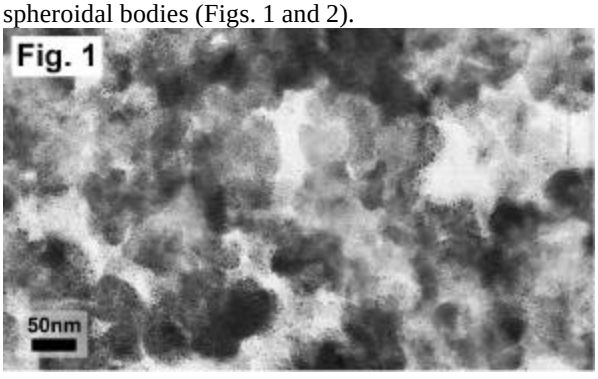
VARIOUS OCCURRENCES OF POTENTIAL MICROBIAL FOSSILS IN MUDSTONES AND INVESTIGATIONS INTO BACTERIAL TAPHONOMY. J. Schieber[1], H.J. Arnott[2]; M. Coviello[3], [1]Department of Geology, [2]Department of Biology, [3]Department of Material Sciences, The University of Texas at Arlington, Arlington, Texas 76019, schieber@uta.edu, arnott@uta.edu.

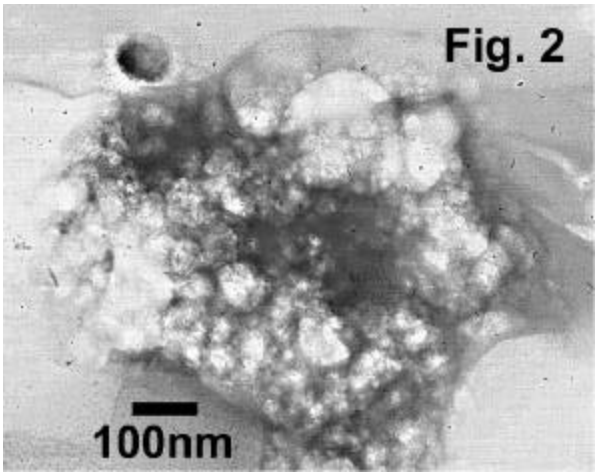
Introduction: Evidence of past microbial life on Earth can be preserved in those portions of sedimentary rocks that have undergone early diagenetic mineralization and/or cementation. Thus, we typically find it in carbonate rocks and especially those portions that have undergone early silicification [1]. Yet, while the literature on fossilized microbes is clearly biased towards carbonates and cherts, microbial fossils have nonetheless also been reported from terrigenous clastics. The latter examples come almost exclusively from mudstones and comprise microplankton assemblages of compressed sphaeromorph acritarchs and carbonized filaments [2,3]. Because modern muds contain an abundance of endosedimentary microbes [4], we examined various mudstones and their early diagenetic minerals in the search for included microbial remains. We found bacteriomorph features preserved in early diagenetic pyrite, in interstitial silica deposits, and also as carbonaceous remains. In order to examine more closely the pyritization of microbes, we set up an experiment in order to examine the associated decay and development of bacterial communities over a time of several months.

Potential Microbial Fossils from Mudstones:

Interstitial silica from microbial mat deposit: Samples of a pyrite mineralized microbial mat deposit from the Proterozoic of Montana were examined by TEM. Intermingled with the clay minerals and the pyritic mat laminae are patches of early diagenetic interstitial silica cement that reveal a clotted texture due to numerous spheroidal bodies (Figs. 1 and 2).

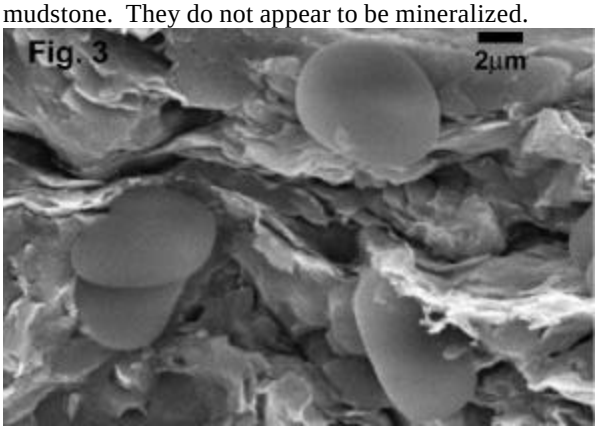


The size of these bodies (Fig. 1, TEM photo) is smaller than 50nm, which places them into the nannobacteria category [5]. The speckles that are seen in portions of the photo are an artifact of carbon coating, necessary because of excessive charging of the sample.



The rounded silica bodies in Fig. 2 are larger than those in Fig. 1 and show internal complexity reminiscent of bacteria.

Carbonaceous bodies in mudstone: Rounded-ellipsoidal bodies of carbonaceous material were observed in a Cretaceous mudstone from Utah. These bodies are several microns long and can in places be associated with kerogen streaks in the rock (Fig. 3). They are found in freshly broken samples of a dense mudstone. They do not appear to be mineralized.

