Fractal analysis of the mesas within Deuteronilus Mensae region of Mars

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Abstract

Deuteronilus Mensae (43.9°N; 337.4°W) is region within the Ismenius Lacus quadrangle, located within the northern hemisphere of Mars. The area is very rich in erosion landforms: flat-top plateaus and butes. The present research investigates the fractal structure of the plateaus (mesas or mensae) within the area. For this purpose using number/area approach a fractal analysis of 90 of these morphostructures was performed. The obtained fractal dimension (FD) of -1.25 is an indicator that the natural processes that created and shaped the topography within this Martian region have the same self-organized and nonlinear nature like those on planet Earth.

Keywords: Mars, Deuteronilus, Plateaus, Mesas, Fractal Analysis, Morphostructures

Introduction

The Ismenius Lacus quadrangle represents series of 30 quadrangle maps of Martian topography created by the United States Geological Survey (USGS) Astrogeology Research Program. The quadrangle occupies the area between 0° - 60°E and 30° - 65°N latitude. The quadrangle covers an approximate area of 4.9 million km^2 or approx. 3% of total area of planet Mars. The Ismenius Lacus quadrangle contains parts of Acidalia Planitia, Arabia Terra, Vastitas Borealis, and Terra Sabaea. The terrain of the Ismenius Lacus quadrangle contains impact craters, smooth planes, mesas and butes (Fig.1). The largest structure within the area is Lyot crater (Fig.2). Its surface is cut by many channels, probably carved by liquid water in the past [1].

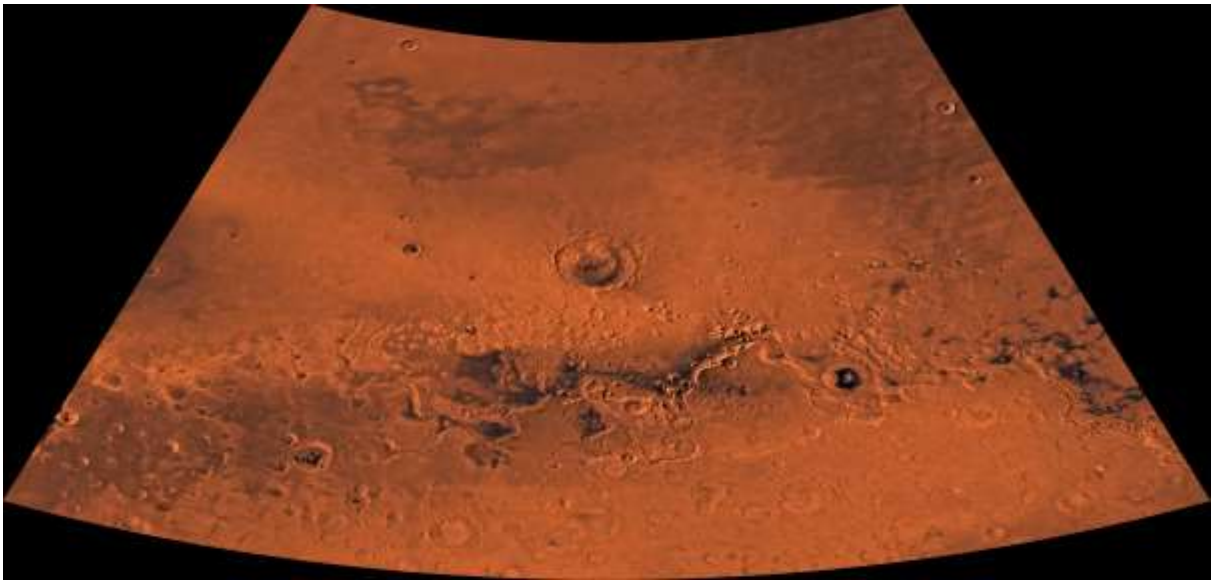

Fig.1: View of Ismenius Lacus region of Mars. The image derived from Viking Orbiter 1 mission. The topography contains impact craters, smooth planes, mesas and butes (Image source: NASA, USGS - https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA00420)

