Biosignatures in Agates from Kerrouchen, Morocco

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(English translation: Douglas Moore and Johann Zenz with the assistance of the translation software DeepL, free version)

In addition to cm-sized cauliflower-shaped bacterial colonies, other biosignatures can be found in agates from Kerrouchen. Microscopically small formations can be found in the areas adjacent to the "cauliflowers" and also in the interior of the agates. Thread-like, roundish and spherical formations are seen along with aggregates composed of these components. Chain-forming and coccoid bacteria are possible causes.

Fig. 1: Agate from Kerrouchen, Morocco. 13.1 cm. The walls of the former cavity are colonized with silicified cauliflower-like formations. In the surrounding orange, red, violet and colorless areas there are chalcedony bands running parallel to each other. Megaquartz is crystallized in the central area. Ulf Thewalt collection and photo.

Introduction

The closer you look at an agate, the more interesting details you can see. To "look closely" you place the agate under a stereo loupe or a microscope and take your time to examine it.

This article examines agates from the Kerrouchen area, a small village in the Middle Atlas Mountains in Morocco.

The bedrock in which the agates occur is a Triassic–aged basalt. The beauty of these agates there has been illustrated in a number of publications (e.g. Mayer 2013 and 2017, Zenz 2014).
Agates from Kerrouchen are the subject of a report that shows what can be measured, calculated and derived using modern physical methods (Natkaniec-Novac & al. 2016).

The role of bacteria in geological processes is increasingly recognized (Campos-Venuti 2022). The richly illustrated work by Schmitt-Riegraf (2015) & Riegraf is another publication that focuses on agates. This publication highlights agates from the Idar-Oberstein area (Germany) - particularly the famous Juchem Quarry.

Once you start looking for traces of microorganisms in agates, you will find them in agates from a large number of locations. The most striking feature of Kerrouchen agates is the cauliflower-like, cm-sized bacterial colonies found in the outer margin of the agates (**Fig. 1**).
They are sometimes referred to as "plumes" (McMahan 2009).
However, the microscopic biosignatures referred to here occur primarily in chalcedony areas further from the margin of the agates and between the "cauliflowers".

A note on the terminology: The cauliflower-like formations or those that look like undergrowth or tubes are referred to below simply as "cauliflowers" or "undergrowth" or "tubes" (in each case with a quotation mark!).

2 Filiform and other elongated formations interpreted as biosignatures

In the interior and at the edges of the "cauliflowers", tubular-looking formations largely dominate the picture. The surrounding areas are different.

Here one finds short and long straight and curved threads without tubular sheaths. Some threads look as if they are made of smooth wire. Others have been moderately encrusted with iron oxides. Aggregates of such components also occur. Bacteria or strand-like bacterial colonies that grew in existing silica gel, i.e. which are younger than the "cauliflower", are likely to have factored in the formation of all these objects.

The fact that the structures float freely in the chalcedony suggests that they were formed in a soft, gel-like silica polymer. As a result, they were fixed at the site of their formation and could not sink to the bottom of the geodes. The so-called gel crystallization in preparative chemistry is similar. Crystalline substances are gently allowed to grow in soft silica gel.

A striking aspect of some of the inclusions are recurring color patterns, especially the distribution of red (hematite) and yellow (goethite). A similar pattern can be observed in the "microspheres" (section 3.1). The question of whether, or to what extent, the originally deposited iron minerals are still present remains to be clarified.

2.1 Curved and spiral-shaped smooth red thread pieces

Such inclusions can be found in the cloudy chalcedony areas surrounding the “cauliflowers”. There they occur as companions of “microspheres” (**Fig. 2, 3**). (For more details on “microspheres” see **section 3.1**). The spiral shapes are particularly striking, resembling spiral-shaped bacteria (spirillae). The filaments have a nearly constant thickness, are of the same color (brown, copper-red) and are not encrusted.

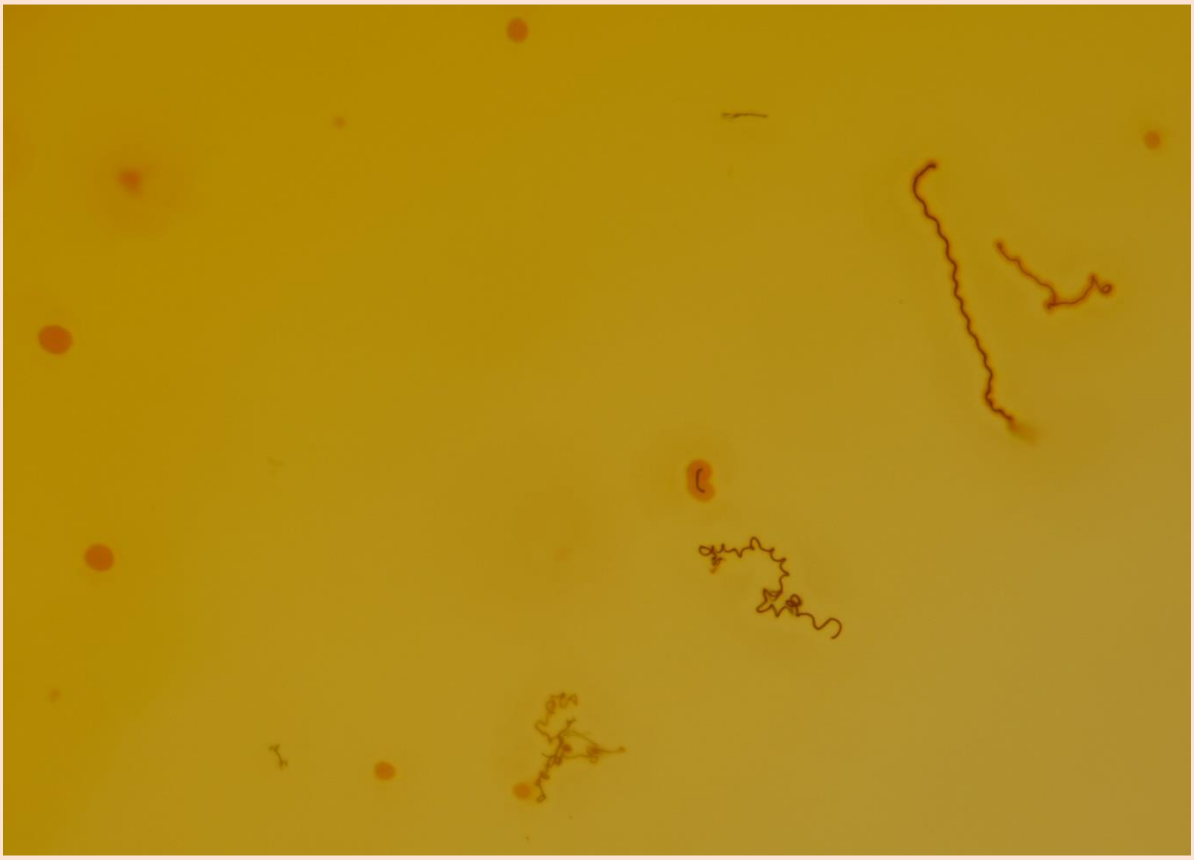

Fig. 2: Pieces of thread floating in the chalcedony matrix. These are probably strands of bacteria that have grown in situ. The dark red color indicates the activity of iron-oxidizing bacteria. Image width 0.6 mm.
All photos in this article are by Ulf Thewalt and all agates are from the Thewalt-Dörfner collection.

