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Taphonomy and palaeoecology of high-stress benthic associations from the Upper Jurassic of Asturias, northern Spain

Franz Theodor Fürsich [a,*], Winfried Werner [b], Graciela Delvene [c], José Carlos García-Ramos [d], David D. Bermúdez-Rochas [e], Laura Piñuela [d]

[a] FG Paläoumwelt, GeoZentrum Nordbayern der Universität Erlangen, Loewenichstrasse 28, D-91054 Erlangen, Germany
[b] Bayerische Staatssammlung für Geologie und Paläontologie, Richard-Wagner-Strasse 10, D-80333 München, Germany
[c] Instituto Geológico y Minero de España, c/. Ríos Rosas, 23, 28003 Madrid, Spain
[d] Museo del Jurásico de Asturias (MUJA), E-33328 Colunga, Spain
[e] Área de Didáctica de las Ciencias Experimentales, Departamento de Educación, Universidad de Cantabria, Avda. de los Castros s/n. E-39005 Santander, Spain

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ABSTRACT

The late Kimmeridgian Tereñes Formation, exposed on the coast of Asturias, northern Spain, displays a complex pattern of directed changes of grain size, carbonate content, and skeletal concentrations. In its upper part, here investigated, the formation represents a protected shelf lagoon in which four major facies types are distinguished: The *Nanogyra virgula* mudstone (1) and the *Corbulomima* concentrations (2) are characterized by concentrations of small bivalves. The carbonate mudstone (3) contains pseudomorphs after gypsum crystals and thin crusts of gypsum, occasionally in connection with thin microbial layers. Finally, the silty to fine-sandy marlstone and micrite and marly silt (4) is highly bioturbated and contains a moderately diverse benthic macrofauna. These facies indicate a generally quiet environment punctuated by brief episodes of high water energy. Two low-diversity macrobenthic assemblages can be recognized, each of them strongly dominated by a single bivalve taxon. The *Nanogyra virgula* assemblage exhibits a higher diversity than the near-monospecific *Corbulomima* assemblage. The former lived in well aerated waters of slightly reduced salinity, and the latter in dysoxic waters of more strongly reduced salinity. The environmental stress responsible for the extremely low species richness and evenness is thought to be multifactorial, produced by reduced salinity, dysoxic conditions, and a soft substrate, and resulted in simple food chains. The eurytopic opportunist *Corbulomima* was the only element of the shelly macrobenthos that was able to thrive in the shelf lagoon under these conditions. It occurs in countless mm- to cm-thick pavements and shell beds which show evidence of winnowing, influence of weak currents, and occasionally of distal storms, as can be deduced from the orientation pattern of shells. These rhythmic *Corbulomima* concentrations are explained as reflecting small-scale climatic fluctuations between wetter, stormier conditions leading to mixing of the water masses and enabling colonization of the lagoonal floor by the bivalve, and drier, more tranquil conditions. The latter resulted in a stratified water mass and anoxia at the bottom. Superimposed on this rhythmic alternation are three higher orders of cycles which are partly climatic controlled, partly reflect changes in relative sea level.

1. Introduction

Palaeosynecological analysis of benthic macrofaunas has been demonstrated repeatedly to be a sensitive tool for reconstructing palaeoenvironments by defining controlling environmental parameters (e.g., Fürsich and Werner, 1986; Oschmann, 1988a; Aberhan, 1992). The approach works best when a particular environmental parameter such as salinity or oxygen is close to the tolerance boundary of the benthic fauna thereby controlling its distribution (e.g., Fürsich, 1981; Oschmann, 1988a). In this situation, the benthic macrofauna exhibits signs of environmental stress, which can be recognized in fossil community relicts by characteristic structural features such as greatly reduced diversity (e.g., Fürsich, 1981; Röhl, 1998). Although the recognition of stressed faunas in the fossil record is usually no problem, to recognize the nature of the stress factor commonly is, especially when the sediment does not yield specific information about particular environmental parameters.

