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Textures on Mars: evidences of a biogenic environment

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Abstract. Sediments on Mars could be explained as the result of simple coalescing structures having the ability to produce oriented concretions and more complex forms, as are intertwined filaments of microspherules, laminae and blueberries, growing from a microscopic scale to a macroscopic one. Of which we have examples in some terrestrial microbial community, especially in regards to cyanobacteria and their organosedimentary products named stromatolites. This study aims to describe the most-often structural features that occur, showing their mutual relations in passing from simple to complex forms. These relationships could explain the genesis and the funny shapes of blueberries as the result of two different processes: by an enrolling sheet of microspherules or by an internal growing of minor spherule aggregates.

Key words. Mars - Meridiani Planum - laminated sediments - Blueberry - filaments of microspherules - Stromatolites like textures

1. Introduction

Is there life on Mars? Our understanding of Mars has increased vastly after the last NASA missions, especially those called Mars Explorer Rover (MER) held, from 2004 until present, on the Mars landscape of Meridiani Planum and Gusev Crater. The pictures of the Mars outcrops, recorded by microscopic imagery (MI), brings forth again the question of occurrence of life, emphasized by the presence on the surface of Mars of several spherules on which Steve Squyres, team leader of NASA's mission, assigned the funny word of blueberries and of which he advanced two hypotheses: the Aeolian-sedimentary origin of the subcrops of Meridiani Planum and the concretionary nature of the spherules (Squyres et al. 2004). Then, a wide scientific discussion was opened about the origin of blueberries and of laminated sediments outcropping everywhere at Meridiani Planum suggesting a volcanic product (McCollom & Hynek 2006) or parallels to terrestrial pisolits, oolits, and other concretionary formations (Coleman et al. 2005) or an eolian turbulent origin by meteorite impacts (Knauth et al. 2005). In fact, life occurrence came out again in 2005 when some Spanish researchers and later other American ones put forward the proposal that the strange spherules at Meridiani Planum could be concretions induced by a community of chemi-

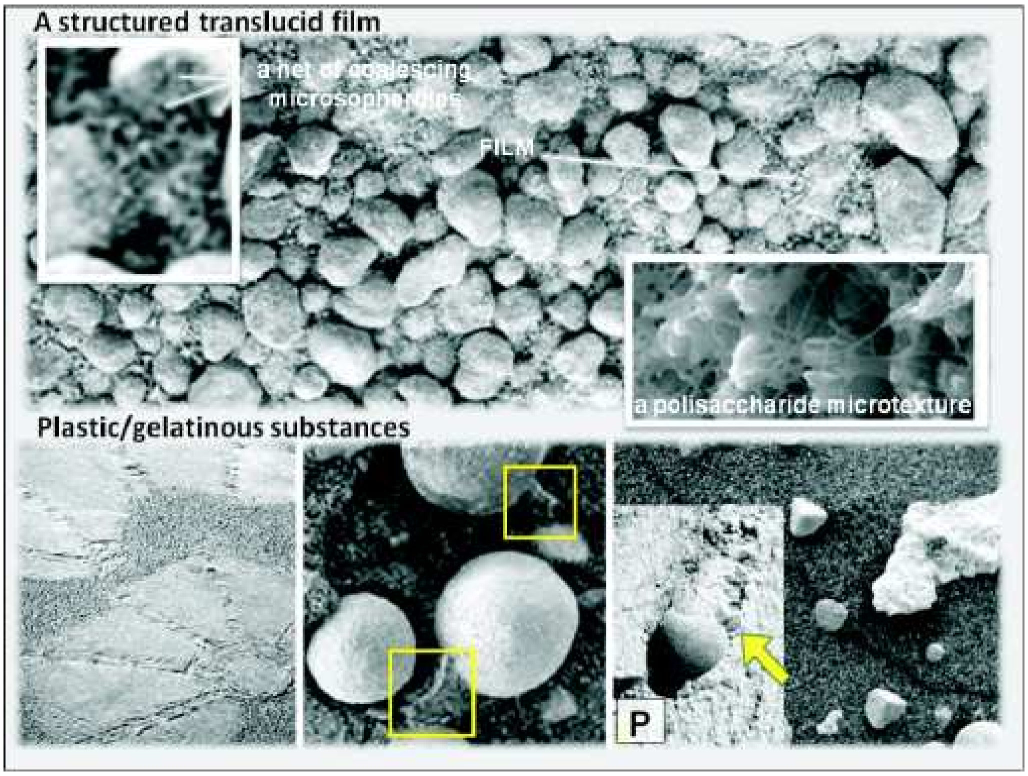

Fig. 1. Structured films and other plastic/gelatinous substances on Mars in comparison to a polysaccharide structure.

