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Response of western South American epeiric-neritic ecosystem to middle Cretaceous Oceanic Anoxic Events

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Little is known about the impact of the mid-Cretaceous Oceanic Anoxic Events (OAEs) on the neritic carbonate systems in South America. In order to fill this knowledge gap, the present paper reports on the record of environmental changes in the Albian–Turonian neritic carbonates from the western South American domain in Peru. Owing to the very expanded and well-exposed sections in the Oyon region of central Peru, the OAE 1d and 2 intervals were sampled at high temporal resolution for both bulk micrite and bulk organic matter carbon isotopes, allowing us to compare the fingerprint of these two events between the northern and central Peruvian regions. This suggests the installation of two marked depositional modes: 1) the Albian–Turonian formation of a regional facies belt constituted by oyster-rich mixed siliciclastic-carbonate deposition along the western South America platform; 2) a restricted oligotrophic environment, characterized by the mass occurrence of *Perouvianella peruviana* and associated miliolids in central Peru during the late Cenomanian–Turonian. These observations advocate for the following scenario: Global warming during the late Albian–early Turonian resulted in humid climate on the western platform. This in turn caused enhanced chemical weathering rates on the Brazilian Shield, resulting in high runoff of nutrients onto the western platform. Nutrient runoff promoted the diversification of benthic oyster communities. Due to the uplift of the Marañon Massif and the installation of the Huarmey Trough, central Peru was isolated from the Pacific and from eastern deltaic influx of the Brazilian continental basement, allowing the local development of oligotrophic conditions during OAE 2. Furthermore, an increased influx of argillaceous sediment and reduced carbonate production is recorded in northern Peru at the onset of OAE 2, marked by a prominent negative shift in $\delta^{13}C$. This negative carbon-isotope excursion has also been identified in other sections in the Pacific domain and can be linked to an increase in isotopically light pCO_2 induced by the formation of the Caribbean large igneous province.

1. Introduction

The mid-Cretaceous (i.e., the Albian–Turonian interval, ca. 110–90 Ma; Ogg and Hinnov, 2012) is considered as a time governed by intensification of greenhouse conditions due to elevated emission of pCO_2 to the atmosphere following massive pulses of ocean crust production and the formation of large igneous provinces (LIPs; Arthur et al., 1985; Barron and Washington, 1985; Larson, 1991; Leckie et al., 2002; Snow et al., 2005; Bodin et al., 2015). The intensified greenhouse conditions enhanced the hydrological cycle, which in turn accelerated continental weathering rates (Berner et al., 1983; Weissert, 1990; Weissert et al., 1998; Hay, 1998; Menegatti et al., 1998; Wortmann et al., 2004; van Helmond et al., 2013; Bodin et al., 2015) and led to increased fluxes of continental nutrients to the oceans. This chain of events stimulated biological productivity, leading to widespread organic-carbon deposition and enhanced marine anoxia and euxinia (Manabe and Bryan, 1985; Föllmi et al., 1994, 2006; Turgeon and Brumsack, 2006; Owens et al., 2013; Pogge von Strandmann et al., 2013; Lechler et al., 2015). The processes described above probably occurred on some level throughout the Cretaceous, but became particularly enhanced during several geologically short intervals (<1 Myr), known as oceanic anoxic events (OAEs). These

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latter are best defined based on carbon isotope ($\delta^{13}C$) excursions that reflect a fundamental perturbation in the global carbon cycle (Erbacher et al., 1996; Leckie et al., 2002). The best-studied OAEs in Europe, North America, and from Atlantic ODP sites include the early Aptian OAE1a, the Albian OAE1b, OAE1c and OAE1d, and the Cenomanian–Turonian OAE2. Additional events, such as the Coniacian OAE3 and the mid-Cenomanian event I (MCEI) represent related phenomena that lack widespread organic carbon-rich facies and/or a significant $\delta^{13}C$ excursion (e.g., Jarvis et al., 2006; Jenkyns, 2010).

OAE1a and OAE2 are conventionally interpreted as the result of massive outgassing of the Ontong Java, Manihiki and Hikurangi LIP (Tarduno et al., 1991; Larson and Erba, 1999; Méhay et al., 2009; Tejada et al., 2009) and by the Caribbean LIP (Snow et al., 2005; Du Vivier et al., 2014). At the onset of OAE1a and OAE2, a negative shift in lithium and calcium isotope ratios is observed, most likely associated to weathering of continental crust (Blättler et al., 2011; Pogge von Strandmann et al., 2013; Lechler et al., 2015). Calcium isotope patterns recorded in the Portland (USA), Pont d'Issole (southeastern France), and Eastbourne (England) sections, suggested that the Caribbean LIP triggered a change in the predominant type of biomineralization (i.e., ocean acidification) at the onset of OAE2 (Du Vivier et al., 2015). As recorded in the geological record, transient periods of high atmospheric CO_2 led to several mass extinctions, most likely because excess CO_2 reduced the ability of carbonate-secreting organisms to secrete their carbonate shells (e.g., Glikson, 2010). In a more qualitative way, sedimentological studies suggest enhanced weathering at the onset of OAE 1a and OAE2, as reflected by the relative abundance of kaolinite (Gertsch et al., 2010; Stein et al., 2012).

