

THE OLIVINE-RICH UNIT AND MAFIC CAPPING UNIT: A VAST SEQUENCE OF VOLCANIC ASHES EXPOSED IN JEZRO CRATER?

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Introduction: The geographically widespread (>50,000 km²) Olivine-Rich and Capping Units of the Circum-Isidis region have been suggested in integrated remote sensing datasets to be best characterized as volcanic ash deposits [1-3]. These units are likely exposed at the current location of the Perseverance Rover as the olivine-carbonate floor and mafic floor units [4] (Crater Floor Fractured Units 1 & 2 and Crater Floor Fractured Rough Unit, respectively in [5]).

Here we use a photogeologic and compositional analysis to investigate the hypothesis that these two units represent a sequence of eruptions (Fig 1). We further discuss possibilities for mechanisms that would cause a stratigraphic transition from ultramafic to mafic geochemistry.

Stratigraphic scenario under consideration

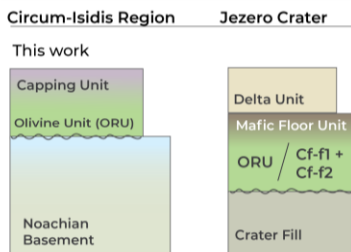


Fig 1. Stratigraphy of the Circum-Isidis region and Jezero Crater. We consider whether the olivine-bearing and mafic units in this region (Capping/Mafic Floor Units) represent a sequence of eruptive deposits.

Methods: We compare these two units in several ways: their geographic/topographic extents, how they drape topography, their tonal banding structures/conformability, and their compositions. Our own measurements for the Capping Unit are compared to those for the Olivine-Rich Unit based on work by [1].

Mapping/morphology: See [3] for a description of mapping methods. High Resolution Science Experiment (HiRISE, [6]) images were used to examine the morphology of tonal bands within each unit as well as stratigraphic contacts.

Topographic analysis: We used Digital Elevation Models (DEMs) created by the HiRISE team at the University of Arizona or in-house using the Ames Stereo Pipeline [7]. This data was used to calculate the dips of four stratigraphic surfaces (see Fig 2G): (1) uppermost Cap Unit surface, (2) contact between the Cap and Olivine-Rich Units, (3) tonal banding within the ORU, and (4) contact between ORU and the basement. The top surface of the Capping Unit is an erosional surface; however, should this surface be within error ($\pm 1^\circ$) of the

other dips, we assume the uppermost surface maintained its original depositional orientation at the outcrop-scale. The geographic distribution of the unit as a function of elevation was determined with data from the Mars Orbiter Laser Altimeter (MOLA) aboard Mars Global Surveyor.

Spectra: We use the technique Guided Endmember Extraction (GEE) to highlight weak spectral components in three CRISM images. GEE uses the statistical method factor analysis on spatially subsetting areas of a hyperspectral image to extract dominant axes of variance within the data. Low-order “eigenvectors” often correspond to mineral signatures [8]. See [4] for a more in-depth description of methods.

Results: Olivine-Rich and Capping units have similar geographic and topographic extents from northern Nili Fossae to Libya Montes (Fig 2A-C). Across 50,000 km², the contact between them is conformable. Compositionally, both show endmember eigenvectors with broad crystal field absorptions at 1 and 2 microns, consistent with laboratory spectra of pyroxenes (Fig 2D). Banding within the Capping and Olivine Rich Units are distinguished by the latter’s bouldery expression. When apparent, these bands each have similar alternating tonalities, meter-scale thickness, and subparallel strikes (Fig 2E). Each unit thinly drapes bowl-shaped topography, and outcrop orientation measurements show that all stratigraphic layers are typically within $\pm 1^\circ$ of each other (Fig 2F-G).

Discussion: The Olivine Rich Unit is much more friable than the Capping Unit, as evidenced by the latter’s crater-retaining surface. This gives the ORU a much higher thermal inertia [9, 10]. Despite these clear differences, there are many similarities that make a compelling case for a future focus on their relationship.

