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Early Cretaceous (late Berriasian to early Aptian) palaeoceanographic change along the northwestern Tethyan margin (Vocontian Trough, southeastern France): $\delta^{13}C$, $\delta^{18}O$ and Sr-isotope belemnite and whole-rock records

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ABSTRACT

Stable carbon, oxygen, and strontium isotope records were obtained from uppermost Hauterivian to lowermost Aptian belemnite rostra, which were collected in well-dated sections from the Vocontian Trough (southeastern France). This data set complements previously published belemnite-isotope records from the uppermost Berriasian-Hauterivian interval from the same basin. The belemnite carbon and oxygen isotope record is compared to the carbonate bulk-rock isotope record from the same sections, and from additional Italian sections. With regards to their long-term trends, both belemnite and whole-rock $\delta^{18}O$ records are well correlated, except for the uppermost Hauterivian-lower Barremian interval, within which they deviate. This discrepancy is interpreted to be linked to the latest Hauterivian Faraoni oceanic anoxic event and its early Barremian aftermath. The Faraoni level is characterized by enhanced sea-water stratification, probably induced by the onset of a warmer and more humid climate along the northern Tethyan margin. The early Barremian was characterized by stronger vertical sea-water mixing reflected by a decrease in density contrast between sea-surface and deeper waters. The belemnite oxygen isotope record shows a more stable evolution with smaller fluctuations than its bulk-rock counterpart, which indicates that deeper water masses were not as much subjected to density fluctuations as sea-surface water. The comparison of belemnite and bulk-rock carbon isotope records allows observing the impact of regional influence exerted by platform carbonate ooze shedding on the carbon cycle. Discrepancies in the two records are observed during time of photozoan carbonate platform growth. The strontium isotopic record shows a gradual increase from the uppermost Berriasian to the uppermost lower Barremian followed by a rapid decrease until the uppermost Barremian and a renewed small increase within the lowermost Aptian. The major inflection point in the uppermost lower Barremian appears to predate the onset in the formation of the Ontong-Java volcanic plateau.

1. Introduction

The Early Cretaceous witnessed numerous episodes of palaeoceanographic and palaeoenvironmental change, which are, for instance, documented by the Valanginian positive shift in the stable carbon-isotope record (e.g. Lini et al., 1992; Weissert et al., 1998; Erba et al., 2004; Duchamp-Alphonse et al., 2007), the latest Hauterivian Faraoni oceanic anoxic event (e.g. Baudin, 2005; Bodin

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et al., 2006a, 2007), or the onset and development of the Urgonian photozoan carbonate platform along the northern Tethyan margin during the late Barremian-earliest Aptian (e.g. Arnaud et al., 1998; Bodin et al., 2006b, 2006c; Föllmi et al., 2006, 2007). All these episodes are linked to important changes in ocean chemistry, nutrient stocks, and temperature, and it is therefore important to improve our knowledge on these very aspects within this interval. One aspect, which is still discussed is the importance of water stratification and coupled with that the capacity of ocean waters to mix and vertically exchange (e.g. Hay, 2002; Friedrich et al., 2008). We therefore performed stable carbon- and oxygen-isotope analyses on well-preserved belemnite rostra from the Vocontian Basin (SE France), in order to obtain a deeper-water signal, and compared our records to whole-rock carbonate records from the same region–which are considered as a near surface-water signal.

Belemnite isotopic proxies approach within the Lower Cretaceous has revealed itself as a valuable tool, which helps to improve our understanding of oceanic water-column characteristics and palaeoceanographic conditions in general (e.g. Van de Schootbrugge et al., 2000; McArthur et al., 2004, 2007b, Mutterlose et al., 2009). Comparison of sea surface to deep-water carbon and oxygen isotopic signals has been performed by numerous studies within the Upper Cretaceous-Cenozoic interval using benthic and pelagic foraminifera. This method has given valuable palaeoceanographic information on various subjects such as, for example, methane hydrate instability during the Holocene (Kennett et al., 2000), upwelling intensity in the Arabian Sea during the latest Neogene (Naidu, 2004), palaeoproductivity across the Cretaceous-Tertiary boundary (Stott and Kennett, 1989), or the influence on warm saline deep water on the Cenomanian-Turonian oceanic anoxic event (Friedrich et al., 2008).

