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Increased thermohaline stratification as a possible cause for the rhythmic Albian black shales (Piobbico core, central Italy): calcareous nannofossil evidence

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The mid-Cretaceous was a time of extreme paleoenvironmental conditions characterized by intense volcanism and increased oceanic crust production. The consequent elevation of atmospheric CO_2 induced a warm climate (greenhouse), low latitudinal gradients and high sea level. Moreover, the mid-Cretaceous is associated with oceanic anoxic events (OAEs), marked by elevated carbon buriaI in marine sediments.

The Aptian-Albian "Scisti a Fucoidi" Formation from the Umbria-Marche basin (central Italy) consists of a pelagic rhythmic varicoloured sequence of marlstone, marly claystone, marly limestone and subordinate limestone. Black shales are abundant and cyclically modulated.

The Albian section of the Piobbico core, from the *Prediscosphaera columnata* (NC8) to *Axopodorhabdus albianum* (NC9) nannofossil Zones, was sampled at high resolution and calcareous nannofossil assemblages were quantitatively analyzed for paleoecological and paleoceanographic reconstructions, also based on Principal Component Analysis (PCA) and Factor Analysis – Varimax rotation (FA).

Nannofossil fertility and temperature indices suggest both an increase of nutrients and warming of surface waters during the Albian. Nannofloral assemblage composition is not strictly related to lithology: meso-eutrophic species are randomly common in black shale, marlstone and marly limestone. Warm-water taxa only occasionally increase in abundance within black shales.

PCA identified three significant components (54.2% of the total variance). The first

and second principal components (PCA 1 and PCA2) showed the highest positive loadings for meso-eutrophic taxa (*Zeugrhabdotus erectus*, *Zeughrabdotus xenotus*, *Discorhabdus rotatorius*, *Biscutum costans* and *Rucinolithus irregularis*) and the highest negative loadings for oligotrophic taxa (*Watznaueria barnesiae*). The PCA 1 exhibited positive scores for 56% of the black shales and the PCA 2 fertility characterizes only approximately 30% of the black shales. The third principal component (PCA 3) showed highest positive loadings for warm-water taxa (*Rhagodiscus asper* and *Zeughrabdotus diplogrammus*), and positive scores for about 60% of the black shales. FA results are consistent with PCA data, but discriminates only one fertility factor loading on approximately 40% of the black shale.

The micropalentological record and statistical analyses suggest that enhanced productivity was not the primary factor controlling the deposition of Albian rhythmic black shales. Nannofossil data confirm that under greenhouse conditions, precipitation and runoff cycles strongly affected the formation of a surface watermass characterized by lower salinity and unsystematically higher nutrient (and terrigenous) inputs. Increased thermohaline stratification of the water column caused bottom water dysoxia-anoxia and deposition of black shales.