VOLCANISM IN VULCAN PLANUM: TOPOGRAPHIC TESTS FOR THE EMPLACEMENT OF SMOOTH PLAINS ON CHARON. M. E. Borrelli[1] and G. C. Collins[1], [1]Wheaton College, Norton MA, borrelli_madison@wheatoncollege.edu.

Introduction: Portions of the southern hemisphere of Pluto's moon Charon observed by *New Horizons* are composed of smooth plains material, named Vulcan Planum. The edges of the plains material in Vulcan curve downward into lower elevation "moats" [1] wherever the plains come into contact with surrounding terrain units. The sloping edges of the moats have been hypothesized to result from either flexure due to elastic plate bending from a load emplaced on the plains [1], or viscous flow of the plains material as it was emplaced [2]. We explore the possibility that the plains may be emplaced as cryovolcanic flows, the fronts of which form the curved edges of the moats. We compare the topography at the edges of Vulcan Planum to topographic profiles that would result from either a plate bending model or a lava flow front model.

Previous works have fit equations for Newtonian and Bingham flows to known or suspected volcanic features on other worlds. For example, Neish et al. [3] fit several models to the shape of salt domes on Earth to determine how the material flowed across the surface as it was forming. This method was also applied to domes on Venus by matching topographic profiles of the domes to profiles given by various flow models [3]. Similar work has also been done within the lunar crater Ina. It was hypothesized that the higher elevation features within the crater are the result of an inflated lava flow. Garry et al. [4] took topographic profiles of the suspected flows on the moon and compared them to topographic profiles of known inflated lava flows on Earth at Craters of the Moon National Monument in Idaho. The two profiles were plotted against each other to find similarities in the topography and provide explanations for the differences based on the lunar environment [4].

Methods: The *New Horizons* image mosaic and the digital elevation model (DEM) of Charon ([1], available on USGS Astropedia) were imported into ArcGIS. Next, we used 3D Analyst to extract topographic profiles across the edge of Vulcan Planum. The profiles were drawn all the way across the moat and extended into the low relief plains, avoiding large impact craters (Figure 1). Six profiles were extracted and imported into MATLAB. The horizontal data for every profile were then trimmed so that the profile always begins at the lowest elevation value in the center of the moat, and then the elevation values were normalized to zero elevation at the bottom of the moat.

Using the fminsearch curve-fitting algorithm in MATLAB, the topography of the edge of Vulcan Planum was plotted against the theoretical curves for a viscous flow front with Bingham rheology, for a loaded continuous elastic plate, and a loaded broken elastic plate. The code requires the user to seed the algorithm with guesses for the values of two equation parameters as starting points so it can begin fitting a curve with reasonable values. It then varies the values for these parameters to minimize the misfit between the theoretical curve and the observed data. Finally, it plots the profile of the lava flow or bending plate model that best matches the shape of the input topographic profile. The code returns a correlation coefficient indicating how well the theoretical curve matches the observed profile, as well as the values of the parameters that best fit the curve. One can then determine if the values necessary to match the shape of the curve are physically realistic. For the plate bending model, the algorithm finds values for the flexural parameter α and the maximum displacement w_0 [5]. For the lava flow model, the algorithm finds values for the best fit flow front velocity and dynamic viscosity. The lava flow model used an equation for the flow thickness as a function of distance from the flow front, depending on constant mass density, ground slope, and gravitational acceleration [6].

Results: Using the above method for one of the profiles, the lava flow model fits the topographic profile slightly better than the plate bending models, though all of the models fit reasonably well. The correlation coefficient for the lava flow model was 0.93 when the front velocity is 6.5 m/s and the dynamic viscosity is 6.4×10^5 Pa s. The temperature on the surface of Charon is 53 K, which could lead to a supercooled, highly viscous cryovolcanic flow. For example, supercooled ammonia-water liquids have a viscosity of 2×10^5 Pa s [7], which we used as a seed value for the curve fitting algorithm. The resulting best fit value for viscosity is therefore within reason. The initial guess entered for flow front velocity was 2 m/s, and the best fit value of 6.5 m/s is also within reason.

For the continuous elastic plate model, the correlation coefficient was 0.90, with an α of 4.3×10^3 m and a w_0 of -1.2×10^3 m. The broken plate resulted in a correlation coefficient of 0.93, with an α of 8.2×10^3 m and a w_0 of -1.3×10^3 m. The initial guess entered for the maximum displacement was the difference between the elevation values at the two ends of the profile. The initial guess entered for α was the midpoint of the horizontal distance data divided by pi.

There remain some ambiguities surrounding the values for the parameters filled in by the model. In the lava flow model, the values for front velocity and dynamic viscosity are multiplied in the equation used to find the shape of the curve. Therefore, we cannot strictly separate which of those two variables is affecting the results. Because velocity and viscosity trade off against each other in the equation, increasing one and proportionally decreasing the other will lead to the same end result.