Fig. 3: Spiral shaped piece of thread. Image width 0.36 mm.

2.2 Tangle-like red thread aggregates

Such formations only occur in some agates (**Fig. 4**). The structures are undoubtedly the remains of colony-forming organisms (bacteria)- as their morphology suggests. The formation and growth of similar-looking three-dimensional Bacterial colonies have been observed in medical microbiology (e.g. Mamou & al. 2016). When such clusters occur, there are several of them. **Fig. 5** shows two clusters that have grown in the same chalcedony band, hinting that they probably formed at the same time.

Abb. 4: Tangle-shaped colony of bacterial strands. Image width 0.8 mm.

Fig. 5: The tangle-shaped aggregates have formed in the same chalcedony band. Image width 1.6 mm.

2.3 Bundles of yellow bacterial strands

Aggregates of several yellow linear or curved structures have been found in several agates from Kerrouchen. Some aggregates appear to consist of elongated crystals (straight shape, tapering to a point). Others look more "organic" (curved shape, forks, sometimes very thin) (**Fig. 6 - 9**). This suggests that they are biosignatures.

Fig. 6: Aggregate of many thin short threads, probably originating from bacteria. Image width 2.4 mm.

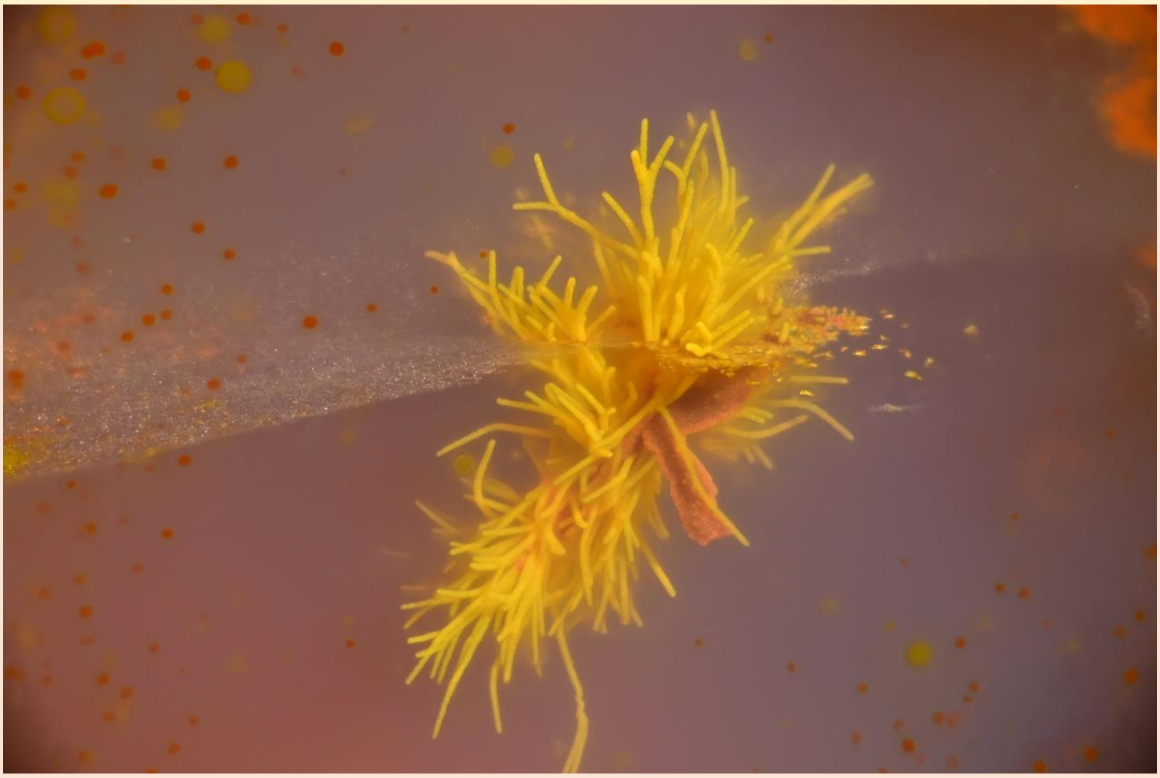

Fig. 7: Aggregate of relatively long components. The morphology suggests that these are biosignatures. Image width 1.6 mm.

