Crater Depth & Diameter and Their Association with Hemisphere & Ejecta Type

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Introduction

The surface of Mars is riddled with craters and has been that way for billions of years. There are not enough erosion or geological processes on the red planet to slowly get rid of them, either. As a result, there is a rich abundance of craters available for scientific study.

There have been some studies done in the past to research the craters but identifying them was always a big hurdle. With recent technological advantages, we now have high resolution maps and images of Mars so that exhaustive lists of craters of significant size (>= 1km diameter) have been released.

There have already been a few studies conducted, but a majority are not done using as much data as we used in our analysis. We attempted to provide a more comprehensive analysis on the nature of martian craters in the hope to gain more complete insight.

During the research, it was decided to focus specifically on the association between crater depth and crater diameter, as well as how those are effected by the ejecta morphology and the hemisphere the craters are located in.

Sample Characteristics

- There are 384,341 craters recorded in this data set.
- Variables used:
  - Response: Diameter, identified by the crater rim, measured in km.
  - Explanatory:
    - Depth: chosen by the lowest point, not including embedded craters, measured in km.
    - Hemisphere: divided into Northern and Southern portions based on latitude and longitude measurements.
    - Ejecta Type: the morphology of the crater layers, in which ejecta type is how the layers surround the crater. Categorized as either hummocky, smooth or unkown.

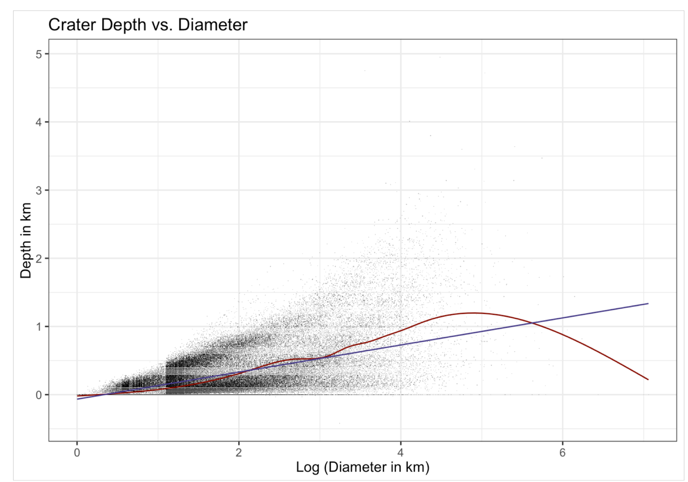
Statistics and percentage of craters lying in each category of the variables:

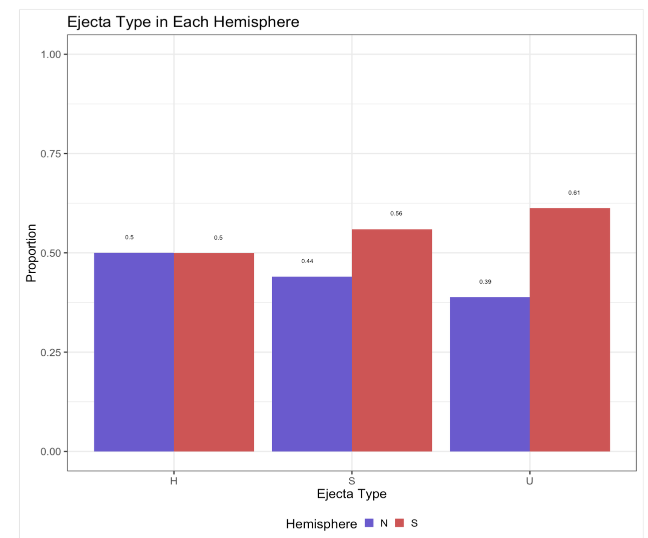
Variable	Mean	Standard Deviation
Diameter	3.56 km	8.59 km
Depth	0.08 km	0.22 km

