Biosignatures in Agates from Aouli, Atlas Mountains, Morocco

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English translation by Johann Zenz, using the translation software DeepL)

In agates from the area of Aouli, Morocco, several types of inclusions with unusual morphology occur. Some examples are presented here - in particular tangle-like, spider-like and brush-like inclusions. Their morphology leaves little doubt that we are dealing with biosignatures.

Fig. 1: Agate from Aouli with multiple inclusions. The microscopically small (mm and sub-mm range) inclusions of interest here occur in the edge areas of the two red bands. 12.7 cm. The photos in this article, unless otherwise stated, were taken by the authors. Unless otherwise stated the objects shown are in the author's collection.

1 Introduction

In previous articles we have described the inclusions in agates from the neighborhood of Kerrouchen in the southern Atlas (Thewalt & Dörfner (2024 a, b)). The quintessence: The agates there are teeming with bio-signatures. The question arises: Does this also apply to material from other deposits in the Atlas region?

This note is about agates from the Aouli area in the Central Atlas. The impetus was provided by the examination of two agates under a stereo loupe which proved to be particularly interesting. Almost all the photos shown below are of these two specimens. The photos concern the aesthetically particularly appealing brush-like and ball-like to spider-like inclusions. A more systematic discussion will have to wait.

2 Spider-like and ball-like formations

The agate from Aouli shown in Fig. 1, brought back from an excursion to Morocco in summer 2011, was made available to us by the German collector Helmut Schumann. There are two red bands in the agate. As can be observed again and again, the color of such bands is caused by roundish red iron oxide particles that seem to float in the colorless chalcedony matrix.

It becomes more interesting when you take a closer look at the outskirts of the red bands. One has the impression of finding oneself in an unreal, bizarre landscape (Fig. 2 - 4). The various filigree red shapes are particularly striking (Fig. 2 - 9). They can be straight or curved. They can appear without branching and with branching. And they can occur individually or as aggregates of a few or many individuals. We had also observed similar formations in agates from Kerrouchen.

By the way and without comment: Completely unexpected fascinating "spider-like" inclusions can also be found in a completely different rock, namely in obsidian. Descriptions come from the mineralogists Gustaf Adolf Kenngott (1869) and Ferdinand Zirkel (1873).

Fig. 2: Edge area of one of the red bands. Image width: 3.6 mm.

Fig. 3: An „UFO“ hovers above the red area with whimsical plants. This consists of several pieces of red thread that have grown on a central body. Image width: 1.8 mm.

Fig. 4: Formations reminiscent of red starfish on a thin white band. The band consists of parallel oriented quartz crystal needles. The red formations are made up of bundles of threads. Image width: 3.6 mm.

Fig. 5: Aggregate of several clumsy appearing rods. Image width: 1.8 mm.

Fig. 6: Two aggregates of red thread fragments. The fragments rest on a band of parallel oriented quartz needles. Image width: 1.8 mm.

What can be said about the structure of the red rods, needles and wires? The color is probably due to hematite and/or goethite. Yellowish-brown threads can also be seen occasionally (Fig. 3). These are probably the primarily formed threads.
Sometimes a kind of reddish translucent halo is also formed around central filaments. The filaments are often curved. This applies particularly to the end areas of relatively long filaments (Fig. 6, 7). Bifurcations also occur. This fits well with biosignatures, but not with inorganic formations.
The relatively short rod-like formations in Fig. 5, on the other hand, may have an “inorganic” origin. However, some of the rods in Fig. 5 are slightly bent. This speaks against a purely inorganic origin.

Two observations that are worth noting should be mentioned here:

(1) In some of the filament aggregates there is a central roundish body (Figs. 6, 8) on which the filaments/rods have obviously grown. These central bodies are hollow. This can be seen in specimens that were accidentally cut through when sawing open the agate (Fig. 8).

(2) Some threads show a spiral structure. This type of thread also plays a role in the agates from Kerrouchen. There, spiral thread fragments floating freely in the chalcedony matrix were particularly noticeable.

Fig. 7: Aggregates consisting of bent threads. The aggregates are located on the convex side of the fine-needled quartz base. Remarkable are the many bends and the small diameter of the threads towards their ends. Image width: 1.8 mm.

Fig. 8: Aggregates of a few rods that look like small sea urchins or spiders.
Image width: 1.6 mm.

Fig. 9: Accumulation of spider-like structures with tapered legs. Image width: 1.8 mm.