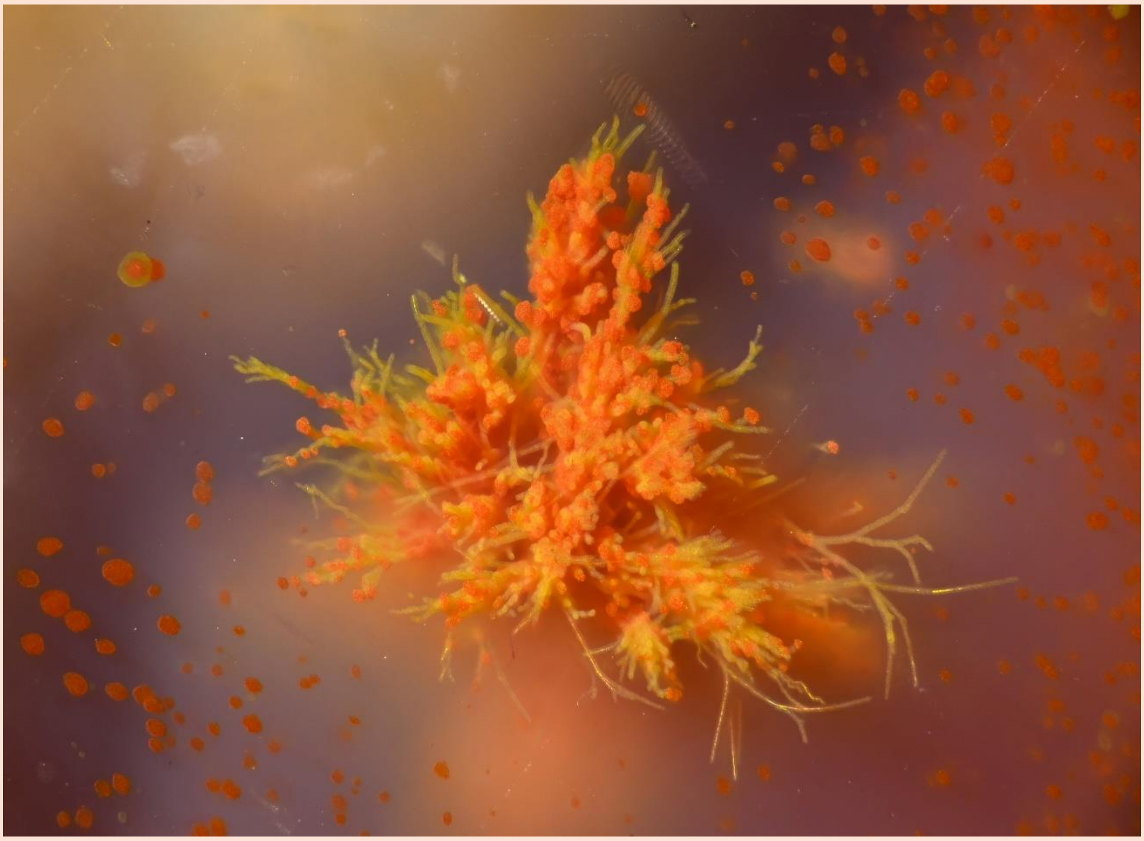

Fig. 8: Many hematite growths resembling parasites have formed on the branches of this yellow aggregate. Image width 1.36 mm.

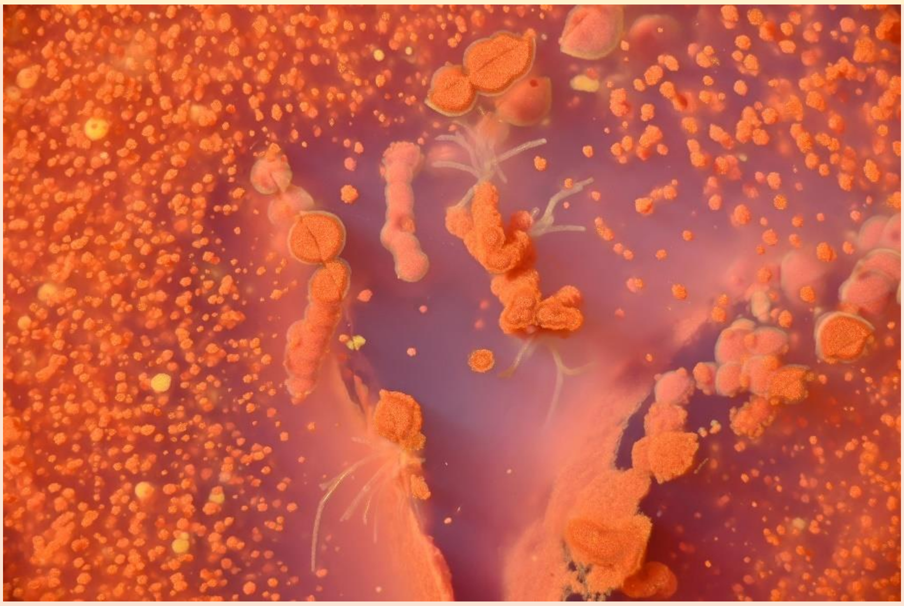

Fig. 9: „Tube-like“ formations with very thin yellow central threads. The latter can be seen in the “tube” at the bottom of the picture. Image width 1.6 mm.

2.4 Very thin filaments

Such threads of considerable length float in the transparent colorless chalcedony matrix and occur in the vicinity of some “cauliflowers” or are conspicuous there (**Figs. 10, 11**). The filaments are more or less strongly curved.

There are also branches that are probably thread-like former bacterial aggregates. They may be central threads of moss agate tubes that have lost their sheaths.

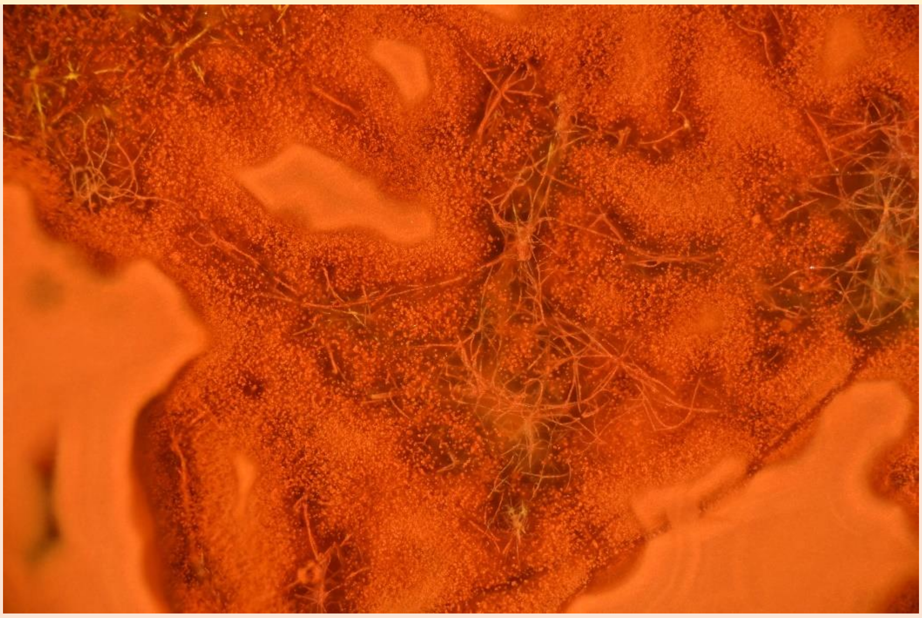

Fig. 10: In the chalcedony areas adjacent to the „cauliflowers“ such long threads, resembling bacterial chains occur. They appear to be covered with a thin crust of iron oxides. Image width 1.6 cm.

