NATURE AND DISTRIBUTION OF OLIVINE AT COPERNICUS CRATER: NEW INSIGHTS ABOUT ORIGIN FROM INTEGRATED HIGH RESOLUTION MINERALOGY AND IMAGING Deepak Dhingra, Carle M. Pieters and James W. Head, Dept. of Geological Sciences, Brown University, 324 Brook St, Box 1846, Providence, RI 02906 USA (Email: deepdpes@gmail.com)

Introduction: Copernicus crater holds a unique status in the lunar context. It was one of the proposed Apollo landing site, has been well-known for its olivine bearing central peaks [e.g. 1, 2, 3], defines the youngest lunar stratigraphic unit (*Copernican*), hosts a newly discovered rock type (Mg-Spinel) [4, 5] and displays a mineralogically distinct sinuous impact melt unit (the only detection so far) [6] . This study focuses on the presence of olivine. The nature and origin of olivine at Copernicus (and by anology at other locations on the Moon) has been discussed in the past and present ranging from a mantle origin to exogenic (for the central peaks) [7, 8].

In this study, we highlight several new observations which provide insights about the nature and origin of olivine and could also provide insight into the cratering process and the formation of central peaks.

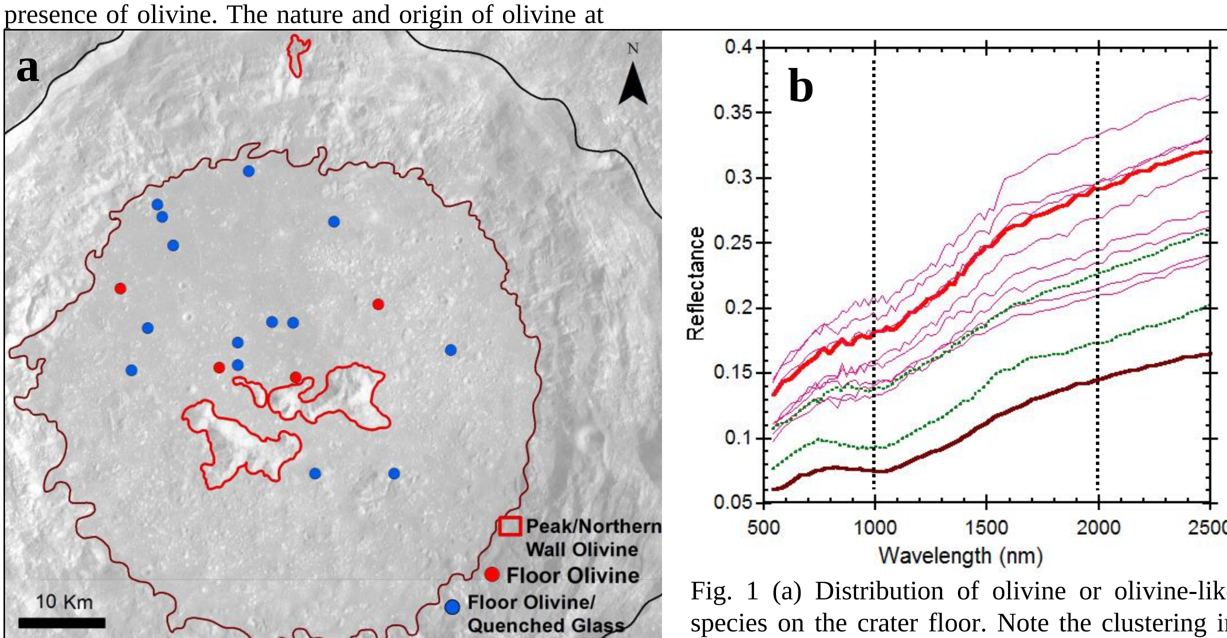
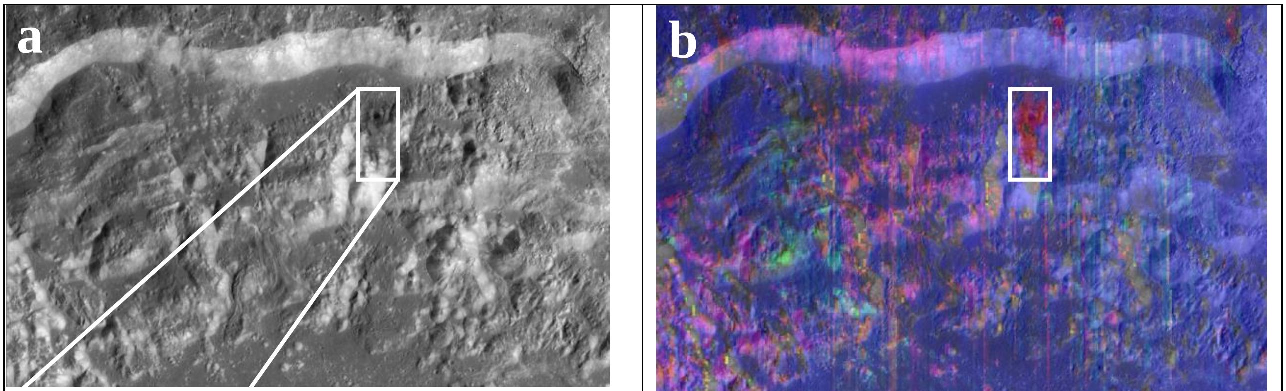


