RECOGNITION OF BACTERIALLY INDUCED MINERAL PRECIPITATES: EXAMPLES FROM CARBONATE, SILICATE, AND MN- AND FE-RICH DEPOSITS.  H.S. Chafetz, Geosciences, University of Houston, Houston, Texas 77030-1305, HChafetz@uh.edu

Microbes, primarily acting as catalysts, induce mineral precipitation under a great range of environmental conditions, significantly greater than the range of conditions under which strictly abiotic (physico-chemical) precipitation can take place and produce a wide morphological range of accumulations. For example, shrub-shaped accumulations due to bacterial action have been well documented from carbonate (1, 2), siliceous (3), and Mn- and Fe-rich (4) deposits. In contrast, microbiologically induced mineral precipitation can occur as less obvious deposits, e.g., dense megascopically essentially non-descript laminae. To further complicate the recognition of microbially induced precipitates, microbes can provide the initial impetus to overcome the kinetic inhibitions to precipitation after which continued growth of the same crystals can then proceed by abiotic processes.

Shrubs commonly are up to 5 cm in height and occur as continuous laminae stretching 10's of meters laterally along the outcrop (fig. 1). Their microbially induced origin in carbonates is indicated by: presence of bacterial fossils or microporosity (former sites of bacteria) within shrubs, absence of bacterial fossils and microporosity in the mineral precipitates enveloping the shrubs, the irregular morphology of the shrubs (i.e., absence of any mineralogically controlled crystallographic orientations such as displayed by dendrites), epifluorescence indicating presence of light hydrocarbons in the shrubs and its absence in immediately adjacent enveloping calcite, demonstrated ability of bacteria to produce shrub morphology, and the demonstrated abilities of bacteria to induce calcite and aragonite precipitation in lab cultures. Most of these same lines of evidence also pertain to the microbially induced origin of the Mn- and Fe-rich shrubs and also the siliceous shrubs (fig. 2). [Mn- and Fe-rich deposits are primarily mineraloids (i.e., lack well-defined crystal structure) and "mature" into minerals with age]. The shrubs are the most obvious manifestation of the bacterially induced precipitation process.

In addition to the shrubs, bacterially induced precipitates also form as layers of silt to medium sand size blebs, coatings on cyanobacterial threads, as well as laminae. Small spherical to irregular calcite blebs occur as laminae commonly associated and intercalated with shrub horizons whereas Mn-rich blebs (oncoids) occur as black masses within carbonate laminae (fig. 3). Both types of blebs display diffuse edges as well as many of the features associated with the bacterial shrubs, e.g., bacterial body fossils, microporosity, epifluorescence, irregular (non-crystallographic) morphology, etc. Associated with these blebs, Mn- and Fe-rich coatings envelope cyanobacterial threads and thus produce black stromatolites (fig. 4). Immediately adjacent to the Mn-rich stromatolites, bacterially induced precipitates form dense, essentially non-descript thin structureless laminae in Mn-rich accumulations. These laminae are only recognized as bacterially induced precipitates when observed at the SEM scale.

The Mn-rich precipitates that form the shrubs, blebs, coatings on cyanobacteria, as well as the dense laminae, all are composed of slightly curved diaphanous sheets. Bacterial fossils, commonly rod-shaped 0.2µ thick and 1µ long, comprise an irregular lattice-work that forms the framework of the Mn-precipitates. That is, the slightly curved to arched sheets drape between the individual fossils. The curved sheets, on the order of 5 microns wide and tens to hundreds of nanometers thick, probably represent replaced biofilm (EPS: extracellular polymeric substance).

Bacteria also occur at the centers of radiating splays of aragonite. These microbes acted as catalysts to overcome the initial inhibition of the aragonite to precipitate, once precipitation began the crystals continued to grow by abiotic precipitation (figs. 5 and 6). Thus, this may be considered a biotically induced precipitate because in the absence of the bacteria, the aragonite splay may never have formed. Nevertheless, the bacterial fossils only occur at the very centers of the splays and thus can readily be missed during investigation.

Bacterially induced mineral deposits range from those fairly obvious on the outcrop, bacterial shrubs and coatings on cyanobacterial threads which produce stromatolites, to those distinctly less obvious, the dense non-descript laminae, to those in which the bacteria only occur as the nucleus around which precipitation is initiated. Nevertheless, all of these precipitates provide evidence for the former existence of bacterial life.

Fig. 1 Layers of bacterially induced carbonate shrubs separated by thin laminae of bacterially induced silt-sized carbonate blebs. Quaternary travertine, Bagni di Tivoli, Italy.

Fig. 2 Horizons of bacterially induced Mn- and Fe-rich shrub layers, bacterial fossils are abundant in the shrubs but absent in the immediately adjacent calcite. Quaternary travertine, Morocco.

Fig. 3 Mn-rich silt-sized bacterially induced blebs or oncoids. Modern travertine, Young Hopeful Geyser, Yellowstone.

Fig. 4 Cyanobacterial threads coated with bacterially induced Mn-rich precipitates. Modern deposit, Young Hopeful Geyser, Yellowstone.

Fig. 5 Aragonite splay displaying well-developed crystal morphology. Modern travertine, Young Hopeful Geyser, Yellowstone.

Fig. 6 Center of figure 5 showing clump of bacterial fossils comprising core of splay.