3 Units that look like bottle brushes

We acquired the agate shown in Fig. 10 from the late German agate dealer Peter Jeckel at the agate show in Niederwörresbach, Germany, in 2014. Even with a simple magnifying glass, it was possible to see that the agate contains special inclusions. Figs. 11 and 12 are from a larger Aouli agate with similar inclusions. Figs. 12 and 13 show the architecture of the inclusions: there is a main shoot around which clusters of several branches are grouped. Figs. 13 and 14 provide information about the structure of the individual tufts: The tufts consist of small branches of approximately the same thickness. These branches (approximately) extend away from the longitudinal axes of the brushes.

There are no overlaps. The branches themselves consist of red and in places yellow material, i.e. iron minerals. In some places, thin threads can be seen or guessed at, bridging branches of neighboring tufts like strings of pearls (Fig. 15). This can be interpreted to mean that inorganic substances have crystallized on an existing organic thread.

According to current knowledge, bacterial strands can be considered as the corresponding threads. It is to be expected that the original threads of organic material have not been preserved. They are now being traced by the deposited mineral particles.

Fig. 10: Agate with inclusions that look like bottle brushes.
The viewing direction is along the axes of the brushes. Width: 6.3 cm.

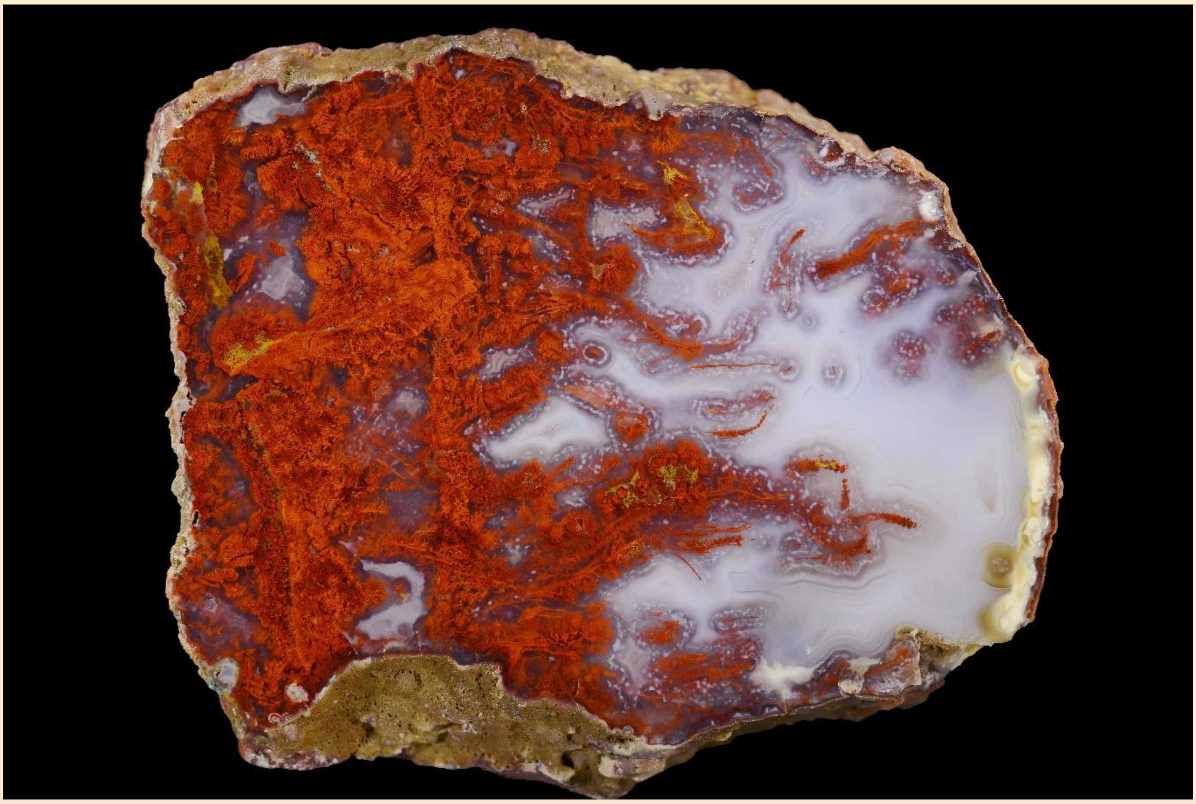

Fig. 11: A comparatively large agate with magnificent “brush inclusions”. Width about 12 cm. Helmut Schumann collection. Wolfgang Waeger photo.