olithoautotrophic bacteria still living on earth in acid environments enriched by iron minerals (Parro et al. 2005; Jepsen et al. 2007). Then, their formation diagenetic mechanism, considering total amount of replacing hematite from the putative sulphate, should be of inclusive-replacive type (Jolliff & McLennan 2007). Other researchers, analyzing again the data from the former Viking Mars Mission, hypothesized that cyclic release of $^{14}CO_2$ biomarker was probably due to circadian rhythmicity of microbial community (Van Dongen et al. 2005), while others proposed the emergence of a likely microbial life based on an H_2O_2 - H_2O intracellular mixture (Houtkooper & Schulze-Makuch 2010). The re-examination of the Viking data has been, recently, remarked by a new study inspired by a detailed analysis of some soil samples conducted by the Mars Phoenix Lander on the Martian soil in May 2008. Phoenix found that most of the chlorine at the landing site was, really, in the form of perchlorate, a putative biosignature resulting by a possible microbial activity on Mars (Navarro-Gonzales et al. 2005). Possible signs of life on Mars was also strengthened by the detection of methane and formaldehyde (Onstott et al. 2006) in the Martian atmosphere (Schulze-Makuch et al. 2008). NASA, itself, established that Martian sediments, recorded by rovers Opportunity and Spirit, were pertinent to water presence (Squyres et al. 2006), as successively confirmed by Phoenix Mars Mission late results. Fossil evidence of ancient microbial life on Mars was, recently, carried out by the same NASA team who discovered the first Martian meteorite ALH84001, 14 years ago. They found, indeed, on its car-

