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Impact of Early Aptian carbon cycle perturbations on evolution of a marine shelf system in the Basque-Cantabrian Basin (Aralar, N Spain)

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A B S T R A C T

The Aptian Oceanic Anoxic Event 1a (OAE1a, ca.120 Ma ago) is one of the most prominent of a series of geologically brief intervals in the Cretaceous reflecting a major perturbation in the global carbon cycle. This carbon cycle perturbation is recorded in the C-isotope stratigraphy. In this study we present a new carbonate and organic carbon isotope record across OAE1a from expanded shallow marine sections (Igaratza and Iribas) in the Basque-Cantabrian Basin (N Spain). The sediments studied were accumulated on a mixed carbonate–siliciclastic and carbonate shelf. The $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ curves obtained show a pronounced negative spike in the *Deshayesites weissi* Zone and a subsequent positive excursion within the newly described *D. deshayesi*–*D. furcata* transition Zone, approximately equivalent to the upper *D. deshayesi* Zone of other sections. Specific changes in facies patterns and a reduction in neritic carbonate production predate the negative C-isotope perturbation. These changes coincide with global carbonate crises in neritic and pelagic environments. Corresponding with the beginning of OAE1a (Selli level) a condensed interval rich in ammonites is observed. This horizon is linked to a major transgression with high biodiversity. The "ammonite bloom" suggests enhanced primary productivity in the surface waters of the Basque-Cantabrian Basin at improving environmental conditions for selected biocalcifiers. The ultimate recovery of shelf carbonate deposition occurred after OAE1a and it coincided in time with the most positive values of the carbon-isotope excursion. Based on carbon-isotope stratigraphy it has been deduced that black shales corresponding to Selli Level are missing in Aralar, so that anoxia is not recorded in the studied sections of the marine shelf environment. An organic-rich interval (Aparein level) postdates the Early Aptian major positive excursion. The Aparein event should be considered in the future research of OAEs.

1. Introduction

The Early Aptian represents a time of major global environmental changes. A major perturbation of the carbon cycle triggered changes in oceanography and climate. The Oceanic Anoxic Event (OAE) 1a, a widespread nannoconids crisis and drowning of carbonate platforms are all expressions of an episode of extreme environmental change (i.e. Menegatti et al., 1998; Skelton, 2003a; Weissert and Erba, 2004; Föllmi et al., 2006). Major fluctuations in δ^{13}C values during the Early Aptian serve as evidence for this carbon cycle perturbation (Menegatti et al., 1998; Bralower et al., 1999; Erba et al., 1999; Herrle et al., 2004; among others). A pronounced negative carbon-isotope excursion and a subsequent positive excursion have been observed worldwide. The beginning of OAE1a coincides with the negative spike in the carbon-isotope curve. The most positive carbon-isotope values were reached after the end of OAE1a (Menegatti et al., 1998; Erba et al., 1999). The sharp negative excursion has been interpreted as the result of CO_2 outgassing associated with volcanism (Ontong-Java and Manihiki plateaus) (Weissert and Erba, 2004; Méhay et al., 2009) and/or with massive release of methane from clathrates (Opdyke et al., 1999, 2001; Jahren et al., 2005) or from thermogenic sources as proposed by Svensen et al. (2007) for the Toarcian C-isotope event.

In this study we trace the sedimentary evolution of a marine shelf environment in the Basque-Cantabrian Basin (N Spain) during the Early Aptian. We investigate how marine shelf ecology and sedimentation were affected by Aptian changes in the global carbon cycle. We establish a high-resolution ammonite biostratigraphy and C-isotope stratigraphy in two sections (Igaratza and Iribas) and compare both Early Aptian sections of 465 m and 120 m in thickness respectively, with the informal Cismon reference section, which has a thickness of about 27 m for the Early and early Late Aptian (Menegatti et al., 1998). The extremely thick succession of Igaratza provides a very high-resolution stratigraphic record.