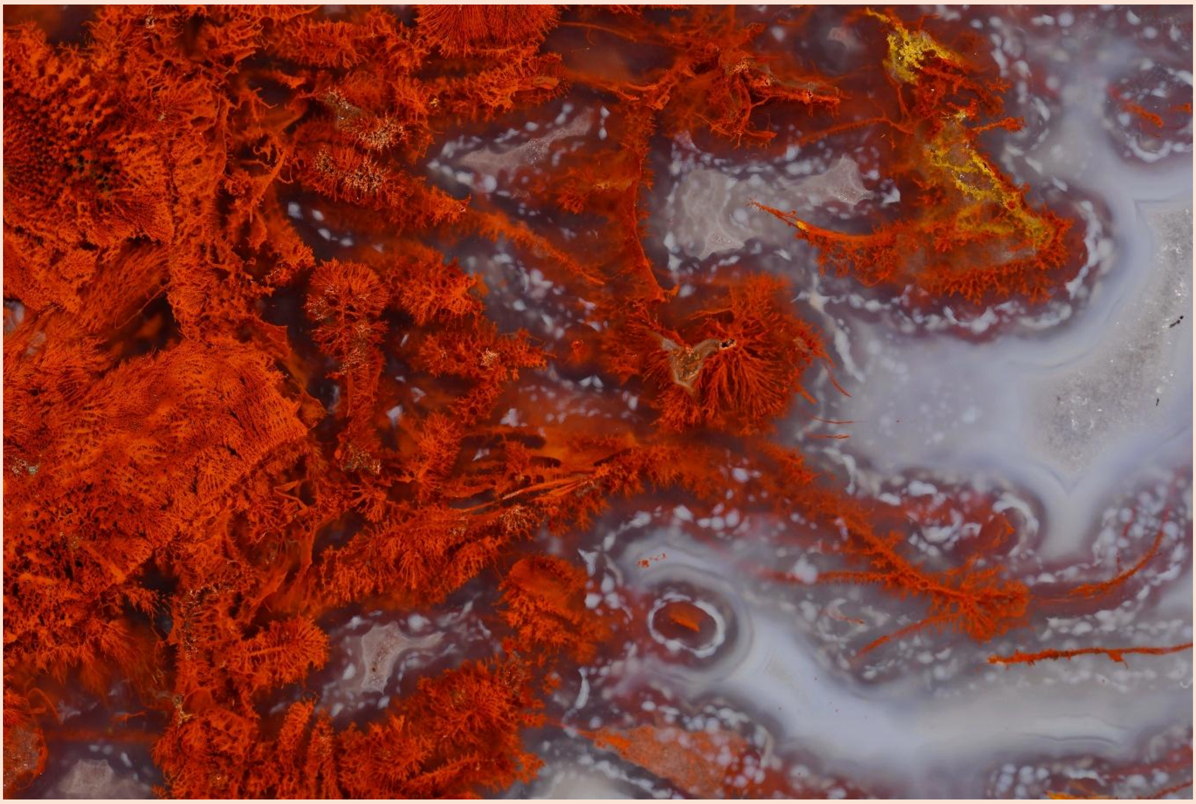

Fig. 12: Detail from Fig. 11. You might think you are looking into a thicket of conifer branches. Helmut Schumann collection. Wolfgang Waeger photo.

Fig. 13: Longitudinal section through a “bottle brush”. Dendrite-like tufts of branches of equal thickness, arranged approximately opposite each other, sit on a central stem. Image width: 3.6 mm.

Fig. 14: Cross-section through a “bottle brush”. Image width: 3.6 mm.

