GEOLOGY OF THE LUNAR MOSCOVIENSE BASIN. S. F. A. Cartwright[1,2] and P. D. Spudis[2], [1]Middlebury College Department of Geology, Middlebury, Vermont 05753 (sfcartwright@middlebury.edu), [2]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (spudis@lpi.usra.edu)

Introduction: Moscoviense is a 640 km-diameter, Nectarian-age, multi-ring impact basin on the lunar far side, centered at 26°N, 147°E. It contains the most prominent of the few mare deposits on that hemisphere and has a number of unique features that distinguish it from other lunar impact structures. Perhaps the most noted feature is an apparent offset of its ring structure, which has been proposed to be the result of either a single oblique impact [1] or the overlap of two unrelated impact basins [2]. Additionally, the lunar crust at Moscoviense has been modeled as thinner than anywhere else on the Moon [3], its floor displays large gravity and thorium anomalies [4], and Mg-spinel was identified in its innermost ring [5]. These characteristics illustrate the complexity of the basin's geology and how little is known about the specifics of its formation and modification.

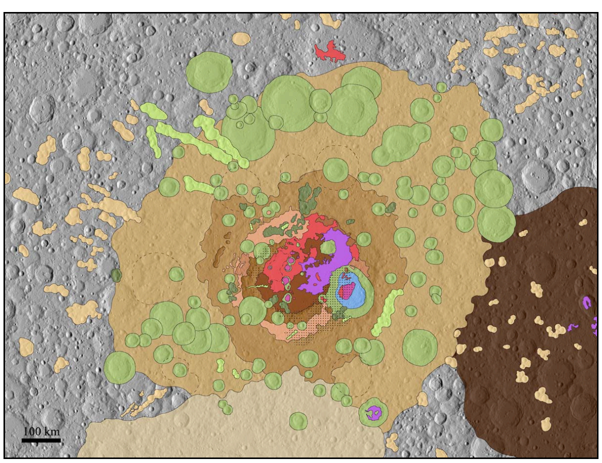
Although Moscoviense has previously been mapped [6], new high resolution data from the Lunar Reconnaissance Orbiter (LRO) and Clementine spacecraft permit maps to be made in greater spatial detail with consideration of observed surface composition. The purpose of this project was to use these new data to compile an updated geologic map centered on the Moscoviense basin. A particular focus was placed on determining the shape and extent of ejecta deposits and on identifying material variations in the basin floor while separating out materials not related to the basin. Combined with structural mapping and compositional analysis, the map offers a new look at one of the Moon's most enigmatic basins.

Methods: Mapping of the Moscoviense basin was completed in ArcMap 10.3.1 using geologic mapping methods outlined by [7]. The delineation of mapped units was based on textural, topographic, and compositional criteria identified through several orthographically-projected data sets. These data included a mosaic of LRO Wide Angle Camera (WAC) images, the Global Lunar DTM 100m topographic model (GLD100), and the Clementine Ultraviolet/Visible (UVVIS) color ratio map. Additional data including LRO Narrow Angle Camera (NAC) images were viewed using the online LRO QuickMap tool [8].

In addition to the geologic map, a correlation chart showing the temporal relations and material groupings of mapped units was made, as well as a structural map outlining the rings and radial troughs of the basin. Color representations for units used established lunar mapping conventions.

In order to determine relative abundances of Fe, Ti, and Th, analysis was carried out in ArcMap using zonal statistics calculations for each mapped unit. The data used in this analysis were from Clementine FeO and TiO_2 maps and Lunar Prospector FeO and Th maps. Additional FeO measurements were collected for craters on the basin floor with the aim of clarifying its origin(s).

Results: The Moscoviense basin, material from surrounding basins, and overlying craters were mapped as 20 distinct units (Fig. 1). Eight units make up the Moscoviense Group, which is divided into interior and exterior units.



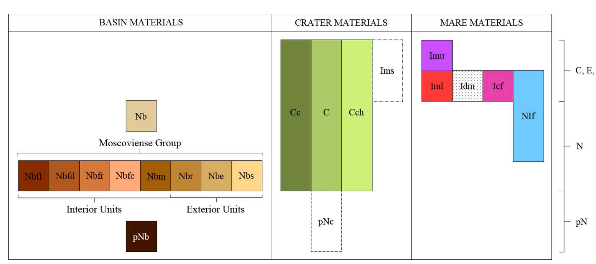


Figure 1 – New geologic map of Moscoviense basin and correlation chart showing relationships between lithologic units. Relative ages are shown at right: C – Copernican, E – Eratosthenian, I – Imbrian, N – Nectarian, pN – pre-Nectarian.

