Marine Micropaleontology 137 (2017) 46–63

Contents lists available at ScienceDirect

Marine Micropaleontology

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

The palynological response to the Toarcian Oceanic Anoxic Event (Early Jurassic) at Peniche, Lusitanian Basin, western Portugal

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ARTICLE INFO

Keywords:
Palaeobiology
Palynomorphs
Provincialism
Toarcian Oceanic Anoxic Event (T-OAE)
Lusitanian Basin, Portugal

ABSTRACT

The uppermost Pliensbachian and lower Toarcian (Lower Jurassic) succession exposed at Peniche in the central part of the Lusitanian Basin, western Portugal, was examined for palynomorphs. The 45 samples span the *Emaciaticeras emaciatum*, *Dactylioceras polymorphum* and *Hildaites levisoni* ammonite biozones (ABs), and the succession includes the Global boundary Stratotype Section and Point (GSSP) for the Toarcian Stage and the Toarcian Oceanic Anoxic Event (T-OAE). A low diversity dinoflagellate cyst flora, typical of the Sub-Boreal Realm, was recovered from the *Emaciaticeras emaciatum* and *Dactylioceras polymorphum* ABs. The dominant element is the cold water species *Luehndea spinosa*, which is an index for the Pliensbachian to earliest Toarcian, and is thought to have migrated from the more northerly Boreal Realm. Prior to the T-OAE, dinoflagellates thrived in the Lusitanian Basin, except during a brief warm period in the earliest Toarcian. Despite the latter, the recovery from this event was relatively rapid and was characterised by a return to relatively cool temperatures. The *Hildaites levisoni* AB at Peniche represents the T-OAE and the overlying strata, and is characterised by a profound reduction in dinoflagellate cyst relative abundances. This dinoflagellate cyst 'blackout', and the associated rise of prasinophytes, reflects significant environmental stress, such as marine anoxia, elevated temperatures and reduced salinity, with the former two probably being most important. The low proportions of dinoflagellate cysts following the T-OAE indicates a protracted recovery phase from the bottom and water column anoxia developed throughout the Lusitanian Basin.

1. Introduction

This study is a documentation of the palynology of the uppermost Pliensbachian and lower Toarcian (Lower Jurassic) strata at Peniche in the southern Lusitanian Basin, western Portugal. The principal aim was to investigate the response of marine microplankton to the Toarcian Oceanic Anoxic Event (T-OAE).

The Peniche section is located at Ponta do Trovão, on a peninsula close to Peniche (Fig. 1). An exceptionally expanded, well exposed and well preserved Pliensbachian-Toarcian transition is part of this coastal succession, which was chosen as the Global boundary Stratotype Section and Point (GSSP) for the Toarcian Stage (Elmi, 2006; Rocha et al., 2016). The Pliensbachian-Toarcian boundary is primarily based on a relative abundance of the ammonite *Dactylioceras* and secondarily on the inceptions of several calcareous nannofossils. These bioevents define the base of Toarcian Stage at the base of Bed 15e (Rocha et al., 2016).

The palynology of the upper Pliensbachian and lower Toarcian strata at Peniche was previously studied by Davies (1985), Oliveira et al. (2007) and Barrón et al. (2013). Abundant dinoflagellate cysts were recently recorded from the lower Toarcian in the northern Lusitanian Basin by Correia et al. (2017). The present study is chiefly on the dinoflagellate cyst floras of Peniche, and it is hoped that these data will help to further characterise the Toarcian GSSP here. Pliensbachian and Toarcian calcareous nannofossils of the Peniche section were studied by Perilli and Duarte (2006), Oliveira et al. (2007), Mattioli et al. (2008, 2013) and Reggiani et al. (2010).

The Peniche section includes one of the major Phanerozoic environmental perturbations, the T-OAE. This was the earliest of the major Mesozoic-Cenozoic oceanic anoxic events (Jenkyns, 2010). The

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http://dx.doi.org/10.1016/j.marmicro.2017.10.004
Received 12 April 2017; Received in revised form 13 October 2017; Accepted 17 October 2017
Available online 21 October 2017
0377-8398/