Northern Hemisphere	Southern Hemisphere
39.3%	60.7%

Hummocky Ejecta	Smooth Ejecta	Unknown Type
3.6%	1.4%	94.9%

Bivariate Analysis



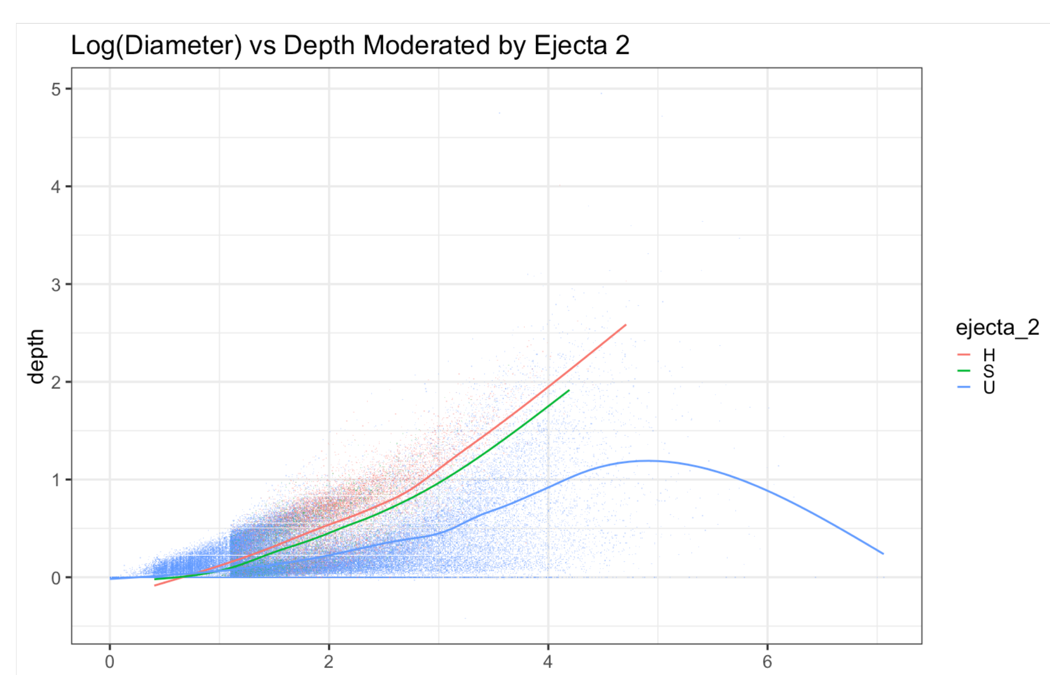


- Log transformed the diameter variable, original skew of data points was obstructive in analysis.
- There is a strong, positive, linear association between depth and the log of diameter (r = 0.72).

- Hummocky craters are evenly distributed among hemisphere.
- Smooth craters occur slightly more often in the South (56%) than in the North.
- Unknown craters occur most often in South (61%).

Moderation in Multivariable Regression

- When moderated by ejecta 2, direction of relationship between log diameter and depth is significantly different among craters of unknown ejecta type.
- The slope estimate for hummocky ejecta is 1.09 (1.07, 1.11), for smooth ejecta is 1.17 (1.13, 1.20), and for unknown ejecta is 2.89 (2.88, 2.89).
- For all slope estimates, $p < .0001$ and $r > .68$, so each relationship is strong and significant.
- Slope value for unknown ejecta is over twice the other two types, we conclude that Ejecta 2 is a moderating variable.
- Tested for moderation in hemisphere variable, found that it did not change the relationship between depth and diameter.

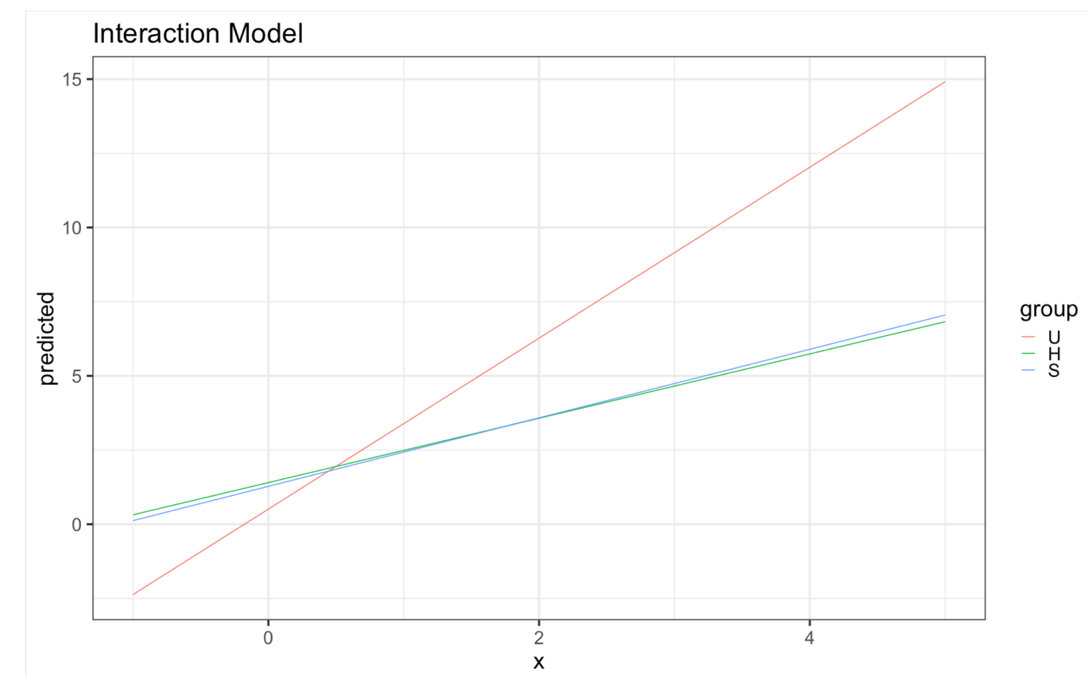


Multivariable Equations, Interpretations

The multivariable model consists of depth, hemisphere, ejecta type, and an interaction between depth and ejecta type as predictors.

