the effect of these events. Figure 5 highlights the excess of Iorm produced by the impact, while Figure 6 conveys the vastness of impact melt and lava flows of the basin.

Acknowledgements

This research would not be possible without the support and guidance from Dr. Mindy Faulkner and the Department of Geology at SFASU.
Thank you SURE for the opportunity to continue this research.
If there are any questions, please contact Kyla Gray at grayks1@jacks.sfasu.edu

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