Fig. 1 (a) Distribution of olivine or olivine-like species on the crater floor. Note the clustering in the NW region. (b) Olivine-like spectral signatures of material on the floor compared with central peak (red spectrum) and northern wall exposure (brown spectrum). The magenta spectra from floor appear similar to the peak while green spectra from floor appear similar to the wall.

Methodology: High spectral and spatial resolution Moon Mineralogy Mapper (M^3) [9, 10] data has been used to extensively map the dominant mineralogical species across Copernicus [11]. The corresponding geological context was mapped using high spatial resolution Kaguya Terrain camera [12] and LRO Narrow angle camera [13] datasets.

Exposures on the Crater Floor: The high resolution mineralogical survey of the floor has revealed several exposures (140-560 m) in the NW region which display a broad 1000 nm absorption band with band center around 1050 nm (Fig. 1b). Based on this spectral similarity with known olivine exposures, we interpret the newly identified locations on the floor to be olivine-bearing. However, a component of quenched glass is also probable since it exhibits a similar band center and lacks or has a weak 2000 nm band. Some of the exposures exhibit the three superimposed bands characteristic of olivine. Others have weaker bands which cannot be resolved to confirm the 3 superimposed bands (Fig. 1a; red and blue symbols respectively). Accordingly, we are referring these floor exposures as tentative olivine identifications based on their spectral similarity with olivine elsewhere in the crater.

Olivine Exposure on the Northern Wall: The northern wall olivine exposure (Fig. 2a) has a strong and broad 1000 nm absorption band (Fig.2b, red patch). Based on previous data for this area suggesting olivine, the central peaks were proposed to be of shallow origin [5]. However, analysis of the high resolution LRO Narrow Angle Camera (NAC) images (Fig. 2c, 2d) of this northern wall olivine unit indicates no direct morphological relation to the olivine in the central peaks. Two different NAC scenes display the olivine bearing unit as a low-albedo thin deposit, starting from a melt pond and descending the walls as a thin band. It appears to mantle the underlying walls and in places, wall material can be observed poking through this low albedo material. A 20 m diameter crater (Fig. 2d, white arrow) has excavated bright material below this dark veneer while another crater of similar size (Fig. 2d, orange arrow) has excavated dark material indicating variable thickness of this deposit. The low albedo material does not represent a rock outcrop or a boulder accumulation, which could be comparable to the central peaks olivine material.



