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Environmental and ammonoid faunal changes related to Albian Bay of Biscay opening: Insights from the northern margin of the Basque-Cantabrian Basin

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ABSTRACT

The opening and ocean floor spreading of the Bay of Biscay began in the earliest Albian. The integrative study of the Albian sedimentary record and its ammonoid fauna (around 250 specimens) from the northern margin of the Basque-Cantabrian Basin indicates that environmental changes, occurred as a consequence of the Bay of Biscay opening, triggered significant ammonoid bioevents. Main bioevents are diversity changes in the ammonoid associations, occurrence of large forms (diameter up to 0.45 m) and the incursion of elements from other basins. Time-correlation of faulting pulses with ammonoid bioevents indicates that transtensive tectonics was ultimately the major control on the marine environmental conditions such as depth, sea bottom physiography, seaways, sedimentary systems and sea-water chemistry. The pulsating faulting during the Albian led to the increment of the subsidence rate, the deepening and widening of the margin and the progressive increase in the oceanic circulation between the margin and the nascent Bay of Biscay and North Atlantic. In addition, Albian synsedimentary faults constituted conduits for ascending magmas and hydrocarbon-rich hydrothermal fluids, which expelled to the seafloor, causing changes in the sediments, the sea-water chemistry (fertilization) and biota. The integration of sedimentological and palaeontological data has given the basis for a conceptual model of the ammonoid habitats.

1. Introduction

Mesozoic rocks deposited in the northern margin of the Basque Cantabrian Basin (BCB) record rifting processes that led to the opening of the Bay of Biscay (Rat, 1988). During the Albian, and coeval to the beginning of the seafloor spreading in the western part of the Bay of Biscay, hyperextension of the crust caused faulting, maximum subsidence and deepening of the margin (Jammes et al., 2009). This allowed for the deposition of a thick succession of deep-water sediments, i.e. the Black Flysch Group, which host a rich and diverse fauna of ammonoids. Besides the biostratigraphical value of these ammonoid associations, which have been the basis for timing the otherwise difficult to date the thick and facies-changing sedimentary successions, their value to understand the environmental conditions and changes in a deepening marine basin are of key interest.

In the last years, ammonoid habitats have been inferred from the study of the conch parameters and hydrodynamic characteristics (e. g., Westermann, 1996) and from the relationship to the sedimentary facies (e. g., Batt, 1993). Recently, new evaluations of the morphology (e. g., Ritterbush and Bottjer, 2012) and the use of stable isotope analysis of the conch (Lukeneder et al., 2010), in addition to new advances in their palaeobiology, have permitted to better understand the environments inhabited by ammonoids (e. g., Lukeneder, 2015). Based on collected ammonoids, this study establishes an Albian biozonation for the entire northern margin of the Basque Cantabrian Basin, distinguishes several local bioevents and addresses the response of the ammonoid fauna to environmental changes inferred from the accurately studied Albian sedimentary record. The integration of these sedimentological and palaeontological data is the basis for the construction of a conceptual model of the ammonoid habitats which provides an improved understanding on the environments in which they thrived and on the environmental changes in a fastly evolving margin of the Bay of Biscay.

2. Geological and palaeontological background

The studied Albian sedimentary rocks and their ammonoid fauna belong to the northern margin of the Basque-Cantabrian Basin (BCB), a Mesozoic peri-cratonic rift basin related to the opening of the North Atlantic and the Bay of Biscay (Fig. 1). The Bay of Biscay is a V-shaped oceanic embayment widened toward the west, formed between Early

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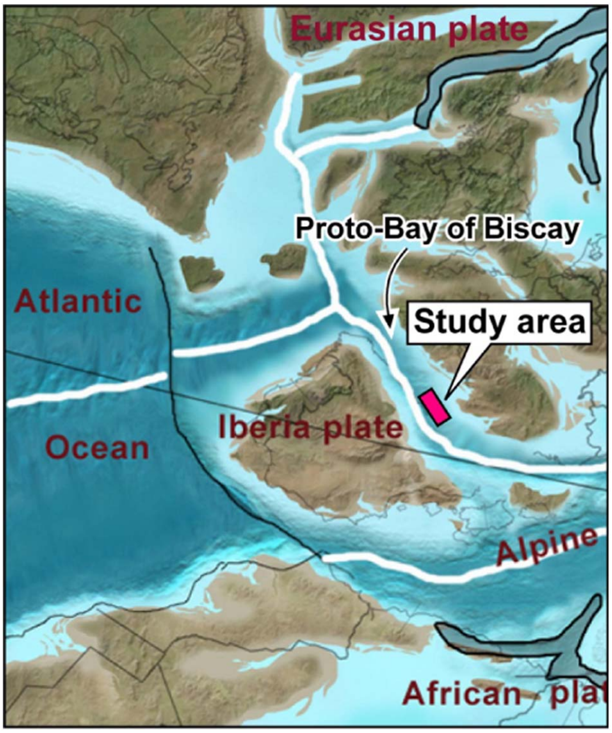

Fig. 1. Albian (100 Ma) palaeogeographic map of the North Atlantic showing the nascent Bay of Biscay between Iberia and Laurasia plates. The studied northern margin of the BCB is indicated.
Source: http://cpgeosystems.com.