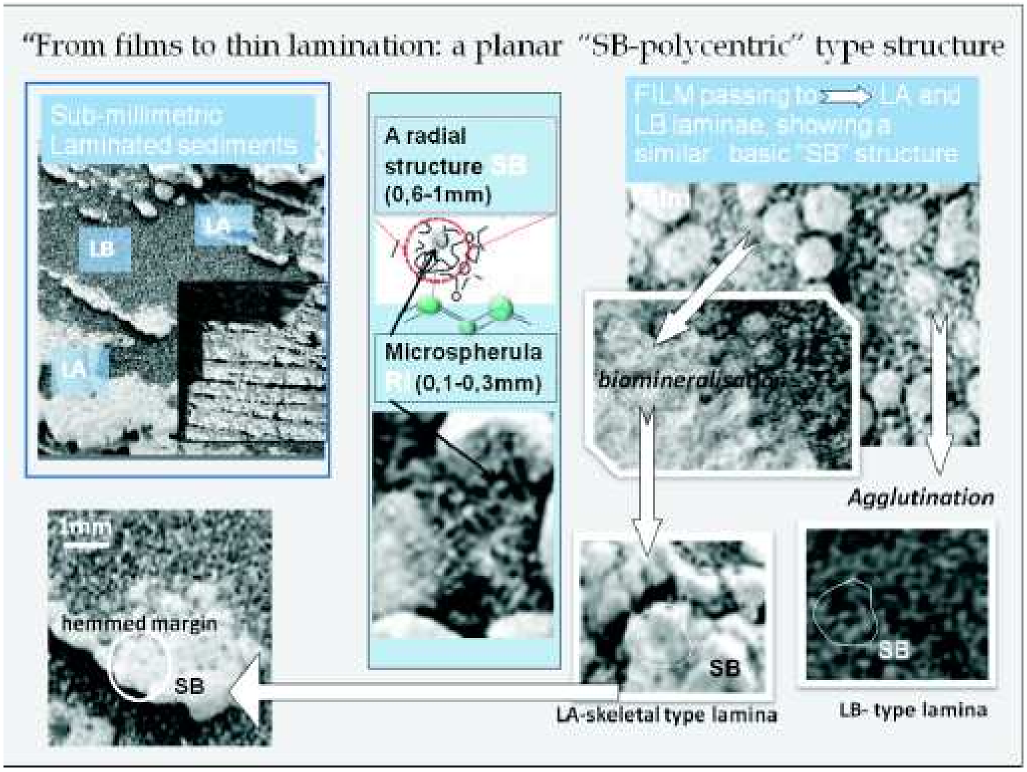

Fig. 2. Structures generating a laminated sequence.

bonate discs a lot of magnetite nanocrystals (Fe_3O_4) probably added by biogenic processes (Thomas-Keprta et al. 2009). Finally a study at strong amplification of textures of layers and fragments, executed by rovers microscopic cameras, never analyzed in previous studies, has shown clear parallels with terrestrial organosedimentary sediments known as stromatolites and with possible remains of more developed fossils (Rizzo & Cantasano 2009). This interpretation was further sustained by the discovery on Mars of some rocks and confirmed by new images of the surface of Mars, sent by Opportunity, that showed these rocks partially covered by a dark shiny patina similar to the terrestrial Desert varnish probably formed by bacteria (Di Gregorio 2010). All the collected data are congruent with each other and to the conclusion supported in this paper.

2. Structural/textural features of laminated sediments and blueberries

2.1. Films and microspherules

As known, occurrence of films and other translucid/plastic substances is relevant in biogenic environment: proofs of their existence on the Martian soil surface was somewhere clearly found or deduced; probably their occurrence is widespread. Figure 1 shows on the top a clear example of translucid film. This film, opportunely amplified, shows a net-structure made by interconnected microspherules, set in radial polycentric arrays (on the top left). Such microspherules (Ri) have generally a dimension of 0,1-0,3 mm, somewhere denoting different transparencies and grey tonalities, but al-

