The diversification of early eukaryotes

Javaux E.J.

→ ej.javaux@ulg.ac.be

Palaeobiogeology-Palaeobotany-Palaeopalynology, Department of Geology, University of Liège, Belgium

The origin of the domain Eucarya is not constrained and limited to debated Archean biomarkers. Unambiguous eukaryotic microfossils only appear around 1.8 Ga in the fossil record. Recent geochemical and biological studies suggest that early eukaryotes did not require as much oxygen as previously thought, implying the possibility of an earlier origin. Comparative morphology, wall ultrastructure and microchemistry of acritarchs, filamentous and multicellular microfossils allow the identification of early eukaryotes, permitting to date their order of branching and to calibrate molecular phylogenies. The pattern and timing of eukaryotic diversification and biological innovations (with or regardless of taxonomy) can then be examined, as well as hypotheses regarding their possible biological, ecological, and environmental causes.

I recently proposed a macro-evolutionary pattern of diversification for early eukaryotes, divided into three steps involving different taxonomic levels (Javaux, 2011). During Period I (?-1.8 to ~1.1 Ga), moderately diverse (mostly stem) eukaryotes appeared, showing evidence for a recalcitrant wall, a flexible lipid membrane, and a cytoskeleton. Assemblages of acritarchs from marine sediments of Australia, India, North China, the USA, and Siberia, are mostly similar. During Period II (~1.1 to 0.63 Ga), a key diversification occurred at the supergroup level, in mildly oxygenated shallow-water above sulfidic and/or ferrous anoxic deep waters, and coincided with major environmental changes, including the formation and fragmentation of the supercontinent Rodinia and low-latitude glaciations. More diversified but again broadly similar assemblages preserved in Australia, Baltica, Canada, Congo, India, North China, the USA, Siberia, Spitsbergen and West Africa included members of all extant supergroups (but one) and unidentified eukaryotes. Notable exceptions include the multicellular Bangiophyte red algae (the oldest eukaryotes that can be related to an extant clade) from the Hunting Fm of Somerset Island, arctic Canada; and biomineralized protist scales from the Lower Tindir Gp, Alaska and Yukon. Major biological innovations consisted of eukaryotic multicellularity, cellular differentiation, sex, biomineralisation, heterotrophy, photosynthesis, and freshwater adaptation, leading to ecological tiering and complex food webs and interactions. During Period III (0.63–0.54 Ga), a second diversification occurred, this time within the supergroups. The Ediacaran recorded highly diversified acanthomorph acritarchs, microscopic animal embryos and encysting protists, macroalgae, the macroscopic Ediacara fauna and mineralized metazoans. Complex multicellularity and animal biomineralization and predation evolved in spreading oxygenated niches, leading to more complex ecosystems and diversification within supergroups. Provincialism is reported from the Ediacaran, although the limited phenotypic diversity of the older assemblages may have masked genotypic heterogeneity. More gentle preparation of material and ongoing microchemical and ultrastructural analyzes may also reveal higher diversity in the future. However, much remains to be done to refine deep time paleogeographic reconstructions, to increase sampling of the Precambrian marine and terrestrial record, and to determine the ecology and evolution of early eukaryotes.

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