Lobateness Study of Impact Craters on the Surface of Pluto

A *New Horizons* Study

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***Abstract:* On July 15th, 2015, *New Horizons* made its closest approach to Pluto at a distance of 12,500 km. This was the first spacecraft to visit the Pluto system. The spacecraft features a suite of instruments. Through analysis of imagery obtained, a study of crater morphology was conducted to learn about its possible ties to the sub-surface composition Pluto. Analysis of fluidized ejecta from various craters on different terrain types on these bodies can be clues to the makeup of what goes on beneath their faces. This paper will make parallels between my personal study of crater morphology on Pluto, and previous research done studying rampart craters on the Martian surface. These craters, as observed originally by Viking, are indicative of subsurface volatiles present on a planetary body as shown by their remnants in a vaporization process generated by the heat of the impact that caused the crater.**

1.) Introduction

Lobate ejecta morphology of that of Plutonian craters is distinctive of that of some morphologies of Lunar or Mercurian craters. The key difference is the fluidization that is theorized to occur due to vaporization of subsurface volatiles due to impacting objects.

I have conducted a study using 88 impact craters of regions of the illuminated flyby hemisphere of Pluto. The purpose of the study was to measure the lobes of these craters and generate a lobateness value for them.

Lobateness is a measure of fluidized crater ejecta as a function of the crater size. For the purposes of this study lobateness can be measured by:

$$\Gamma = P/\sqrt{(4\pi A)}$$

Where Gamma is lobateness, P is the perimeter of the lobate ejecta blanket. A is the area covered by the ejecta blanket.[1]

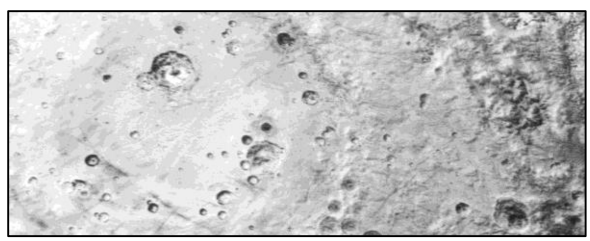


Figure 1: Impact craters on Pluto, center, ejecta blankets can be seen.

Of the 88 craters studied, craters fell into three categories as follows:

1. Single Lobe Ejecta (SLE)
2. Dual Lobe Ejecta (DLE)
3. Multi Lobe Ejecta (MLE)

Crater data gathered was done so using the *New Horizions* spacecraft during its July 15th, 2015 flyby. The Craters cover multiple terrain types, however most of which are in the vicinity of Sputnik Planum (SP) as it was the most prominent feature of the flyby hemisphere.

Previous work into the research of the relationship of crater lobateness and the nature of impacted terrain has been established and research primarily with Mars, but also other solar system bodies such as Ganymede and Europa. [2]

2.) Methods

To initialize the survey, I began a series of crater counting and indexing over images from both the LORRI (Long Range Reconnaissance Imager) instrument and the MVIC (Multispectral Visible Imaging Camera) instrument. After going through roughly 11GB of image data I had compiled from relevant spacecraft times. I had over 100 craters indexed. However, I had to choose craters with proper illumination in order to allow proper measurements of their characteristics.

The software tool I used for these crater investigations was the United States Geological Survey's Integrated Software for Imagers and Spectrometers (USGS ISIS.) ISIS is able to process 'cubes' (.cub file, multilayered images) and render them into numerous different data formats. Cubes, as they are known, have to be carefully calibrated in conjunction with SPICE (Spacecraft & Planetary ephemerides, Instrument C-matrix and Event Kernels) data. Careful use of SPICE allowed me to geometrically correct images for values such as Longitude and Latitude and enabled me to take measurements of different craters for the study.

To start the study of surveyed craters, I took a North-South approach that I utilized to measure the necessary crater features (lobate ejecta perimeter, and ejecta area) in descending latitude. This allowed me to mark my craters off and limited the chances of mistakenly revisiting craters for measurements.

Additionally, I created a spreadsheet to track crater data as it came and tied it to images that served as the origin for a crater.

With my data sheet of craters, I computed lobateness values for each of the 88 craters included in the survey using the equation above.

3.) Results

Of my 88 craters surveyed they broke down into the following groups:

Single Lobe Ejecta (SLE) – 72

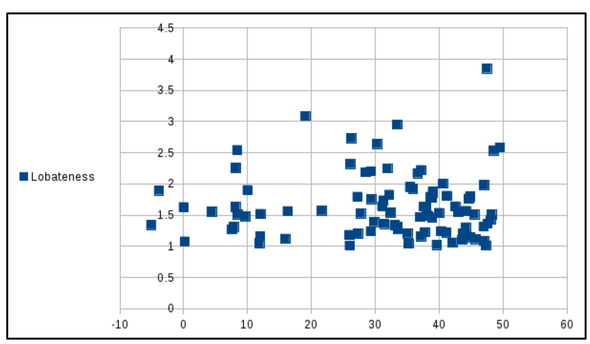
Dual Lobe Ejecta (DLE) – 14

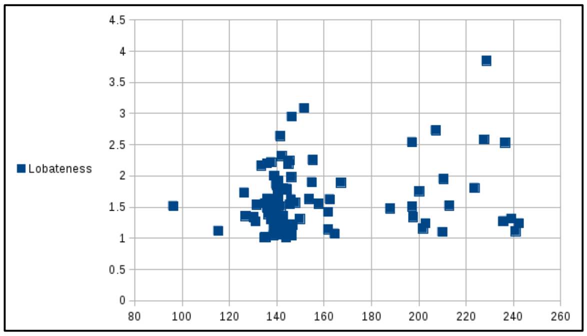
Multi Lobe Ejecta (MLE) – 2

Raw Lobateness Values Ranged from 1.008 – 3.848

Craters ranged from 3km-50km in diameter.