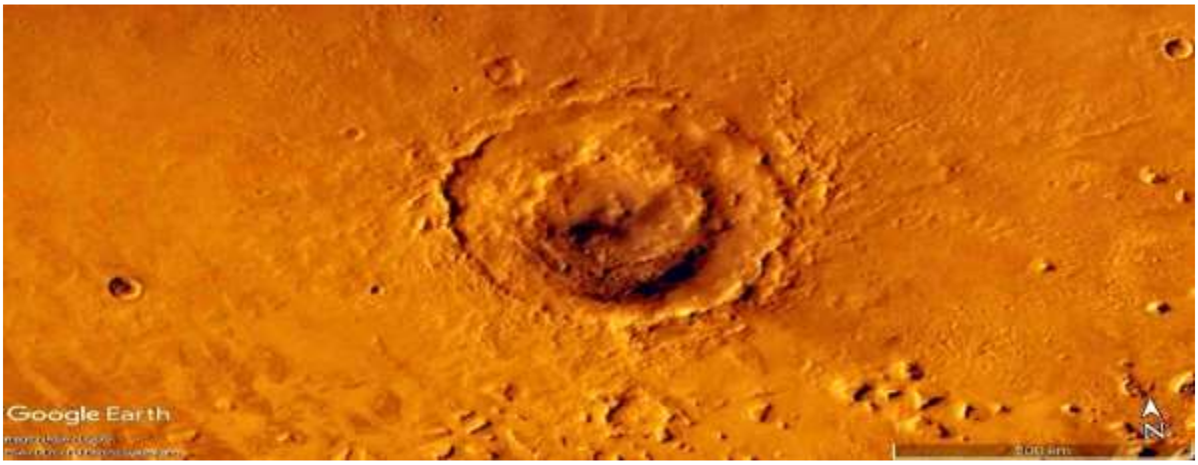

Fig.2: Lyot crater is most prominent landform within Ismenius Lacus quadrangle (Image source: Google Earth)

The most wealth of features within the quadrangle is the Deuteronilus Mensae (43.9°N; 337.4°W) region (Fig.3). There are many erosion landforms – flat-top plateaus (mesas or mensae) and butes. These landforms probably are product of glacial activity [2]. Subsequently, they have been refined by other erosion processes and impact events.

Fig.3: View of the Deuteronilus Mensae (43.9°N; 337.4°W) region. On the satellite image, many flat-top plateaus or mesas are well distinguished. Some were destroyed by collisions with asteroids or comets that left visible craters. (Image source: Google Earth) Within the present study using fractal analysis the Martian mesas were analyzed. Regarding Martian topography the fractal approach previously was used by Turcotte [3], Ching et al. [4] and Demin et al. [5]. Their results enriched our ideas about the geology of the "red planet". In present study using the Google Earth app, the areas of 90 mesas were measured and a fractal analysis was performed to them. The study showed that the dimensions of individual plateaus vary from a few tens to tens of thousands of square kilometers. The fractal analysis showed moderate fragmentation values in the size distribution of the mesas

Methods and Data

Number/area aprroach for fractal analysis

The methodology, based on the correlation number-area, is following the algorithm presented and effectively applied in a previous research [6; 7; 8; 9; 10]. The analytical procedure includes the following steps:

1. Calculation of total number of mesas (N) with corresponding area (in respective units) for the graphic.

2. Presentation of the results in graphic form – on the X axis – surfaces of the mesas in logarithmic scale are plotted (I), and on the Y axis - the corresponding number in linear scale respectively.

3. The fractal dimension (D) has been calculated using the formula:

$$D = \Delta \log I / \Delta N \qquad (1)$$

where D is fractal dimension, ΔlogI is logarithm of iteration and ΔN is total number of mesas involved in the study.

Data and Software

The exploration of the Martian mesas was performed using imagery data derived from Mars Digital Image Model (MDIM) 2.1 [11]. The imagery data is a product of Mariner 9 and Viking Orbiter missions and has spatial resolution 256x256 m. Visualization of the imagery data on the Mars topography and, respectively, the calculation of the area of the study mesas is made using the free Google Earth app. In the course of the study a total of 90 structures were located and analyzed (Table 1).

