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Pyrite framboid size distribution as a record for relative variations in sedimentation rate: An example on the Toarcian Oceanic Anoxic Event in Southiberian Palaeomargin

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ABSTRACT

The Early Toarcian Oceanic Anoxic Event (T-OAE) represents one of the major alterations of the carbon cycle of the Mesozoic period. Despite being globally recognized, and particularly represented within the Tethys realm, its expression in the sedimentary record is highly variable depending on the studied section, which suggests local environmental factors exert a major control on the resulting lithological appearance of the event. We investigated the Fuente Vidriera section, in the eastern External Subbetic of the Betic Cordillera (Spain), where the Lower Jurassic is represented by alternate layers of marls and marly limestones, and the T-OAE is identified by a major $\delta^{13}C$ excursion, micropalaeontological, ichnofacies and geochemical evidences. For this study, we analyzed pyrite framboid size distribution of the sedimentary sequence in Fuente Vidriera. The outcome, according to previous studies on pyrite framboid distribution, is contradictory when compared to all other evidences, suggesting oxygen depletion during the T-OAE. The results have been reinterpreted in the light of Crystal Size Distribution Theory and we conclude that not only growth time but also geochemical environment controls pyrite formation. Since growth time is directly related to burial rates, this approach allows us to reconstruct relative variations of sedimentation rates during the Early Jurassic in this location. Based on the obtained results, we provide new evidences for wide-spread transgression during the Early Toarcian in the South Iberian palaeomargin, which induced low sedimentation rate and lower energetic conditions, as well as favored oxygen impoverished bottom waters.

1. Introduction

The Early Toarcian Oceanic Anoxic Event (T-OAE) is recognized as one of the most important environmental changes during the Mesozoic. Its dramatic impact on marine biota is evidenced by a significant mass extinction event in benthic and pelagic groups (e.g., Hallam, 1986; Little and Benton, 1995; Aberhan and Baumiller, 2003; Wignall et al., 2005; Danise et al., 2013). The sedimentary record of the T-OAE is characterized by organic-rich “black shale” sediments associated with a distinctive negative excursion in the $\delta^{13}C$ (e.g., Jenkyns and Clayton, 1997; Jenkyns et al., 2002; Jenkyns, 2003; Cohen et al., 2004; van Breugel et al., 2006; Hesselbo et al., 2007; Hermoso et al., 2009; Sabatino et al., 2009; Bodin et al., 2010; Littler et al., 2010; Reolid, 2014a).

The stronger incidence of the T-OAE is registered in the boundary of subboreal Tenuicostatum–Falciferum zones and sub-Mediterranean and Mediterranean Polymorphum–Serpentinum zones and Polymorphum–Levisoni zones, and finish esessentially at the boundary of the Exaratum and Falciferum subzones (Levisoni/Falciferum subzones in the Mediterranean biozonation).

There is no general agreement about the causes or triggering mechanisms of the T-OAE, including the production of thermogenic methane during the concomitant intrusive eruption of the Karoo–Ferrar province (e.g., McElwain et al., 2005), or the massive enrichment of isotopically light carbon and its transfer between the different reservoirs (e.g., Hesselbo et al., 2000; Kemp et al., 2005; Gröcke et al., 2011). Several environmental changes may have been involved in the mass extinction event, mainly affecting benthic organisms, such as generalized anoxia, the enhancement of greenhouse conditions and a warming trend, or the incidence of sea-level changes (e.g., Hallam, 1986; Elmi, 1996; McArthur et al., 2000; Bailey et al., 2003; Ruban and Tyszka, 2005; Wignall et al., 2005; Gómez and Goy, 2011).

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Pyrite framboid size distribution has been successfully applied in previous studies as an indicator for anoxia–euxinia in ancient marine sediments and the reconstruction of bottom water oxygenation (e.g., Wignall et al., 2005; Bond and Wignall, 2010; Liao et al., 2010; Wang et al., 2013; Guan et al., 2014; Tian et al., 2014; Takahashi et al., 2015; Wei et al., 2015). Nevertheless, pyritization does not always have a straightforward interpretation and its reliability as a redox proxy is still questionable (e.g., Roychoudhury et al., 2003). In this work we analyze the size distribution of pyrite framboids in a selected Upper Pliensbachian–Lower Toarcian section from the Southiberian Palaeomargin where clay minerals (Palomo, 1987), stable isotopes (Jiménez et al., 1996; Reolid, 2014a), geochemical proxies (Rodríguez-Tovar and Reolid, 2013), trace fossils (Rodríguez-Tovar and Uchman, 2010) and microfossil assemblages (Reolid, 2014a,b) have previously been analyzed. The objective of this research is to interpret the incidence of the T-OAE in this area of the westernmost Tethys (Subbetic), to examine the pyrite framboid distribution as a proxy for palaeoenvironmental reconstruction, the comparison with previous biotic and abiotic data, the controlling parameters in the pyrite growth in hemipelagic environments and its implications on the studied sedimentary sequence.