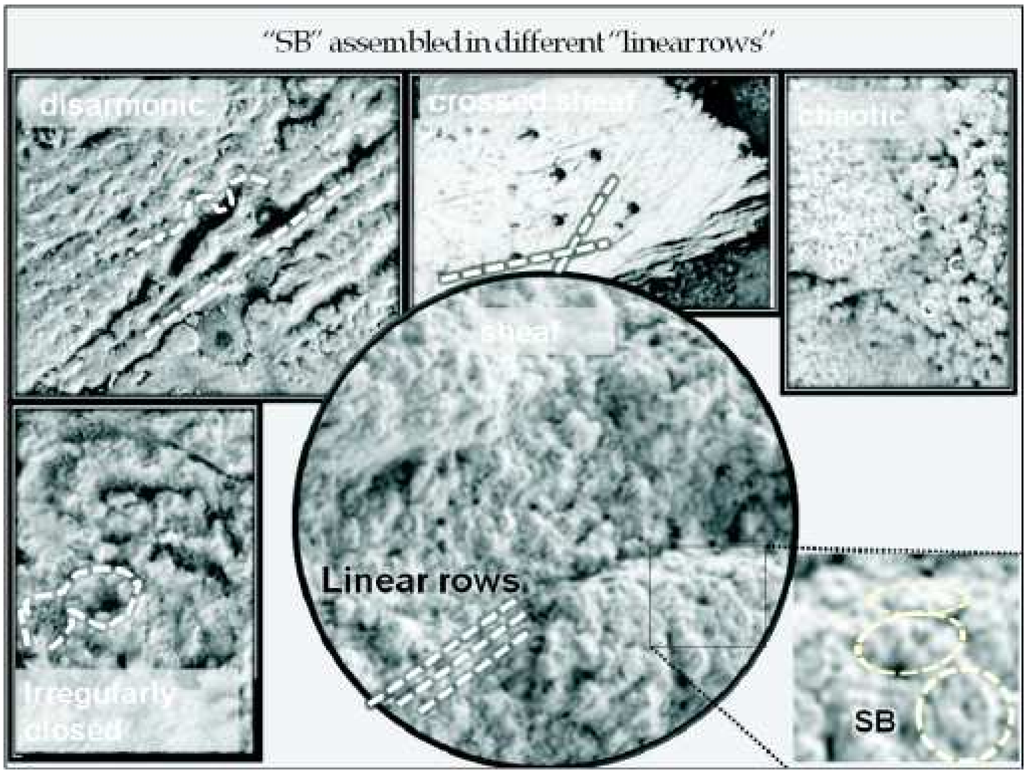

Fig. 3. Variety of SB massive structure type found on layers.

ways darker than the thin transparent interconnection, all forming a transparent film, covering pre-existing underlying bodies (and resembling a structure of polysaccharide-like material; Fig. 1). Plasticity of soil was noted by NASA after rover landing (Fig. 1, below on the left); a rare occurrence of massive transparent substances were also noted in MI imagery (see squares), resembling slightly structured bodies, forming tubular (square above) or microspherules assembled shapeless bodies (square below). Plastic flow of granular sediments at very low slope-angle were also noted (Fig. 1, below on the right); while picture P shows a cover tear denoting a plastic deformation (arrow), probably due to a transient no-lithic consistence.

2.2. Laminated sediments

Films play a role in forming whitish covers by progressive mineralization (an example is given in Fig. 2, on the right). A process that has also been supposed for laminated sequences and other structures, because they are made by the same repetitive microspherules radial structures (an SB basic structure having dimension of 0,6-1 mm and forming a planar SB-polycentric type structure) observed on films (Fig. 2, on the central side). After mineralization the SB structure assumes a typical shape, like a rosette, and then the margin of LA become typically segmented/hemmed (Fig. 2, bottom left). Black lamina LB shows, in spite of its different colour and composition, a similar radial array resembling an aggluti-

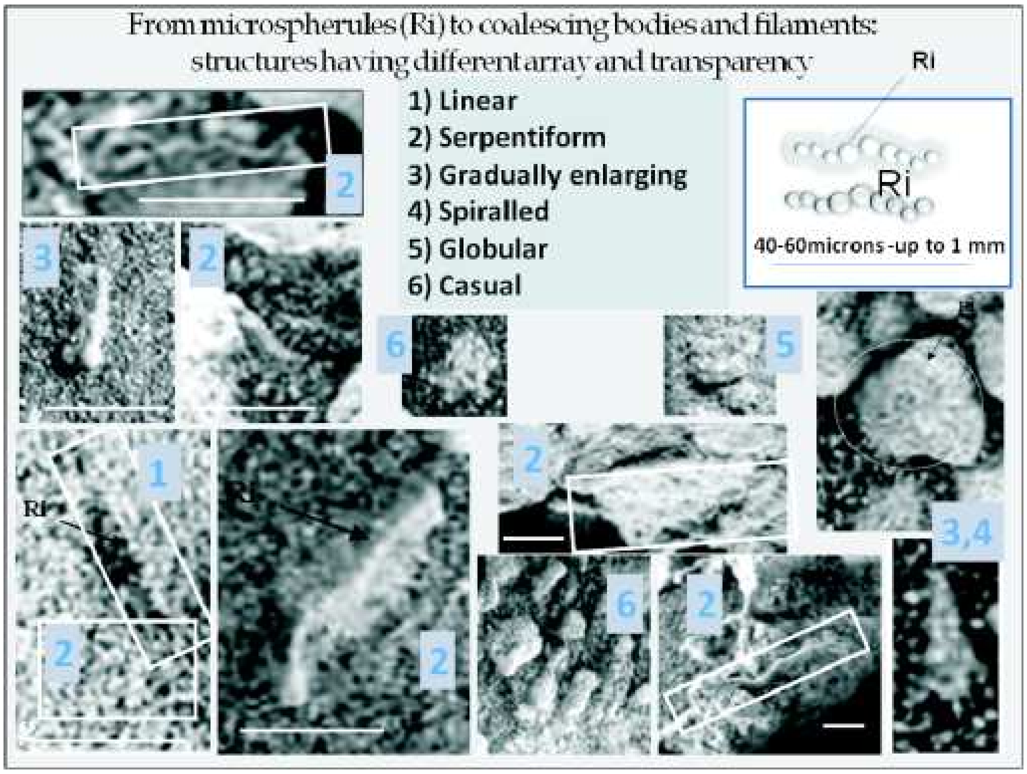

Fig. 4. Filaments of coalescing microspherules.