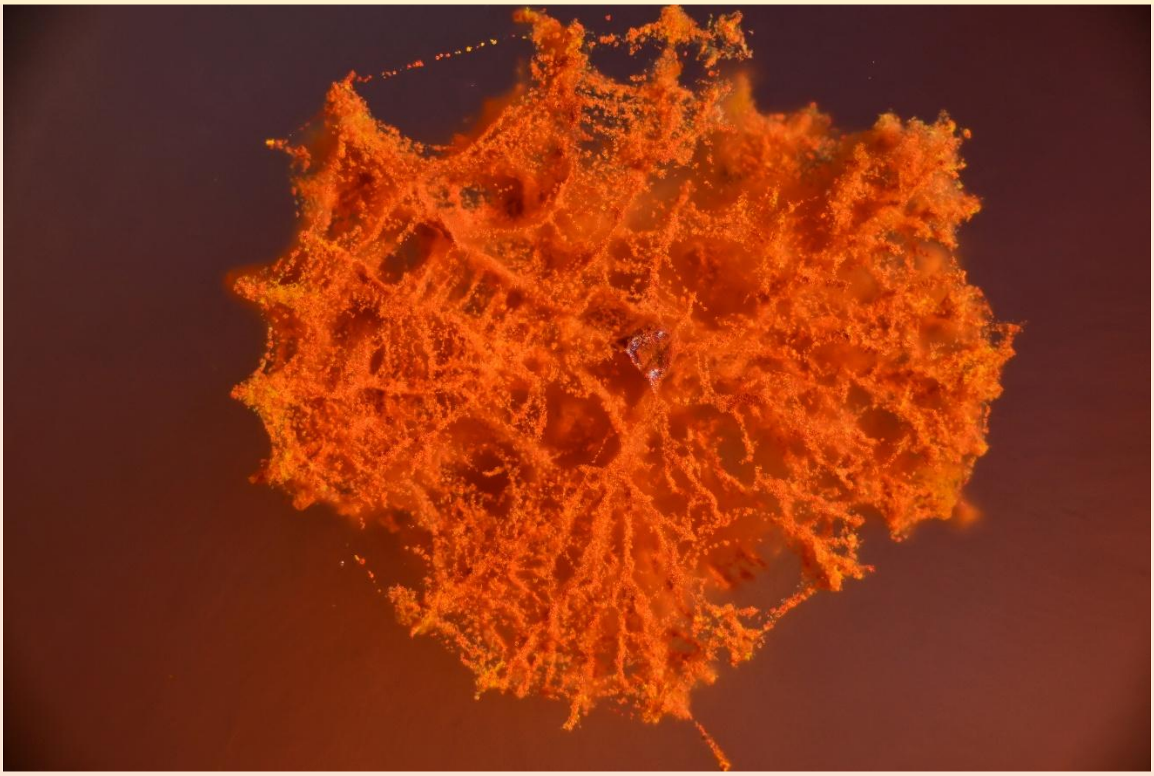

Fig. 15: Cross-section through a "bottle brush". In this specimen, the bridging threads between neighboring tufts are striking. Image width: 1.7 mm.

Fig. 16: Cross-section through a "bottle brush". The formerly filigree red tufts have become comparatively clumsy formations. The process of silicification of a "bottle brush" by successively deposited chalcedony layers is documented here. Image width: 3.6 mm.

The architecture of the clumps indicates that diffusion-controlled aggregation (DLA) in three dimensions played a role. Particles that already existed in the surrounding solution and/or formed from dissolved substances on growing bacterial filaments were aggregated (i.e. accumulated). The remarkable thing here is that DLA and bacterial growth appear to have occurred simultaneously.

Obviously, the “bottle brushes” are more than just piles of bacteria sticking together. Rather, they are based on a sophisticated construction plan.
Division of labor and communication between the microorganisms involved within the “brush aggregates” and with neighbors probably played an important role. The similarity with multicellular organisms cannot be overlooked.

The small dendrite-like tufts that have joined together to form a larger whole can be regarded as the (formal) building blocks of the “brushes”. However, this type of fusion only seems to have occurred or been preserved under special conditions (special local chemical environment?).

The tufts occur much more frequently in the form of individual small three-dimensional dendrites separated from their peers (Fig. 18); and also in the form of relatively large cushion-like colonies, which can be regarded as parallel packings of small dendrites.

This means: The differently sized and differently complex structures mentioned are just different manifestations of one and the same species.
There are also references to the ageing and decay of the “bottle brushes”.
A closer look at Figs. 14 to 17 reveals an increasing coarsening of the structure. Curtain-like formations replace the filigree tufts. Plump, lifeless-looking figures and finally the central columns of the bottle brushes remain.

We have not found any really suitable information in the literature on fossilized bacterial colonies with the brush structure described above. The information provided by Schmitt-Riegraf & Riegraf (2015) comes closest. These authors show photos of filaments of the species *Gallionella ferruginea* in agates from the Permian of the Saar-Nahe syncline (Germany). In their Fig. 18A, a division into main strand and perpendicular lateral filaments can be recognized.