2. Geological setting

This research was carried out in the Fuente Vidriera (FV) section, located on a ravine slope (38°03′19.8″N; 2°07′01.7″E) 15 km west of the village of Barranda, near Caravaca de la Cruz (Fig. 1). The Fuente Vidriera section belongs to the Eastern External Subbetic (Betic Cordillera, southern Spain). The Subbetic is a distal setting, featuring pelagic swells with low subsidence and subsident central troughs. Jurassic sedimentation in the External Subbetic is characterized by shallow-shelf deposits of the lowermost Jurassic (Gavilán Formation), overlain by hemipelagic facies of marls and marly limestones dating Pliensbachian–Aalenian (Zegrí Formation), along with pelagic cherty limestones and nodular limestones of Middle–Late Jurassic age (Ammonitico Rosso Formation). In the Subbetic region overall, the External Subbetic represents swell areas produced by fragmentation of large carbonate platforms during the middle Early Jurassic (García-Hernández et al., 1989).

The studied Lower Toarcian section comprises an approximately 30-m-thick succession of marls and marly limestones. Biostratigraphic ammonite zonation within the Lower Toarcian of the Fuente Vidriera section was proposed by Jiménez and Rivas (2007). Thus, the *Dactylioceras polymorphum* and *Harpoceras serpentinum* biozones

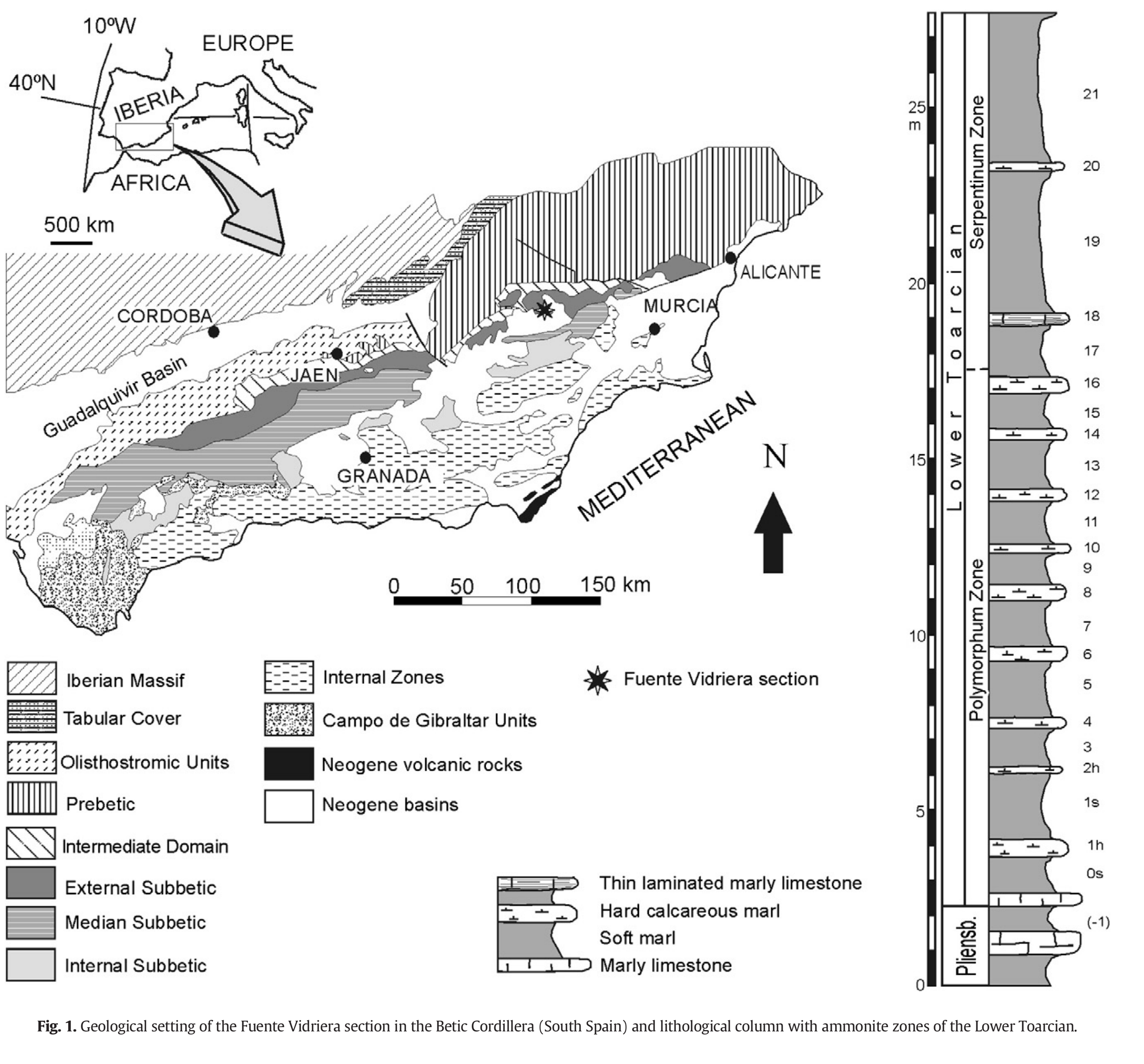

Fig. 1. Geological setting of the Fuente Vidriera section in the Betic Cordillera (South Spain) and lithological column with ammonite zones of the Lower Toarcian.