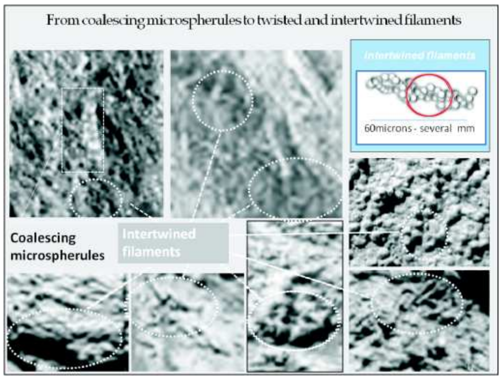

Fig. 5. Twisted and intertwined filaments.

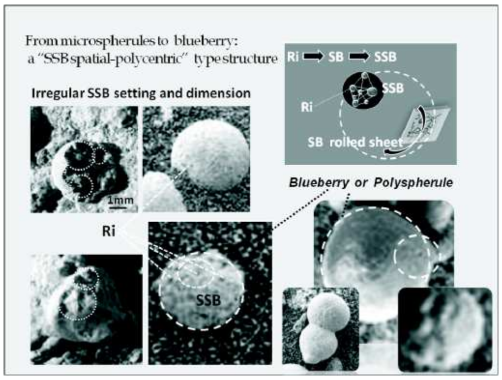

Fig. 6. Structure of Blueberry.

nated granular sediment. The passage from the film to the LA lamina is a fundamental process that generates the sequence LA/LB or a massive growth of LA.

2.3. A basic SB structure

In the massive growth the SB structure can assume linear arrays, resembling parallel rows, and the body seems to be made up a sheaf