Future work: Our initial results support the idea that the moats around Vulcan Planum could be formed by cryovolcanic flow fronts. This project is ongoing and we will continue to fit curves to more profiles along the edge of Vulcan Planum to test the robustness of these initial results. We will also test alternative formulations for fitting flow topography [e.g., 3,6]. We will also compare the elastic flexure values obtained in the fits to those obtained by Beyer et al. for the neighboring graben flanks on Charon [8].

References: [1] Moore et al., Science 2016; [2] Schenk et al., ISPRS (abstract) 2016; [3] Neish et al., Icarus 2008; [4] Garry et al., JGR 2012; [5] Turcotte and Schubert, *Geodynamics*, 2014; [6] Dragoni et al., JGR 2005; [7] Kargel et al., Icarus 1991; [8] Beyer et al., Icarus 2017.

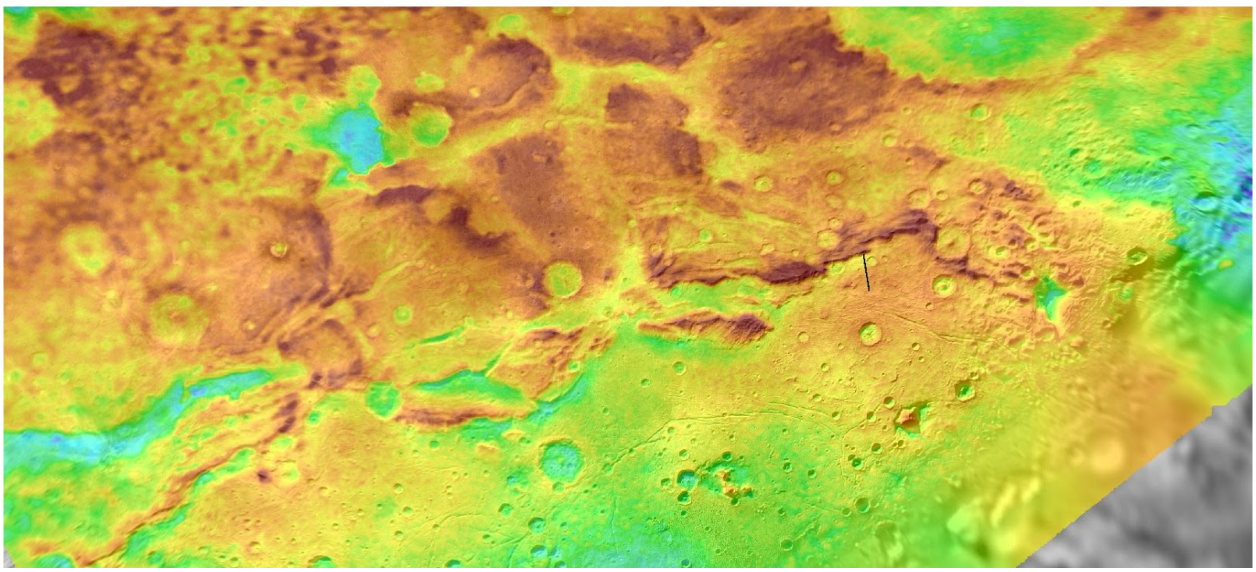

Figure 1: The location of the first of six profiles (black line) along the northern edge of Vulcan Planum, taken from the New Horizons DEM of Charon [1]. Red indicates areas of higher elevation (+6000 m), while blue indicates areas of low elevation (-5000 m). The image extends from 55°N to 15°S and 85°W to 75°E.

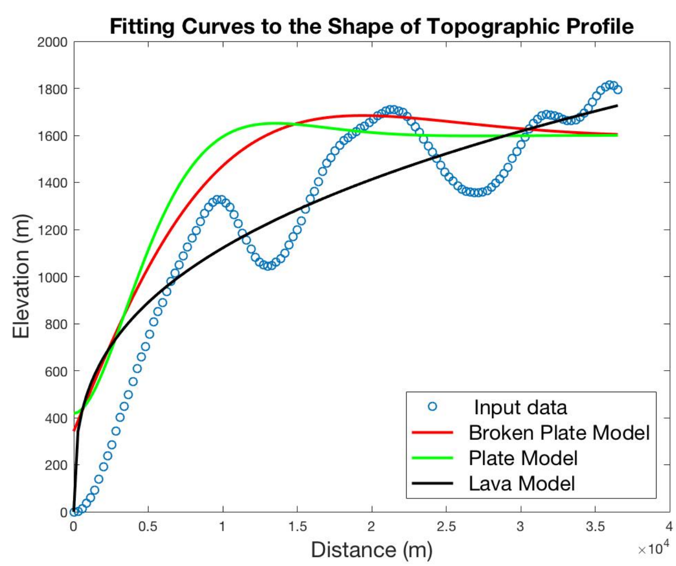

Figure 2: The topographic profile shown in figure 1 is plotted as blue circles, while the graphs of the best fit lava flow model and the plate bending models are solid lines. In this case, the lava flow model fits the shape of the topography slightly more closely than the plate bending models, though all three are reasonable fits to the data.