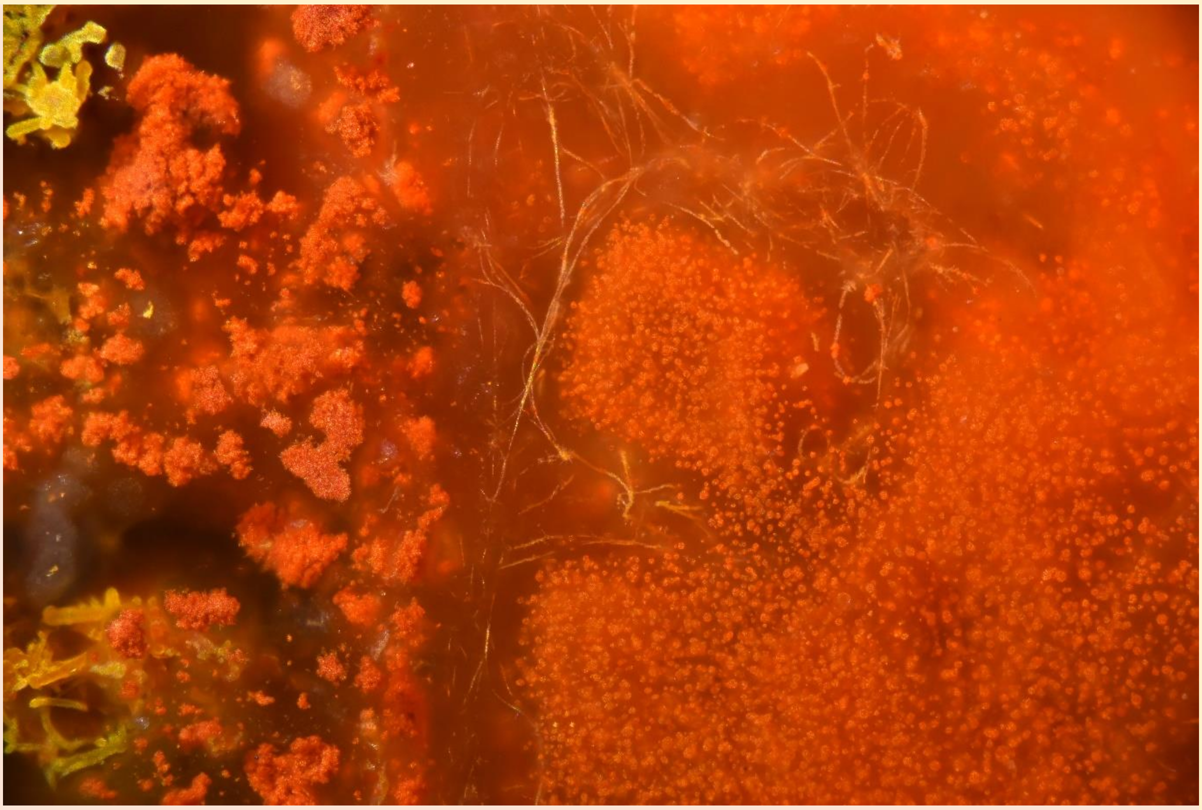

Fig. 11: Thin long filaments; less encrusted as in Fig. 10. Image width 0.8 mm.

3 Other (probable) biosignatures

3.1 Red and yellow roundish inclusions („Microspheres“)

The colors of agate bands in Kerrouchen agates range from deep red to orange to canary yellow. It is assumed that the colors are the result of inclusions of hematite (red) or goethite (yellow) (Götze 2011, Götze & al. 2020).

It is possible that the occurrence of iron oxide deposits in agates is caused by iron-oxidizing bacteria, hence the roundish inclusions mentioned here. Schmitt-Riegraf & Riegraf (2015) argues that organisms were involved in the formation, particularly of the red specimens, referred to as "microspheres".

Different color shades of the agate bands in agates from Kerrouchen are caused by different quantities and sizes of the red and yellow "microspheres". As with agates from other locations, bands with exclusively red or yellow inclusions often lie directly next to each other. Bands in which red and yellow "microspheres" are mixed are also not uncommon. There are also "microspheres" with one color on the inside and another on the outside. "Microspheres" on which "microspheres" of the other type sit like small parasites are also not uncommon (**Fig. 12**). The upper section of Figure 12 also shows that "microspheres" can be made up of smaller "microspheres". Also one can easily find examples of local accumulations of "microspheres" within an agate band

and note that aggregates of “microspheres” of different sizes have grown together (**Fig. 13**).

The observations outlined above are consistent with the biotic formation of “microspheres”.

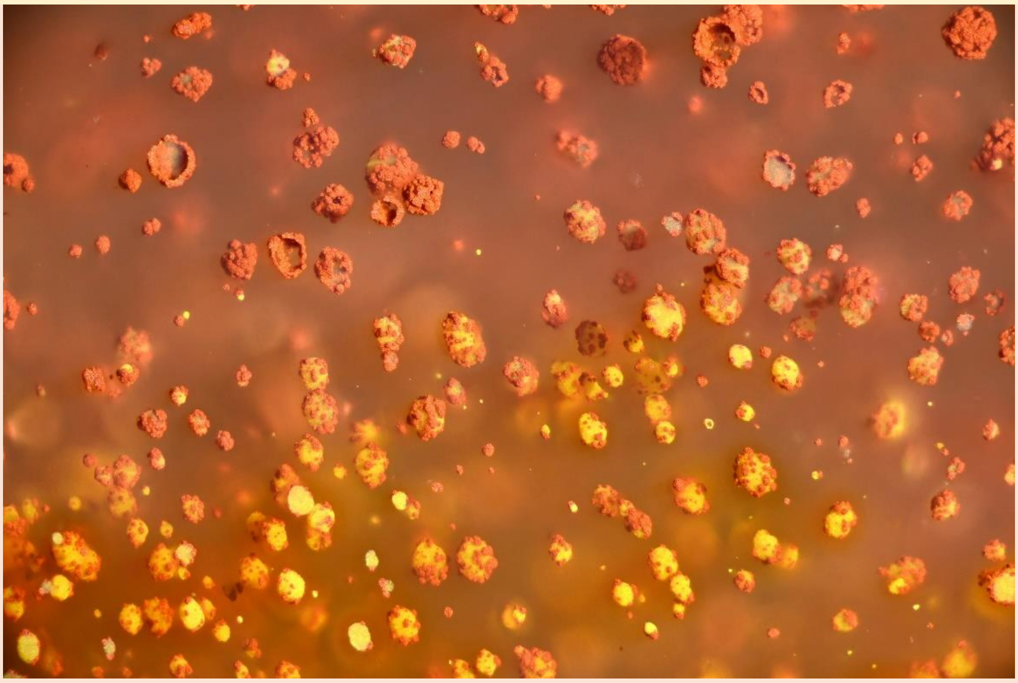

Fig. 12: Yellow microspheres are colonized by smaller red “microspheres”. If the encrustation is on a larger scale, you have “microspheres” that are yellow on the inside and red on the outside. The upper part of the picture shows that red “spheres” are made up of smaller “microspheres” and can also be hollow. Image width 1.6 mm.

