The Relationship between Martian Terrains and Crater Size Distributions

Shital Oli
Quantitative Analysis Center, Applied Data Analysis
Wesleyan University, Middletown, 06459

Introduction

- Mars, like other planets in our solar system, is estimated to be around 4.6 billion years old. Due to its proximity to Earth and its strikingly similar features, Mars has been a key focus of scientific study.
- Over the past several decades, scientists have deployed landers, rovers, and photographic instruments to better understand the global mineral composition and geomorphology of Mars (Christopher et al., 2024).
- Building on the current investigation into Mars' geographical characteristics, an effective approach is to analyze the craters and their locations, as these features provide valuable insights into the planet's composition. The visual identification of impact craters on planetary surfaces is one of the most widely accepted methods for studying the composition of Mars' crust (Souness et al., 2012). This study tests whether the location of an impactor affects the size or the volume of the resulting crater on Mars.

Research Questions

- What is the relationship between Martian crater sizes and its location?
- Does the geographic location of the craters correlate with the volume of these craters?

Methods

- Sample: This study is based on the Mars Global Crater Database, created by Stuart Robbins, one of the most detailed datasets of Martian craters. The database includes information on 378,540 craters with diameters of 1 km or greater. From this dataset, a subset of 76,804 craters with depths greater than 0 km was selected, as measurable depths provide valuable insights into crater formation and the relationships between size, volume, and geographical location.
- Measures: For each crater in the sample, latitude and longitude coordinates were recorded, and a unique crater ID was assigned. Diameter and depth values were extracted from the database. Additionally, a new variable, volume, was calculated using these measurements.

