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Microbialites on Mars: a fractal analysis of the Athenaôs microscopic images

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Abstract

The Mars Exploration Rovers investigated Martian plains where laminated sedimentary rocks are present. The Athena morphological investigation [1] showed microstructures organized in intertwined filaments of microspherules: a texture we have also found on samples of terrestrial (biogenic) stromatolites and other microbialites and not on pseudo-abiogenic-stromatolites. We performed a quantitative image analysis in order to compare 50 microbialites images with 50 rovers (Opportunity and Spirit) ones (approximately 30,000/30,000 microstructures). Contours were extracted and morphometric indexes obtained: geometric and algorithmic complexities, entropy, tortuosity, minimum and maximum diameters. Terrestrial and Martian textures resulted multifractals. Mean values and confidence intervals from the Martian images overlapped perfectly with those from terrestrial samples. The probability of this occurring by chance was less than $1/2^8$, $p<0.004$. Our work show the evidence of a widespread presence of microbialites in the Martian outcroppings: i.e., the presence of unicellular life on the ancient Mars, when without any doubt, liquid water flowed on the Red Planet.

1. Introduction

Microbialites/stromatolites are the oldest evidence of life on Earth; they are rocks formed by microbial mats trapping, binding and/or precipitating minerals . Stromatolites/microbialites are an organization of primitive cyanobacteria into large structures, analogous to coral reefs. They grew in vast colonies. Fossil stromatolites, as well other microbialites, can be identified through their macro- meso.- micro-characteristic structures that results from the growth patterns of their constituent bacteria**.**

Rizzo and Cantasano in 2009 claimed the presence of microstructures that resembled stromatolites/ microbialites in the Opportunity Rover microscopic images [2], Wagstaff and Corsetti in 2010 wrote on the absence of stromatolites in the Opportunity images, analyzing 4 Martian photos at macro level [3].

To solve the problem, we have performed a quantitative morphometric approach of the microstructures present in the stromatolites and other microbialites, Earth comparing them with themicrostructures present in the outcrops photographed by Opportunity and Spirit, Mars.

2. Materials and methods

We have performed a quantitative fractal analysis comparing 50 terrestrial microbialites images with 50 rovers (Opportunity and Spirit) ones, corresponding, approximately to 30,000 terrestrial and 30,000 Martian microstructures. Contours were extracted by a Canny edge filter (fig.1) and fractal indexes were obtained: geometric and algorithmic (LZ) complexities, entropy, at low and high scales, and tortuosity (Dmin). Minimum and maximum diameters were also evaluated.

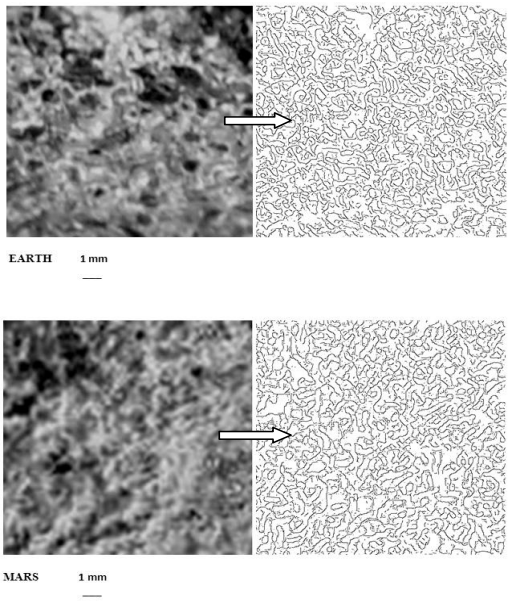

Figure 1: A texture of microspherules and intertwined filaments appears in terrestrial living or fossilized microbialites/stromatolites, as well in Martian sediments, after a canny-edge filter is applied

3. Results

The morphometric analysis reveals that both the textures, from biogenic microbialites (Earth) and from selected rover images (Mars), present a multifractal aspect (fig.2).

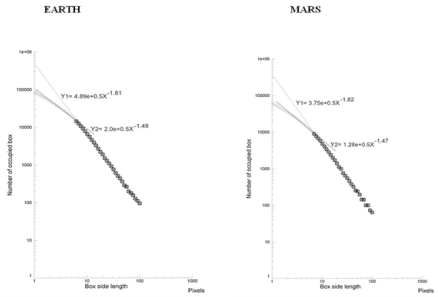

Figure 2: Multifractality in terrestrial microbialites (left) as well in the analysed Martian sediments.

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Table 1: Fractal parameters and diameters of the Martian microscopic microstructures are overlapping the ones of terrestrial biogenic microbialites. The probability of this occurring by chance is less than $p<0.004$.

	Earth (mean/SD)	Mars (mean/SD)
Complex, High	1.82(0.02)	1.81(0.02)
Complex, Low	1.48(0.05)	1.52(0.07)
Entropy, High	1.88(0.01)	1.87(0.02)
Entropy, Low	1.41(0.05)	1.44(0.05)
LZ index	0.46(0.04)	0.48(0.04)
Dmin	0.79(0.03)	0.78(0.03)
Max Dia (mm)	0.08(0.001)	0.08(0.001)
Min Dia (mm)	0.21(0.003)	0.21(0.003)

4. Summary and Conclusions

Microtexture indexes, multifractality and diameter values present in biogenic stromatolites and other microbialites are extremely similar to those present in the Martian images taken by the Opportunity and Spirit Mars Rovers. The probability of this occurring by chance is less than $1/2^8$ (less than $p<0.004$). Our work show the evidence of a widespread presence of microbialites in the Martian outcroppings: i.e., the presence of unicellular life on the ancient Mars, when without any doubt, liquid water flowed on the Red Planet.

References

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