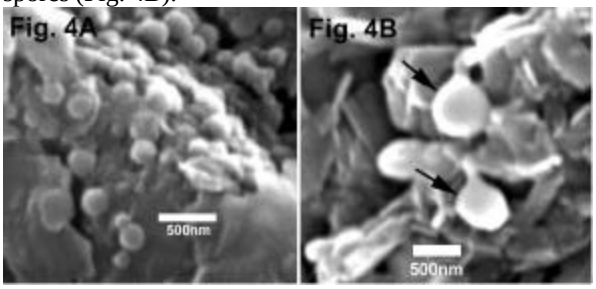


Early diagenetic pyrite: Diagenetic pyrite grains from various mudstone successions have been examined by SEM and TEM for microbial remains. Most contain rounded to ellipsoidal pyritic bodies that are within the size range expected for bacteria [6]. At the moment we assume that these features are the pyrite-mineralized remains of bacteria that lived in the sediment at the time of active pyrite formation.

Whereas features shown in Figs. 1 and 2 are less than 200nm in size and thus considered by some too

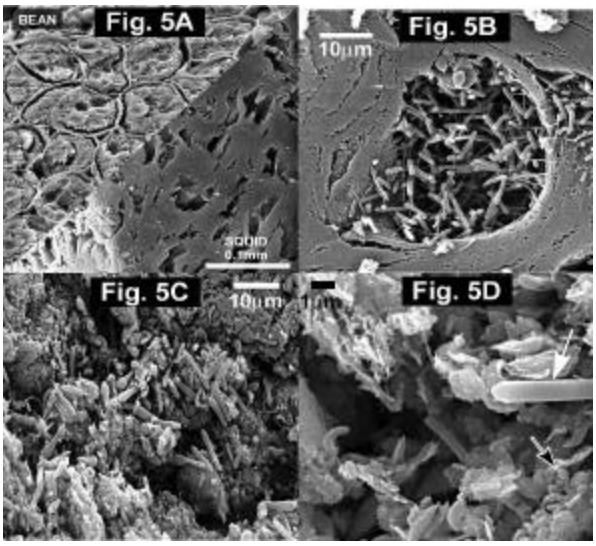
small for viable bacteria [7], features in Fig. 3 and pyritized features pictured in [6] are within the size range of viable microorganisms [7]. We conclude from our survey of random mudstone samples that mudstones may contain a range of preserved features suggestive of microbial origin. While morphological studies are one way to make a case for a microbial origin, an alternative approach is the attempt to produce these features experimentally under the envisioned conditions of formation.

An Experiment in Microbial Taphonomy: Taphonomy describes the transfer of organic remains from the biosphere to the lithosphere. We set up an experiment where pieces of organic matter (squid) were buried in mud that contained a source of soluble iron and water at saturation with $CaSO_4$. Eight weeks later samples were removed and examined. The squid tissue had vanished, and mud in the vicinity had been blackened by iron sulfide. Microscopic examination of blackened clumps showed small rounded bodies on clay flakes (Fig. 4A), as well as stalked bodies resembling bacterial spores (Fig. 4B).



Because of very rapid decay, the squid experiment was repeated to more closely track the decay process, and a plant tissue experiment with beans was added as well. When removed from the tank, organic tissues were fixed with Gluteraldehyde and Osmium Tetroxide. At day 2, squid and bean still showed good integrity (Fig. 5A) while fostering intensive bacterial growth (Fig. 5B). At day 9 most of the squid tissue had been metabolized (Fig. 5C). After 2 weeks there was essentially nothing left. By comparison, the beans deteriorated more slowly at first, but after 2 weeks what remained was mostly the more resistant seedcoat.

While at the onset of decay, squid and bean tissues were dominated by just one type of a rod-shaped bacterium (Figs. 5B, C), bacterial diversity increased when the most readily metabolizable material diminished. Smaller and differently shaped bacteria increased in abundance (small arrow in Fig. 5D points to bacterial bodies of a few hundred nanometers size), while the numbers of the initial rod-shaped bacteria dropped sharply (white arrow points to bacterium of the type that dominated in early decay).



The latter (Fig. 5A) are much larger and of different shape than the bacteriomorphs shown in Fig. 4. Also, under a light microscope, fresh smears of the blackened mud reveal a wide variety of microorganisms, including abundant small motile forms. The difference in bacterial diversity between fresh and fixed samples, as well as the size and shape difference between bacteria from fixed samples (Figs. 5) and late stage bacteriomorphs (Fig. 4), suggests that early diagenetic preservation of bacteria is a complex issue. Timing and rate of mineralizing and decay processes determines whether bacteria will be preserved at all, and which portion of the evolving microbial assemblage will be preserved in the rock record. The same event (e.g. burial of a dead fish) may at different instances lead to the preservation of different microbial assemblages.

Microbial remains in the sedimentary rock record will most likely be the key piece of evidence when we search for life on other planets. Credible claims of such a nature require a sophisticated understanding of bacterial taphonomy in a variety of geochemical settings. We also need to improve our knowledge of the interrelationships and interdependencies between bacterial metabolism and mineralizing processes.

References: [1] Schopf J.W. & Walter M.R. (1983) In: Schopf J.W. (Ed.), Earth's Earliest Biosphere, 214-239. [2] Horodyski et al. (1992) In: Schopf J.W. & C. Klein (Ed.), The Proterozoic Biosphere, 185-193. [3] Damassa S.P. & Knoll A.H. (1986) *Alcheringia, 10*, 417-430. [4] Bird D.F., Juniper S.K., Ricciardi-Rigault M., Martineu P., Prairie Y.T. & Calvert S.E. (2001) *Marine Geology, 174*, 227-239. [5] Folk R.L. (1993) *Geology, 63*, 990-999. [6] Schieber J. (2001) Lunar and Planetary Science 32, Abstract #1072. [7] Nealson K. (1999) *in* Size Limits of Very Small Microorganisms: Washington, D.C., National Acad. Press, 39-42.