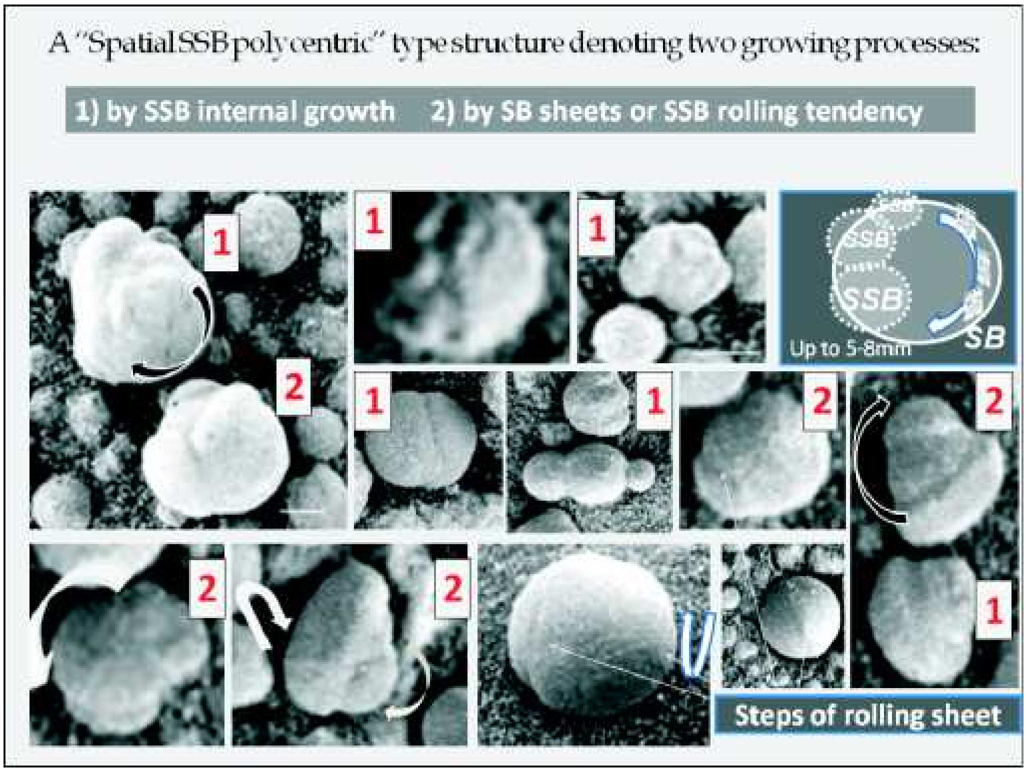

Fig. 7. Blueberry denoting two growing processes.

(Fig. 3, below). In other cases, they are a result of rovers intersections forming crossed sheaves; or show disharmonic sets and sudden passages from linear to convolute arrays; or they can even become chaotic; or they assume irregular closed arrays (Fig. 3). In the end, what we are looking at, in such structures, is always a planar or massive path of SB-microspherules structures.

2.4. Filaments of coalescing microspherules

Such structures can assume a wide range of dimensions, starting from the limit of accuracy and different transparencies and arrays, examples of which are shown in figure 4. Filaments are generally in a serpent-form, but they could also assume the form of a straight line; more rarely in a gradually enlarging or in a spiraled structure. The spiraled examples shown in figure 4 (to the bottom right) have been developed over a transparent film. One can also observe a change in transparency and a tendency of films to become whitish budding from the described structures.

2.5. Intertwined filaments

A more developed structure is represented by intertwined filaments, generally assuming a massive consistence. A structure that, similarly to the previous case, occurs at very different scales, from the MI microscopic limit of resolution to the lower limit of PANCAM (Fig. 5).

Polispherules or Blueberries. Blueberries are made by similar even more complex structures: a polycentric set of microspherules, spa-

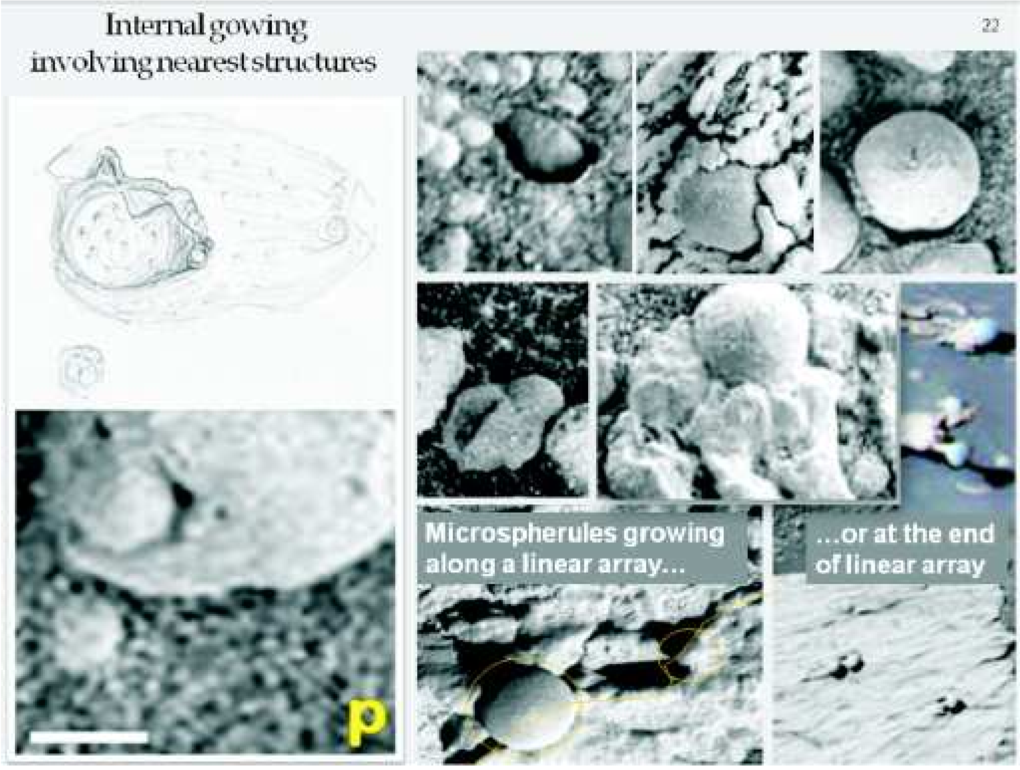

Fig. 8. Examples of internal growing (evident on the left picture;hypothesized in the other cases).