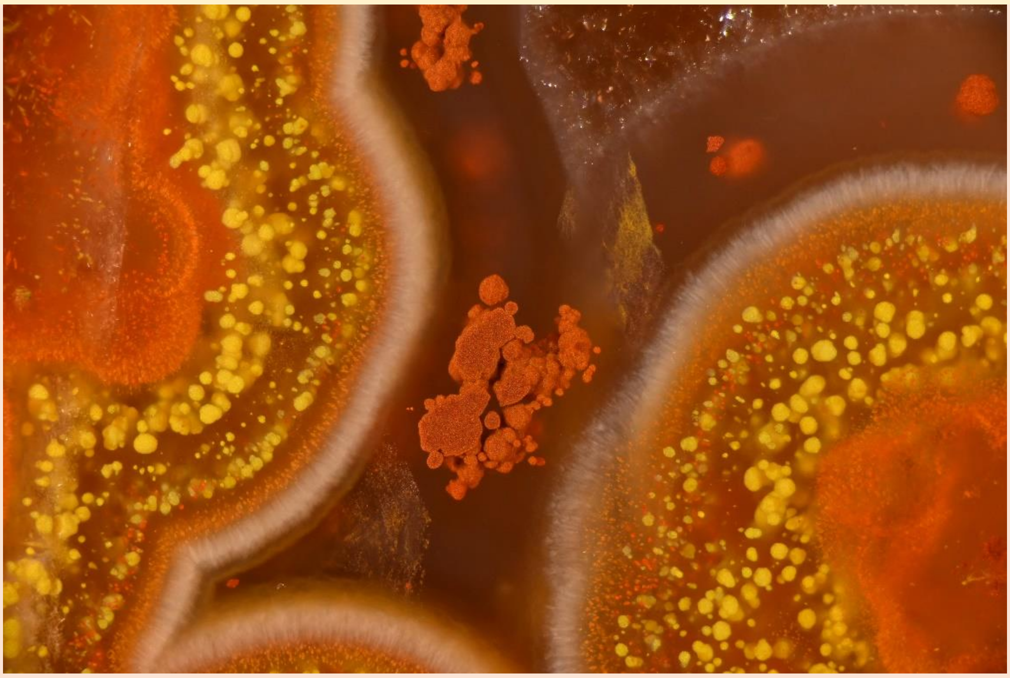

Fig. 13: In the center of the image, an aggregate of several „microspheres” that have grown together. Image width 1.6 mm.

3.2 „Microspheres“ with straight and curved outgrowths

The formations described below are difficult to interpret. In some agates there are red “microspheres” on which clumsy-looking outgrowths occur (**Fig. 14**). There are also quite attractive ones (**Fig. 15, 16**). The last two photos resemble small sea urchins in murky water. The outgrowths are partly straight, partly slightly curved. Their shape indicates that they are not precursors of the tangle-like formations of **Fig. 4 and 5**: In **Fig. 16**, the spiral shape of one of the outgrowths is striking. Outgrowths also occur on yellow “microspheres” (**Figs. 17, 18**), apparently only one per “microsphere”. The spines in **Fig. 18** are slightly sickle-shaped and pointed. The shapes of these outgrowths also suggest the involvement of organisms in their formation rather than a purely inorganic origin.

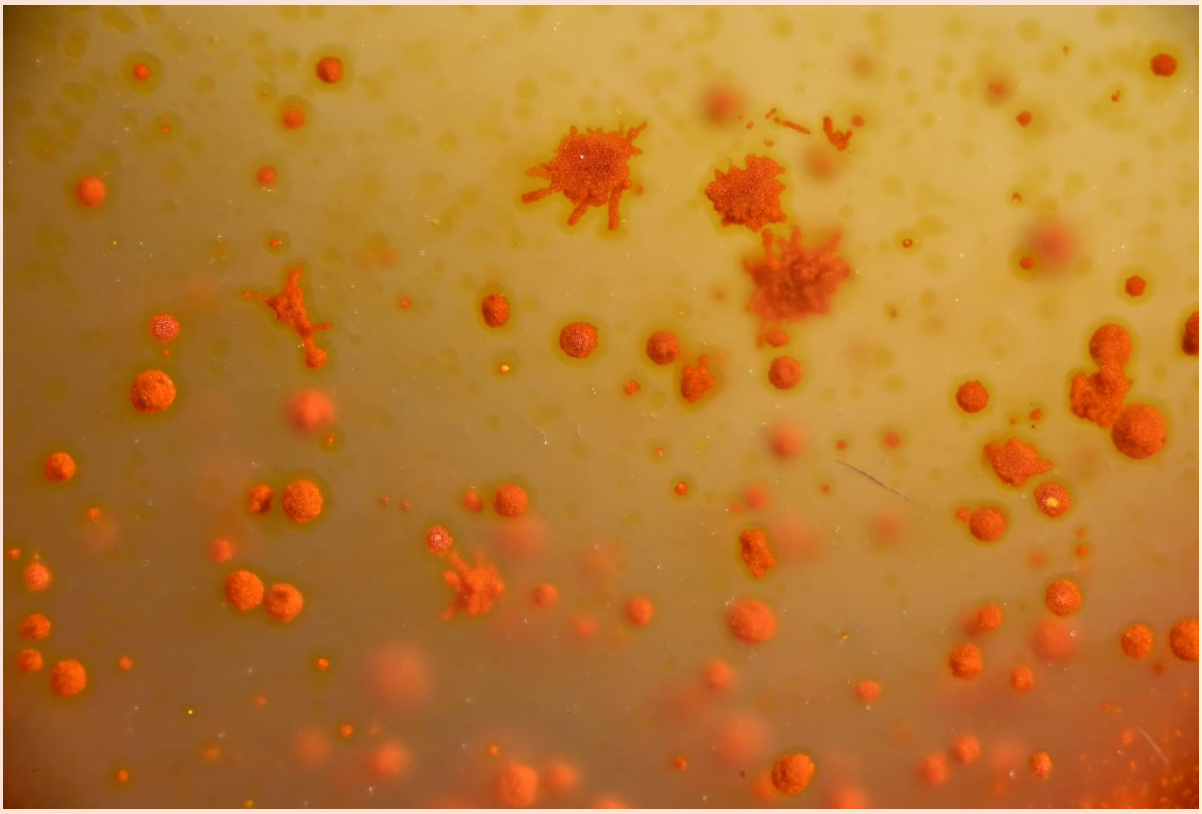

Fig. 14: Short rod-shaped growths on a red “microsphere”. Image width 1.6 mm.