On the basis of the Aralar expanded sections, with a unique ammonite biostratigraphy and high-resolution chemostratigraphy, we reconstruct the relationship between carbon cycle, global paleoenvironmental changes, local sedimentation and ammonite occurrence.

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2. Geological setting and studied sections

The Basque-Cantabrian Basin lies between the Pyrenean and Cantabrian Mountains. It was formed as a consequence of the rifting and opening of the North Atlantic Ocean and the Bay of Biscay, accumulating a thick sequence of Mesozoic (mainly Cretaceous) and Tertiary sediments (e.g. Montadert et al., 1974; García-Mondéjar, 1990; Cámara, 1997; García-Mondéjar et al., 2004). Specifically major extension occurred along the NE–NW direction while transtension affected the basin along the NW–SE direction during the Cretaceous (e.g. Le Pichon et al., 1971; Rat, 1988; García-Mondéjar, 1990). Basque-Cantabrian Basin subsidence was very pronounced during the Aptian and Albian, allowing the accumulation of a 7 km thick prism of sediments (Cámara, 1997). According to García-Mondéjar et al. (2005) a subsidence pulse called pulse I in the Early Aptian, related mainly to NE–SW extensional movements and linked to the rift axis in the Bay of Biscay, led to deposition of the thick succession of the Aralar area studied in this paper.

The two sections studied are located in the Aralar Mountains, forming the southeast margin of the Basque-Cantabrian Basin (Fig. 1). The Igaratza section is located between Errenaga and Puttarri mountains and it is topographically situated between 1230 m and 1261 m. The Iribas section is located about 2 km southwest of the Iribas village at an altitude of 610 m. The horizontal distance between the two sections is 9.5 km.

3. Methods

In this study the Igaratza and Iribas sections were sampled for $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ analyses. Samples for $\delta^{13}C_{carb}$ from the Igaratza section (west) were taken with intervals of 1.5 m in the Sarastarri Limestones Formation. Here the uniform carbonate lithology of this unit makes systematic sampling possible. Samples for $\delta^{13}C_{org}$ from Igaratza section were taken, where possible, in increments of 1 m both in the Errenaga and Lareo Formations. Sarastarri Formation was not sampled for $\delta^{13}C_{org}$ analysis because of the lack of organic matter. Samples from Iribas section (east) for $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ analysis were taken in increments of about 3 m. The analyses have been carried out at the Stable Isotope Laboratory of the Swiss Federal Institute of Technology Zurich (ETH).

The isotopic composition of calcite was measured on bulk rock samples from limestones, marly limestones, sandy limestones and siltstones from both sections. Carbonate powder was extracted with a micro drill in order to avoid large fossil fragments (rudists, massive corals or oysters) and diagenetic calcite from veins. Approximately 200 μg of powder was reacted with 100% phosphoric acid at 70 °C in a ThermoFisher Kiel IV carbonate device connected to a ThermoFisher Delta V PLUS mass spectrometer. The reproducibility of the measurements based on replicated standards was ±0.02‰ for $\delta^{13}C$ and ±0.06‰ for $\delta^{18}O$. The instrument is calibrated with the international standards NBS19 and NBS18. The isotope values are reported in the conventional delta notation with respect to VPDB.

The isotopic composition of organic carbon was measured on bulk rock samples from siltstones and marls from siliciclastic formations (Errenaga and Lareo Formations) in both studied sections (Igaratza and Iribas). A few milligrams of decarbonated powder were weighted in tin capsules and measured using a ThermoFisher Flash-EA coupled to a Delta V PLUS mass spectrometer. The reproducibility of the measurements based on replicated standards was ±0.1‰ for $\delta^{13}C$. The instrument is calibrated with the international standards NBS22 and IAEA-CH-6 and the isotope values are reported in the conventional delta notation with respect to VPDB.

