

Original article

## Calcareous nannofossil biostratigraphy of the Thomel Level (OAE2) in the Lambruisse section, Vocontian Basin, southeast France<sup>☆</sup>

*Biostratigraphie à nannofossiles calcaires du Niveau Thomel (OAE2) dans la coupe de Lambruisse, Bassin Vocontien, Sud-Est de la France*

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### Abstract

The Thomel Level of the Lambruisse section in the Vocontian Basin (southeast France), which is marked by intercalations of black shales and organic-rich marls, accumulated during the oceanic anoxic event 2 (OAE2) occurring in the Cenomanian-Turonian (C-T) boundary interval. Calcareous nannofossil biostratigraphic investigation of this interval revealed a total of five nannofossil zones, corresponding to the UC3-UC8 zones (Middle Cenomanian-Middle Turonian) as defined by Burnett. Biostratigraphically important taxa observed in the section include *Cretarhabdus striatus*, *Axopodorhabdus albianus*, *Lithraphidites acutus*, *Corollithion kennedyi*, *Helenea chiastia*, *Quadrum gartneri*, *Q. intermedium*, *Eiffellithus eximius*, *Eprolithus octopetalus* and *E. eptapetalus*. The two nannofossil events commonly used in the delineation of the C-T boundary, namely the LO of *H. chiastia* and the FO of *Q. gartneri*, occur less than 2 m apart in the studied section. These two bioevents define the limits of the UC6 nannofossil Zone and occur within the *Whiteinella archaeocretacea* foraminifer Zone. Previous litho- and chemostratigraphic analyses indicate that the  $\delta^{13}\text{C}$  profile of the section corresponds well with changes in lithofacies and fluctuations in the total organic carbon (TOC) and calcium carbonate content of the section. Initial increase in the  $\delta^{13}\text{C}$  values occurs within the UC3-UC4a undifferentiated zone, coinciding with the onset of the deposition of the organic-rich sediments of the Thomel Level and a drastic decline in the  $\text{CaCO}_3$  values. The plateau of high  $\delta^{13}\text{C}$  values, on the other hand, occurs within the UC5 zone, between the LO of *C. kennedyi* and the LO of *H. chiastia* (and FO of *Q. gartneri*). This interval of high  $\delta^{13}\text{C}$  values also corresponds to the interval of high TOC and low  $\text{CaCO}_3$  values. The integrated nannofossil, planktonic foraminifer and  $\delta^{13}\text{C}$  data provide a precise biostratigraphic and chemostratigraphic framework of the C-T boundary in the Lambruisse section that can be used in future studies in the Vocontian Basin and allow correlations with other well-studied C-T boundary sections.

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**Keywords:** Calcareous nannofossils; Biostratigraphy; Cenomanian-Turonian boundary; Oceanic anoxic event 2 (OAE2); Vocontian Basin; Southeast France

### Résumé

Le Niveau Thomel de la coupe de Lambruisse dans le Bassin Vocontien (SE France), caractérisé par des intercalations de black shales et de marnes riches en matière organique, s'est déposé durant l'événement océanique anoxique (OAE) 2, à la limite Cénomanién-Turonien. L'étude biostratigraphique des nannofossiles calcaires de cet intervalle a permis la reconnaissance de 5 zones de nannofossiles, correspondant aux zones UC3-UC8 (Cénomanién moyen-Turonien moyen) définies par Burnett. Les taxons importants pour la biostratigraphie et reconnus dans la coupe sont : *Cretarhabdus striatus*, *Axopodorhabdus albianus*, *Lithraphidites acutus*, *Corollithion kennedyi*, *Helenea chiastia*, *Quadrum gartneri*, *Q. intermedium*, *Eiffellithus eximius*, *Eprolithus octopetalus* et *E. eptapetalus*. Les deux bio-événements généralement utilisés pour définir la

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limite Cénomanién-Turonien, correspondant à la dernière occurrence (LO) de *H. chiastia* et à la première occurrence (FO) de *Q. gartneri*, sont séparés de moins de 2 m dans la coupe étudiée. Ces deux bio-événements définissent les limites de la zone de nanofossile UC6 et sont reconnus dans la zone de foraminifère planctonique à *Whiteinella archaeocretacea*. Des analyses litho- et chimostratigraphiques réalisées sur cette coupe dans une étude précédente, montrent que les variations observées du  $\delta^{13}\text{C}$  correspondent aux changements du lithofaciès et des teneurs en carbone organique (COT) et carbonate de calcium. L'augmentation initiale des valeurs du  $\delta^{13}\text{C}$  est reconnue dans les zones de nanofossiles calcaires UC3-UC4a, coïncidant avec les premiers dépôts de sédiments riches en matière organique du Niveau Thomel, et avec une chute drastique de la teneur en carbonate de calcium. Puis les valeurs élevées du  $\delta^{13}\text{C}$  forment un plateau, daté de la zone de nanofossile UC5, et situé entre les dernières occurrences de *C. kenedyi* et de *H. chiastia* (et la première occurrence de *Q. gartneri*). Ce plateau correspond également à un intervalle où le COT est élevé et les teneurs en  $\text{CaCO}_3$  faibles. Les données intégrées : nanofossiles calcaires, foraminifères planctoniques et  $\delta^{13}\text{C}$ , fournissent un cadre biostratigraphique et chimostratigraphique précis de la limite C-T dans la coupe de Lambruisse, pouvant être réutilisé dans les études futures du Bassin Vocontien, et permettant des corrélations avec les autres coupes bien étudiées de la limite C-T.