Results

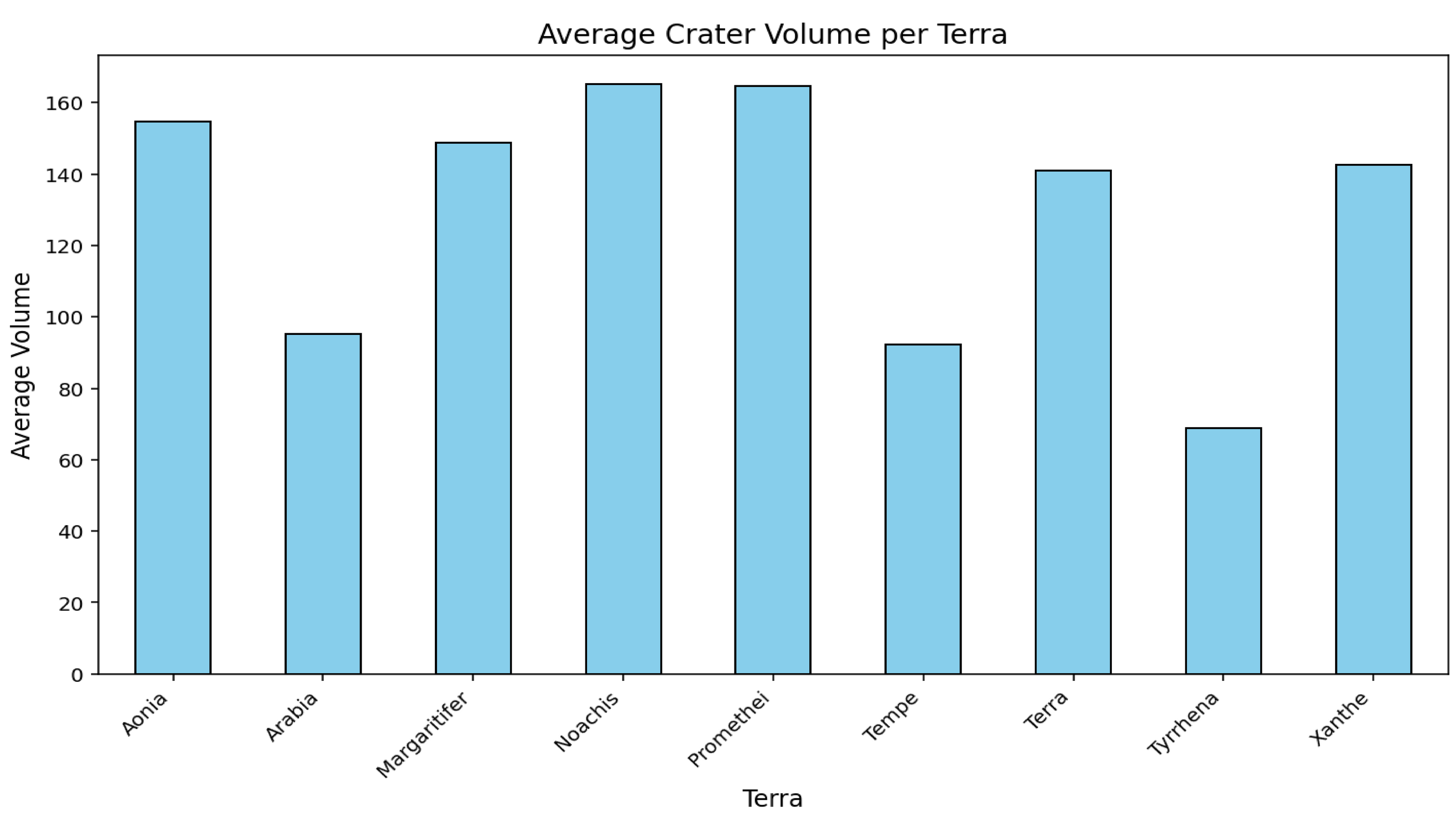

Figure 1: Bar graph showing the relationship between Martian Terras and the average volume in each of the Terras.

Bivariate:

- When examining the association between the Martian Terras (categorical variable) and the average volume of craters in each of the Terras (response variable), an Analysis of Variance (ANOVA) revealed that crater volumes differ based on the region that the impactors hit.

ANOVA p-value: 0.0004

- The notably small p-value of 0.0004 indicates that the null hypothesis which states that there is no relationship between Martian Terras and crater size can be rejected. There is a significant relationship between Martian Terras and crater size, confirming that the size and the volume of the craters differ based on the regions that the impactors hit.