Albian and Santonian times (Montadert et al., 1974). The oceanic floor spreading led to the anticlockwise rotation of the Iberian plate by 35–37° with respect to Eurasia and the opening of the Bay of Biscay (Van der Voo, 1969). In the front of this propagating ocean three main Mesozoic rift basins, i.e. Basque-Cantabrian, Parentis and Maule-Arzacq basins, were formed (Vergés et al., 2001). These basins experienced an Albian phase of maximum extension and subsidence coincident with the initiation of the sea floor spreading in the Bay of Biscay (Brunet, 1994). Recent works interpret these basins as magma-poor hyperextended rifts characterized by extremely thinned crust and locally also exhumed mantle (Jammes et al., 2009), but without oceanization. Cenozoic inversion of the BCB led to intense folding and thrusting of their sedimentary records (Vergés et al., 2001).

The Cretaceous northern margin of the BCB belongs to the European plate and exhibits a main NW-SE structural orientation (Fig. 2). This margin is adjacent to the Landes Palaeozoic massif (European plate) by the NE and is limited to the SW by the Leitza-Elgoibar fault which is assigned to the plate boundary between the Iberia and Eurasia plates (Agirrezabala, 1996; García-Mondéjar et al., 1996; and references therein). The stratigraphic architecture and sedimentologic characteristics of the Albian sedimentary record of the margin indicate an overall southwest sedimentary polarity (Agirrezabala, 1996). During the Albian the northern margin was sited at a palaeolatitude of ca. 35° with a subtropical warm and wet climate (Dercourt et al., 2000). Open sea waters on the margin were warm and with a normal salinity (García-Mondéjar, 1990).

In the last thirty years, the collection of an important sample of Middle and Upper Albian ammonoids hosted in offshore marine successions made possible the accurate dating of these successions. This collection is today hosted in the Department of Stratigraphy and Palaeontology of the University of the Basque Country (UPV/EHU; Leioa), in the Museo de Ciencias Naturales de Araba (MCNA; Vitoria-Gasteiz) and in the Nautilus Museum of the Basque Coast Geopark (NM; Mutriku, Gipuzkoa). However, no Lower Albian ammonoids have been found up to date; the dating of this part of the succession has been possible by means of orbitolinids (foraminifers). The first references to ammonoids in the study area come from Gómez de Llarena (1958), Rat (1959) but they only refer to identifications of scarce specimens with biostratigraphic value. The only descriptive works on ammonoids of the study area are those of Wiedmann and Boess (1984) and Agirrezabala et al. (1992). Afterwards, the accurate biostratigraphy for the Middle-Upper Albian with indication of the associated species has been given in Agirrezabala (1996) and Agirrezabala et al. (2002) for the eastern part of the study area, and in López-Horgue et al. (2009) and López-Horgue and Bodego (2012) for the western part.

3. Methods

This paper presents a synthesis of stratigraphic, sedimentological and palaeontological data from twelve main Albian sections distributed along the northern margin of the BCB, summarized in a cross-margin transect to illustrate the history of the Albian environmental changes and local bioevents. In each section, detailed description and interpretation of sedimentary facies and collecting and study of fossils (principally ammonoid) have been carried out. A total of > 250 ammonoid specimens have been considered, spanning from the basal Middle Albian to the Upper Albian. These ammonoids were published in two previous papers by Agirrezabala et al. (2002) and López-Horgue et al. (2009). The correlation among the sections is based on ammonoid biostratigraphic data and, to a lesser extent, on inoceramid and foraminifera data. In addition, published detailed mapping of lithostratigraphic units, physical event deposits (megabeds, bentonite beds, volcanic flows) and erosional/non-depositional features (unconformities), and chemostratigraphic intervals (^{13}C–depleted deposits) are used as complementary correlation tools (Robles et al., 1988; Agirrezabala, 1996, 2009; Agirrezabala and García-Mondéjar, 1989). Thus, a margin-scale robust chronostratigraphic framework was obtained in which 6 ammonoid zones and subzones are distinguished, previously recognized by Agirrezabala et al. (2002) and López-Horgue et al. (2009). Although the specimen richness of collected ammonoids is not enough for an exhaustive statistical analysis, it is high enough for inferring major changes in the ammonoid assemblages, which may be related to environmental perturbations.

The study and correlation of the ammonoid faunas from the northern margin of the BCB allows us: i) to discriminate stratigraphic intervals with different diversities (number of species) at a resolution level of ammonoid biozones (maximum resolution for margin-scale correlations); ii) to distinguish ammonoid associations with different features (morphology, ornamentation and size of the conch, and palaeogeographical affinity); and iii) to recognize local bioevents. In this paper, we use the term “local bioevent” as a short-term evolutionary, ecologic and biogeographic change recorded in the fossil biota of a limited area (100 mi) in response to rapid environmental changes (see Kauffman and Hart, 1996); these environmental changes (tectonics, climate, sea-level, volcanism, chemistry, etc.) may also cause correlative changes in the sedimentological record (Kauffman and Hart, 1996). Finally, we discuss the interrelationships between the ammonoid record and the environmental changes deduced from both the sedimentary facies and depositional architecture.

4. Results

4.1. Albian sedimentary record

The main stratigraphic and sedimentologic characteristics of the Albian sedimentary record of the northern margin are documented in Robles et al. (1988), Agirrezabala and García-Mondéjar (1989) and Agirrezabala (1996). In addition, many specific and detailed geological studies have been recently carried out in the area. Fig. 3 depicts a synthetic NE-SW stratigraphic cross-section for the Albian record of the