tially interconnected. A structure that could be considered as an extension of the already described SB array, where spatial interconnection forms a structure of SSB type (drawing in Fig. 6). Two different growing processes were considered in order to explain what has been observed: by SSB internal growths and by an SB or SSB rolling tendency (drawing in Fig. 7). In fact, the internal structure of blueberries show regular/irregular polycentric sets, where an internal growth of an SSB set could generate a polyspherule that can also be both protruding or expelling. Examples given on figure 8 show such polyspherules structures at different levels. In other cases blueberries shows surface steps due to the overlapped sheet and denoting a rolling tendency. Examples given on figure 7 show occurrence of both processes: SSB protruding and rolled SSB prevailing structures (above) or enrolling SB prevailing structures (below). The different incidence of two such processes generate the strange bodies and the funny shapes that we can observe. Then, from microspherules to blueberries, from planar to spatial arrays, in the end blueberries are polyspherules made by spherules of microspherules, whose basic components are the Ri and SB/SSB type structure (Figs. 6- 7): internal structures show compatible dimension on the whole and always explain what we are looking at.

Other findings prove the occurrence of an internal growing process. A clear example is given in figure 8 (picture p), where a little spherule is expelling from a bigger one; existence of both tear and deformation in this last denote a probable temporary semi-lithic consistence. In the other pictures of the same figure blueberries seem to grow involving to the nearby structures while on the pictures to the right, they seem to be the result of a micro-

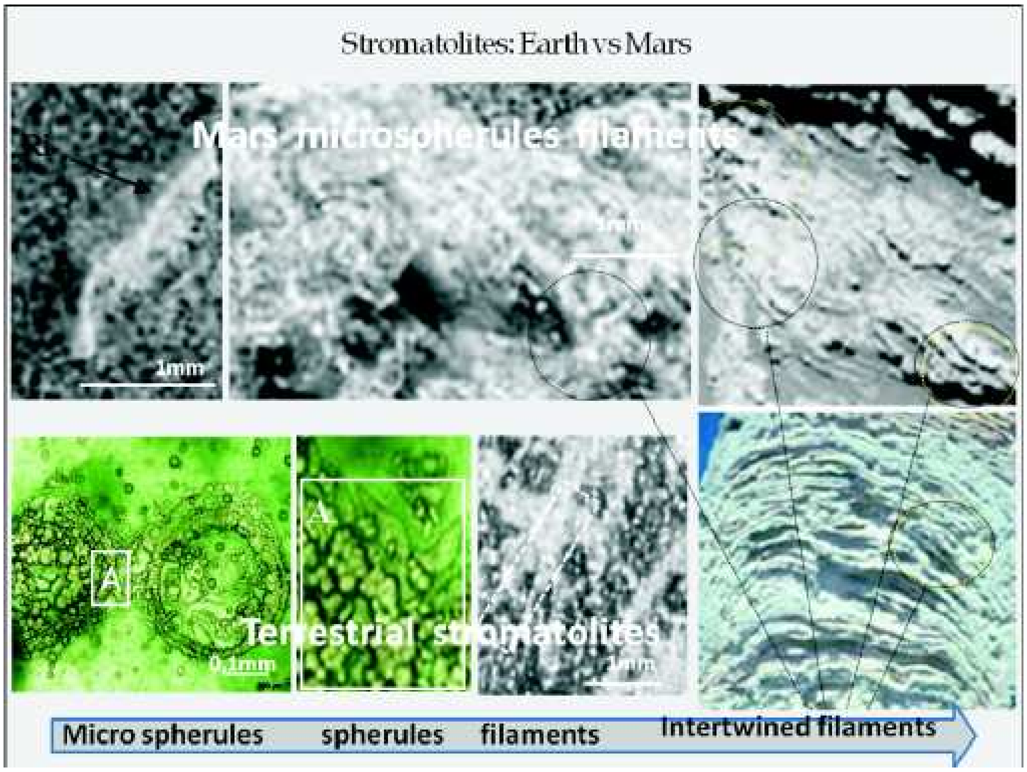

Fig. 9. Comparison of Mars textures to those of terrestrial stromatolites.

spherule growing - along or at the end - of a filament.

