# Deciphering the record of early life in Precambrian oceans using combined microscopy and microchemistry of organic-walled microfossils.

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Organic-walled microfossils (acritarchs) can be exquisitely preserved in fine-grained siliciclastics and chert through the Proterozoic and conceivably in the Archean. These fossils record crucial steps in the early evolution and diversification of complex ecosystems, and their morphology indicates the evolution of major biological innovations. However, the taxonomy of these fossils is often impossible to resolve beyond the level of domain.

Acritarchs are conventionally interpreted as algal cysts but most probably include a larger range of organisms such as prokaryotic sheaths, heterotrophic protists or even parts of multicellular beings. The organic remains can be studied in thin sections with optical microscopy and with Raman micro-spectroscopy to prove endogenicity. They can then be isolated from the rock by gentle acid maceration to be further studied by FTIR micro-spectroscopy, SEM and TEM microscopy to reveal morphological and ultrastructural details, and biopolymer composition, permitting in some cases to determine their biological affinities by comparison with extant clades. We present how combining microscopy (light microscopy, Scanning and Transmitted Electron Microscopy) with micro-spectroscopic analyses of individual Proterozoic microfossils (FTIR and Raman micro-spectroscopy) offers further insights into the paleobiology and evolution of early microorganisms in Precambrian oceans.

Such a multidisciplinary approach offers new possibilities to investigate the record of early life on Earth and beyond.

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# The most probable Earth composition

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Redox and isotopic criteria for Earth primitive materials clearly select a unique chondrite family, which, whatever its conditions of formation, can be modelled simply by a mixture in variable proportions of three mineral types: silicates (enstatite with minor amounts of oligoclase and free silica), metal (Si-bearing kamacite) and sulfides of Fe, Ca and Mg (evolving to metal, oxides and silicates with increasing temperature and decreasing $f_{S2}$).

The modelling of a million such mixtures results in well defined elemental correlations, which can be used efficiently to test the obtained compositions versus high pressure mineralogy and seismological data. About a quarter of them have Fe contents compatible with the Earth's Core/Mantle ratio and mantle range of densities. Their composition is perfectly compatible with the geophysical constraints in their present state of accuracy

They predict Lower Mantle features long advocated (eg enrichment in silica and/or iron).

In our model mantle iron derives largely from the reaction:

$$SiO_2 + 3Fe \rightarrow FeSi + 2FeO$$

This results in a strong correlation between bulk mantle iron content and core silicon content ($Si_n = 1.5\ Fe_m - 5.9$).

There is also a well marked anticorrelation between silica saturation and iron content of the lower mantle (Perovskite% = 100 (1.07-0.015$Fe_m$%)). That is, the denser it is , the softer it is.

Finally the Lower Mantle is strongly depleted in major radioactive elements (U~7ppb).

From the presently available experimental high pressure melting experiments a primitive pyrolitic upper mantle is obtained by an average 25-40% partial melting of the original solid silicate part

Earth envelopes'compositions hence are as follows:

Primitive Upper mantle: pyrolitic

Lower Mantle: $Mg_{0.81}Fe_{0.15}Al_{0.03}Ca_{0.01}Si_{0.97}Al_{0.03}O_3$

Core: 85.3% Fe, 5.7% Ni, 6% Si, 3% O.