ASSESSMENT OF LUNAR VOLCANIC MORPHOLOGICAL DIVERSITY: DISTRIBUTION OF FLOOR-FRACTURED CRATERS.

J. Korteniemi[1], D. L. Eldridge[2], T. Lough[3], L. Werblin[4], K. I. Singer[5] and D. A. Kring[6], [1]Astronomy, Department of Physics, University of Oulu, Finland (jarmo.korteniemi@oulu.fi), [2]University of Colorado at Boulder, CO, USA, [3]University at Buffalo, NY, USA, [4]Mount Holyoke College, South Hadley, MA, USA, [5]University of Tennessee, Knoxville, TN, USA, [6]Lunar and Planetary institute, Houston, TX, USA.

Introduction: Out of the hundreds of thousands of craters on the Moon, a few hundred have been noted to have fractures on their floors [1-3]. The floor-fractured craters (FFCs) occur in clusters, most in regions exhibiting spectral characteristics of not yet sampled materials (see Fig. 1 and e.g. [4]). The FFC fractures are often sources for pyroclastic materials and flood lavas regularly covering much of the crater floor. Adjacent craters or even adjacent fractures in a single crater may exhibit different styles of volcanic deposits. No FFCs have been positively identified on Earth, and, apart from Mars, no planet exhibits as much variety in the FFC diversity as the Moon. See a comprehensive review of past FFC work in the solar system in [5]. The lunar FFCs are thus ideal for studying the magma propagation in a heavily fractured bedrock and megaregolith. Younger impacts into the fractured terrain may expose the plumbing systems feeding the vents. The composition and age of flood lavas, pyroclastic deposits and the flux / evolution of both regional and global lunar volcanism [see also 6] may be addressed in FFCs, providing insight into most current, open scientific questions concerning the lunar evolution [7]. This study describes the currently accepted mechanisms for FFC formation, and reports the total number and distribution of lunar FFCs, including those previously unidentified.

Geologic background: Post-impact fracture fields on crater floors are generally thought to be associated with intrusive magmatism [1-3]. FFCs exhibit moats adjacent to the inner rim wall or intense fracture networks cutting the floor [3]. The patterns appear to generally conform to the crater shape, being either parallel to the crater rim or roughly perpendicular to it. Fractures are often associated with purely volcanic surface features such as lava ponds or pyroclastic deposits. The concentric fractures are generally situated on top of few tens to hundreds of meters high ridges.

Some FFCs are intimately associated with pyroclastic eruptions. Often several local mantling deposits (LMDs) center on the fractures inside a single crater (e.g. Alphonsus, Oppenheimer, Lavoisier). Many LMDs are believed to be thin [8,9] and make vertical outcrops ideal sites for in-situ sampling of multiple layers of pyroclastic deposits to study the evolution of eruption(s). The currently accepted model for lunar pyroclastic eruptions indicates that the magma origin is located in the upper mantle [10], while FFC development suggests that rising magma forms a sill (horizontally extensive reservoir) below the crater floor before erupting [3]. The models may therefore contradict each other with the origin and/or the upwards propagation of the magmatic materials. This will be an important issue to address in sample return missions.

Some FFCs are partially or entirely filled by mare-type smooth dark-albedo lacus (lakes) or smaller ponds, suggesting that the fractures provided vents for flood lavas. Entirely buried FFCs are suggested to have provided vents for at least some large scale mare flood eruptions [11]. If this is the case, visible FFCs provide access to stalled stages of mare development, from intrusion through small and large eruptive episodes to fully flooded basins. Some mare-border FFCs have been flooded by lavas from outside sources. Both situations make FFC floors good sites for sampling various types of basalts, possibly originating from different depths, especially if fracturing has in some parts post-dated the floor flooding.

FCC distribution: Schultz [3] mapped 206 FFCs on the Moon. While digitizing his work, we found 110 additional and 85 putative FFCs from Lunar Orbiter and Clementine images, bringing the total number of FFCs between 316 and 401 (Fig. 1). The distribution of the newly identified FFCs is roughly the same as in [3]: FFCs border the nearside maria and occur widely in the South Pole – Aitken basin. The highest concentration of FFCs is located in a spectrally distinct region on the western margin of Oceanus Procellarum, possibly rich in KREEP materials [4].

Schultz classified FFCs into several types depending on the location and extent of the fractured region, indicating the evolution of the sub-crater intrusions [3]. Unfortunately he did not indicate which craters belong to which class. The FFCs found in this study include craters from each type described in [3], as well as additional craters with regional, non-crater confined fractures crossing into them. The latter 1) were included in order to obtain a comprehensive list of all possible crater-related volcano-tectonic sources, and 2) provide only a minor contribution to the overall distribution. For the sake of simplification, all FFCs are here considered as one diverse group

The size range for the FFCs is very large, extending from 10 to 319 km in diameter. Most are large complex craters (average D ~62 km, geometric mean ~47 km) [3]. The smallest FFCs are simple craters, usually situated inside or adjacent to larger complex craters. Indications of < 10 km FFCs do exist, e.g. near the Gruithuisen domes, but cannot be affirmed at this time. The low end cutoff diameter is probably due to resolution limits and the filling of simple craters, and should be looked into with higher resolution images than are currently available (e.g. LRO images).

