

INVESTIGATION OF ORIENTALE'S DARK ANNULAR RING WITH MOON MINERALOGY MAPPER AND LUNAR RECONNAISSANCE ORBITER DATA. M. J.B. Henderson^{1,2} and N. E. Petro², ¹Center for Space Sciences and Technology, University of Maryland, Baltimore County, Baltimore, MD 21250, marie.j.henderson@nasa.gov, ²Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771

Introduction: The Orientale basin on the lunar surface has a distinct dark albedo annular ring surrounding a southwest section of a basin ring. Spectral imaging from the Moon Mineralogy Mapper (M³) [1] can determine lunar deposits' mineralogy. Combining spectra with data collected from the Lunar Reconnaissance Orbiter (LRO) [2]. There have been multiple previous hypotheses for the formation of the annular ring. The goal of our analysis will be to integrate spectral and morphological data to resolve how this unique dark ring formed.

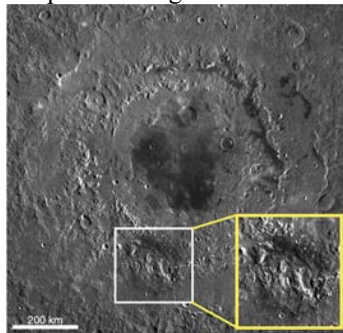


Figure 1: LRO WAC mosaic of the Orientale multi-ringed basin. The box outlines the annular ring deposit to the southwest of the basin [NASA/GSFC/ASU]

Background: Orientale is a large multi-ring basin located on the western rim of the Moon centered at 20°S and 95°W [3]. A dark annular ring appearing symmetric and diffuse with a ~154 km diameter is located in the southwestern part of the Orientale Basin along the Montes Rook ring [4]. Within the center of the ring is an elongated depression was identified by Clementine imagery [5] and has been hypothesized as the source crater for eruptive pyroclasts that formed the ring [4].

Clementine UV/VIS spectral data for the Orientale ring showed a slight absorption at 0.9–1.0 μm and were perceived to be dominated by glasses similar to the Aristarchus spectra [5]. Other interpretations from Clementine suggested that the deposit could be ilmenite-rich dark mantling material [6]. Others proposed that the dark ring is from a pyroclastic eruption from the vent that erupted below the surface, sending the pyroclasts into the symmetric ring while accounting for the lack of pyroclastic material between the vent and the deposit [4]. Previous preliminary M³ analysis [7] suggested that the pyroclastic deposits that initially composed the ring have weathered, leaving only glass-rich material in small fresh craters.

Categorizing the Orientale annular ring as a unique lunar pyroclastic deposit (LPD) formed through explosive volcanism has a distinct mineralogical

signature. Explosive eruptions on the Moon create flat draping deposits through radial dispersion of pyroclasts. LPDs, or dark mantling deposits, are low-albedo units believed to have formed during ancient explosive volcanic eruptions. Over 100 LPDs have been identified [8] and are composed of juvenile magmatic minerals (e.g., clinopyroxene (CPX) and olivine), glass (quenched and partially crystalline glass beads), and local country rock (orthopyroxene (OPX) and plagioclase in the lunar highlands; CPX in the mare) [9]. The deposits exhibit an extensive range of sizes [10], representing a primitive material that could help to characterize the lunar interior and to expand our understanding of lunar basaltic magmatism [8].

Methods: An M³ mosaic of Orientale Basin was constructed with bounds 246–281°E and 3–37°S with 34 spectral images (Fig 2) using methods described in [11, 12]. M³ observations of Orientale have a resolution of 140 m/pixel in 86 spectral channels [1], with data obtained in optical period 1B [13].

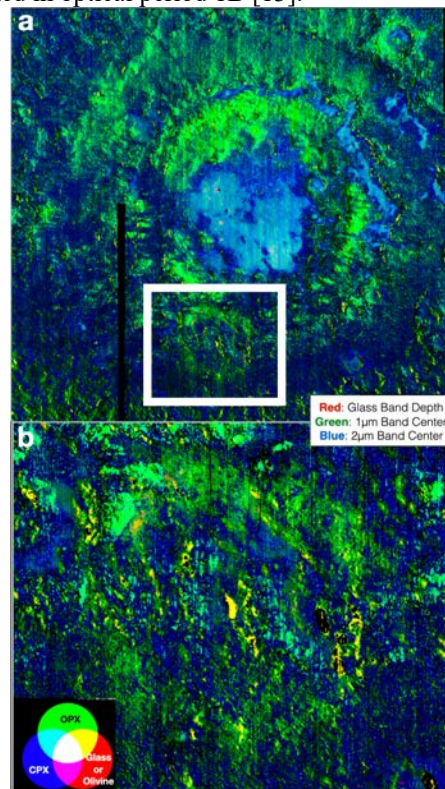


Figure 2: Mosaicked composite RGB spectral maps from M3 data of (a) Orientale Basin and (b) the dark annular ring.