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*Mots clés* : Nanofossiles calcaires ; Biostratigraphie ; Limite Cénomanién-Turonien ; Événement océanique anoxique 2 (OAE2) ; Bassin Vocontien ; Sud-Est de la France

## 1. Introduction

The Oceanic Anoxic Event encompassing the Cenomanian-Turonian (C-T) boundary interval, called OAE2, is considered the type example of the Mesozoic OAEs (Schlanger and Jenkyns, 1976; Kolonic et al., 2005). The event was associated with a large and abrupt perturbation in atmospheric  $p\text{CO}_2$  (Kuypers et al., 1999), changes/turnover in the marine macro- and microfauna (Erbacher et al., 1996; Premoli Silva et al., 1999; Gale et al., 2000; Leckie et al., 2002; Erba, 2004), changes in ocean water chemistry (Kuypers et al., 2002; Snow et al., 2005), and a pronounced positive excursion in the  $\delta^{13}\text{C}$  record of the marine carbonate and marine and terrestrial organic matter (Scholle and Arthur, 1980; Pratt and Threlkeld, 1984; Jarvis et al., 1988; Gale et al., 1993; Jenkyns et al., 1994; Hasegawa, 1997; Tsikos et al., 2004). The positive shift in the  $\delta^{13}\text{C}$  curve has been hypothesized as related to the widespread burial of isotopically light ( $^{12}\text{C}$ -enriched) organic matter, in response to enhanced oceanic productivity due to injection of biolimiting metals into the surface waters during the formation of the Caribbean Plateau large igneous province (LIP) and increased submarine volcanism, ocean crust production and hydrothermal activity (Schlanger and Jenkyns, 1976; Duncan and Bralower, 2002; Leckie et al., 2002; Erba, 2004). Basalts from the Caribbean Plateau LIP were previously determined to have radiometric ages of about 88–91 Ma (Turonian-Coniacian interval; Sinton and Duncan, 1997; Shipboard Scientific Party, 2000). Recent studies, however, suggest a slightly older age of 92–95 Ma, within the C-T interval (Duncan and Bralower, 2002). This new radiometric age confirms the presence and the possible contribution of a major submarine volcanism in the deposition of the OAE2 black shales. This assumption is further substantiated by a drop in the strontium isotope ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) and trace metal distribution data across the C-T boundary due to increased rates of ocean crust production and elevated submarine volcanism (Bralower et al., 1997; Leckie et al., 2002; Snow et al., 2005). Similar to the Early Aptian OAE1a, OAE2 is also considered as a high productivity oceanic anoxic event (P-OAE; Erbacher et al., 1996).

Since the pioneer work of Schlanger and Jenkyns (1976), several studies have already been done with respect to the impact of OAEs on the evolution and distribution of marine organisms. A number of these investigations concentrated on the carbonaceous sediments from the C-T boundary interval, resulting in a comprehensive global picture of the event (Erbacher et al., 1999). Calcareous nanofossils and other microfossils (i.e., radiolaria, benthic and planktonic foraminifers) experienced a high rate of turnover within this interval as a result of the rapid sequence of extinction of several taxa prior and during the main period of the OAE2 anoxia (Premoli Silva et al., 1999; Leckie et al., 2002; Erba, 2004). Changes in calcareous nanofossil assemblages across the C-T boundary have already been documented in the Western Interior Basin (Bralower, 1988), and in several localities of the Boreal, Tethyan and Atlantic Regions: Northern Europe and Southern England (Bralower, 1988; Jarvis et al., 1988; Paul et al., 1999; Gale et al., 2000); Spain (Lamolda et al., 1997); Italy (Luciani and Cobianchi, 1999; Premoli Silva et al., 1999; Erba, 2004); Jordan (Schulze et al., 2004); North Africa (Bralower, 1988; Bauer et al., 2001); and the equatorial Atlantic (Hardas and Mutterlose, 2006, 2007).

Black shales of local to regional importance crop out in the Vocontian Basin in southeast France. Although a number of calcareous nanofossil studies have already been done in the area, most focused on older black shale deposits (e.g., Herrle, 2003; Giraud et al., 2003; Herrle and Mutterlose, 2003; Herrle et al., 2003; Reboulet et al., 2003, 2005; Bornemann et al., 2005; Heimhofer et al., 2006; Duchamp-Alphonse et al., 2007). Studies regarding OAE2 black shales in France are limited to planktonic foraminifers and ammonite biostratigraphy, geochemical and carbon isotope analyses (e.g., Crumière, 1990; Crumière et al., 1990; Thomel, 1991; Grosheny and Tronchetti, 1993; Grosheny et al., 2006).

The present study reports on the nanofossil assemblages, their distribution and biostratigraphy, along with TOC, carbonate and  $\delta^{13}\text{C}$  data across the C-T boundary interval of the Lambruisse section. The present study, in addition, aims to provide a refined, integrated biostratigraphic and chemostratigraphic framework for better constraining this boundary in the Vocontian Basin.

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