Summary: 1) The complex fracture networks make floor-fractured craters unique and easily accessible locations to sample cross-sections of various volcanic materials, and also to learn about impact crater formation and modification. 2) We identified 316 FFCs and 85 potential FFCs on the Moon. They are distributed on the edges of the near-side maria – especially on the western Oceanus Procellarum edge and around Mare Humorum, Nubium and Nectaris – and inside the South Pole – Aitken basin. 3) Higher resolution images (e.g. LRO) are needed to confirm some FFCs and to identify their relationships with volcanic deposits. 4) Due to their diverse nature, FCCs may provide good locations to sample volcanic deposits.

Acknowledgements: This work is part of the 2009 Lunar Exploration Summer Intern Program at LPI, Houston, co-sponsored by NASA Lunar Science Institute. We thank the LPI staff for their help and support.

References: [1] Masursky H. (1964) *Astrogeologic Studies (USGS open file ann prog rept A.),* 103–134. [2] Pike R.J. (1968) *Ph. D. Thesis,* Michigan Univ, 404pp. [3] Schultz P.H. (1976) *Moon 15*, 241-273. [4] Singer K. et al. (2010) *LPSC 41*, subm. [5] Korteniemi J. et al. (2006) *Proc. 40 ESLAB symp.: 1st Intl. Conf. on Impact cratering in the Sol. Syst., ESA SP-612,* 193-198. [6] Lough T. et al. (2010) *LPSC 41*, subm. [7] NRC (2007) *The Sci. Cntxt. for Expl. of Moon Fin. Rep.,* 120pp. [8] Gaddis L.R. et al. (2003) *Icarus 161*, 262-280. [9] Head J.W. et al. (2002) *JGR 107*, 10.1029/2000JE001438. [10] Shearer C.K. & Papike J.J. (1993) *LPSC24,* 1285. [11] Head J.W. et al. (1981) *Basaltic volcanism on the terrestrial planets,* Pergamon Press Inc., 701-802.

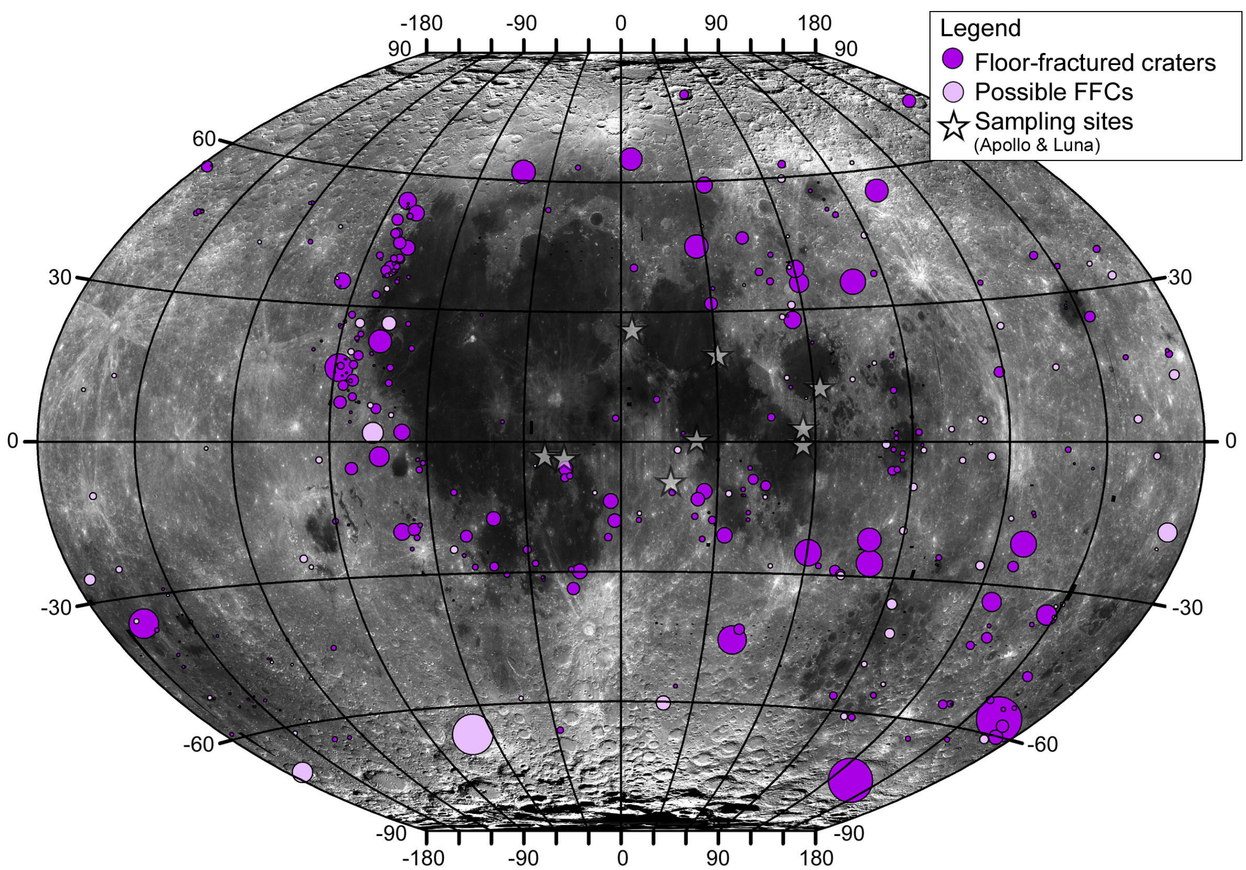

Figure 1. Distribution of all 401 lunar floor-fractured craters, 206 of which were identified already by [3]. Putative ones (85) are those which appear to have fractures but are impossible to confirm with current data resolution and quality (August 2009). The circle sizes correspond to the sizes of the impact craters.