Spectral diversity maps were created by parameterizing the 1- and 2- μm absorption bands in the M^3 mosaic. In this study, spectral variability was assessed using two types of spectral parameters: (1) spectral indices using simple arithmetic (e.g., Glass spectral parameter detects the wings of the glass iron absorption based on the average band depth below the continuum at 1.15, 1.18, and 1.20 μm .) and (2) 1 and 2 μm band position, area, and shape parameters derived from our continuum removed mosaic.

Preliminary Results: To complete our spectral analysis, we constructed an M^3 mosaic of Orientale Basin, which was used to create a spectral diversity composite map (Figure 2) and specific parameter maps (glass, CPX, OPX). The subtle horizontal striping across the M^3 frames in Fig 2 is due to slight resolution and detector sensitivity changes.

The annular ring deposit is not spectrally distinct from the rings of Orientale Basin in the RGB composite images (Figure 2). Analyses of these data reveal that the Orientale annular ring has mineralogy differing from the inner-peak ring floor but not the basin rings. Spectra collected from the potential vent and the Orientale annular ring are shown in Fig 3, along with reference lab spectra. The potential vent has bands centered near 1.05-1.10 and 1.85-1.9 μm and strong shoulders to long wavelengths on the 1 μm band, consistent with a

mixture of glass and pyroxene and supporting an explosive origin (Fig 3) [11, 14]. Olivine is unlikely to be a significant contributor based on the band center positions, a 2 μm band, and the 1 μm band asymmetry. Spectra collected from the annular ring unit exhibit bands near 0.95-0.98 μm and 1.85-1.98 μm . The 1 μm band is narrow without any additional absorption that could be attributed to olivine or glass (Fig 3), consistent with an orthopyroxene-rich interpretation.

Discussion: The spectral results from M^3 show that the predicted lunar pyroclastic deposit does not have the expected glass abundance commonly associated with explosive lunar pyroclastic deposits [11, 15]. However, there could be a minor contribution from glass mixed with the orthopyroxene-rich deposit. In contrast, the vent that has been hypothesized as the source for the annular ring deposit [4, 16] has spectral properties associated with glass-rich mineralogy. Ultimately, the absence of significant glass in the annular ring does not support formation through a sustained eruption of juvenile materials.

Future Work: To complement the spectral interpretation, we will include LRO datasets to make additional morphological analyses of the Orientale annular ring. For thermophysical properties, the Diviner thermal inertia instrument data [17] and Mini-RF data [18] will be utilized as an indicator of differences in the textures, roughness, and pyroclasts properties.

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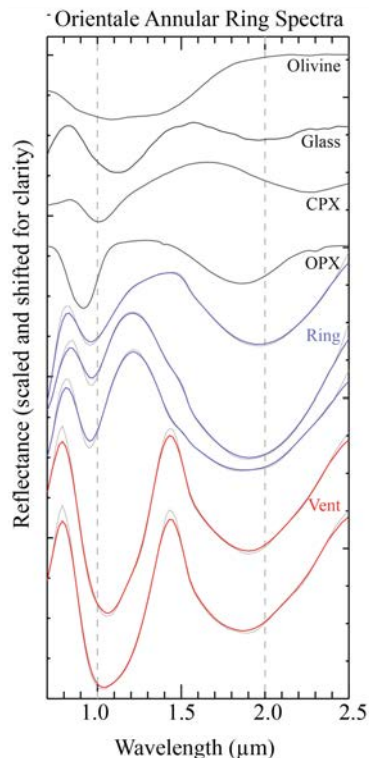


Figure 3: Laboratory Spectra (black) and continuum removed and smoothed M^3 spectra extracted from Orientale's dark annular ring (blue) and the potential vent (red). Unsmoothed spectra are light gray in color.