4. Results

4.1. Sedimentology and stratigraphy

The sedimentary record of the studied Igaratza and Iribas sections consists of a mixed carbonate–siliciclastic facies succession of Early Aptian age. Three lithostratigraphic units the Errenaga, Sarastarri and Lareo Formation have been distinguished (Lertxundi, 1997; Millán et al., 2005, 2007; García-Mondéjar et al., 2009) (Fig. 2). Age control is provided by ammonite biostratigraphy (García-Mondéjar et al., 2009), orbitolinids *Palorbitolina lenticularis* (Blumenbach), *Iraqia simplex* (Henson) (Duvernois et al., 1972; Cherchi and Schroeder, 1998) and rudists (Caprinidae, *Caprina parvula*) (Masse, 2003; identified by

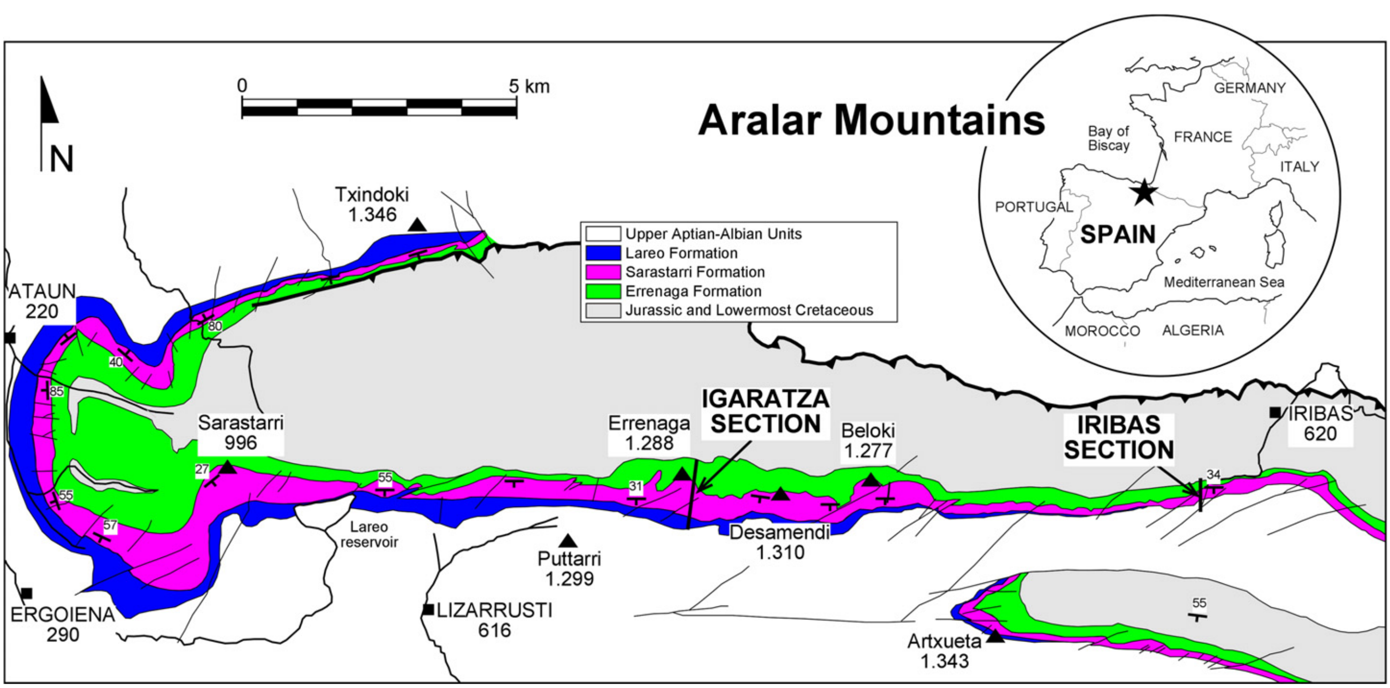

Fig. 1. Simplified geological map of Aralar (N Spain) and location of the studied sections.
(Modified after García-Mondéjar et al., 2009).