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# Evidence for a complex Valanginian nannoconid decline in the Vocontian basin (South East France)

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ABSTRACT

The Early Cretaceous is punctuated by widespread biocalcification crises. These are characterized by decrease in the carbonate platform growth and, in the pelagic realm, by a decline in *Nannoconus* relative abundance in the calcareous nannofossil assemblages. The Valanginian *Nannoconus* decline started before the positive $\delta^{13}C$ excursion characterizing the Weissert Event. The nannoconid decline is investigated in two sections of the Vocontian Basin, La Charce and Vergol, which are biostratigraphically well-constrained and contain well-preserved calcareous nannofossils. Absolute and relative abundances of *Nannoconus* show a polyphased decline, with a first decrease in the interval from the Campylotoxus to the Verrucosum Ammonite Subzones before the positive $\delta^{13}C$ shift, and a second decrease from the end of the Peregrinus to the base of the Radiatus Ammonite Zones concomitant with the long-term decrease in $\delta^{13}C$. These two declines are separated by an important increase in the *Nannoconus* abundance from the Verrucosum to the Peregrinus Ammonite Subzones concomitant with a slight short-term decrease of $\delta^{13}C$. Biometric analysis shows size changes of *N. steinmannii* and *N. kamptneri* along the nannoconid decline. The patterns of abundances and size changes seem to be related to paleoenvironmental changes, mainly characterized by a temperature decrease and variable nutrient supply. The described Valanginian nannoconid recovery seems to occur during the most intense phase of the cooling event and is recorded in the Vocontian basin as well as in the Atlantic and Tethys Oceans. These spatial correlations suggest a supra-regional character for the Valanginian nannoconid recovery event best recorded in the Vocontian Basin and at low latitudes.



## 1. Introduction

The Valanginian is marked by a 1.5 to 2‰ positive carbon isotope excursion (CIE) measured in carbonates of Tethyan sections and some ODP/DSDP sites in the Atlantic and Pacific Oceans (Lini et al., 1992; Channell et al., 1993; Lini, 1994; Hennig et al., 1999; Wortmann and Weissert, 2000; Erba et al., 2004; Bornemann and Mutterlose, 2008). Gröcke et al. (2005) documented a similar CIE in fossil wood. Thus both ocean and atmosphere reservoirs recorded the isotope anomaly. The beginning of the positive CIE and its climax have been used to define the Weissert event (Erba et al., 2004). This event corresponds to the upper part of magnetic chron CM12 and the base of magnetic chron CM11 in Tethyan sections (Lini et al., 1992; Channell et al., 1993; Erba et al., 2004). Biostratigraphic studies show that this event spans the NK3B and NC4A nannofossil Zones, the Campylotoxus ammonite Zone, and the radiolarian UAZs 16–18 (see Erba et al., 2004 for a synthesis). The duration of the event has been estimated to ~2 Ma (Erba et al., 2004) or 2.3 Ma (Sprovieri et al., 2006). A recent cyclostratigraphic study of the Vergol/La Charce composite section (Vocontian Basin), also studied here, provides a precise duration of 1.8 Ma for the positive CIE until the interval where $\delta^{13}C$ values start decreasing (Gréselle and Pittet, 2010; Gréselle et al., 2011).

Some studies have tentatively related the Weissert event to volcanic activity in the Paranà–Etendeka trapps (South America and South Africa; approximately $134.7 \pm 1$ Ma) (Renne et al., 1992; Weissert et al., 1998; Erba et al., 2004; Weissert and Erba, 2004; Thiede and Vasconcelos, 2010) or to the 132 Ma old Comei–Bunbury Large Igneous Province

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(LIP) (Zhu et al., 2009). However, there are no radiometric ages to directly calibrate the CIE with geochronology and at present the correlation of the Weissert event and volcanic activity is controversial.

Environmental and biotic perturbations occurred in the Valanginian oceans, namely a significant cooling suggested by both faunal and floral migrations (Kemper and Schmitz, 1981; Kemper, 1987; Hoedemaeker, 1990; Mutterlose and Kessels, 2000; Melinte and Mutterlose, 2001), by the occurrence of glendonites at high latitudes (Price, 1999) and by the geochemical records of fish teeth and belemnites (Pucéat et al., 2003; McArthur et al., 2007). However, Littler et al. (2011) recorded little variability in the sea-surface temperature records, even during the Valanginian carbon-isotope excursion. The positive carbon excursion is concomitant to a carbonate production crisis both in neritic and pelagic domains at least in western Tethys and Caribbean/proto-Atlantic areas (Weissert et al., 1979; Erba and Tremolada, 2004; Erba et al., 2004; Föllmi et al., 2006; Gréselle and Pittet, 2010) and the sparse occurrence of organic carbon enriched sediments (Channell et al., 1993; Weissert et al., 1998; Weissert and Erba, 2004; Westermann et al., 2010). In the Vocontian basin, thin levels enriched in organic matter, namely the Barrande layers, mark the very beginning of the event (Reboulet et al., 2003).

