Nitrogen isotope evidence for the stepwise oxygenation of the mid-deep ocean across the Yangtze Block during the Ediacaran-Cambrian transition in South China

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The Ediacaran–Cambrian (E–C) transition witnessed profound biological and oceanic changes, among which the appearance of explosive radiation of skeletonized animals is considered as the most remarkable one. Although the prominent rise of oxygen concentration in atmosphere and ocean is believed to be the major trigger of the “Cambrian Explosion”, it is still an open question about the persistence of anoxic/ferruginous deep waters. In this study, the δ^{15}N_{bulk}, δ^{13}C_{org} values, TOC and TN contents, as well as trace elements concentrations of Well ZK4411 fresh core samples are analyzed to explore redox conditions of deep ocean, the nitrogen cycle and their relationships with biological evolution. The Mo concentrations, Mo–U covariations and Th/U ratios of studied samples indicate the oxic water condition of the mid-depth ocean during the late Ediacaran and Cambrian Fortunian stage, widespread anoxic/euxinic water conditions with temporarily sulfidic water condition during Cambrian Stage 2 and early Stage 3, and oxic water condition during the middle and late Stage 3. Based on a combination of δ^{15}N_{bulk} values from this study and other published data, the low δ^{15}N_{bulk} values (4^\circ assimilation in the photic zone, and the extinction of Ediacaran-type and small shelly-type animals during widespread anoxic event of Cambrian Stage 2 and early Stage 3. However, the high δ^{15}N_{bulk} values, close to those of modern ocean sediments, imply that an established large NO_{3}⁻ reservoir and the existence of the well-oxygenated mid-depth ocean during the middle to late Stage 3, which is coincident with the appearance of larger, diversified skeletonized animals as exemplified by the Chengjiang Biota. All these results indicate a stepwise oxygenation of the early Cambrian deep ocean and an increasing supply of nitrogen nutrient, which leads to the Cambrian diversification and ecological radiation.