The Upper Jurassic Tereñes Formation, well exposed in coastal cliffs of Asturias (Fig. 1), is a typical example of this dilemma. Concentrations of mono- to paucispecific molluscan faunas which, based on comparable faunas from the neighboring Lusitanian Basin of central Portugal, indicate reduced salinities (Fürsich, 1981; Fürsich and Werner, 1986),

* Corresponding author.
E-mail addresses: franz.fuersich@gzn.uni-erlangen.de (F.T. Fürsich), w.werner@lrz.uni-muenchen.de (W. Werner), g.delvene@igme.es (G. Delvene), jcgramos.muja@gmail.com (J.C. García-Ramos), bermudez.rochas@gmail.com (D.D. Bermúdez-Rochas), lpinuela.muja@gmail.com (L. Piñuela).

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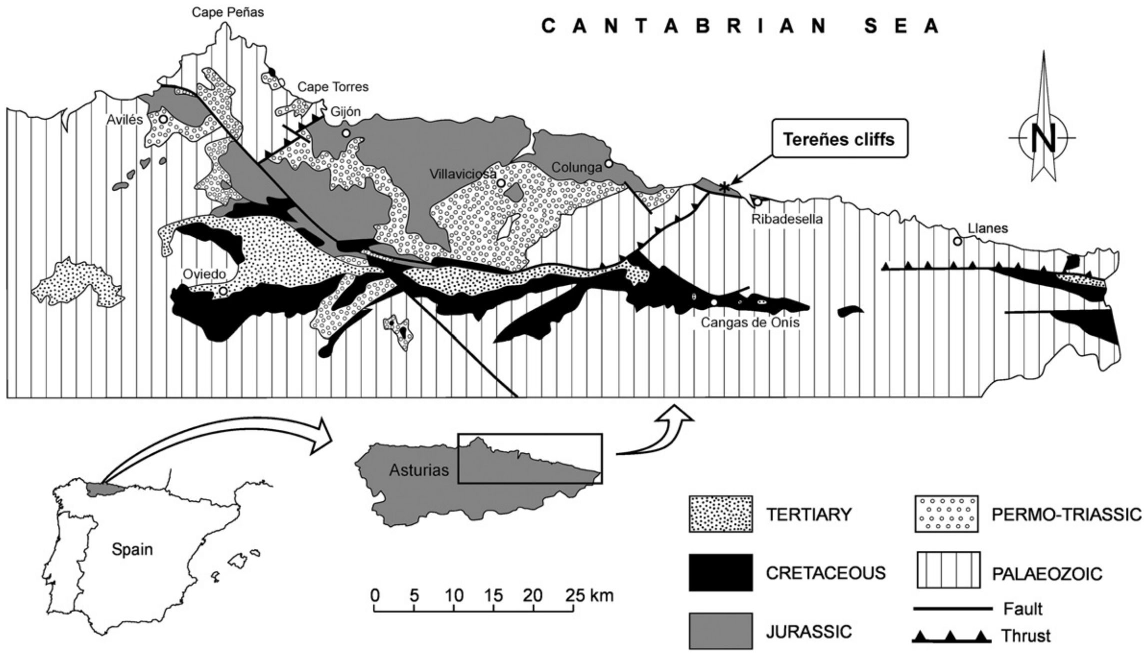

Fig. 1. Geologic sketch map with the distribution of the Mesozoic-Tertiary rocks in Asturias and location of the investigated section of the Tereñes Formation.

occur in very fine-grained (argillaceous to silty) sediments possibly indicating very soupy substrates. The dark colour, presence of abundant pyrite, and seemingly undisturbed laminations at many levels suggest lowered oxygen values, whereas the presence of carbonate mudstone levels rich in gypsum crystals and thin gypsum layers points to phases of hypersaline conditions. Thus, we have four environmental parameters (lowered and raised salinity, respectively, of the water body, a poorly oxygenated substrate and lowermost part of the water column, and a very soupy boundary layer at the sediment–water interface), which might have controlled the benthic macrofauna. Is the distribution pattern of the benthic fauna the result of a combination of all or several of these factors or does one of these factors strongly predominate? If so, which one is it?

