NEW RING STRUCTURE ESTIMATES OF LADON BASIN, MARS, FROM MAFIC MINERAL MAPPING WITH CRISM. S. F. A. Cartwright and K. D. Seelos, Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd, Laurel, MD 20723, samuel.cartwright@jhuapl.edu

Introduction: Ladon basin is a >1000 km-diameter, Pre-Noachian multiring impact basin situated in southwest Margaritifer Terra, Mars (Fig. 1). Having formed ~4.17 Ga, it is considerably older than other large Martian impact basins with clear topographic expression and exhibits a magnetic anomaly in its floor suggesting the Martian dynamo was still active at the time of its formation [1, 2]. During the Late Noachian to Middle Hesperian, Ladon hosted the Uzboi-Ladon-Morava outflow system which carried liquid water from Argyre basin northward through a series of channels and paleolakes to Margaritifer Terra and eventually to the northern plains. Degradation from this fluvio-lacustrine activity and impacts subsequent to basin formation has led to uncertainty about the number and placement of the structural rings that define the basin, with cited diameters ranging from 270 to 1700 km for a total of 3 to 6 rings [3, 4, 5, 6]. While previous estimates were based on orbital images and topographic expression, this work aims to use mineralogical data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument in tandem with other remote sensing datasets to constrain the number and diameter of Ladon's rings.

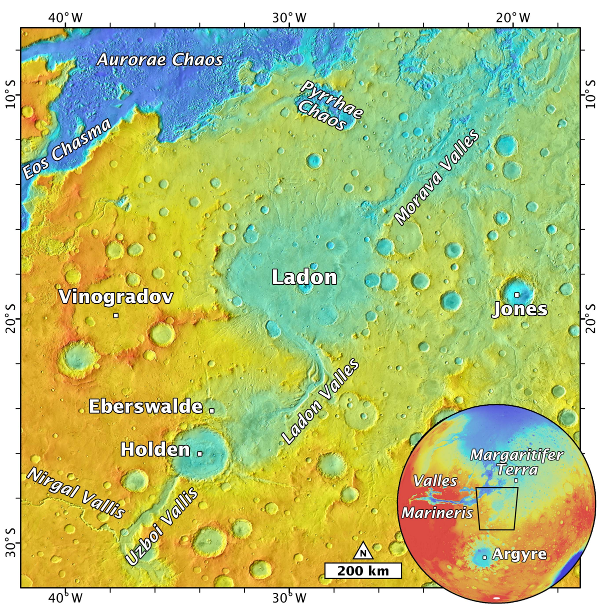

***Figure 1**. Context map showing the location of Ladon basin and surrounding topographic features. MOLA colorized elevation over THEMIS daytime IR mosaic.*

Background: The structures of multiring basins are formed through a combination of initial crustal uplift and subsequent structural collapse, resulting in the inner and outer rings of the basin, respectively [7]. This process is echoed in smaller-scale impact features such as complex craters, where central peaks are derived from the greatest crustal depth while rims and ejecta are more shallowly sourced [8]. On Mars, where older, deeper crust is enriched in low-calcium pyroxene (LCP) compared to high-calcium pyroxene (HCP) in younger crust, these impact processes leave mineralogical signatures on the surface which can help decipher crustal stratigraphy and identify materials from different depths and ages. For example, elevated LCP content in central peaks mapped by [8] have been used as evidence of deep crustal uplift. Here we use these mafic signatures as indicators of Ladon's ring structure by evaluating the distribution of LCP-enriched material that potentially represents crustal uplift associated with ring formation.

Methods: A series of orbital datasets were utilized for the identification and mapping of mineralogic features in the study area (7–32°S, 17–42°W) (Fig. 1). These included controlled mosaics of daytime infrared and thermal inertia from the Thermal Emission Imaging System (THEMIS), elevation data from the Mars Orbiter Laser Altimeter (MOLA), and derived products from visible-near infrared CRISM data.

CRISM Data Processing. In addition to targeted observations (18–36 m/px) used for localized spectral analysis, the CRISM instrument collects mapping observations (100–200 m/px) that can be compiled into 5×5-degree tiles and used for the assessment of mineralogic variability on a regional scale. For this work, radiometrically calibrated mapping data were processed and assembled using a pipeline approach that includes photometric and atmospheric corrections, filtering, calculation and balancing of summary parameters (e.g., band depths [9]), and finally map projection and mosaicking. This workflow is similar to, but not exactly, that of the map tiles which will be delivered to the Planetary Data System.

A total of 36 map tiles that cover the study region were compiled into a series of 3-color composites (browse products) which highlight particular mineral assemblages [9]. Most critical to this project was the mafic (MAF) browse product which uses the olivine, LCP, and HCP mineral indices in an RGB composite (respectively) to show olivine in shades of red and LCP in shades of cyan and green. Additionally, the enhanced false color tandem (TAN) browse product was used for evaluating scene illumination and the Phyllosilicates with Fe and Mg (PFM) browse product for the identification of phyllosilicates which can also appear red in MAF.

Mapping. Exposures of olivine- and LCP-rich material observed in the MAF browse product were mapped at a 1:100,000 scale in ArcMap 10.5. The study region was sub-divided into 100 sections which were mapped iteratively and each mapped feature was assigned a series of attributes: mineral type (LCP, OLV, PHY), confidence level (low, medium, high, inferred across data gap), primary morphologic association (e.g., knob, crater), secondary morphologic association (e.g., crater floor, crater rim), and any additional notes.