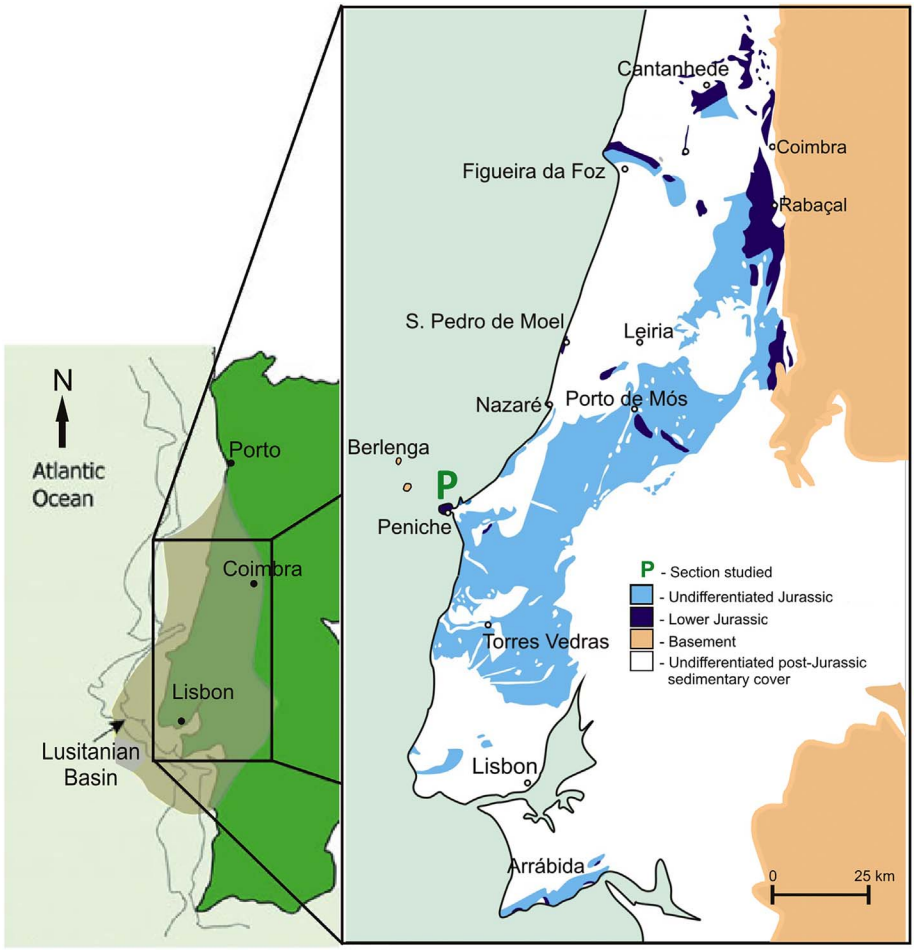

Fig. 1. The location and geological setting of the Lusitanian Basin of western Portugal (adapted from Duarte et al., 2010). The section studied at Peniche, which is the Toarcian GSSP, is near to Peniche city, is indicated by the letter P at 39°22′15″N; 9°23′07″W.

T-OAE is global and caused marine extinction and stratification, anoxia, and a rapid increase in seawater temperatures at ~182 Ma (e.g. Harries and Little, 1999; Cohen et al., 2007; Suan et al., 2008a,b, 2010, 2011; Al-Suwaidi et al., 2010, 2016; Gómez and Arias, 2010; Izumi et al., 2012; Danise et al., 2013; Xu et al., 2017). This event is characterised by a negative carbon isotope excursion ($\delta^{13}C$), recorded in marine carbonates and sedimentary organic matter. This characteristic geochemical signal has been confidently recognised in the Lusitanian Basin (Duarte et al., 2004, 2007; Hesselbo et al., 2007; Suan et al., 2008a; Pittet et al., 2014). The T-OAE may have been caused by a massive carbon injection into the atmosphere from oceanic gas hydrates, and/or methane release from sedimentary rocks due to intrusive volcanism (Hesselbo et al., 2000; Kemp et al., 2005; McElwain et al., 2005; Svensen et al., 2007; Hesselbo and Pieńkowski, 2011; van de Schootbrugge et al., 2013). It may have been terminated by fire-feedbacks to atmospheric oxygen concentrations (Baker et al., 2017). The more recent Paleocene-Eocene Thermal Maximum (PETM, ~56 Ma) was also a short-lived interval of elevated temperatures caused by an injection of greenhouse gases into the atmosphere. However, the PETM only caused relatively minor and localised marine anoxia in comparison to the T-OAE (Cohen et al., 2007; Kender et al., 2012).

The distribution and growth of dinoflagellates, which are planktonic organisms, are influenced by factors such as light, nutrients, ocean currents, oxygen levels, salinity, temperature and water depth (Taylor and Pollingher, 1987; Dale, 1996). Toarcian marine plankton populations would therefore have been significantly affected by the T-OAE. Hence, research on Toarcian dinoflagellate cysts and other marine microplankton will help the understanding of this major environmental perturbation (e.g. Prauss, 1996; Prauss et al., 1991; Bucefalo Palliani et al., 2002).

2. Geological background

The Lusitanian Basin is a major marine depocentre on the Atlantic coastal margin in western central Portugal (Fig. 1). This basin is oriented NE-SW, and is 300 km in length and 150 km wide. The depocentre is filled by a maximum thickness of 5 km of Mesozoic (Middle?–Upper Triassic to uppermost part of Lower Cretaceous) strata, but most of the succession is Jurassic (Rasmussen et al., 1998; Kullberg et al., 2013). Its initiation and evolution were associated with the fragmentation of Pangaea during the opening of the North Atlantic.

Lower Jurassic strata are well developed in the Lusitanian Basin, especially in the Peniche area (Duarte et al., 2017). Here, the upper Pliensbachian and lower Toarcian are represented by an expanded succession of interbedded fossiliferous limestones, marls and calcarenites (Wright and Wilson, 1984; Duarte, 1997, 2007; Duarte and Soares, 2002). The upper Pliensbachian comprises the uppermost part of the Vale das Fontes Formation and the majority of the Lemede Formation. The Vale das Fontes and Lemede formations represent the *Amaltheus margaritatus*, *Emaciaticeras emaciatum* and lowermost *Dactylioceras polymorphum* ammonite biozones (ABs) (Fig. 2). The Vale das Fontes Formation is composed of interbedded relatively thick (ca. 10 cm–1 m) marls and thinner (< 10 cm) limestones, both of which are abundantly fossiliferous (Duarte et al., 2010; Silva et al., 2011, 2015). The overlying Lemede Formation is heavily bioturbated and also cyclic; it comprises interbedded relatively thick (~10 cm–40 cm) limestones and thinner (< 10 cm) marl interbeds. Both lithotypes are richly fossiliferous (Duarte and Soares, 2002; Comas-Rengifo et al., 2016). In this study, only the uppermost Lemede Formation was studied (Figs. 2, 3).

The Toarcian of the Peniche region is represented by the Cabo Carvoeiro Formation, which is subdivided into five members (Duarte