Table 1: Statistical peculiarities of the mesas within the study area

Statistical parameter	**Value**
Total number of the study structures	90
Minimal area of the study structures (km^2)	37
Maximal area of the study structures (km^2)	31781
Standard Deviation (σ) of the area of the study structures (km^2)	5004.65

Results and Discussion

The results of the fractal analysis of the Martian mesas are show in Figure 4.

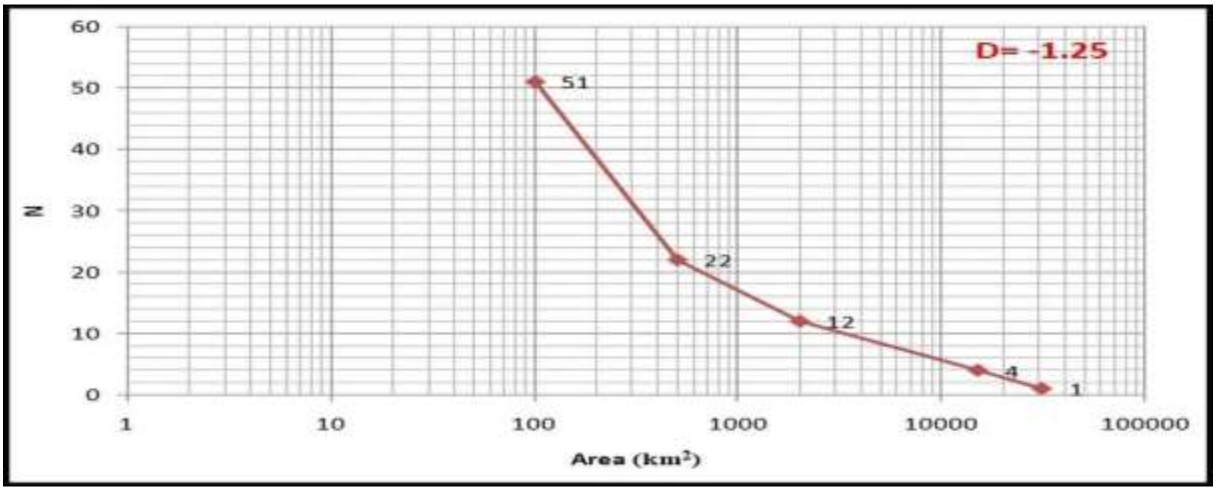

Fig.4: Fractal analysis of the mesas within the Deuteronilus Mensae (43.9°N; 337.4°W) (43.86°N; 49.4°E) region.

Fractal analysis of Martian plateaus determined a fractal dimension (FD) value of -1.25. The negative value of the FD is determined by formulae (1) and has a negative (-) sign due to the rule that any decreasing function has negative angular coefficient. The value is an indicator of moderate fragmentation values, i.e. the difference in size of individual morphostructures is not so large. The low numbers (1-4-12) of the large sized structures is indicative that the large size elements are relatively more rare than the minor sized elements. This transition started from very small elements (100-1000 km^2) and continued to the massive structures (over 10 000 km^2). This is a clear sign of the intensity of the erosion processes that shaped the topography of the study area. In this regard, the impact phenomena (asteroids and comets) were not powerful enough to disrupt the initial fractal structure of the studied morphostructures. That is how it has been preserved to this day.

Conclusion

In this study, fractal analysis of plateau morphostructures within the Martian region Deuteronilus Mensae was performed. The results show that the natural forces that created and shaped the terrain of Mars have the same fractal properties as those on planet Earth [3]. At least within the solar system, the fractality of natural objects seems to be a universal property, distributed in all forms and variants. This is confirmed by numerous examples throughout the solar system. This is valid almost to many different morphostructural elements observed within many planets and satellites within the solar system. Almost everywhere they have clear fractality with different fractal dimensions [7]. The presented research has a modest contribution to this.

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