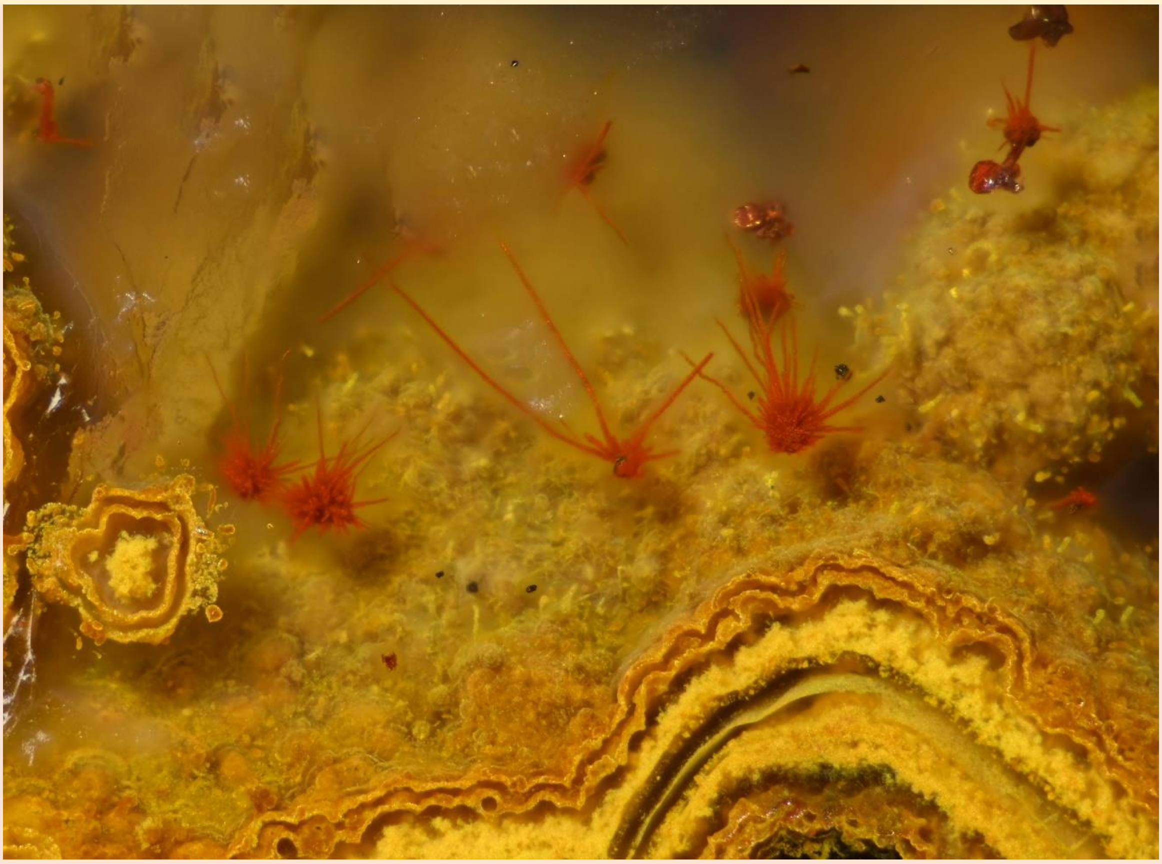

Fig. 15: „Microspheres“ with a few spiky growths each.
Image width 1.24 mm.

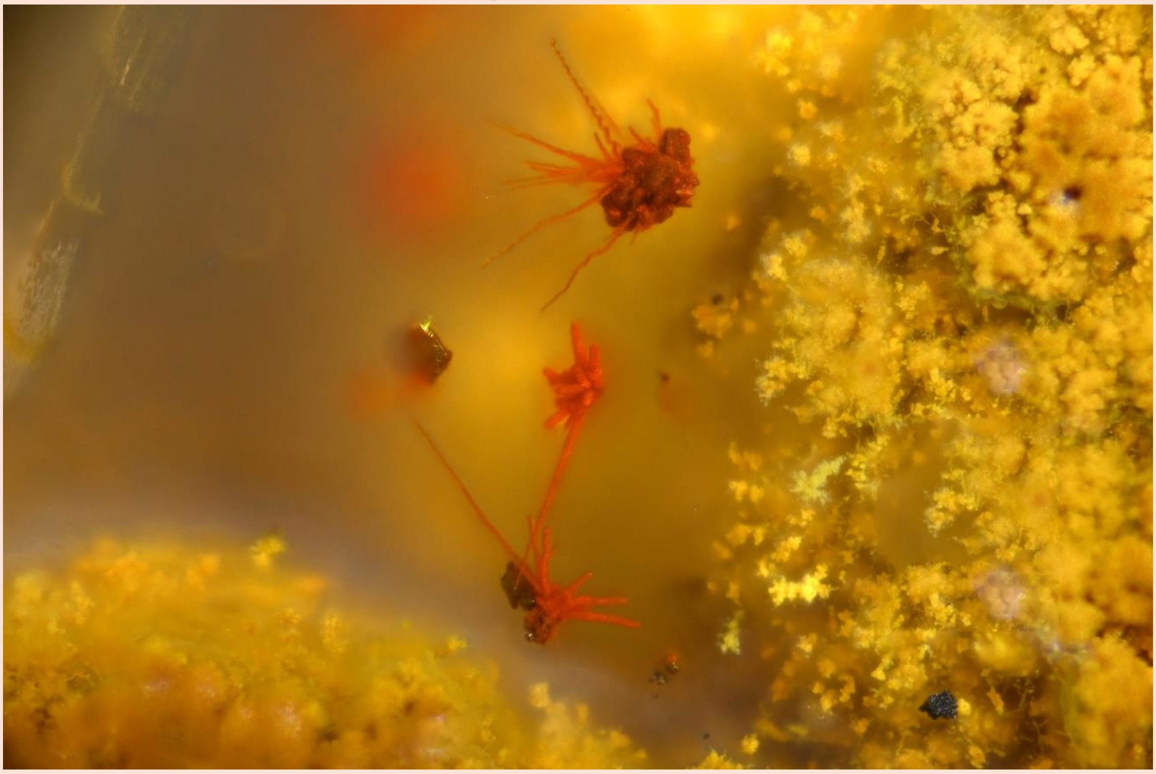

Fig. 16: Similar red formations as in Fig. 15. The spiral shape of one of the spines in the upper part of the picture is striking. Image width 0.8 mm.