Possible causes for the ultramafic to mafic geochemistry of this “sequence” include a pre-depositional geochemical shift in a volcanic source or post-depositional alteration by aqueous processes [11]. If the former, analyses of melt inclusions in sample olivine crystals would resolve competing hypotheses for a putative global shift in Mars volcanism ~ 3 Ga [12, 13]. If the latter, in-situ and lab analyses would help determine the timing and conditions of aqueous activity at Jezero Crater.

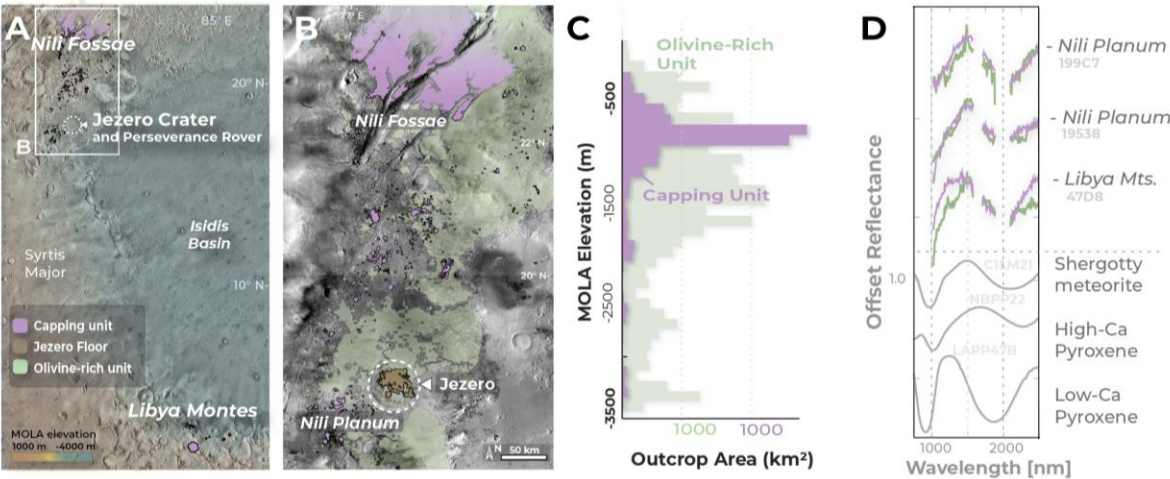
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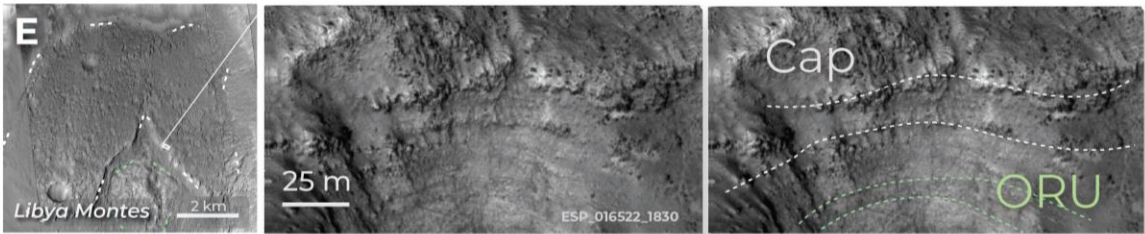
Fig 2. (A) Context map of the circum-Isidis region with MOLA elevation overlaid on a THEMIS basemap. (B) Extents of the Capping Unit (Cap) and Olivine-Rich Unit (ORU) on Isidis' NW margin. (C) Topographic extents of the ORU and Cap Units. (D) Eigenvectors extracted from regions of interest over ORU (green) and Cap Unit (purple) outcrops compared to RELAB laboratory spectra (grey). (E) Comparison of tonal banding in the ORU and Cap Units. Note similarities in vertical spacing, tonality, and morphology as well as the conformable contact. (F) An interpreted cross-section of the ORU and Cap Unit draping bowl-shaped topography in Nili Fossae. Olv = ORU. (G) Layer orientation measurements for seven outcrops on Isidis' NW margin.

Geographic and topographic extents

Composition



Tonal banding structures



Draping of topography

