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Calcareous nannoplankton across the Early Toarcian anoxic event: implications for paleoceanography within the western Tethys

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Different sections and boreholes were studied for nannofossils in various settings of the Jurassic western Tethys. The analysis of the assemblage composition by means of Principal Component Analysis (PCA) allowed a better understanding of the way nannoplankton reacted to environmental changes during the Early Toarcian anoxic event (T-OAE). As it is observed in modern oceans, Toarcian nannoplankton seems to have had a different distribution within the water column, with the majority of the species that behad as shallow-dwellers and a couple of taxa (*Crepidolithus crassus* and *Mitrolithus jansae*) that probably thrived in the lower photic zone. A different distribution of the various species of nannofossils is observed along a latitudinal gradient, and probably translates a temperature control on Toarcian nannoplankton distribution. The taxa that preferentially occur along the northern margin of Tethys have abundance peaks below and at the very base of the T-OAE. This pattern might translate the effects of a temperature control. This is consistent with isotope oxygen analyses that indicate a major cooling across the Late Pliensbachian / Early Toarcian. At the same time, some meso- eutrophic taxa are recorded that translate a relatively high trophic level in surface waters before the T-OAE. Accordingly, a trend to positive values of δ^{13}C is noticed for the base of the Toarcian before the negative excursion that corresponds to the T-OAE. The production by nannoplankton collapsed during the acme of the T-OAE, as demonstrated by the lowest absolute abundance of nannofossils measured in all the studied sites. This collapse is thought to be primary, not induced by the diagenesis of carbonates because: (1) at the same time a decrease or disappearance of other planktonic groups (i.e., dinoflagellates) is observed, along with (2) the dominance of *Tasmanites* (green algae) and the bacterial Chlorobiaceans, that were planktonic

organisms probably adapted to extreme environmental conditions (low salinity, and anoxic photic zone, respectively); (3) a significant reduction of the size of different nannofossil taxa is observed; and last but not least (4) nannofossil preservation in optical and scanning electron microscopes does not appear to be worse than in the rocks of the intervals below and above the T-OAE. Delicate and solution-susceptible species are also commonly recorded in the black shales.

The lowest absolute abundances recorded during the acme of the T-OAE correspond to the peak of a factorial axis on which loads *Calyculus*. This species has a peculiar morphology: the inner wall extends distally to form an umbrella-like coccolith. The ecological preferences of *Calyculus* are controversial, but according to the results of this work, it seems that it was a shallow-dweller, thriving in surface waters in times of anoxia at least temporarily attaining the base of the photic zone (as testified by the occurrence of biomarkers of the Chlorobiaceae in the black shales). It was also probably better adapted to low salinities in surface waters, inferred on the basis of the peak of *Tasmanites*' abundance, and the anomalistically low δ^{18}O values recorded at that time. The umbrella-like coccolith shape might have produced a double-layered coccosphere, able to trap a small quantity of water in equilibrium with the cellular mean, in proximity of the cytoplasm. A useful strategy in times of reduced surface water salinity.

At the end of the T-OAE, the lowest species diversities are recorded along the N-tethyan margin, and the dominance of *Crepidolithus crassus*. These data may be interpreted in terms of recovery of the nannoplankton community after the development of hostile conditions in the water column. *C. crassus* was probably a species able to colonize new habitats more efficiently than other fossil coccolithophorids, and in particular it re-colonized the lower photic zone previously hostile because of anoxia. This phase is preceding the recovery of the entire nannoplankton community, testified by absolute abundances that are high again towards the end of the Early Toarcian.