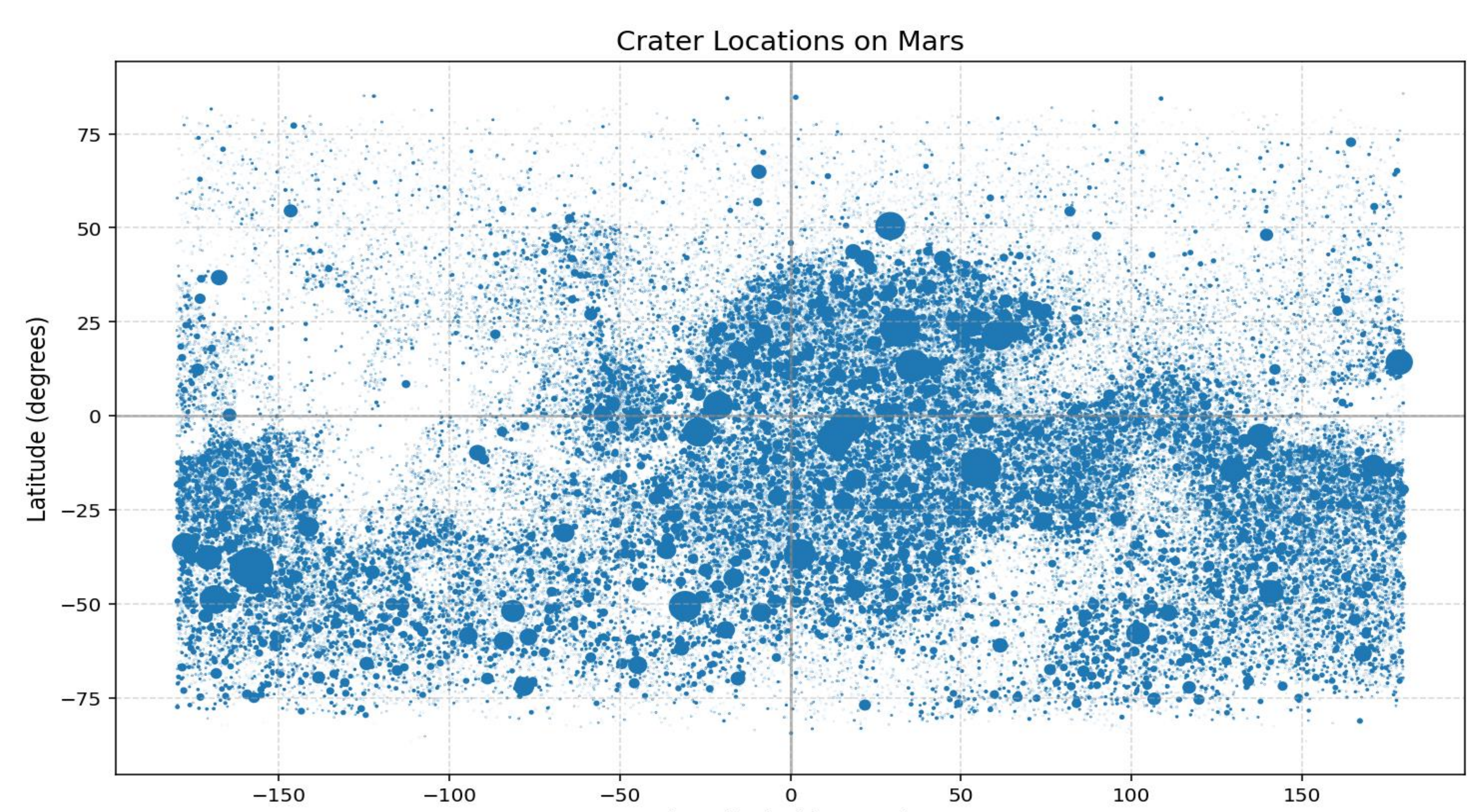

Figure 2: Scatterplot showing the locations of the craters, with latitude and longitude coordinates on the axes. The size of each plotted point corresponds to the volume of the crater.

Multivariate:

- The multivariate graph illustrates the relationship between crater location, cluster distribution, and crater volume across different Terras. Multiple linear regression tests were performed to examine the relationship between crater volume and location within each Terra. Significant associations were found between crater size and location for the following Terras: Arabia (p-value = 0.016), Tempe (p-value = 0.012), and Tyrrhena (p-value = 0.007).
- The p-values for the three Terras indicate a statistically significant relationship between crater location (Arabia, Tempe, and Tyrrhena) and crater size. This finding aligns with the bivariate graph, as Arabia, Tempe, and Tyrrhena have the three smallest average crater volumes.

