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Traces of life on Mars are likely to be very small and very challenging to find

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The volcanic materials at the surface of Mars provide an ideal potential habitat for chemolithotrophic microorganisms that obtain their energy from chemical reactions at the surfaces of minerals and their carbon from inorganic sources in the environment. If life ever appeared on Mars, hydrated environments in the Noachian period (1,2) could have hosted such life forms (3). Other types of microorganisms that could possibly have lived at the surface during the Noachian include heterotrophic microorganisms that obtain their carbon source form organic carbon (either the degraded remains of pre-existing organisms or abiogenic sources (e.g. meteoritic materials). The rapid degradation in the environmental conditions at the surface of Mars imply an initially frozen and then dry surface that is unfavourable to the development of more sophisticated microorganisms, such as photosynthesisers. Whereas the latter produce readily recognisable macroscopic to microscopic structures, such as stromatolites and microbial mats, the former do not and their traces are very subtle and challenging to reveal.

Fossilised chemolithotrophic microorganisms in littoral volcanic sands from the Early Archaean epoch (the Kitty's Gap Chert in the Pilbara of Australia, $\tilde{3}$.45 Ga) represent ideal analogues for eventual Noachian life in martian shallow water sediments (3,4). Surficial materials from this period, e.g. sediments and igneous rocks, have been largely silicified because of high seawater silica saturation and extensive hydrothermal flushing of the environments (5) and the Kitty's Gap sediments as well as their microorganisms have been silicified.

Investigations of the morphological and geochemical biosignatures of the early Archaean microfossils provide valuable information about the methods necessary to identify the fossils (4). The bulk carbon contents of the Kitty's Gap Chert is < 0.01% and carbon isotope signatures range from – 25.9 to – 27.8 %■. The microfossils are small, dividing coccoids 0.4-0.8 μm in diameter that occur in colonial associations of many hundreds of individuals, the colonies reaching sizes of several tens of μm in diameter. Because these sediments have been silicified, specific sample preparation involving delicate acid etching is necessary to reveal the microfossils.

Although there may be other modes of preservation of microorganisms on Mars, the recent revelations of amorphous hydrothermal silica (6) suggest that Noachian volcanic lithologies may have been silicified, as in the Early Archaean. Future in situ martian missions, such as MSL and ExoMars, carry microscopes but they will not be able to reveal the presence of individual microfossils like the chemolithotrophs of the Kitty's Gap Chert and probably not even the colonies given the sample preparation necessary (the resolution of the MSL microscope is 12μm and that of ExoMars is 4 μm). However, Raman spectroscopy could identify carbonaceous phases and GC-MS could provide details of the organic composition, even at low bulk C concentrations. On the other hand, organic molecules in the Early Archaean cherts are very degraded and have generally lost their biogenic specificity (7). It may therefore not be possible to unambiguously identify martian biosignatures using in situ instrumentation and returning samples to Earth for detailed analysis in a terrestrial laboratory will probably be necessary.

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