INVESTIGATING PYROCLASTIC AND FLOOR-FRACTURE FEATURES IN VITELLO.

S. R. Burnette[1], S. Ravi[1], M. S. Robinson[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA

Introduction: Vitello is a floor-fractured crater (FFC) on the lunar nearside exhibiting low reflectance material (potentially pyroclastic deposits) distributed on the crater floor. Here we present a meter-scale morphologic map with interpretations of Vitello crater, derived from Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) images. The NAC images were supplemented with stereo and laser based topographic information (LRO) to identify and map relevant landforms and interpret their origin. Lunar pyroclastic deposits offer insight into the composition and conditions within the mantle [1] and represent potential high-value resources (Fe, Ti, O, He).

Mapping Area and Objectives: Vitello is a 40-km crater on the southern margin of Mare Humorum (30.4°S, 322.4°E). Vitello is categorized as an archetypal representation of Class 2 FFCs [2], which are defined as medium-sized craters with strong concentric fractures and an uplifted central region [3]. Large-scale fractures dominate the topography of the crater floor.

Geologic Mapping: Two controlled mosaic products produced by the LROC team formed the map base. A large-incidence angle (67.9°) product was used to identify general morphology features while a small-incidence angle (31.8°) product was used to map features based on albedo differences. Clementine UVVIS Color Ratio and FeO and TiO2 maps [4] were also used to delimit the boundaries of potential pyroclastic material based on comparisons to FFCs with known deposits such as Oppenheimer and Doppelmayer craters as well as nearby mare areas. Selene-LRO Digital Elevation Model (SLDEM, [5]) topographic data was used to categorize features based on elevation.

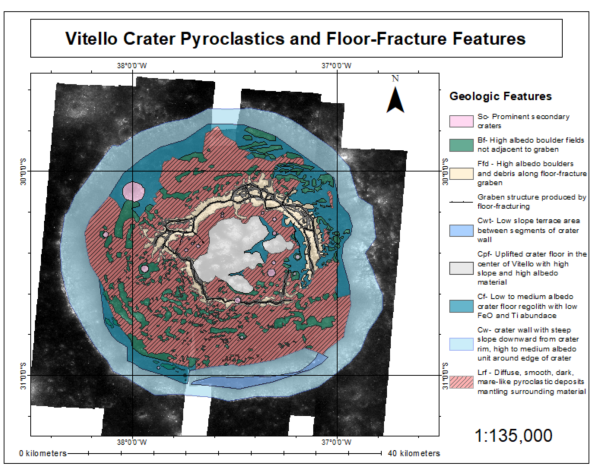

***Figure 1**: Geomorphic map of Vitello with interpreted geologic units.*

Unit Descriptions: *Floor Fracture Graben (Ffg)*. The concentric fracture feature indicative of a floor fractured crater is most prominent in the northern side of the central peak but is present on all sides. The northern segment of the feature has a length of ~35 km while the southern segment appears to be ~10 km long. The wall slope of the graben ranges from 15-22° and the width of the extensional feature ranges from a few hundred meters to two km. The bottom of the graben is dark, mature material that contrasts with the high albedo debris along the slopes.

Floor Fracture Debris (Ffd). The slopes of the grabens are characterized by high reflectance debris with large blocks and boulders (>2 m). These debris fields are often intercalated by lower reflectance materials interpreted as pyroclastic deposits. The southern section of the concentric graben exhibits less debris than the rest of the graben, which may be due to the concentration of pyroclastic material in that region.

Low Reflectance Material (Lrm). This unit is characterized by low reflectance (18-25%) material throughout the crater that is interpreted as pyroclastic features. The presence of pyroclastic features associated with floor fractured craters is well documented by [2] and [6]. Low incidence images of Vitello reveal areas of diffuse, smooth, and mare-like deposits with low albedo that mantles the surrounding material which is typical of localized pyroclastic deposits on the Moon [6] These deposits appear to be widespread throughout the crater, on a larger scale than similar FFCs such as Doppelmayer and Oppenheimer, although no pyroclastic vents have been identified.

Pyroclastic deposits in Doppelmayer and Oppenheimer are orange-red in the Clementine Color-Ratio map and show a high (~10-15% wt) abundance of FeO and TiO2 which contrasts with the non-pyroclastic crater floor [7]. Vitello has similar characteristics to these craters throughout, although the resolution of the Clementine data is much lower than that of the NAC images. This made the mapping of the pyroclastics more difficult as the boundaries between likely pyroclastic material and mature crater floor material is not distinct.

Secondary Craters, Crater Wall, and Crater Wall Terrace (Sc, Cw, Cwt). Secondary craters in Vitello were mapped when notably large (>2 km in diameter) or in areas with notable unit boundaries but are in no way comprehensive. Several secondaries display superpositions with the floor fracture features and the local ejecta appear similar in albedo distribution to the boulder fields in the Bf and Ffd units. The crater wall of Vitello is roughly circular with a terrace feature only present in the south. The 20° slope indicates that pyroclastic materials would have been carried down the wall during localized landslide events.