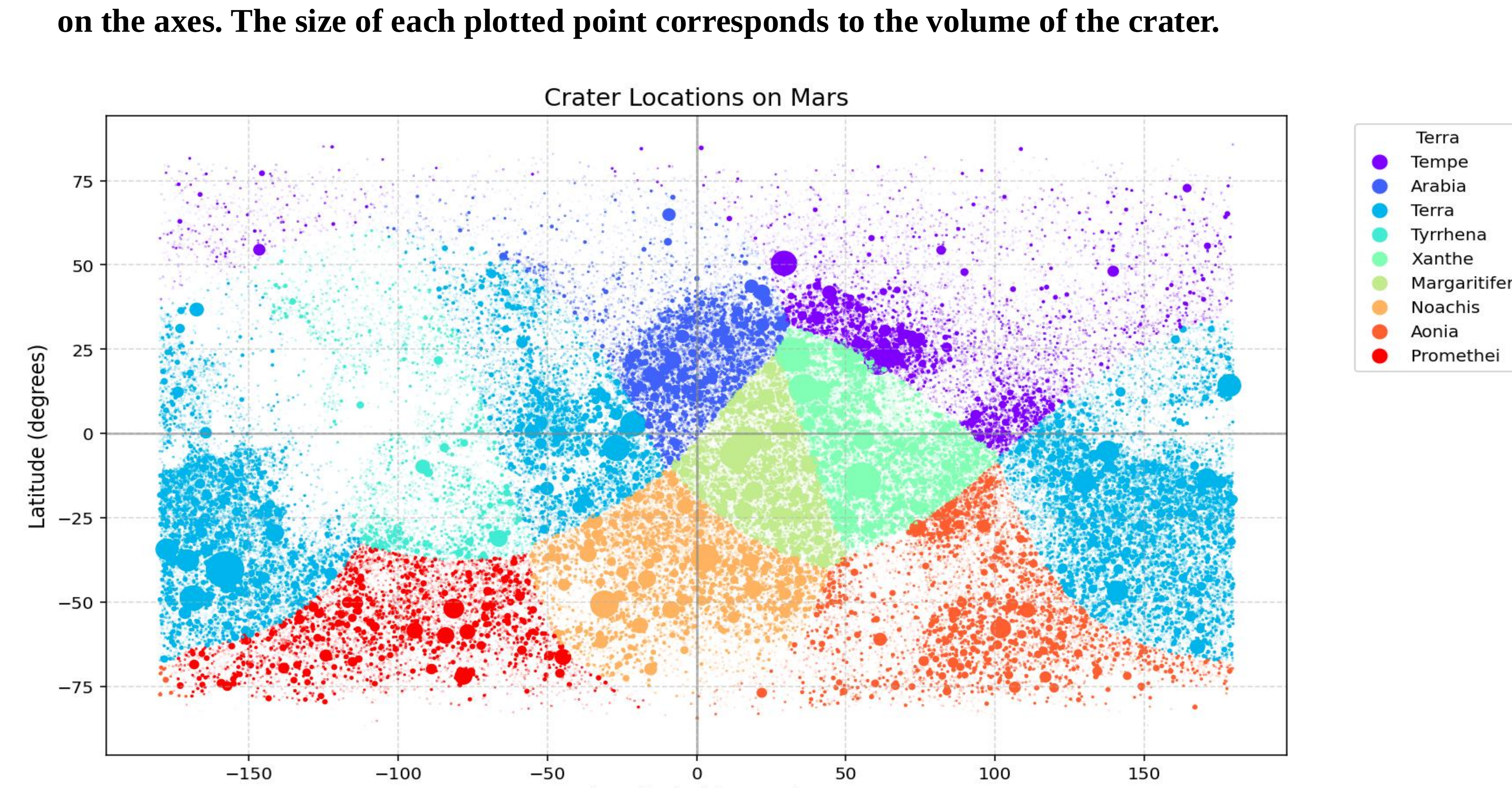

Figure 3: Scatterplot showing the locations of the craters with latitude and longitude coordinates on the axes. The size of each point corresponds to the volume of the crater. This plot conveys the same information as Figure 1, but with each terrain type colored and labeled, accompanied by a key on the side.

Discussion

- Both the bivariate and multivariate graphs show a statistically significant relationship between crater size and location. Combining the results reveals that Arabia, Tempe, and Tyrrhena exhibit the strongest correlation between crater size and location. These Terras also have the smallest average crater sizes on Mars, as shown in the bivariate graph.
- In contrast, other regions do not show statistically significant differences in crater size, with p-values greater than 0.05. This suggests that crater size variation is concentrated in specific Terras, while other regions are more similar in size.
- This finding implies that the materials in Arabia, Tempe, and Tyrrhena result in smaller impacts. The research demonstrates that rocky, mountainous terrain tends to produce larger craters, while sandy, desert-like areas absorb or cover the impact, leading to smaller craters.

References

Christopher, Hamilton, J. S., Walton, E. L., Tornabene, L. L., Lagain, A., Benedix, G. K., Sheen, A. I., Melosh, H. J., Johnson, B. C., Wiggins, S. E., Sharp, T. G., & Darling, J. R. (2024). The source craters of the martian meteorites: Implications for the igneous evolution of Mars. Science Advances, 10(33). https://doi.org/10.1126/sciadv.adn2378

Souness, C., & Hubbard, B. (2012). Mid-latitude glaciation on Mars. *Progress in Physical Geography: Earth and Environment*, *36*(2), 238–261. https://doi.org/10.1177/0309133312436570