The "boring billion": An exciting time for early eukaryotes!

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The so-called 'boring billion' (~1.8-0.8 Ga) was characterized by a stratified ocean with anoxic ferruginous deep water, euxinic mid-water-column layer or wedges, and oxygenated shallow-water. These conditions are thought to have delayed eukaryotic diversification by limiting nutrient availability.

Here, we present a new, exquisitely preserved and morphologically diverse assemblage of organic-walled microfossils from the 1.1 Ga Taoudeni Basin of Mauritania. The assemblage includes diverse protists (ornamented and process-bearing acritarchs), possible multicellular xanthophyte algae, unidentified microfossils including smooth sphaeromorphs, prokaryotic filamentous sheaths and filaments, as well beautifully preserved microbial mats. Several taxa are reported for the first time in Africa.

This new microfossil assemblage, and others documented during the "boring billion", evidence the early and worldwide diversification of eukaryotes. Stem eukaryotes appeared before or at the start of that time, had evolved a cytoskeleton, a nucleus, multicellularity, and diversified in mostly (but not only) shallow-water settings. Between 1.2 and 0.75 Ga, a major diversification of crown group eukaryotes occurred at the supergoup level, with key biological innovations such as cell differentiation, sexual reproduction, and eukaryotic photosynthesis by primary and secondary endosymbioses. Soon after the boring billion, a second diversification occurred but within supergroups, together with the evolution of eukaryotic biomineralisation and predation, and later on in the Ediacaran, tissue and organ-grade multicellularity.

Thus, the chemical state of the mid-proterozoic ocean does not entirely explain the pattern and timing of eukaryotic diversification, started well before the onset of global ocean ventilation around 0.8 Ga.

To better understand the paleobiology and paleoecology of early (stem or crown, aerobie or anaerobie) eukaryotes, we combine our morphological, microchemical and ultrastructural studies of microfossils, with high-resolution paleoenvironmental and paleoredox characterization.

The genesis of Enstatite Chondrites and the Earth.

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The multielemental isotopic convergence between the Earth's Mantle and Enstatite Chondrites (E Chondrites) likely results from a large scale high temperature isotopic equilibrium within the same isotopically homogeneous medium (« mother nebula »). High temperatures insured nearly total isotopic homogeneisation, the residual differences between E chondrites and Earth being due to a temperature gradient inside the mother nebula, and/or cooling of a zone where E chondrites appear after the main accretion episode of the Earth. The mother nebula resulted from the high temperature (1550-1650K) processing of a mixture of solar gas with concentrated (150 ±20 times), dehydrated, and partially reduced CI dust, resulting in volatile (S, Na) and transitional (Si, Mg, Fe, Ni) elements' enrichment and refractory (Al, Ca REE, actinides) elements depletion. The dust-gas proportion and the condensation temperatures are, respectively, constrained from the isotopic compositions of nitrogen and silicon. The mother nebula genesis likely took place during the Sun's T Tauri phase. An appropriate location is the « dust chemical reactor » around 1AU, described in recent studies of T Tauri stars [1]. This also agrees with the idea that terrestrial planets accreted dominantly from a 0.7-1UA circumsolar annulus [2]. At 10^{-3} atmospheres the condensation sequence of such compositions reproduces the chemical and mineralogical composition of « primitive » EH3 Chondrites around 1150 K, and Earth's bulk compositions at 1280-1420K, with large variations of the volatile (S, Na) contents and moderate changes of the Mg/Si ratio. The enhanced (Si +Mg)/O ratio of the dust-enriched mixture and the corresponding increase in oxygen uptake by the condensates, explain the very low oxygen fugacities observed, especially in the E chondrites' temperature domain.

[1] Dullemond &Monnier (2010) An *Rev. Astro.Astrophys* 205-239 [2] Walsh *et al.* (2011) *Nature* **475** 206-208

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