NO STROMATOLITES ON MARS? F. Westall[1], F. Foucher[1], B. Cavalazzi[1]. [1]Centre de Biophysique Moléculaire, CNRS and University of Orléans, Rue Charles Sadron, 45071 Orléans, France (frances.westall@cnrs-orleans.fr)

Stromatolites, photosynthetic microorganisms and Mars: Numerous upcoming martian missions will be searching for traces of life. With the observational instrumentation that will be available on future robotic missions, such as MSL and ExoMars, the most obvious traces to search for will be macroscopic to microscopic laminations produced by microbial mats, such as stromatolites. Stromatolites are three dimensional structures constructed primarily by photosynthesizing microorganisms that obtain their energy from sunlight. At their apogee in the Proterozoic epoch (2.5-0.5 Ga), they reached many meters in size. However, during the early history of the Earth (Early to Middle Archaean period, 3.5-3.2 Ga), when environmental conditions were most similar to those of early Mars, i.e. anaerobic [1], stromatolites were much smaller in size, reaching up to about 10 cm [2]. This is because the photosynthesisng microorganisms forming them were anaerobic, therefore less energetically efficient than aerobic life forms that use oxygen.

The early stromatolites, although macroscopically visible, were however quite rare. Stratiform biolaminated sediments [3-5], also formed by photosynthesising microorganisms, were more common in that period. The physical interaction of the gelatinous, sticky microbial mats with sediments left characteristic structural, textural and compositional imprints.

The reliance of the photosynthetic microorganisms on sunlight for energy puts constraints on their environment of occurrence: they have to live in shallow water to littoral environments that are bathed in sunlight. Such environments, represented by small seas and infilled impact or crater basins, would have been common on early Mars. Theoretically therefore, there would have been plenty of suitable environments in which photosynthesizing microorganisms could have flourished.

However, the evolution of photosynthetic microorganisms on Mars is doubtful, and therefore the existence of the kinds of characteristic macroscopic to microscopic structures formed by them. Why is this? The fact is that photosynthesis is a relatively sophisticated microbial metabolism that probably required significant time to evolve. The oldest traces of life on the early Earth, ~3.5 Ga old, testify their existence [2,6] but by 3.5 Ga Mars was a cold, inhospitable desert whose surface environment was not conducive to life. Could such microorganisms have evolved earlier on Mars? If, as [7] suggest, the surface of Mars was already becoming waterless and inhospitable by 4.2-4.0 Ga, there seems to be little likelihood that such organisms could have evolved. Yert another obstacle to the possible evolution of photosynthesizing microorganisms on Mars is the *availability* of sunlight bathed shallow water/littoral environments in its early history. Early in the formation of the Solar System, Mars was situated outside the habitable zone where water is stable on a planet's surface. Even if, after planet consolidation and fractionation, surface temperatures were high enough to support the presence of liquid water, they would have rapidly cooled such that standing bodies of water were probably ice-covered [8]. Except where hydrothermally heated, the littoral, shallow water environments especially would have been ice-covered. Thus, although plentiful, these environments would not have been bathed in sunlight. It is therefore questionable whether photosynthetic microorganisms could have evolved in such conditions.

Expected life forms on early Mars – anaerobic and subtle: It is widely accepted that, having the naturally-occurring ingredients of life, simple life forms could have evolved on the red planet. These would have been the kinds of microorganisms that could live off the inorganic resources of the planet, such as chemolithotrophs feeding off minerals and rocks, or heterotrophs feeding off the organic remains of the former, or even abiogenic organic matter. Such life forms were abundant on the early Earth [9,10]. The only problem is that these life forms do not leave behind traces that are readily observable or measureable. Like the early photosynthesisers, they were anaerobic and therefore small with limited biomass production. This means that their traces will be very subtle.