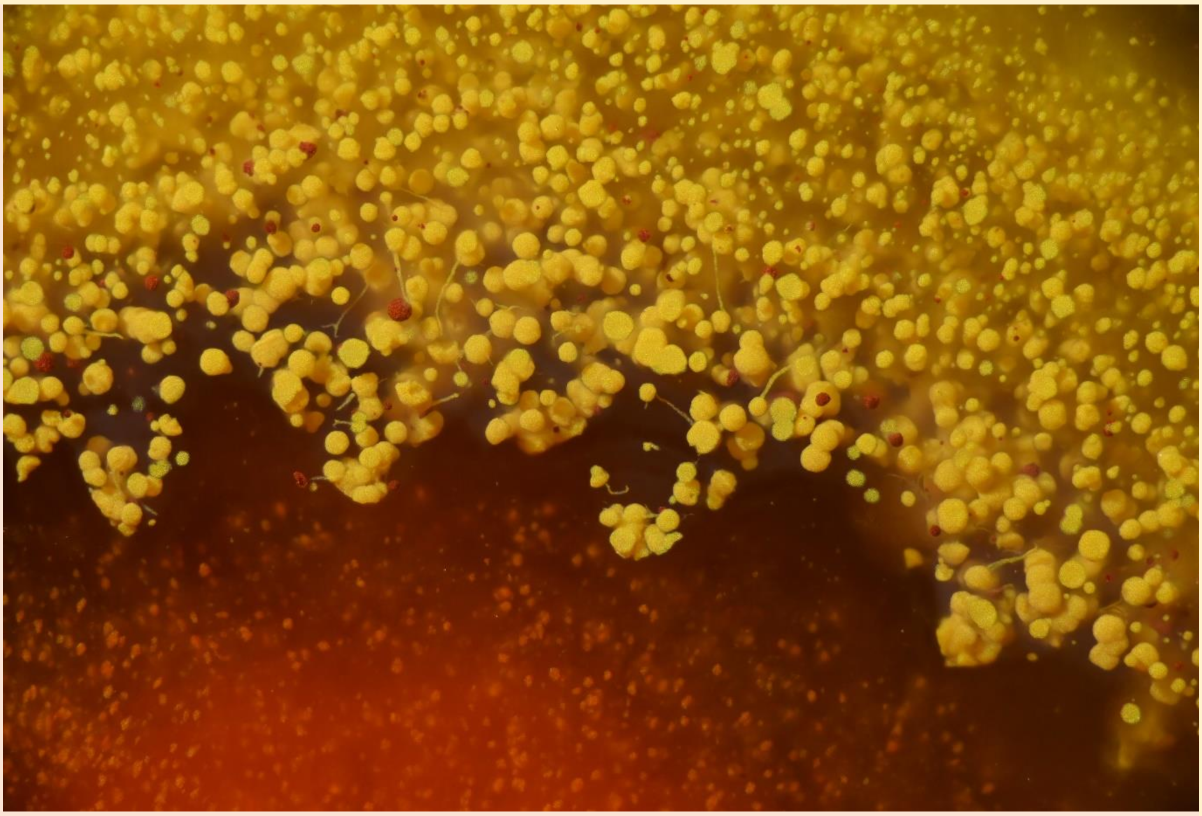

Fig. 17: Some of the yellow „microspheres“ are each covered with a curved “spine”.
Image width 1.6 mm.

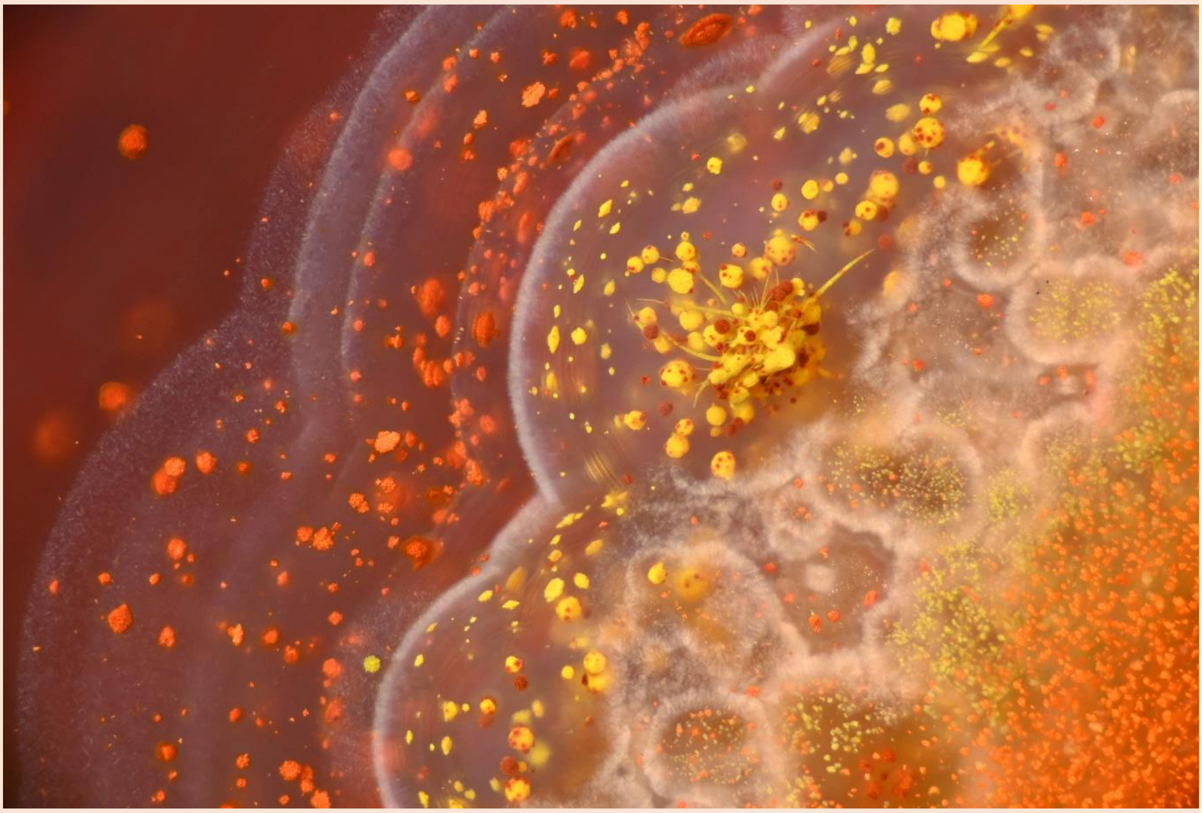

Fig. 18: Loose aggregate of several yellow “microspheres”, each with a “spine”.
Image width 1.6 mm.

3.3 Coccoid bacteria as possible starting objects of spherulites

In one of the vein agates from Kerrouchen, large quantities of spherical inclusions are seen in the vicinity of "cauliflowers" (**Fig. 19, 20**). Agates with clusters of small spherules are also known from other sites in the Atlas Mountains. Compared to the "microspheres" of paragraph **3.1**, they are not only roundish, but actually spherical. Coccoid bacteria may have acted as a kind of seed crystals for the crystallization of acicular SiO_2 crystals.

