Tonian Evolution and Geobiology

SHUHAI XIAO[1,*] QING TANG[1], KE PANG[1,2], NATALIA BYKOVA[1,3], QIN YE[1,4], XUNLAI YUAN[2]

[1]*Department of Geosciences, Virginia Tech, Blacksburg, VA 24061, USA*

[2]*State Key Laboratory of Paleobiology and Stratigraphy, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing 210008, China*

[3]*Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch Russian Academy of Sciences, Novosibirsk 630090, Russia*

[4]*State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Wuhan 430074, China*

The Tonian Period (ca. 1000–720 Ma) has become a focus of recent geobiological investigations. Emerging geochemical data indicate that major environmental changes may have occurred in this geological period: atmospheric oxygen content may have reached moderate levels that would permit the rise of animals, predominantly euxinic mid-depth seawaters may have transitioned to being mostly ferruginous, and fundamental changes may have happened to the global phosphorus and nitrogen cycles. What roles did cyanobacteria and eukaryotes play in these environmental changes, and how were the evolutionary trajectories of these organisms impacted by environmental changes? To address these questions, we carried out a systematic paleobiological investigation of Tonian successions in the southern margin of North China, and also analyzed the global taxonomic and morphological diversity of Tonian eukaryotes, including acritarchs and macroalgae. Although the taxonomic diversity of eukaryotes shows a notable increase in the Tonian Period compared with preceding geological ages, morphological disparity shows only a modest increase and is dwarfed by Ediacaran eukaryotes. Thus, the geobiological significance of Tonian fossils must be sought in their specific traits that are relevant to global biogeochemical cycles, rather than overall diversity. In this regard, the demonstration of the multicellular nature of certain Tonian fossils such as *Chuaria*, which was traditionally regarded as unicellular, and the discovery of filamentous cyanobacteria with differentiated akinetes (and, by implication, differentiated diazotrophic or nitrogen-fixing heterocysts) from Tonian strata in North China, are important. In particular, the rise of mutlicellular diazotrophic cyanobacteria with specialized nitrogen-fixing heterocysts may have been an evolutionary response to the combined geobiological effects of the increasing availability of bioessential metals (such as Mo and V) and the rise in atmospheric oxygen levels in the Tonian Period.