It is the main purpose of this paper to demonstrate that these questions can be answered through a taphonomic and palaeoecological analysis of the benthic macrofauna in combination with a detailed analysis of the microfacies. Moreover, the origin of the cyclic repetition of the biofacies will be explained as caused by changes in relative sea level and climate.

2. Geological framework

Spectacular outcrops of Jurassic rocks extend along a practically continuous segment of the Asturian coast (NW Spain) between Cape Torres (west of Gijón) and 2 km east of Ribadesella (Fig. 1). The outcrops are terminated by important faults, which bring the Jurassic rocks in contact with the Palaeozoic basement (Fig. 1). The 900 to 1000 m-thick Jurassic succession has been divided into a lower carbonate-dominates part, Early to Middle Jurassic in age (Villaviciosa Group), and an upper, mostly siliciclastic Upper Jurassic (Kimmeridgian) part (Ribadesella Group) (Fig. 2). The two groups are separated by a high relief disconformity, produced by tectonic movements at the end of the Middle Jurassic.

The Ribadesella Group comprises the La Ñora, Vega, Tereñes, and Lastres formations. The siliceous conglomerates and sandstones of the La Ñora Formation, exposed only close to Gijón, represent alluvial fan deposits in the proximal parts of the basin; the basis of the formation filling palaeo-valleys eroded into the Lower-Middle Jurassic rocks. Towards the east, the La Ñora Formation gradually passes into an alternation of conglomerates, sandstones, and red mudstones of a meandering river system (Vega Formation). The latter formation passes gradually into the Tereñes Formation. The Tereñes Formation is predominantly composed of grey silty marls, countless shell beds, and micritic siltstones formed in a shelf-lagoon with supposed tectonic confinement. It is transitionally overlain by sandstones with intercalations of grey mudstones, including shell beds, of the Lastres Formation, which represent fluvial-dominated deltaic systems. Towards the west, i.e. the Gijón-Oles sector (Fig. 2), the latter formation replaces the Tereñes Formation (García-Ramos et al., 2010a).

The Tereñes Formation, 160 m in thickness, is the lateral and distal equivalent of the Lastres Formation (Fig. 2) and has been divided into three informal members, separated by minor erosional discontinuities (Fig. 3). The lower member, 20 m thick, consists of grey silty marls, limestones, sandstones, and occasional mud- and sand-supported calcareous intraformational conglomerates. Bivalve shell beds are only present at the base of the member; the upper half is characterized by the occurrence of several horizons of calcretes, rhizoliths, and rootlets. These features suggest a continental to coastal environment.

The middle member is only 10 m thick and is characterized by the common occurrence of dinosaur footprints. Bivalve shell beds and scattered gastropods are also common. Most of this member is organized in coarsening-upward hemicycles, in which the carbonate content increases upwards. Dinosaur footprints and mud cracks are found at the top of the cycles, which are interpreted as shallowing-sequences in a transitional environment.

The upper member that comprises most of the Tereñes Formation is 130 m thick. Silty clay and argillaceous siltstones with varying carbonate content and occasional carbonate concretions, interbedded with bivalve shell beds, are the most common lithologies. Occasionally, thin micritic limestone bands, commonly with thin streaks of gypsum, are present. Several discrete terrigenous intercalations occur in the upper 100 m of the formation, formed by centimetre-thick, normal-graded beds of sandstone or siltstone; they are interpreted as prodelta deposits, pointing to the proximity, in space and time, of deltas represented by the Lastres Formation. This upper member exhibits a complex hierarchy of cycles, the most conspicuous of which coarsen-upward, whereby the carbonate content increases and the density of shell beds decreases.

The succession studied here in detail belongs to the upper part of the upper member of the Tereñes Formation (Figs. 3–5). Based on ostracods, the formation has been dated as Late Kimmeridgian (Schudack and Schudack, 2002).