Calcareous nannoplankton were important primary producers in the pelagic realm and were highly diversified in the Cretaceous (Bown et al., 2004; Erba, 2004). Among these, *Nannoconus* (*incertae sedis*) is represented by robust nannoliths commonly recorded in Cretaceous rocks in epicontinental areas from the western Tethyan to the Caribbean region (Thierstein, 1976; Roth and Krumbach, 1986; Applegate and Bergen, 1988; Noël and Busson, 1990; Mutterlose, 1992; Erba, 1994; Bown et al., 1998; Street and Bown, 1998; Bown, 2005). Nannoconid relative abundance and fluxes dramatically decreased in the nannofossil assemblage during the Weissert event (Bersezio et al., 2002; Erba and Tremolada, 2004; Erba et al., 2004; Duchamp-Alphonse et al., 2007; Bornemann and Mutterlose, 2008). This decline started before the positive shift in $\delta^{13}C$ and persisted during an interval corresponding to magnetic chrons CM12 through CM10 (Erba and Tremolada, 2004). A morphological shift from specimens with "narrow canal" to "wide canal" *Nannoconus* has been observed in association with the nannoconid decline (Erba and Tremolada, 2004; Duchamp-Alphonse et al., 2007), however nothing is known so far about species-specific changes within the nannoconid group, nor about changes in *Nannoconus* size. Yet identification of such changes is crucial to better constrain the evolution of pelagic carbonate production during the Weissert event, as those large-sized nannoliths were important carbonate producers during the Early Cretaceous (Noël and Busson, 1990; Busson and Noël, 1991).

This work presents new data on relative and absolute abundances, species richness and biometry of different species of the genus *Nannoconus* in the Valanginian. Two sections deposited in hemipelagic environments of the Vocontian Basin are studied here, namely Vergol and La Charce. These environments were very sensitive to weathering changes and related continent-derived nutrient flux (Reboulet et al., 2003; Duchamp-Alphonse et al., 2007; Gréselle and Pittet, 2010; Gréselle et al., 2011). The studied sections are characterized by an excellent ammonite biostratigraphical control (Reboulet, 1996; Reboulet and Atrops, 1999; Hoedemaeker et al., 2003; Reboulet et al., 2006; 2009). The micropaleontological results acquired here are then compared to the evolution of both previously published geochemical temperature proxy data and newly acquired fish tooth $\delta^{18}O$. These comparisons are used to discuss environmental and climatic perturbations characterizing the nannoconid decline that occurred during the Weissert Event.

## 2. Materials and methods

### 2.1. Geological setting and stratigraphy

The Vergol and La Charce sections are located in the central part of the Vocontian basin of southeast France, at a distance of ~30 km from each other (Fig. 1A). Both outcrops are well-studied and the abundant record of macro- and microfossils provides a good biostratigraphic frame (Magniez-Jannin and Dommergues, 1994; Reboulet, 1996; Reboulet and Atrops, 1999; Janssen and Clement, 2002; Gardin, 2008; Reboulet et al., 2009). The sections are characterized by continuous sedimentation from Valanginian to Hauterivian. Precise lithologic and biostratigraphic correlations exist between these two sections from the Petransiens to the Furcillata Ammonite Zones (Cotillon et al., 1980; Gréselle et al., 2011). Numerous first and last occurrences of nannofossil taxa were documented at Vergol and La Charce (Fig. 1) that allowed the recognition of zones NK 3A and NC 4 (Gréselle et al., 2011).

The Vocontian basin was surrounded by carbonate platforms including the Jura platform to the north, the Vivarais platform to the west and the Provence platform to the south (Wilpshaar et al., 1997; Reboulet et al., 2003; Fesneau et al., 2009; Gréselle and Pittet, 2010). Sediments are bioturbated marl–limestone alternations (Cotillon et al., 1980), occasionally interrupted by slumps (Atrops and Reboulet, 1995). In order to avoid the slumped intervals and to have a continuous sedimentary succession for most part of the Valanginian, the Vergol and La Charce sections are tied together in a composite section as proposed by Gréselle and Pittet (2010) (Fig. 1B). Nannofossil absolute abundance, assemblage composition and preservation are comparable in both sections.

### 2.2. Sample preparation

#### 2.2.1. Stable isotopes

Fifty fish remains, consisting of millimeter-size teeth, cuspid fragments and one cutaneous cuticule were picked from the 125–500 μm fraction of 20 marly levels from the La Charce section. The sediments (about 10 kg per level) were degraded over 24 h in acetic acid 10% before sieving. Of the 20 studied levels, only 9 levels grouped in 5 samples (Fig. 1B) yielded enough material (4 to 15 fish elements) to perform analyses. The fish remains were taxonomically determined at the genus level (Table 1). All identified elements appear to belong to demersal fishes and sharks according to the Cappetta (1987) taxonomic determination. Eleven cuspids belong to an undetermined group, which was likely endemic to the Vocontian Basin. Their shapes are comparable to the Squatinidae group (except for the apron), with a relatively flat basal face, a cuspid perpendicular to the tooth base and a pair of lateral cusplets. Their originality is the presence of two labial protuberances of the root. This character is close to the morphology of the Symmoridae family, a Paleozoic selachian group. The dental morphology of these selachians also argues for a nectobenthic life-style.

Oxygen isotope analyses of fish remains were performed at the North Bavarian Center of Earth Sciences (University of Erlangen-Nürnberg/Germany). The apatite samples were dissolved in nitric acid and chemically converted into $Ag_3PO_4$ using a modified version of the method described by O'Neil et al. (1994). Oxygen isotope ratios were measured on CO using a High Temperature Conversion Elemental Analyzer (TC-EA) connected online to a ThermoFinnigan Delta

**Fig. 1.** (A) Geographic location of the studied sections and paleogeography of the Vocontian basin in the Early Cretaceous, modified after Ferry (1991) and Fesneau et al. (2009). (B) Stratigraphy of the composite section of Vergol and La Charce (Gréselle and Pittet, 2010) and positions of samples in which calcareous nannofossils (left) and fish teeth (right) were studied. $\delta^{13}C$ data from Hennig et al. (1999) and Gréselle et al. (2011). According to the definition of Erba et al. (2004), the Weissert event is placed between the base of the positive excursion of the $\delta^{13}C$ curve and the end corresponds to the $\delta^{13}C$ climax. Nannofossil zones are established according to the work of Bralower et al. (1989; 1995). The symbols I to V represents the concatenate layers of fish teeth samples.