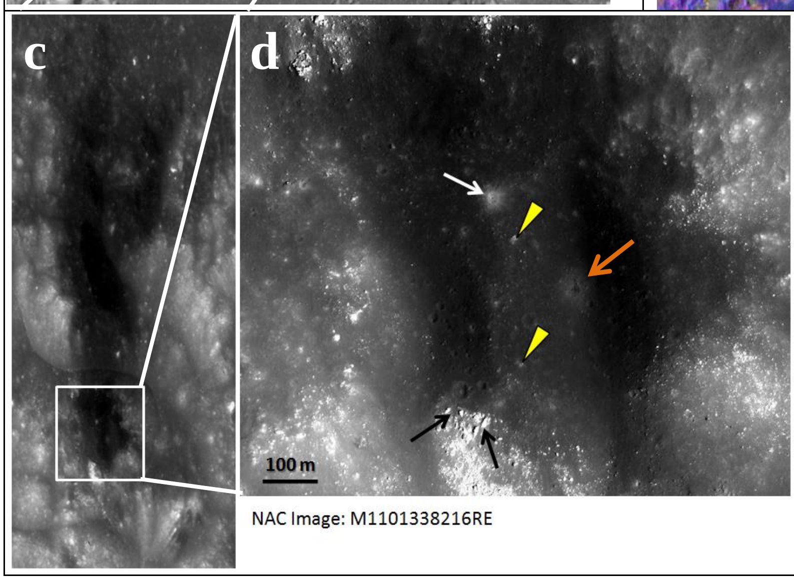


Fig. 2 Nature of olivine bearing material in the northern wall. (a) Kaguya TC image showing the northern wall and the olivine deposit (white box) (b) M^3 standard color composite overlain on the Kaguya TC image. Red–1000 nm absorption depth, Green-2000 nm absorption depth, Blue– albedo at 1489 nm. The red patch marked by the box is olivine bearing. (c) LRO Narrow angle camera image of the olivine bearing region shows it as a low albedo mantling deposit. (d) The bottom part of the low albedo (olivine bearing) unit. White and orange arrows show craters excavating bright and dark material through the dark veneer. Yellow triangles mark locations where subsurface material is poking out. Black arrows mark the abrupt boundary of the low albedo unit.

Possible Origin of Olivine: Based on the distribution and form of olivine observed on the floor and wall, it is clear that origin of olivine at Copernicus is complex. A simple model of a subsurface olivine/troctolite source which was uplifted from below the transient cavity to form the central peak is inadequate for all exposures. If the olivine found across the floor is related to that in the central peaks, then the olivine bearing horizon was sufficiently extensive to allow part of it to be entrained with other components during melting while only the troctolitic component formed the central peaks. The distinctive nature of olivine on the northern wall is a mystery but appears to require a separate origin. Possibilities include: i) products of a mafic impact melt (breached flow, devitrified glass, fractional crystallization), ii) excavation and exposure of material derived from dark mantling deposit, etc. Either case presents additional evidence of heterogeneity of impact products at Copernicus [6]. This wealth of new information about the nature, origin and distribution of olivine at Copernicus provides new constraints on the complexity of impact processes at this scale.

Acknowledgement: NLSI grant no. NNA09DB34A

References: [1] Pieters C.M. (1982) *Science*, **90**, 1151–1154. [2] Lucey P.G. et al.(1991) *GRL*, **18** (11), *2133-2136* [3] Pinet P. et al. (1993) *Science*, **260**, *797-801* [4] Pieters et al. (2011) *JGR*, 116, 10.1029/2011JE003727 [5] Dhingra et al. (2011) *LEAG Meeting*, .#2024 [6] Dhingra et al., (2013) *GRL*, **40**, 1043-1048 [7]Pieters and Wilhelms (1985) *JGR*, C415-420 [8] Yue et al. (2012) *Nature Gosci.*,**6**, 435-437 [9] Pieters et al. (2009) *Curr Sci.*, **96**, 500-505 [10] Green et al. (2011) JGR,116, 10.1029/2011JE003797 [11] Dhingra et al., in prep. [12] Haruyama et al. (2008) *EPS*, **60**, 243-256 [13] Robinson et al. (2010) *Space Sci. Rev.*, **150**, 81-124