The observation that the diameters vary can be explained by the fact that the globules were not formed at the same time. The globules are often encrusted with crystals of a yellow mineral (goethite?). Some globules show a shell-like structure. Accumulations of similarly large formations, interpreted as the remains of purple bacteria, from an agate from Idar-Oberstein are illustrated in Schmitt-Riegraf & and Riegraf (2015).

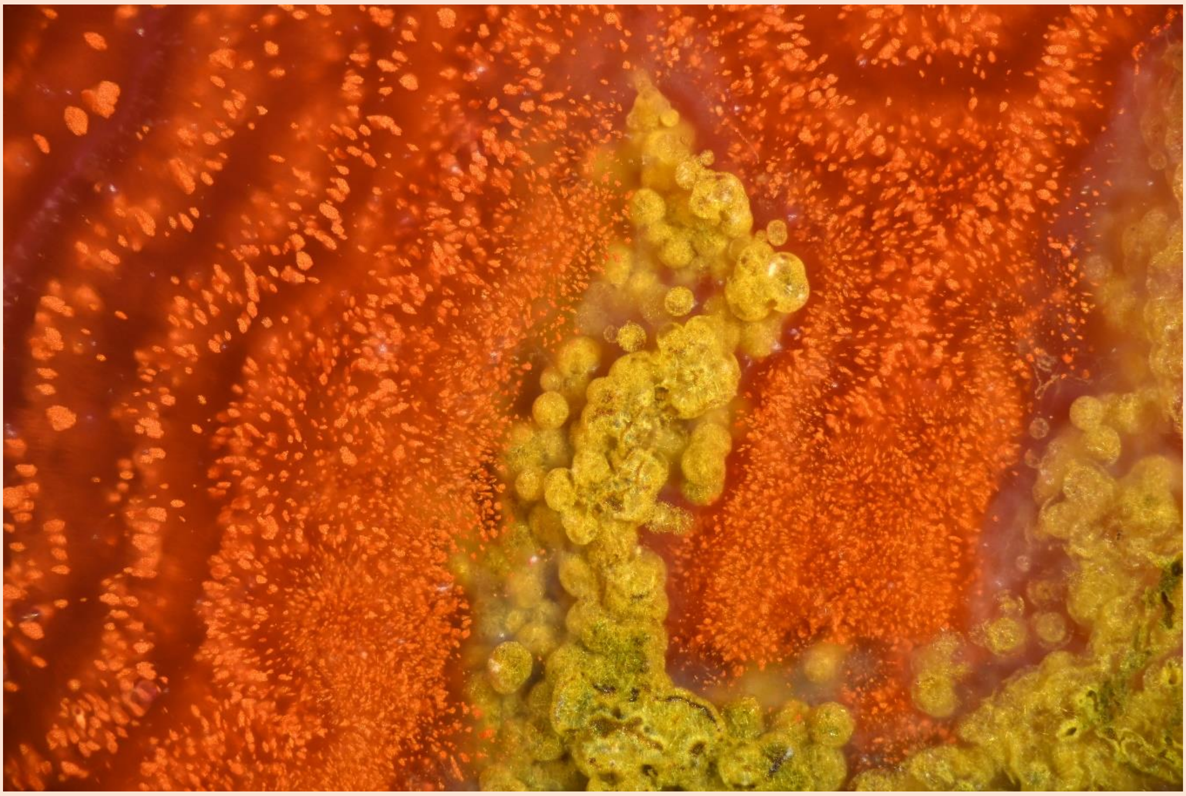

Fig. 19: Accumulation of spherulitic structured globules.
Their formation may have been initiated by coccoid bacteria.
Image width 1.6 mm.

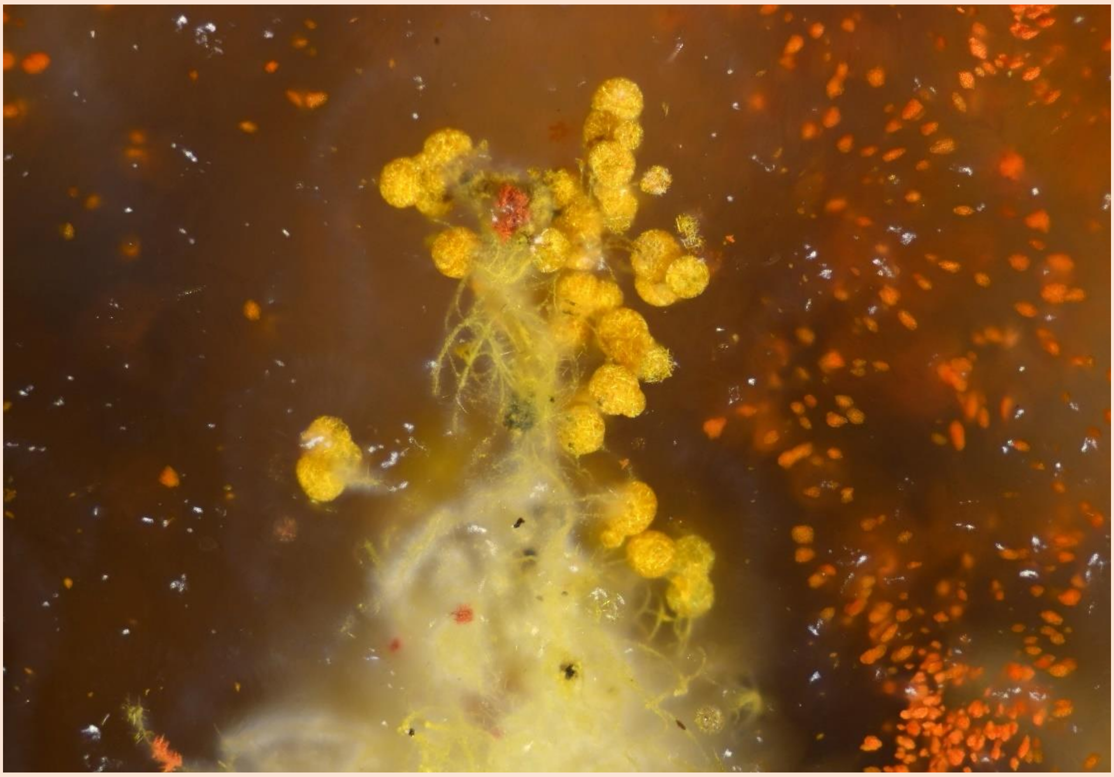

Fig. 20: The spheres occur here with filamentous biosignatures.
Image width 1.6 mm.

Comments

The agates pictured in this report were acquired at mineral shows and purchased on Ebay. All photos were taken of polished specimens using a classic microscope equipped with a system camera.

Several individual images were "stacked" using the Helicon Focus program (HeliconSoft, 61062 Charkiv, Ukraine). This resulted in increased depth-of-field as compared to individual images.

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