Interpretation: The mapping supports the interpretation that Moscoviense was created by an oblique impact from the southwest by documenting scoured topography to the northeast of the basin (consistent with modeling by [9]), a linear offset of its ring structure, and a compositional asymmetry of its ejecta deposit (Nbe). The maps do not show direct evidence in support for the alternative theory that Moscoviense consists of two distinct, nearly co-located basins. This interpretation is partly based on the large mantle plug and exceptionally thin crust at Moscoviense as well as mapping the inner two rings as concentric. Further study is required to determine whether these characteristics can be explained by an oblique impact.

Compositional analysis of the units mapped yielded a few unexpected results (Table 1). The dark cratered (Nbfl) and draped (Nbfd) basin floor materials have higher-than-expected concentrations of Fe and Ti, indicating a more mafic composition for the basin melt sheet than suggested by the composition of basin ejecta [10]. It was also found that post-basin craters on Nbfl have ejecta with a higher Fe content than the surrounding material, suggesting the presence of more mafic material at depth there. One possible explanation is that ejecta from the Mendeleev impact covered some early volcanic infilling which was later mixed into the regolith by cratering. Alternatively, the possible near-surface presence of lunar mantle here [11] could mean that the inner basin floor is made up of Mendeleev ejecta mixed with ultramafic mantle to create a high-Fe unit. Supporting the idea of uplifted mantle close to the surface is the presence of Mg-spinel, a high-pressure mineral phase, in deposits around the inner basin ring [5].

Clementine maps show elevated FeO contents to the east and northeast of Moscoviense within the basin ejecta and rim deposits (Nbe, Nbr). A separate compositional analysis was carried out to compare the eastern and western halves of these units. The crater Steno Q appears to have excavated deep enough (~1.7 km [8]) to excavate highly anorthositic material from beneath the relatively mafic basin ejecta.

Conclusions: New geologic and structural maps of the Moscoviense basin were compiled as well as related compositional analyses of mapped units. Moscoviense ejecta appears similar in bulk composition to the Orientale basin [12]. No unambiguous, unmodified basin melt deposits were identified, but the mafic nature of the inner basin floor (Nbfl) might indicate either a mafic impact melt composition or mixing of uplifted lunar mantle with subsequent Mendeleev ejecta. The findings of this mapping project have identified more intriguing characteristics in this unique basin that may warrant further study.

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Geologic Unit	FeO wt % ± 1σ	TiO2 wt % ± 1σ	Th ppm ± 1σ
Basin Ejecta (Nbe)	3.73 ± 1.42	0.43 ± 0.17	0.43 ± 0.27
Cratered Basin Floor (Nbfc)	4.06 ± 1.70	0.47 ± 0.23	0.55 ± 0.25
Dark Cratered Basin Floor (Nbfl)	10.64 ± 3.03	1.97 ± 1.11	1.41 ± 0.47
Draped Basin Floor (Nbfd)	10.13 ± 1.78	1.40 ± 0.51	0.61 ± 0.26
Rough Basin Floor (Nbfr)	4.92 ± 2.76	0.62 ± 0.42	0.77 ± 0.20
Basin Massifs (Nbm)	3.57 ± 1.96	0.43 ± 0.18	0.65 ± 0.16
Basin Rim (Nbr)	3.69 ± 1.67	0.42 ± 0.16	0.42 ± 0.16
Basin Secondaries (Nbs)	3.56 ± 1.81	0.37 ± 0.22	0.40 ± 0.25
Freundlich-Sharonov Deposits (pNb)	2.36 ± 0.99	0.29 ± 0.11	0.38 ± 0.14
Mendeleev Deposits (Nb)	3.27 ± 0.73	0.40 ± 0.10	0.50 ± 0.21
Fractured Crater Floor (Icf)	11.20 ± 2.54	1.53 ± 0.72	1.20 ± 0.30
Fractured Highlands (NIf)	8.38 ± 3.04	0.91 ± 0.47	0.94 ± 0.15
Lower Mare (Iml)	13.31 ± 1.92	2.06 ± 0.86	0.94 ± 0.43
Upper Mare (Imu)	14.47 ± 3.15	4.34 ± 2.39	1.40 ± 0.61
Mare Swirls (Ims)	13.67 ± 1.52	2.02 ± 0.68	0.98 ± 0.13
Pyroclastics (Idm)	6.19 ± 3.43	0.67 ± 0.50	0.66 ± 0.41

Table 1 – Results of compositional analysis carried out on mapped basin and mare units.