Evidences of a sudden influx of siliciclastic material coeval to OAEs have been reported in the North Atlantic and the Tethys domains (Weissert, 1990; Wortmann et al., 2004) and are indicative of a change to more humid and warmer conditions (Weissert, 1990; Weissert et al., 1998; Wortmann et al., 2004). This concept is exemplified in the evolution of the northern Tethyan platform during the Early Cretaceous, where carbon isotope ($\delta^{13}C$) excursions occurred at times of elevated nutrient levels due to intensified continental weathering rates (Erba, 1994; Weissert et al., 1998; Immenhauser et al., 2005; Bodin et al., 2006; Föllmi et al., 2006; Huck et al., 2010, 2011, 2012, 2013, 2014). This caused a change from oligo- to meso- or eutrophic conditions, ecological reorganization, phases of carbonate platform development and drowning episodes (Weissert et al., 1998; Immenhauser et al., 2005; Bodin et al., 2006; Föllmi et al., 2006; Huck et al., 2011). However, these hypotheses have yet to be applied to sections in South America, which record the response of shallow-marine carbonate depositional environments of a southern hemisphere continent adjacent to the Pacific Ocean.

The western South America platform (Fig. 1) was characterised by a large oceanic basin to the west and a very large uplifted continental basement area to the east. The enormous dimensions of this region make this a challenging natural laboratory to understand southern hemisphere Earth System behaviour under extreme climates. The aim of this paper is to document and discuss the Albian to Turonian sedimentological and palaeoecological evolution of the epeiric-neritic ecosystem of the western platform in central Peru (Oyon region; Jaillard, 1986; Fig. 2). The assessment of potential spatial and bathymetric variability in epeiric-neritic DIC patterns is placed in context with a previously published northern Peru reference composite section (Cajamarca region, Fig. 3, Navarro-Ramirez et al., 2015, 2016). Specific attention is paid to environmental stressors associated to OAE1d and OAE2 and the manner in which they affect the main carbonate producers such as oysters, gastropods, echinoids, and endemic large benthic foraminifera (*Perouvianella peruviana,* Steimann) that have so far only been reported from these sections (Jaillard and Arnaud-Vanneau, 1993).

2. Regional tectonic and stratigraphic setting

The South America margin was largely influenced by late stages of Gondwana breakup that culminated in the separation of Africa and South America and the opening of the Equatorial Atlantic Ocean during the Aptian–Albian transition (Moulin et al., 2010; Fig. 1). This allowed for the connection of North and South Atlantic Ocean water masses towards the Turonian (Eagles, 2006). This tectonic event caused the activation of the western South America volcanic arc in the Early Cretaceous (Huarmey-Trough, Atherton and Webb, 1989; Soler and Bonhomme, 1990; Jaillard et al., 1999, 2000; Winter et al., 2010) and subduction took place along the western portion of South America where sedimentation was

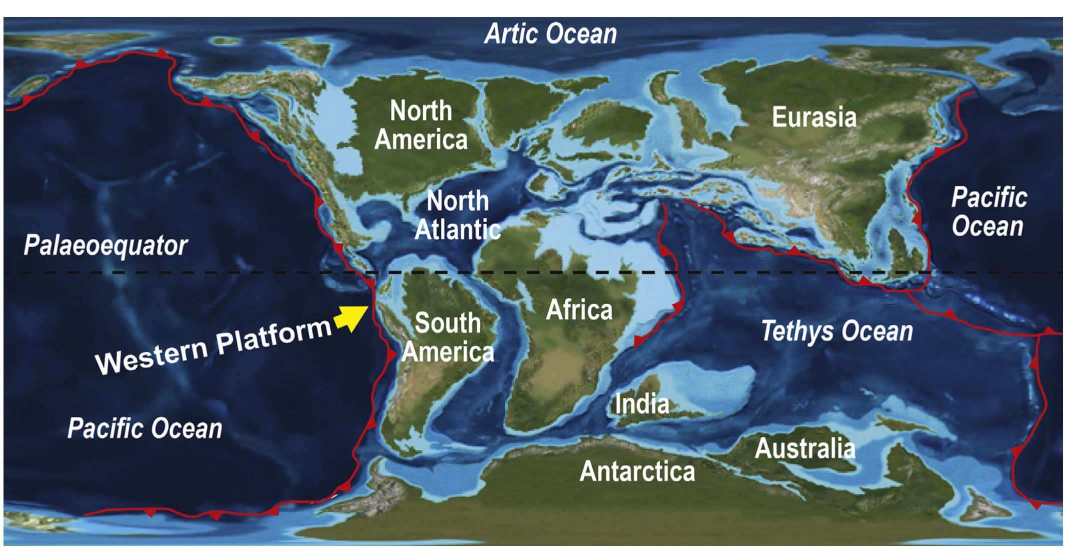

Fig. 1. Palaeogeographic reconstruction for the mid-Cretaceous (modified after Blakey, 2011) indicating the position of what today is the Western Platform of South America (yellow arrow).