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Spatial geochemistry of Upper Jurassic marine carbonates (Iberian subplate)

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ABSTRACT

Chemostratigraphy applied to ancient marine carbonates is commonly based on one-dimensional (stratigraphic) sections or core data. As demonstrated from modern oceans, this approach underestimates the spatial complexity of physico-chemical seawater properties. Here, a several-hundred-kilometer long transect consisting of seven Upper Jurassic sections from settings ranging from (proximal) neritic middle shelf to the epioceanic (distal) fringe across the southern and eastern palaeomargins of the Iberian sub-plate reveals variability in sedimentologic, stratigraphic, and geochemical records. The comparison of isotopic and elemental data from different carbonate materials (matrix micrite, carbonate cements in veinlets, belemnite rostra, and ammonite shells) reveals differential diagenetic pathways. Microfacies, cathodoluminescence and geochemical data retrieved from biostratigraphically well constrained sections reveal that epioceanic matrix micrite geochemical data provide valuable proxies for palaeo-seawater properties. Our data are reviewed in the context of published Late Jurassic records. The outcome shows a higher level of complexity including the potential admixture of marine, continental, and diagenetic geochemical signals in the epicontinental record. The stratigraphic trend in carbon isotopes of epioceanic sections agrees upon that of Upper Jurassic reference sections from the northern Tethyan margins, while oxygen isotope ratios are relatively ^{18}O-enriched. Palaeo-seawater temperatures across the transect investigated were estimated using δ^{18}O as tentative proxy for interpreting distance from shore, differences in water masses, relative depth variations, and potential local forcing factors. Palaeoenvironmental conditions evaluated through the combined record of isotope (δ^{18}O), elemental (Mn), and skeletal content contrast with relative fluctuations in sea level. Site-specific changes in palaeoceanographic parameters such as water depth, seawater temperature, salinity and upwelling are considered in comparison to examples from ancient and modern oceans.

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1. Introduction

1.1. Characterizing ancient sea waters — a message from the present

The record of Earth's climate and changes in marine seawater properties through geological time is largely based on evidence provided by a wide range of proxies, usually lithofacies, fossil assemblages or geochemical information. In Earth sciences, observation and interpretation of geochemical data are commonly derived from one-dimensional section or core, or an averaged “composite curve” from several localities (e.g., Shackleton et al., 1993; Immenhauser et al., 2002; Weissert and Erba, 2004; Föllmi et al., 2006; Dera et al., 2011).

Whereas the fundamental validity of time-series data sets from particular sites is not questioned here, modern oceans clearly show complex, three-dimensional organization of water masses with space and time changes in physical–chemical seawater properties (Astraldi et al., 2002; Cardin et al., 2011; Turpin et al., 2012, 2014). Moreover, in coastal settings or in shallow epeiric seas, local influences modify regional or global signals, usually through relative changes in sea-level and climate fluctuations that drive changes in continental runoff (Holmden et al., 1998; Fanton et al., 2002; Panchuk et al., 2005; Dopieralska et al., 2006; Panchuk et al., 2006; Immenhauser et al., 2008). The complexity in trace elemental and isotopic properties of present day oceanic water masses stresses the relevance of spatial approaches, both when modern and ancient marine records are concerned.

Oceanographers deal with spatial records of modern marine dynamics at all scales, from global and latitudinal distribution of chemical elements in seawater and marine sediments (e.g., Elderfield, 2006; Dessai et al., 2011; Radic et al., 2011; Slemons et al., 2012), to their ocean or basin-wide characterization including the analysis of selected skeletal hardparts embedded in sediments (Chester, 2000; Lacan and Jeandel, 2001; Amini et al., 2004; Kato et al., 2011; Middag et al., 2011; Wei et al., 2012). Recently, the understanding of the three-dimensional structuring of present-day water masses and components of the related ocean/atmosphere coupling has been improved significantly (Cacho et al., 2000; Gutjahr et al., 2010; Voelker et al., 2010; Radic et al., 2011; van de Poll et al., 2013). On smaller scales, the environmental complexity of present-day proximal-to-distal transects has been demonstrated across particular shelves and basins (e.g., Great Bahama Bank; Swart and Eberli, 2005; Gischler et al., 2009; Swart et al., 2009; Turpin et al., 2012).

Despite the vast available information for modern day settings, attempts to interpret the spatial variation of ancient marine water masses from the proxy record of carbonate deposits point to a challenging, at present under-explored, research area. Late Jurassic examples mainly refer to selected epicontinental, intra-basin geochemical analyses of bulk and skeletal samples rarely covering the full duration of the Late Jurassic (Riboulleau et al., 1998; Bartolini et al., 2003; Lécuyer et al., 2003; Zakharov et al., 2005; Brigaud et al., 2008). Other workers focused on selected stratigraphic boundaries recorded in structured palaeo-margins (Rais et al., 2007) or through correlation of distant data provided by different authors (e.g., Žák et al., 2011). The inherent incompleteness of the stratigraphic record (e.g., Wetzel and Allia, 2000; El Kadiri, 2002; Dogan et al., 2006; McLaughlin et al., 2008), diagenetic alteration (Dickson and Coleman, 1980; Cicero and Lohmann, 2001; Morse et al., 2007; Macouin et al., 2012) and lateral discontinuity of facies belts (Bhattacharya, 2011) commonly limit attempts to reach a precise characterization of ancient water masses and to separate palaeoenvironmental signals from noise.

The present research approaches the chemostratigraphic characterization of ancient carbonates and related sea water properties along a proximal-to-distal transect connecting two major marine palaeoenvironments (i.e., neritic/epicontinental and epioceanic waters). To place the outcome in a broader context, a review of the palaeoenvironmental background during the Jurassic “greenhouse” world is relevant for establishing a link between major palaeoceanographic events and how they may relate to potentially recorded geochemical trends.

1.2. Palaeoceanography, sea-level fluctuations and variations in seawater geochemistry — a Late Jurassic background

Numerous palaeoclimatic interpretations of the Jurassic world have been published (e.g., Hallam et al., 1993; Abbink et al., 2001; Hallam, 2001; Gröcke et al., 2003; Cecca et al., 2005; Dera et al., 2009). Still, understanding the links between driving mechanisms and related climatic changes is complex (Hallam, 2001; Sellwood and Valdes, 2006) as exemplified in present oceans. Large-scale (global) modeling has provided useful latitudinal information. Examples include Boreal/Tethyan water mass characterization and general climate inferences (Hallam, 2001); latitudinal characterization of ocean temperature in relation to upwelling influence (Gröcke et al., 2003; Muttoni et al., 2005); or the establishment of latitudinal climate belts based on sedimentary and fossil records (Hallam et al., 1993). Concerning inter-tropical areas, it is not obvious if the temperature–depth structure of Late Jurassic oceans should be compared with that of modern tropical seas (Ziegler et al., 2003). Jurassic “greenhouse conditions” would argue for increased evaporation in low-latitude shallow seas (Ziegler et al., 2003) and the formation of Tethyan warm, saline bottom waters has been proposed (Arthur et al., 1987). As a consequence, the Jurassic Tethys Ocean most likely acted as source of warm and saline waters for much of the world's oceans (Kutzbach and Gallimore, 1989).