Two conditions were apparently met for the uniquely good preservation of the bacterial structures in the agate from Aouli: Firstly, a completely calm environment during growth (aqueous stagnant solution in the geode cavity).

Secondly, the deposition of silica polymer on the bacterial aggregates before they became too large or disintegrated.

Fig. 17: The sad remains of aged “bottle brushes”. Image width: 3.6 mm.

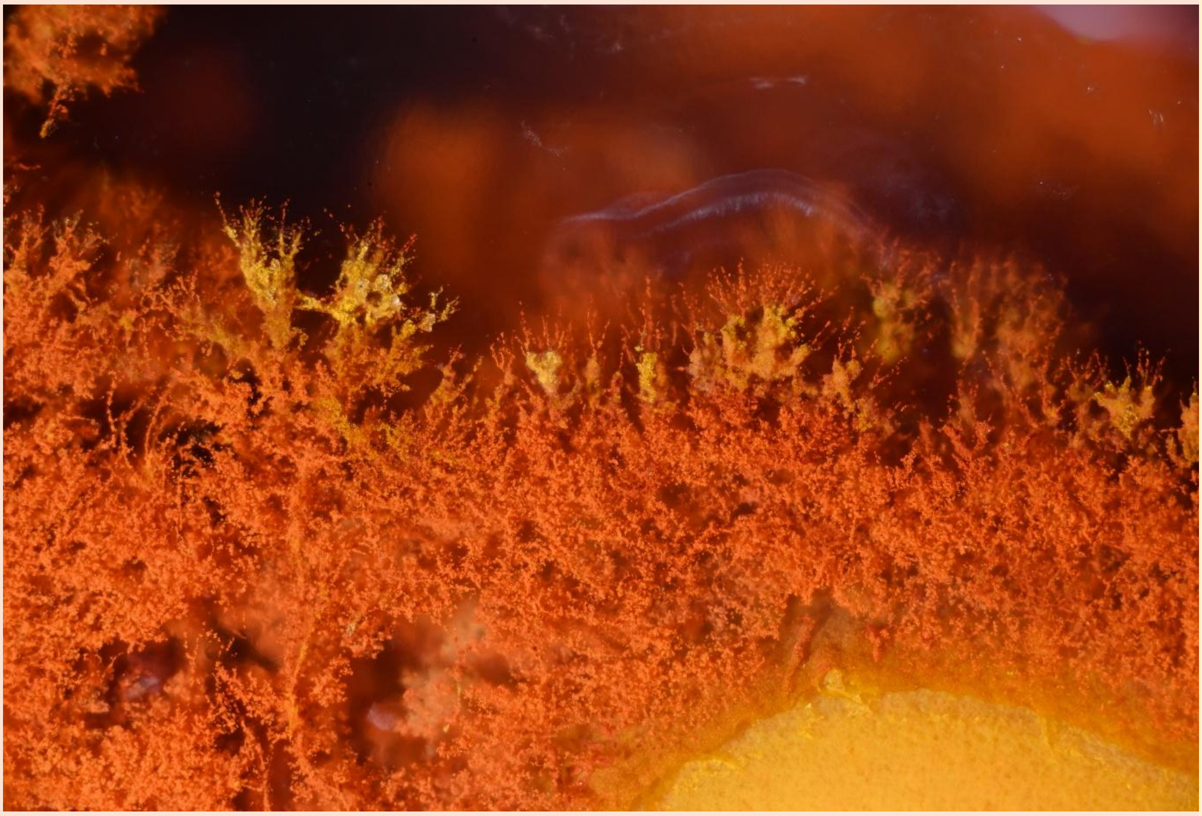

Fig. 18: Microdendrites in statu nascendi. Image width: 3.6 mm.

4 On the (probable) formation of the described inclusions

Much has been speculated and written about thread-like and tubular inclusions in agates. Let's keep it short. The morphology of the inclusions described above indicates the involvement of organisms, more precisely bacteria. Arguments derived from the morphology of such "filaments" are presented by Hofmann & al (2008). Chemical arguments are provided by Schmitt-Riegraf & Riegraf (2015) and Thewalt & Dörfner (2012).

The relevant processes are discussed in detail and with many references by Konhauser (2007). The oxidation of dissolved iron(II) salts plays a central role.

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