The Cenomanian/Turonian oceanic anoxic event: Response of the atmospheric CO_2 level

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The Cenomanian/Turonian (C/T) transition is characterized by a world-wide deposition of laminated organic matter-rich marine facies. The absence of benthonic faunas and the low abundance and diversity of planktonic microfossil groups indicates that these sediments were deposited under oxygen deficient conditions (Jarvis *et al.*, 1988). At the C/T boundary a sharp increase in $^{13}C/^{12}C$ ratios for marine carbonates and organic matter (OM) is observed (Arthur *et al.*, 1988). This positive isotope excursion of *c.* 2.5‰ is thought to reflect ^{13}C enrichment in oceanic and atmospheric CO_2, resulting from an increase in the rate of burial of isotopically light organic carbon (C_{org}) as a response to the so-called C/T Oceanic Anoxic Event (C/T-OAE). If true, this enhanced C_{org} burial rate must have led to a significant drop in pCO_2 (Arthur *et al.*, 1988). Accumulation rates for these OM rich sediments ('black shales') are highest in the southern North Atlantic Ocean where the *W. archaeocretacea* zone (*c.* 0.8 Ma) reaches a thickness of up to 90 m, allowing a detailed investigation of the C/T-OAE. In this study, the distribution and ^{13}C-contents of molecular fossils from sediments from an abyssal site (DSDP site 367) and a shelf site (Tarfaya, well S13) of the southern North Atlantic Ocean are used to reconstruct the environmental conditions that led to 'black shale' deposition during the C/T-OAE. In addition, terrestrial derived biomarkers from site 367 are used to study the effects of the enhanced C_{org} burial rate on the -Cretaceous atmosphere.

The sediments of C/T age of the Tarfaya coastal basin (Morocco) were deposited in an open shelf sea with a water depth at the depocentre of 200–300 m. The sediments are almost exclusively of marine origin, with organic matter and biogenic chalk as main contributors (Kuhnt *et al.*, 1990). The samples used in this study were taken from exploration well S13 situated in the depocentre, where sedimentation rates were high, with values of up to 120 cm/ky. for the *W. archaeocretacea* zone (Kuhnt *et al.*, 1990). The aliphatic hydrocarbons present in the sediments consist mainly of short-chain *n*-alkanes (with no obvious odd-over-even carbon number predominance), isoprenoids of bacterial and/or algal origin, bacterial-derived hopanoids and algal-derived steroids. Isorenieratene derivatives were found in all the samples studied from this site, showing that euxinic conditions extending into the photic zone periodically occurred throughout the section. During and after the isotopic excursion, the concentrations of isorenieratene derivatives show strong fluctuations, which are thought to be related to changes in the frequency and extent of periods of photic zone euxinic conditions. The positive isotope excursion, well established for carbonate, was also found for individual biomarkers. However, strong differences were observed in the extent of the excursion. For carbonate, typically a shift of 2.5‰ is observed. In contrast algal derived steranes and bacterial hopanes show isotopic excursions of 5–7‰.

DSDP site 367 is situated close to the equator and its palaeodepth has been estimated at 3700 m. The sediments consist of a mixture of terrigenous silicates and clay minerals, OM (up to 50 wt.%) and some biogenic carbonate. The OM is almost exclusively of marine origin as revealed by the high Rock Eval hydrogen indices (Herbin *et al.*, 1986) and the low abundance of lignin pyrolysis products observed from the kerogen. The aliphatic hydrocarbon fraction consists mainly of short-chain *n*-alkanes (with no obvious odd-over-even predominance), isoprenoids of bacterial and/or algal origin, bacterial-derived hopanoids and long-chain *n*-alkanes with a strong odd-over-even carbon number predominance (CPI = 2.7–5.1) derived from leaf waxes of higher plants (Kolattukudy *et al.*, 1976). The latter components were probably aeolian transported from the north African continent (Gagosian *et al.*, 1985). The presence of both marine and terrestrial biomarkers in sediments from this section enabled the comparison of the timing and nature of the carbon isotope excursion on land and in the marine environment. The $\delta^{13}C$ shift of 10–16‰, observed for terrestrial-

derived leaf wax components of DSDP site 367, is far larger than expected for shifts introduced by changing concentrations and ^{13}C-contents of atmospheric CO_2. Possibly a change in the north African plant community occurred where plants using the C_3 photosynthetic pathway were succeeded by plants using the C_4 pathway. The appearance of plants using a CO_2-fixation mechanism (C_4) is in agreement with the decrease in pCO_2 that was predicted to result from enhanced OM burial during the C/T OAE (Arthur *et al*, 1988). Following this, a 50–90% decrease in CO_2 levels in *c.* 30 ky is deduced for the C/T boundary interval. Preliminary results for site 367 show the presence of isorenieratene derivatives in most of the samples also suggesting periodic photic zone euxinic conditions for this deep-sea site.

These results indicate extreme anoxic conditions (with free H_2S in the photic zone) in the southern North Atlantic during the C/T OAE and confirm the hypothesis of an enhanced C_{org} burial rate as major cause for the $\delta^{13}C$ excursion of marine carbonate and organic matter at the C/T boundary. They further show that the increased burial of OM in the oceanic realm had a profound effect on the north African continental ecosystem through a significant reduction in atmospheric CO_2 levels.

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