Palaeogeography, Palaeoclimatology, Palaeoecology 312 (2011) 167–180

Contents lists available at SciVerse ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

The Madotz Urgonian platform (Aralar, northern Spain): Paleoecological changes in response to Early Aptian global environmental events

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ARTICLE INFO

Article history:
Received 14 March 2011
Received in revised form 10 September 2011
Accepted 13 October 2011
Available online 20 October 2011

Keywords:
Carbonate platform crisis
Carbon cycle
Orbitolinid-rich facies
Early Aptian
Aralar
N Spain

ABSTRACT

Sudden addition of carbon dioxide to the atmosphere can reduce the $CaCO_3$ saturation and weaken the biocalcification potential of marine organisms in shallow water and in open marine settings. In this study, the response of an Aptian neritic carbonate environment to sudden addition of carbon dioxide at the beginning of Oceanic Anoxic Event 1a is investigated. The beginning of the OAE1a was coupled with a major perturbation on the carbon cycle as indicated by a negative carbon isotope excursion in the sedimentary record. This isotope anomaly is regarded as a proxy for massive addition of volcanic or methane-derived CO_2 to the atmosphere within only a few 10^4 years. The impact of a rapid change in atmospheric pCO_2 on biocalcifiers in low latitude shallow-water settings can be studied in a well preserved Aptian carbonate shelf succession cropping out today in the Aralar mountains (NE Spain). The Madotz section (N Spain) preserves a continuous shallow water record that was deposited on a mid-latitude, Atlantic-oriented mixed siliciclastic–carbonate ramp. Lower Aptian sediments consist of two neritic limestone successions separated by orbitolinid-rich marlstone enriched in organic matter. The lower neritic limestone succession ends with a submarine hardground and the transition from the lower neritic limestone to the orbitolinid marlstone coincides with a negative spike in the organic carbon isotope record. This negative spike can be correlated with the negative carbon isotope anomaly marking the base of OAE1a. The paleoecological change coinciding with the base of OAE1a occurred at a time of sea level rise and it coincided with a demise of heavily calcified nannoconids in the Tethys and Pacific Oceans. The paleoecological change observed in the Madotz section corresponds to a comparable change seen in the more distal and more expanded carbonate ramp section (Igaratza) at the Aralar Mountains. Ocean acidification caused by sudden increase in pCO_2 may explain reduced calcification potential of some shallow water calcifiers. Calcification crisis was amplified by rising sea level, increasing temperatures and increased flux of detrital material and nutrients from continents into coastal seas.

1. Introduction

Climate models predict that increasing concentrations in atmospheric CO_2 will not only shift our climate into a greenhouse mode but that they will have an impact on the chemistry of oceans. Acidification of surface water is predicted to affect biocalcifying organisms in both pelagic and shallow water environments (e.g., Doney et al., 2009). Research on episodes of rapid change in atmospheric CO_2 in the geological past may provide additional insight into response mechanisms of marine biota and specifically of marine calcifiers to increased pCO_2 levels. Multiple carbon dioxide pulses marked the Cretaceous, one of the most prominent of them is dated as Early Aptian in age (around 120 million years ago).

The Early Aptian major perturbation of the carbon cycle was caused by a sudden addition of volcanic CO_2 to the atmosphere and oceans (Larson and Erba, 1999). This carbon cycle perturbation, evidenced by a negative carbon isotope excursion in the sedimentary record (e.g. Méhay et al., 2009), marks the beginning of Oceanic Anoxic Event 1a (OAE1a) and it coincides with widespread demise of shallow carbonate platforms along the northern Tethys and the central North Atlantic Ocean (Föllmi et al., 1994; Wissler et al., 2003; Burla et al., 2008, 2009; Föllmi and Gainon, 2008; Heldt et al., 2010; Najarro et al., 2011a,b). Carbonate platform-drowning sensu Schlager (1981) is seen as a consequence of a biocalcification crisis, which coincided with a “nannoconid crisis” in pelagic environments (e.g. Erba, 1994; Erba and Tremolada, 2004; Erba et al., 2010).

Neritic limestone and marlstone successions today cropping out in the Aralar Mountains (NE Spain) provide a record of the evolution of an Atlantic-oriented mixed siliciclastic–carbonate ramp leading up to and during the time of OAE1a in the Early Aptian. The Aralar successions permit a study of the response of a carbonate system to changes in

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doi:10.1016/j.palaeo.2011.10.005

global carbon cycling and to a rapid increase in atmospheric CO_2. In contrast to other carbonate ramps of the Northern Tethys, the Aralar ramp did not experience a terminal drowning episode but it was affected by major changes in paleoecology and by partial reduction of biocalcification which resulted in a demise of the platform. The Madotz section is located in a relatively proximal part of the carbonate ramp and provides an excellent record of paleoenvironments and carbon cycle driven by local subsidence and global sea level changes. A revised bio-, litho-, and sequence stratigraphy and a new chemostratigraphy permit an accurate comparison of the Madotz sedimentation history with other carbonate platform and ramp records. These include the nearby Igaratza section of the more distal part of Aralar ramp, the Cresmina section in Portugal, the Zuestoll–Rawil composite section in the Helvetic nappe pile Switzerland and the Wadi Mu'Aydin section in Oman (van Buchem et al., 2002; Wissler et al., 2003; Linder et al., 2006; Burla et al., 2008; Millán et al., 2009).

