LUNAR FLOOR-FRACTURED CRATERS: A CASE FOR VISCOUS RELAXATION. S. Ravi and M. S. Robinson, School of Earth and Space Exploration, Arizona State University, Tempe, Arizona 85281, USA (sravi@ser.asu.edu)

Introduction: Lunar floor-fractured craters (FFCs) are impact craters that underwent subsequent deformation by tectonic processes as evidenced by the presence of radial, polygonal, or concentric fractures, and sometimes host volcanic landforms such as pyroclastic deposits and mare basalt infill [**1**]. Previous morphometric studies show that FFCs have low depth/diameter ratios (d/D) compared to morphologically fresh craters (i.e., Copernican and Eratosthenian) of the same size range **[1,2]**. FFCs are typically located along the boundaries of the maria, in particular western Oceanus Procellarum **[1,2]**. However, at least 10% of FFCs are present in the highlands, away from mare contacts **[1,2]**. There are two leading formation hypotheses: viscous relaxation and magmatic intrusion. Both mechanisms could contribute to the shallowing of crater floors; however, only the former could cause a reduction of the crater rim height **[1,2,3]**.

Recent studies interpret heterogeneous gravity signatures associated with FFCs are a result of magmatic intrusions of varying density **[4]**. However, the floors of morphologically fresh craters also exhibit heterogeneous gravity anomalies, inconsistent with the magmatic intrusion hypothesis. Therefore, understanding the formation mechanism of FFCs is essential to constraining lunar magmatic evolution and, by extension, the thermal history of the Moon.

Methods: We measured volumes and exterior rim crest heights of FFCs and a subset of non-FFCs from the Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) GLD100 Digital Terrain Model (DTM; 100 m pixel scale [**5**]).

1. Volumetric analysis

We computed and compared the volumes of a subset of unmodified craters in Copernican and Eratosthenian (N = 170 **[6]**), Imbrian (N = 14 **[7]**), Nectarian age (N = 30 **[7]**), and FFCs (N = 126 **[2]**), to investigate the extent of modification craters undergo as a result of fracturing. Imbrian craters with mare basalt infill (N = 9 **[7]**) were excluded from volumetric computation.

2. Exterior rim crest height measurements

Pike **[8]** noted that relationship between rim crest height and diameter of fresh craters of two size ranges (D > 17km and D ≤ 17km) as:

$R_e = 0.236\ D_r^{0.399}$ (D > 17km)

$R_e = 0.036\ D_r^{1.014}$ (D ≤ 17km)

where, R_e is the external rim crest height, and D_r is the rim diameter.

We measured and compared the exterior rim crest heights of newly identified FFCs (N = 102; this study), Copernican and Eratosthenian craters **[6],** Imbrian craters (N = 23 **[7]),** and Nectarian craters (N = 30 **[7])** in order to test the viscous relaxation hypothesis. Rim crest height for each crater was computed by subtracting the average elevation of the surrounding region beyond the ejecta blanket from the average elevation of the rim.

Results:

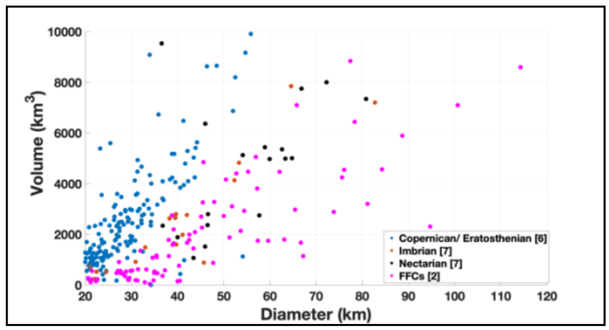

Fig. 1: Volume vs. diameter for FFCs **[2]**,Copernican and Eratosthenian craters **[6]**, Imbrian craters **[7]**, and Nectarian craters **[7]**.

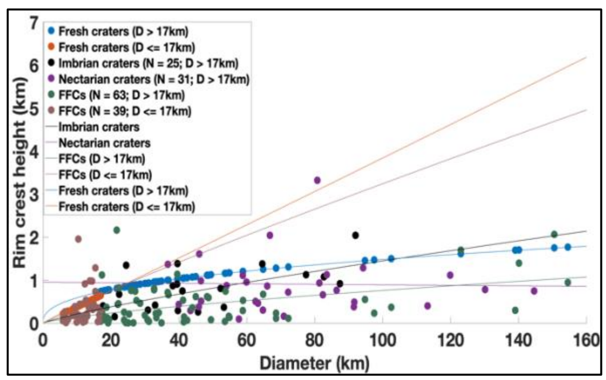

Fig. 2: Rim crest height vs. diameter for FFCs (this study), Copernican and Eratosthenian craters **[8]**, Imbrian craters **[7]**, and Nectarian craters **[7]**.

Discussion: We find that the volumes of FFCs are only 45%, 90%, and 35% that of non-FFCs in Copernican plus Eratosthenian, Imbrian, and Nectarian age craters respectively (**Fig. 1)**, implying that either mechanism could have contributed to the formation of FFCs.