Investigations of such life forms in rocks formed on the early Earth can give us clues as to what we might expect on Mars and how to look for the traces. Silicified volcanic sands from the Pilbara, 3.346 Ga-old, represent sediments deposited in a littoral environment [10] (Fig. 1). Such volcanic sediments would have been common on Noachian Mars. The Pilbara sands contain the remains of chemolithotrophic microorganisms preserved as silicified microfossils. These microfossils consist of coccoids < 1 µm in size that formed colonies on the surfaces of the volcanic grains, as well as in layers of settled, fine grained volcanic dust. The carbonaceous remains are heterogenously dispersed within the sediment although the bulk carbon contents of the sediment are low, < 0.01%. Carbon isotope ratios are about - 26‰ and are consistent with the fractionation of carbon by microbial metabolisms.

There is no macroscopic indication in the rock for the presence of fossilised life forms (Fig. 1A) and the microfossils are too small to be observed in petrographic thin section or in reflected light microscopy, although occasionally the microbial colonies may be visible as amorphous dark patches of kerogenous matter attached to particle surfaces (Fig. 1B). High resolution scanning electron microscopy coupled with delicate acid etching of the chert is necessary to visualize the microfossils (Fig. 1C). Microscopes on the future Mars missions will, thus, not be able to resolve eventual traces of such fossilised microorganisms (the MSL microscope has a resolution of 12 µm, that of ExoMars 4 µm). Moreover, kerogens (carbonaceous remnants of biological origin) of this age (~3.5 Ga) tend to be extremely degraded owing to (1) metamorphism, even though the latter was only burial metamorphism (prehnite-Pumpellyite/lower greenschist facies) and (2) the great age of the materials. This means that functional groups that aid identification of the molecules have been lost. The ancient kerogens therefore consist of generic carbon molecules that can be collectively termed PAHs (polyaromatic hydrocarbons, mostly aromatic and some aliphatic molecules, plus ketones). Individually these molecules cannot be traced back to a specific biogenic molecule, although atomic scale structural details may point to a previous biogenic source (e.g. [11]). Rocks on the Noachian surfaces of Mars may have undergone some burial metamorphism but probably not to the extent of those on the Archaean Earth. Organic molecules in Noachain-age rocks may therefore be less degraded than terrestrial kerogens. Moreover, despite the low bulk carbon concentrations in the early Archaean microfossiliferous cherts, two ExoMars instruments, MOMA and Urey, should be able to analyze organic molecules in martian materials in low quantities (ppt-ppb range).

Conclusions: Traces of past martian life in Noachian-aged materials are likely to be very subtle because of the small size of the anaerobic life forms, their heterogeneous distribution and the low carbon contents. Although *in situ* missions will probably not be able to visualize the traces of these life forms, it is possible that the organic analytical instruments on ExoMars could detect organic molecules. However, in order to definitively identify martian life, combined *in situ* observational and compositional analyses in a laboratory will be required. This argues for bringing suitably-chosen rocks back to Earth in a Mars Sample Return Mission.

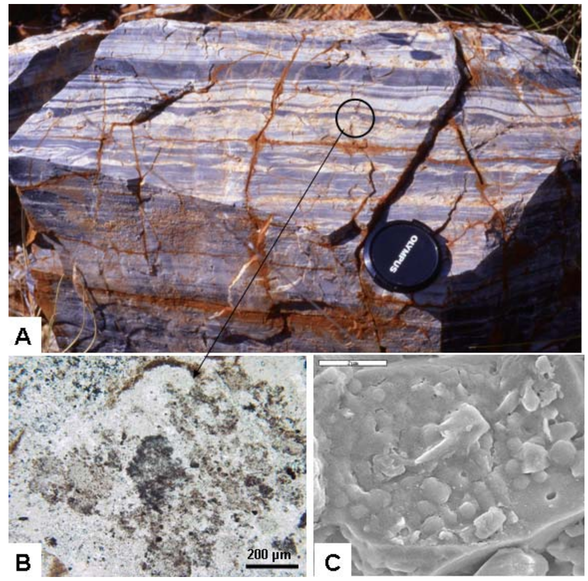

Figure 1. 3.346 Ga silicified shallow water sediments from the Pilbara containing subtle traces of life. A-Field view of the laminated sediments with no macroscopic traces of life. B- Thin section micrograph of a pumice grain in (A), some of the dark patches are carbonaceous. C- Silicified colony of small coccoidal chemolithotrophic microorganisms, revealed by HR-SEM.

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