Furthermore, we systematically analyzed the belemnites for their strontium-isotope signals, in order to establish a high-resolution record, which is well calibrated against Tethyan ammonite biostratigraphy. The strontium-isotope record is informative with regards to the relative importance of volcanic episodes versus continental runoff (e.g. Hodell et al., 1991; Jones et al., 1994, McArthur et al., 2004).

2. Material

The geochemical results used here are derived from our own investigations and from previously published studies on hemipelagic sections from the Vocontian Trough (SE France; Fig. 1). Additional bulk rock isotope data were gathered from Emmanuel and Renard (1993), Duchamp-Alphonse et al. (2007), Van de Schootbrugge et al. (2000), Godet et al. (2006) and Wissler et al. (2002) for the uppermost Berriasian, Valanginian-lowermost Hauterivian, Hauterivian, upper Hauterivian-Barremian, and Barremian, respectively. Additional belemnite isotope data were compiled from McArthur et al. (2007b) and Van de Schootbrugge et al. (2000) for the uppermost Berriasian-upper Hauterivian and Valanginian-Hauterivian, respectively.

70 belemnites were collected in uppermost Hauterivian to lowermost Aptian sedimentary rocks of the Vocontian Trough (see Table 1 for a detailed list of sampled belemnites). 64 new belemnite results presented here stem from the Angles section, which is the stratotype section for the Barremian stage (e.g. Vermeulen, 2002) and is situated near St. André-les-Alpes (see Bodin et al., 2006a, for a more precise location). Additional results were obtained from other sections, close to Angles (Saut-du-Loup, Clos de Barral, and Combe Lambert; Delanoy, 1998; Vermeulen, 2002). These additional sections provided the possibility to sample specific horizons, which correlate to levels which in the Angles section are presently not well exposed or barren in belemnites.

During the Early Cretaceous, the Vocontian Trough was surrounded to the north, west, and south by the northern Tethyan carbonate platform and open in an eastward direction to the Tethys (Masse, 1993). It was situated at a palaeolatitude of 20–30° N, in the northwestern part of the Tethys. The sections of the Vocontian basin sampled here are composed of hemipelagic marl-limestone alternations, which are well dated by ammonite biostratigraphy (e.g. Bulot et al., 1992; Bulot and Thieuloy, 1994; Delanoy, 1998; Vermeulen, 2002; Duchamp-Alphonse et al., 2007).

3. Methods

The procedure for belemnite sample preparation used here follows the one described by McArthur et al. (2007b). Belemnites were first cleaned in an ultrasonic bath, and consequently the exterior layer, the apical region, and the alveolus were removed. The remains were cleaned in a 10% HCl solution for one minute, dried and crushed intp small pieces of approximately 1 mm diameter, which were once again cleaned within a sieve with a 10% HCl solution and ultra-pure water. After drying, non-opaque pieces,

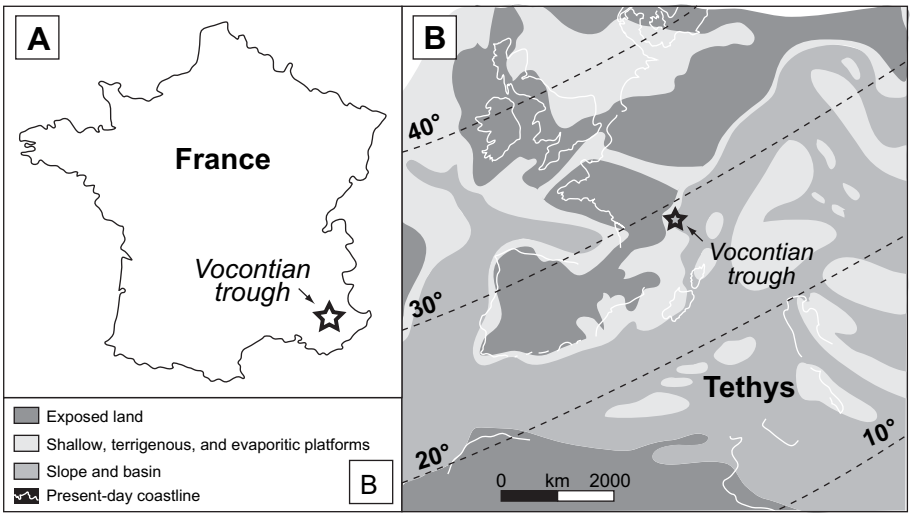

Fig. 1. A, Map of France showing the actual position of the Vocontian Trough. B, Early Aptian paleomap of the western Tethyan realm showing the original location of the Vocontian Trough (after Masse et al., 1993).