Jozwiak et al. **[2]** compared the rim crest height of FFCs with that of fresh non-FFC Copernican plus Eratosthenian age craters **[8]**, and noted that both FFC and non-FFC groups exhibited the same rim crest height with respect to diameter, leading them to discount the viscous relaxation hypothesis. However, we observe at least 40% of FFCs (identified in this study) exhibit lower rim heights with respect to diameter. We note that the rim crest height of FFCs (this study) are lower than that of fresh craters of the same size range (D > 17km) **[8],** contrary to the observations of Jozwiak et al. **[2]** (**Fig. 2**) and consistent with that of Hall et al. **[3]**. While this observation could be interpreted simply as an effect of weathering over time, we observe that in general the rim heights of FFCs (this study) are lower than Imbrian and Nectarian non-FFC craters of the same size range (D > 17km) (black and purple lines in fig. 2 respectively). However, we note that FFCs (D ≤ 17km) approximately follow the same trend as fresh craters of the same size range in terms of rim crest height with respect to diameter, which is consistent with Schultz **[1]** (**Fig. 3**).

Additionally, we expanded the catalog of FFCs from **[2]** by identifying 102 additional craters and extending the size range down to D < 20km (N = 47) (**Fig. 3**). We note that at least 16% of the newly identified FFCs comprise dark mantle deposits (DMDs) that were not previously characterized as pyroclastic deposits by **[9]**.

Conclusions: While volumetric analysis shows that craters hosting fractures underwent extensive modification to their topography, the results do not discriminate between viscous relaxation vs. magmatic intrusion hypotheses. However, comparison of exterior rim crest heights of the newly identified FFCs (this study; N = 102) with that of unmodified craters of Copernican plus Eratosthenian **[8]**, Imbrian **[6]** and Nectarian **[6]** age groups is consistent with viscous relaxation, contrary to the results of **[2,4]** that reject that possibility. Since a majority of FFCs are located along the boundaries of the maria, thermal anomalies associated with basin formation events could have contributed to the relaxation of short wavelength topography such as crater rims.

References: [1] Schultz P.H. (1976) *The Moon, 15,* 241-273; [2] Jozwiak L.M. et al. (2012) *JGR, 117,* E11005 ; [3] Hall J.L. et al. (1981) *JGR*, *86,* 9537-9552; [4] Jozwiak L.M. et al. (2017) *Icarus, 283,* 224-231; [5] Scholten F. et al. (2012), *JGR, 117,* E00H17; [6] Ravi S. et al. (2017), *AGU Fall Meeting* #229297; [7] Wilhelms D.E. (1987) *USGS Prof. Paper 1348*; [8] Pike R.J. (1977) *Proc. Symp. Planet. Crater. Mechanics,* 489-509; [9] Gustafson J.O. et al. (2012) *JGR Planets, 117,* E00H25. [10] Robinson M. S. et al. (2010) *SSR*, *150*, 81-124.

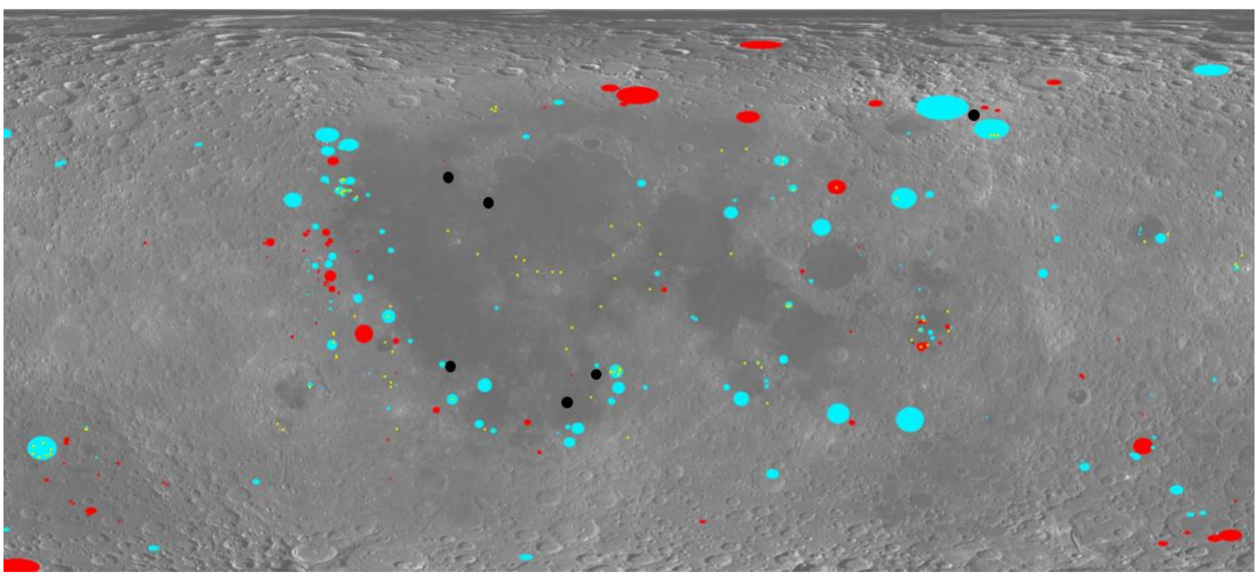

Fig. 3: Spatial distribution of FFCs, pyroclastic deposits (in yellow **[9]**), and silicic volcanic constructs (in black). FFCs identified by Jozwiak et al. **[2]** and this study represented in turquoise and red respectively. Basemap: LROC WAC global monochrome mosaic **[10]** with longitudinal extents from -180° to 180° and latitudinal extents from -60° to 60°.