3. Mars structures/textures in comparison to terrestrial stromatolites

The described structures are very similar to those of terrestrial stromatolites, both in form and dimensions (Fig. 9). Especially as regards: a) layering, made by a sequence of re-petitive pairs of submillimetric laminae, of 0,6-0,8mm, one of which is an agglutinated lamina, resembling LB, and the other is a skeletal one, resembling LA; b) biomineralized spherules and at different scale, resembling microspherules Ri (Fig. 9, pictures below on the left); c) occurrence of twisted and intertwined filaments (comparison at macroscopic scale are given on Figure 9, to the right side); d) presence of films and gelatinous substances.

Other parallels are shown in figure 10, including a sheathed colony of cyanobacteria, the rapid change of lamina from planar to spherical (see the arrow), normally considered a proof of organosedimentary origin for terrestrial stromatolites (Wacey 2009). Similarity also occurs (Fig. 11) in regards: to a typical regressive sequence of stromatolites (to the left); to surface of tabular stromatolitic type (in the center) and of columnar type (to the right side), and in regards to occurrence of Ri and SB basic structures having similar dimension (Fig. 12).

4. Conclusions

All described coalescing textures are not pertinent to the known abiotic terrestrial environment while on Earth the ability to carry

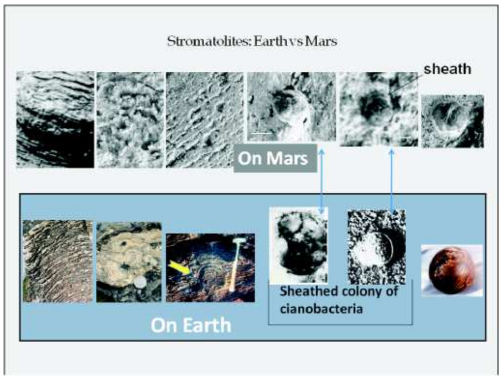

Fig. 10. Other parallels of Mars textures versus terrestrial stromatolites.

Fig. 11. Structure comparison at macroscopic scale.

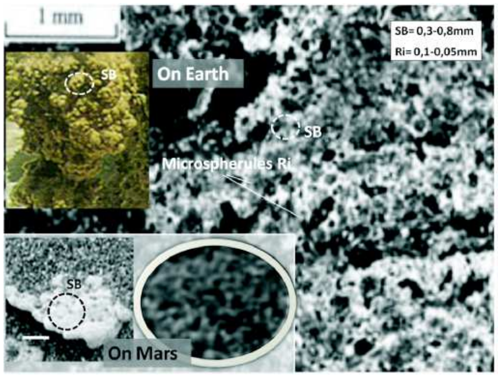

Fig. 12. Other comparison at microscopic scale.

out biomineralization processes in the shape of tubules, threads, chambered and/or oriented structures is typical of microbial activity made by an heterogeneous group of colonial microfossils, which include many morphologically dissimilar organisms, all having a tendency to assume a complex array. Above all we note that internal growing, intertwined filaments and irregular lamina convolution, that we can find on terrestrial stromatolite as well as on Mars sediments, are in contrast with basilar principles of inorganic sedimentation. In fact, it is generally assumed that all sedimentary bodies develop by overlapping layers everywhere from and on the top of existing surfaces - layer by layer - on the external surface. At the same time it is known that, as an opposite, structures generated by organic sedimentation are peculiar, distinctive and complex. The inorganic sedimentary processes follow simple rules, whereas the structures we described denote complex products, congruent to the terrestrial biogenic environment: life has existed and is still alive on Mars.

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