The goal of this study is to test in the Aralar successions if changes in the global carbon cycle triggered changes in paleoecology and if there is evidence for changing biocalcification patterns which could have been caused by acidification of surface water. This paper complements earlier studies in the Aralar Mountains of the Errenaga Formation (García-Mondéjar et al., 2009; Millán et al., 2009), as well as previous work on the biostratigraphical aspects of the Madotz section (Schroeder, 1963; Ramírez del Pozo, 1971; Duvernois et al., 1972; Cherchi and Schroeder, 1998).

2. Geological setting

The investigated succession crops out in the southeastern Aralar Mountains (N Spain) (Fig. 1A). The Madotz section was measured along the outcrop situated at the western side of the small village of Madotz in Navarra province (Fig. 1B). Palaeogeographically the area

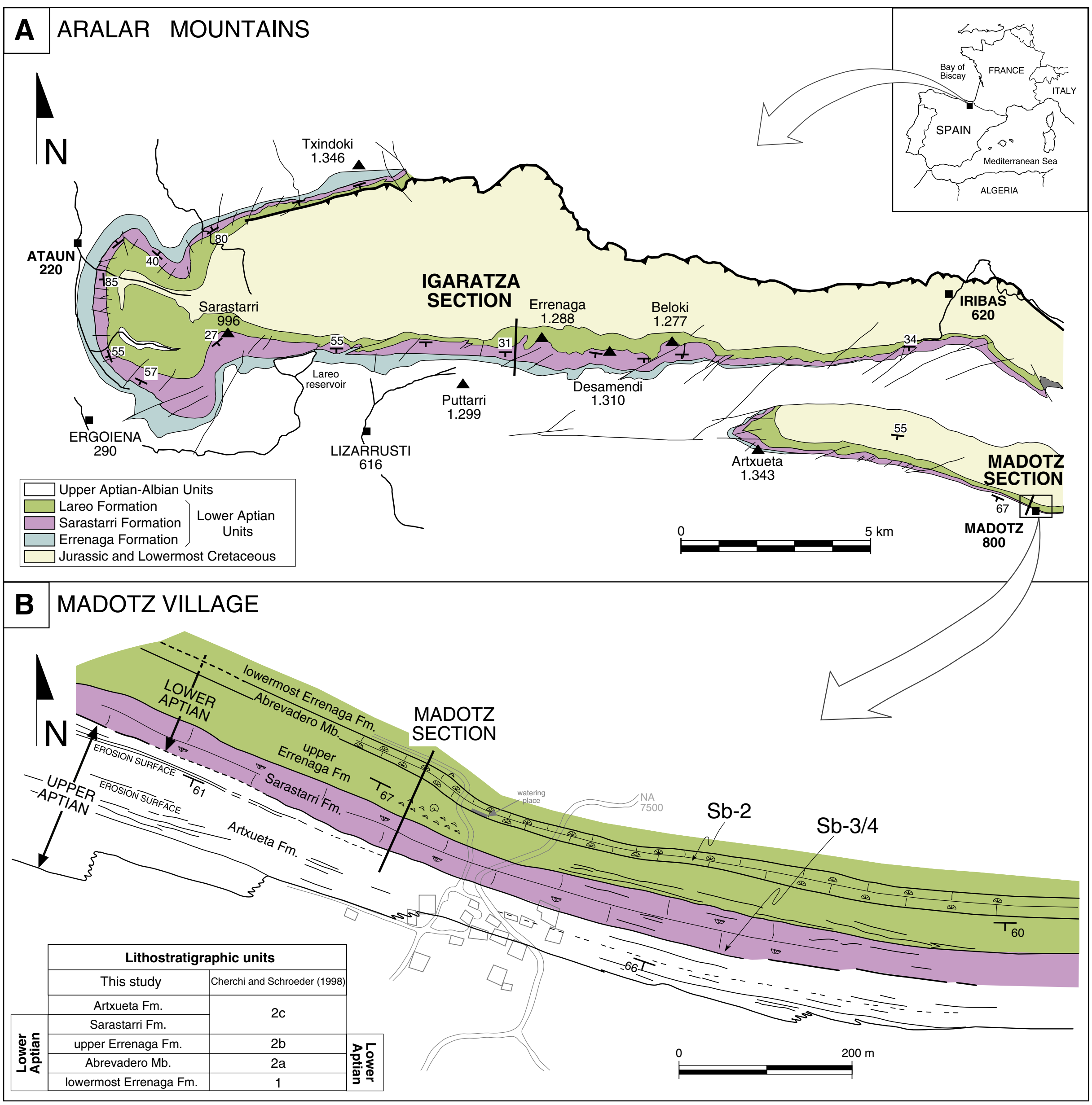

Fig. 1. (A) Simplified geological map of Aralar Mountains with the location of the Igaratza and Madotz sections (modified after Millán et al., 2009). (B) A detailed geological map of the Madotz area with indication of the lithostratigraphical units described in the text. Inset below left: lithostratigraphic units in Aralar against lithological units described by Cherchi and Schroeder (1998) in the same area.