The lobateness values for craters typically increased around the areas of North-Eastern Sputnik Planum as evidenced by figures 2 and 3 (the SP region could be boxed as -10 ° thru 50 ° latitude and 140 ° thru 190 ° longitude.)





Figures 2 & 3: Both graphs above describe crater lobateness across latitude and longitude respectively.

4.) Discussion

The behavior for prevalence in SLE morphology follows that of Mars, Ganymede, and Europa. This supplements theories that suggestion common behavioral patterns for fluidized ejecta morphologies across the solar system. This is interesting due to the appreciable differences in conditions on these different bodies. Although both icy bodies, Pluto has an appreciable atmosphere mired with many haze layers, Europa does not. Mars as a Terrestrial Planet, has a completely different form of surface geology compared to that of Kuiper Belt Dwarf Planet Pluto. [3]

The lobateness features of craters near the North Eastern border region of Sputnik Planum and C'thulu Regio suggests volatiles there were more readily vaporized during impact. There is research currently into the geologic nature of Sputnik Planum, but one of the leading theories points to Nitrogen ice have a glacial behavior over the feature. The lower melting point of Nitrogen then that of Pluto's rigid water ice could be used as evidence for Nitrogen's presence in Sputnik Planum due to its relative ease for vaporization and lobe forming. [4]

The theorized glacial behavior of Nitrogen on Sputnik Planum when put into perspective of Pluto's 248-year orbit period is of particular interest to the smooth and unmarred face of Sputnik Planum. Regardless of processe(s) in place that resurface Sputnik Planum. I observed craters along a border region in figure ___ that could be in the process of that resurfacing. I felt that they were of particular interest when found during the course of my survey.

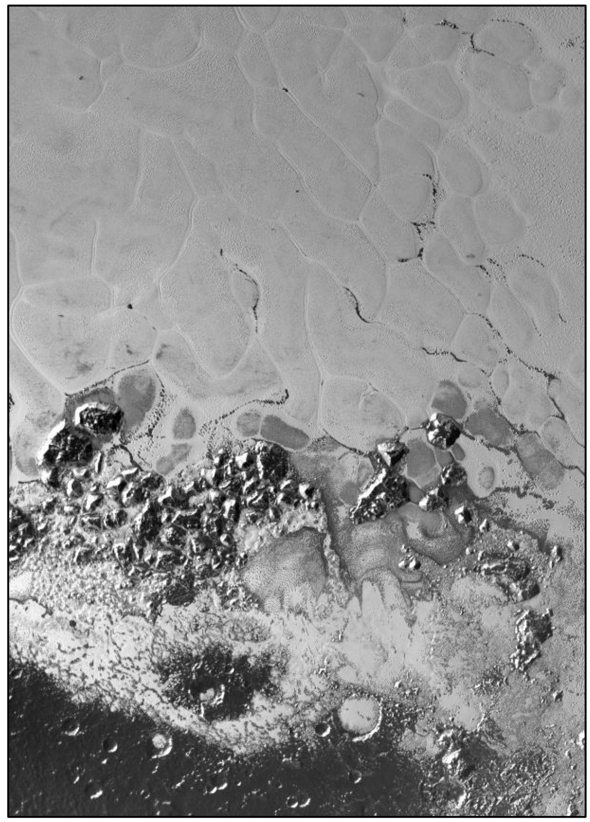


Figure 4: Impact craters bordering SP, what could be nitrogen ice depositing in the large crater in the foreground

5.) Follow On Research

If this study was conducted at a larger-scale, more craters surveyed, more regions covered, and more images used. A strong model for crater morphology on Pluto could be made.

Furthermore, if this study was also conducted on craters surveyed on Pluto's natural satellite Charon, it could yield data about similarities between the two bodies.

Any additional data collected on craters in the area of Sputnik Planum could be useful in terms of identifying what is the resurfacing behavior of the region.

Lastly, any scientific investigation based upon New Horizons data is limited simply by the nature of the New Horizons flyby mission. Without an expanse of data and images taken from many orbits, photographing the entire surface of the Dwarf Planet to a certain resolution, much of Pluto's secrets will be kept from us.

6.) References

[1] N. Barlow, "Sinuosity of Martian rampart ejecta deposits," Lunar and Planetary Institute, Houston, Texas, May 1994

[2] J. Boyce, N. Barlow, P. Mougins-Mark, S. Stewart, "Rampart craters on Ganymede: Their implications for fluidized ejecta emplacement," Meteoritics & Planetary Science, October 2010

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[4] J. Moore, W. McKinnon, J. Spencer, A. Howard, P. Schenk, R. Beyer, F. Nimmo, K. Singer, O. Umurhan, O. White, S. Stern, K. Ennico, Cathy B. Olkin, H. Weaver, L. Young, R. Binzel, M. Buie, B. Buratti, Et al, " The geology of Pluto and Charon through the eyes of New Horizons," Planetary Science, March 2016

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