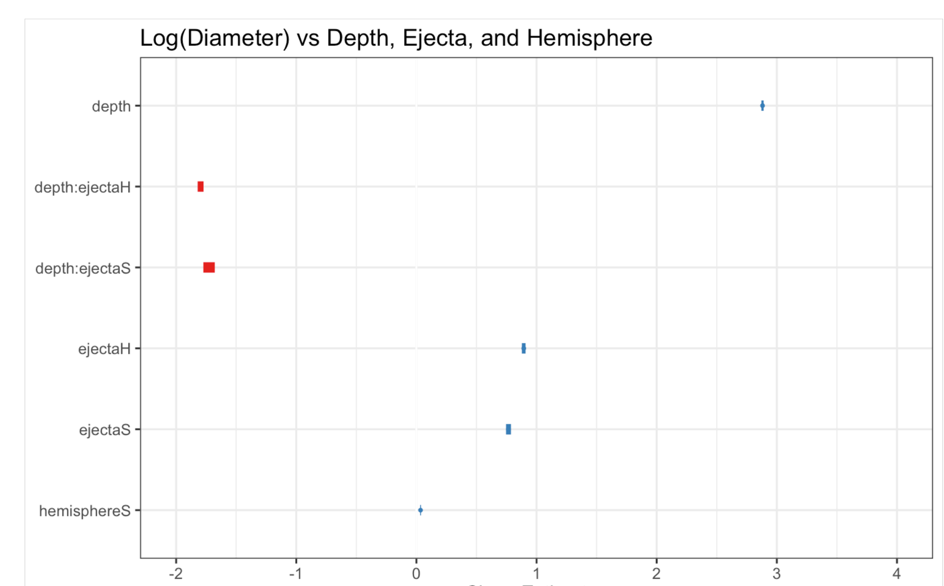
For each category of ejecta type, we have a multiple linear regression equation:

- Unknown: $\log(\text{diam}) = 0.47 + 2.88 \cdot \text{Depth} + 0.03 \cdot \text{South}$
- Hummocky: $\log(\text{diam}) = 1.36 + 1.08 \cdot \text{Depth} + 0.03 \cdot \text{South}$
- Smooth: $\log(\text{diam}) = 1.24 + 1.16 \cdot \text{Depth} + 0.03 \cdot \text{South}$



- Unknown type craters increase in log of diameter about twice as rapidly as the other two types when the depth increases.
- Since hemisphere is not a moderating variable, the slope value on the South variable is constant.

Plot of Confidence Intervals for Slope Estimates:



- Because this data set consists of over 384,000 observations, the confidence intervals for the slope estimates are extremely narrow.
- The estimates can only be interpreted once they have been exponentiated, since they were used to predict the log of diameter.

Diameter	Slope Estimate	Exp(Slope Estimate)	Confidence Interval
Intercept	0.47	1.607	(1.603, 1.612)
Depth	2.88	17.826	(17.656, 17.995)
Southern Hemisphere	0.03	1.035	(1.032, 1.039)
Hummocky Ejecta	0.89	2.443	(2.406, 2.481)
Smooth Ejecta	0.77	2.153	(2.109, 2.197)
Depth:Hummocky Ejecta	-1.80	0.166	(0.162, 0.170)
Depth:Smooth Ejecta	-1.72	0.178	(0.170, 0.187)

- The diameter of a crater increases about 1,7826% each time the depth increases 1 km. Craters located in the Southern hemisphere of Mars are about 3.5% wider than craters in the Northern hemisphere.
- As seen from the confidence intervals, these estimates seem to leave little room for error, which is entirely due to the extremely large sample size.

Conclusion and Limitations

- Some of the most impactful findings we got out of the research pertained to the diameter and depth. We found that the relationship between the depth and diameter of a crater is very strong.
- This relationship remains true in the Northern and Southern hemispheres, indicating location does not play a key factor.
- The ejecta morphology surrounding the crater does affect the association between depth and the log of diameter.
- Diameter is close to linear when log transformed. So there are possible deviations from normality and non-constant variance.
- Modeling the bivariate and multivariate relationships linearly may not be the best fit, a polynomial model might be more appropriate.
- The sample size is very large, we might have gotten more accurate results if we removed observations with unknown entries. But they were the majority of observations, so we left them in for analysis purposes.
- Little variety in the variables, tough to create any more associations.
- For future research, our findings justify narrowing the pool of craters to just one specific population, i.e. one ejecta type.

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