New Geological Map of the Lunar Orientale Basin

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Introduction: Orientale is the youngest and best preserved multi-ring impact basin on the Moon [1]. Situated on the extreme western edge of the near side, observation of the basin from Earth is limited and only possible at a highly oblique angle. Therefore studying the basin effectively has been restricted to the analysis of spacecraft images and compositional maps. Recent missions such as the Lunar Reconnaissance Orbiter have provided much higher resolution images of the surface than previous missions, allowing detailed study of the surface of the moon and its features.

The most recent geological map of the Orientale Basin was made in 1978 using data from the Lunar Orbiter and Zond 8 missions [2]. The aim of this project was to create a new geological map of the Orientale Impact Basin using images and topographic data from the Lunar Reconnaissance Orbiter Camera (LROC) and LOLA topographic maps. Data from the Moon Mineralogy Mapper (M^3) and Clementine FeO and TiO_2 maps were used to determine the extent of differentiation of the impact melt sheet (if any) [3]. The updated map shows a more accurate representation of the distribution of units both inside and outside of the basin and provides a clearer insight into the distribution of the melt sheet, the geological context of impact melt inside the basin and nature of the basin-forming impact.

Methods: A WAC image mosaic of the western hemisphere of the moon (formed from images taken by the LROC) was centered on Orientale and used as a base-map in ArcGIS 10.0. Mapping data were taken from the WAC images and the GLD100 global topographic map derived from LOLA and WAC stereo images [4]. Clementine FeO and TiO_2 images [5] were used to aid in the identification and mapping of various units (for example finding areas of mare material with high FeO content in the texturally similar Maunder Plains). Separate units were defined by position within the basin, surface texture, composition, structure and stratigraphic (overlap) position. The unit names of the Orientale Group [5] and colors similar to those used on the map of Scott et al. [2] were used here in the updated map for maximum continuity with existing lunar maps; some of the formations were subdivided into a number of constituent members based on one or more of their characteristics varying throughout the formation.

Following the creation of the geological map, we conducted an analysis of the composition of the basin impact melt sheet (the Maunder Fm. [3]). Using ArcGIS, the FeO and TiO_2 contents of the different formations could be analyzed by overlaying the different formations onto the Clementine maps and performing a statistical analysis of the element concentrations and distributions within the areas of the separate formations. Using this technique, the compositions of the ejecta blankets of over 300 craters within the Maunder Formation were analyzed to examine the lateral variations in melt sheet composition. To test for variation with depth, we analyzed crater size as a function of FeO content (based on the idea that larger craters excavate deeper material) [1, 3, 6].

Results: The basin interior displays a number of small melt ponds previously unmapped (recognized from comparison with the Clementine FeO map [4]). The Maunder Formation has been subdivided into two units – a smooth (plains) and a fissured member. Maunder fissured deposits have a relatively large range of surface topography. Maunder smooth member is flat and, in some areas, fractured by normal faults and graben.

The Montes Rook Formation has been split into three members – knobby , plains-like, and massifs. The knobby member contains large knobs or hummocks of material giving these areas a blocky and uneven appearance. However, flow lobes have been found in this unit adjacent to massifs or against some areas of the Cordillera Ring. The smooth member is concentrated in the southwestern quadrant of the basin interior. The final member of the M. Rook Fm. includes basin massifs of the Inner and Outer Montes Rook basin rings. These rings consist of blocky, equant massifs arranged in a circular pattern, unlike the scarp-like morphology of the inner most (shelf) and outer (Cordillera) rings.

The Hevelius Formation (basin exterior ejecta) has been split into four members: smooth, highland plains similar to the Imbrium basin Cayley Fm., radially textured ejecta (deposits lineated radial to the basin center), transverse ejecta (textured material oriented parallel or concentric with the basin rim), and a secondary crater facies. The radial ejecta is mostly situated to the north and south of the basin rim with the transverse ejecta facies being found mostly to the east and west. The radial facies seem to have greater average extent than the transverse facies, extending roughly 540 km and 350 km from the basin rim crest respectively.

Smooth plains are in small, localized areas within the ejecta blanket and are more widespread outside of it. Secondary craters are abundant to the northwest, southeast and southwest; relatively few are found to the east and northeast.

Analysis: The Maunder Fm. fissured member are thinner areas of the melt sheet that have been draped over lower-lying areas of massif material. Maunder smooth plains member are flat due to the melt sheet ponding and being locally thicker. Topographic analysis of the Inner Rook ring can be used to estimate a thickness of the melt sheet (as there are areas where the ring is completely covered by melt). The largest range is 6.2 km suggesting the melt sheet is ~6 km or less thick [3].

The Montes Rook Formation may contain some fraction of the impact melt due to the presence of flow lobes near to Cordillera Ring and extensive areas of the plains in certain locations. The origin of the knobby surface morphology remains an unsolved but important lunar problem [8].

The “bilateral symmetry” of ejecta distribution of the Hevelius Formation appears similar in some ways to the “butterfly pattern” of ejecta formed from low-angle impacts [e.g., 1]. The concentration of plains in certain areas, the distribution of secondary craters, and the distribution of ejecta facies all support the idea that the Orientale basin formed by an oblique impact from the east-northeast [1].

The composition of Orientale basin deposits are discussed in detail in a companion abstract [9]. Previous work based on partial coverage of the basin suggested a relatively uniform, anorthositic norite composition for all deposits [10]. This relation is still essentially correct, although some significant variations have been noted [9]. We specifically examined the composition of the Maunder Fm. of the basin to asses the possibility of differenatiation of the basin impact melt sheet [3, 9]. So far, we have found no evidence for such differentation. Numerous massifs that make up the Inner Rook Mts. are composed of pure anorthosite [10, 11], suggesting that this rock type occurs as a major regional unit at shallow depths.

Conclusions: An updated map of the Orientale basin and its surrounding ejecta shows the relations of basin units. The distribution of ejecta suggest that the basin formed by an oblique, low angle impact coming from east to west. The impact melt sheet (Maunder Fm.) has a maximum thickness of a few km at most. Orientale basin ejecta is very feldspathic, including outcrops of pure anorthosite within its rings.

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Fig. 1 – An updated geological map of the Orientale impact basin. Hemisphere centered on -19°, -95°.