Boulder Fields (Bf). The boulder fields present in the Ffd unit are also found separately from the floor fracture graben throughout the crater. These fields are commonly on shallow to medium slopes and are likely due to mass wasting events or tectonics based on the presence of boulder tracks. The high reflectance of this unit (~30%) contrasts with the adjacent units. The blocks can be resolved down to a few meters long.

Crater Floor (Cf). The crater floor unit consists of low reflectance material relative to the surrounding units without pyroclastic features. Additionally, this unit is not diffuse and looks similar to standard crater floors across the lunar surface. Boundaries with the Lrf unit are numerous but hard to differentiate due to similar reflectances and low resolution Clementine data in some areas.

Central Peak Feature (Cpf). The central peak feature is an uplift feature with a large number of boulder tracks and signs of mass wasting. The slope reaches up to 20 degrees relative to the crater floor and high albedo boulders cover the sides of the peak.

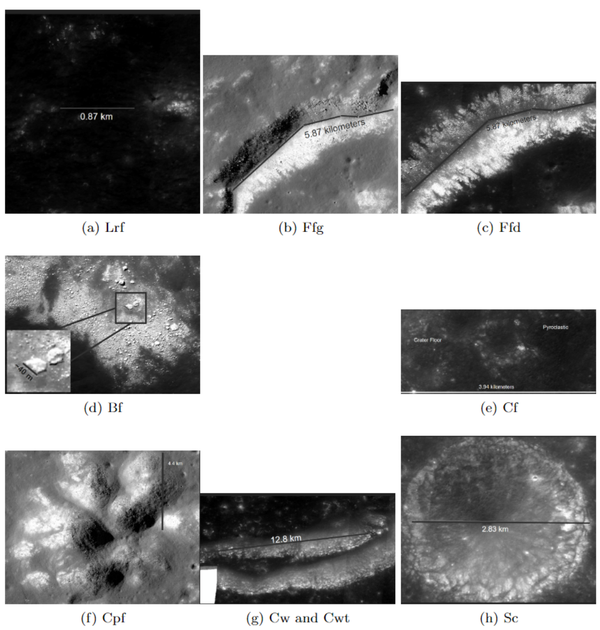

Figure 2*: Geologic units of Vitello*

Discussion: FFC formation is generally associated with the alteration of the crater floor and is observed in similar geologic settings as pyroclastic deposits [3]. There are two leading formation mechanisms: viscous relaxation and magmatic intrusion. In the former model, an older basin moving towards isostatic equilibrium causes brittle deformation and subsidence in the superimposed crater topography [3,10]. In the latter model, magma intrudes through the mantle and forms a laccolith that uplifts the crust. In both cases, the hotter mantle undergoes plastic deformation while lower temperatures near the surface result in brittle deformation and fractures that could act as pathways for magma intrusion. Alternatively, a laccolith may provide a magma source near the surface that allows for pyroclastic venting through fracture features.

The large extent of Vitello pyroclastics may indicate a preexisting pyroclastic deposit that was excavated by the impact event. A localized dark mantle deposit was expected in Vitello but mapping shows evidence for a larger scale deposit more in line with the size of a regional dark mantle deposit [8]. Suspected pyroclastics can be seen to infill topographic lows and no pyroclastic vent has been identified; both of which are atypical of lunar pyroclastic deposits. One section of the Lrf unit appears to be cross cut by the floor fracture graben, indicating that the unit was present before the floor fracturing event which supports the formation of Vitello near a pre-existing deposit. The sharp morphology of Vitello indicates that a direct impact on pyroclastics would be unlikely.

Conclusion and Future Work: The Lrf unit covers roughly 50% of the crater floor and appears more widespread than similar features in other floor-fractured craters with localized dark mantle deposits. The concentric floor-fracture features (Ffg, Ffd) appear to be younger than the pyroclastics based on cross cutting relationships and are consistent with other FFCs. Higher resolution (2 meter) multispectral observations with similar wavelengths to the Clementine dataset would be required to further constrain the boundaries and scope of the Lrf unit. The method of analyzing mineralogy maps outlined in [9] could be extrapolated to Vitello to better understand the eruption style that produced the pyroclastic deposits. Additionally, a more robust comparison with FFCs known to have pyroclastic deposits could provide insight into the potential excavation of pyroclastics during the impact that formed Vitello.

References: [1] Delano J.W. (1986) *JGR,91(B4)*, 201–213. [2] Jozwiak L.M. et al. (2012) *JGR., 117,* E11005. [3] Schultz P.H. (1976) *The Moon, 15*, 241–273. [4] McEwen A.S. and Robinson M. S. (1997) *Adv. in Space Res., 19, 10,* 1523-1533. [5] Barker M.K. et al. (2015) *Icarus, 273*, 346–355. [6] Gustafson J. O. et al. (2012) *JGR., 117*, E00H25. [7] Shkuratov Y.G. et al. (2018) *PSS, 153,* 22–38. [8] Gaddis L.R et al. (2003) *Icarus, 161,* 262–280. [9] Bennett K.A. et al. (2016) *Icarus, 273,* 296–314. [10] Hall J.L. et al. (1981) *JGR, 86,* 9537-9552.