Findings: A total of 1,595 features were mapped, consisting of 1,377 exposures enriched in LCP, 206 in olivine, and 12 in phyllosilicates (used to eliminate false-positive olivine detections) (Fig. 2). Approximately 48% of exposures were assigned a confidence of high or medium while 65% were associated with knobs and crater rims/ejecta. Mapped features show a wide distribution of mafic mineral exposures in and around Ladon with a notable number of spatially extensive, low confidence or inferred outcrops in the north of the study region.

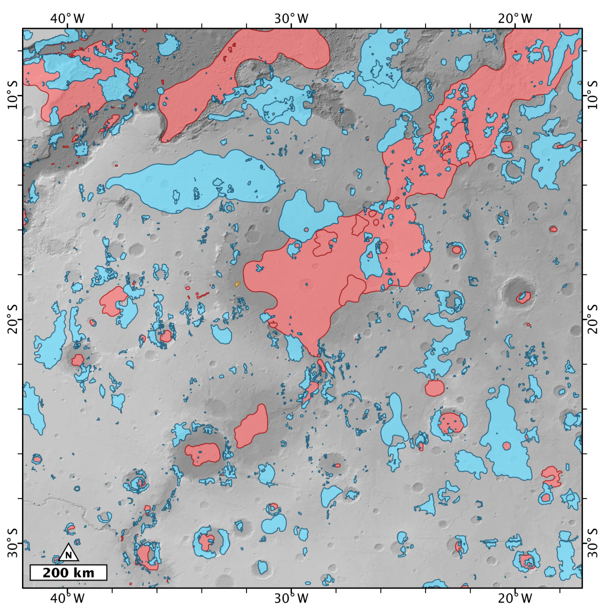

Figure 2. *Map of mafic mineral exposures in and around Ladon basin: LCP = blue, olivine = red, phyllosilicates = orange. MOLA grayscale elevation and hillshade basemap.*

The wide distribution of LCP-enriched outcrops associated with crater rims and ejecta as well and central peaks indicates the presence of LCP sourced from a variety of depths within the crust. However, the pronounced massifs in the northwest center of the basin often cited as remnants of one of Ladon's inner rings [e.g. 5, 6] show unexpectedly weak LCP signatures given their inferred excavation from the greatest depth. This suggests there may be a lower limit of LCP enrichment in the crust, though the presence of LCP outcrops in the southeast of the inner basin may instead indicate variability in LCP content with depth.

Ladon ring structures were inferred by connecting arcuate series of LCP-enriched knobs in combination with morphologic or topographic features. We find that six rings (Fig. 3) with averaged diameters of approximately 460, 575, 675, 830, 1035, and 1275 km best fit the observations. In addition to these structures, two rings were inferred for a subsequent basin that obscures the southwest of Ladon (referred to as Holden basin by [10]) with averaged diameters of 290 and 620 km.

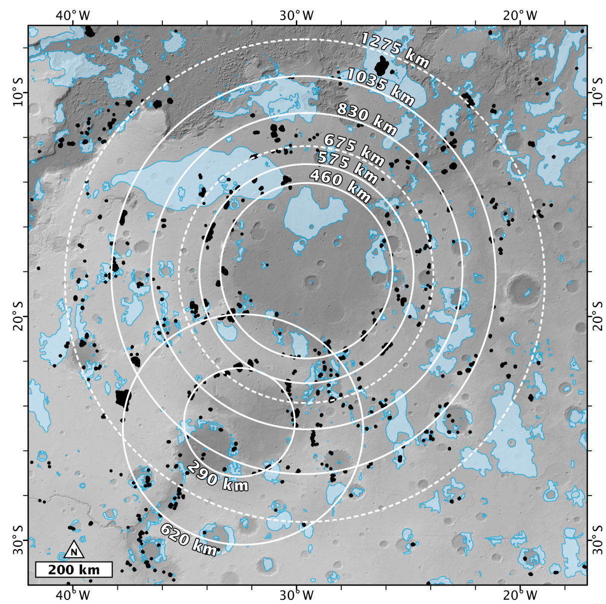

Figure 3*. Summary of inferred ring structures of Ladon and Holden basins: solid white lines = high confidence, dashed white lines = moderate confidence, annotations give averaged diameters. Mapped LCP exposures are shown in blue while black outlines highlight exposures associated with knobs and massifs.*

References: [1] Robbins, S. J., et al. (2013) *Icarus, 225,* 173–184, [2] Lillis, R. J., et al. (2013) *JGR, 118,* 1488–1511, [3] Schultz, P. H., et al. (1982) *JGR, 87,* 9803–9820, [4] Pike, R. J., and Spudis, P. D. (1987) *Earth Moon Planet, 29,* 129–194, [5] Schultz, R. A., and Frey, H. V. (1990) *JGR, 95,* 14175–14189, [6] Lillis, R. J., et al. (2008) *Icarus, 194,* 575–596, [7] Head, J. W., et al. (1993) *JGR, 98,* 17149–17181, [8] Skok, J. R., et al. (2012) *JGR, 117,* E00J18, [9] Viviano-Beck, C. E., et al. (2014) *JGR, 119,* 1403–1431, [10] Wilson, S. A., et al. (2018) *JGR, 123*, 1842–1862.