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Research paper

Integrated sequence stratigraphy: Facies, stable isotope and palynofacies analysis in a deeper epicontinental carbonate ramp (Late Jurassic, SW Germany)

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Abstract

Sequence stratigraphy in deeper water, epicontinental carbonates such as in the Upper Jurassic of southern Germany is difficult because the recognition of parasequences, sequences and sequence boundaries is impeded by the paucity in diagnostic sedimentological criteria or stratal surfaces. Using the "genetic stratigraphic" approach, and integrating facies, stable isotope (C, O) and palynofacies analysis two types of genetic depositional sequences can be discriminated: small-scale sequences are stacked into medium-scale sequences which may record a 400 kyr Milankovitch signal. The medium-scale sequences were correlated regionally using both gamma-ray logs and stable isotope records. Regional correlations show that the depocentres are controlled by underlying palaeotectonic elements (Late Palaeozoic troughs).

The rise/fall turnarounds of medium-scale sequences are marked by negative δ^{18}O peaks (temperature maxima) and reduced absolute palynoclast contents.

The fall/rise turnarounds are marked by positive δ^{18}O peaks (temperature minima) and high absolute palynoclast contents. The initiation and termination of sponge/microbial mounds show characteristic patterns: thrombolitic microbialites form during intervals of (1) reduced input of terrestrial palynomorphs interpreted as an increase in distality, (2) decreasing δ^{13}C trends interpreted to be related to decreasing nutrient supply and (3) decreasing δ^{18}O values interpreted as phases of warming and rising relative sea-level. In contrast, thrombolitic/stromatolitic microbialites were found to occur during phases of (1) increasing input of terrestrial palynomorphs interpreted as an increase in proximality, (2) increasing δ^{13}C values interpreted to reflect increasing terrestrial input and nutrient supply as well as increasing δ^{18}O values (interpreted as phases of cooling and relative

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sea-level falls). Isotopic and palynofacies evidence suggests that bioherms were terminated by sudden input of nutrients during relative sea-level falls.

Sedimentological criteria were clearly not sufficient to delineate a robust sequence stratigraphic framework.

Keywords: Upper Jurassic; Sequence stratigraphy; SW Germany; Sponge/microbial bioherm; Gamma-ray log; Palynology

1. Introduction

Deeper ramp, epeiric carbonates, deposited below and up to storm wave base such as the Upper Jurassic of southern Germany are relatively uniform in lithological character (Pawellek and Aigner, 2003b). These deposits are poor in diagnostic sedimentological criteria commonly used for the identification of sequence boundaries or maximum flooding surfaces. Thus, when applying classical sequence stratigraphic methods, sequence boundaries are difficult to delineate. This paper attempts to document sequence stratigraphic patterns characteristic for deeper ramp carbonates. Facies, sequence, stable isotope and palynofacies analysis were integrated, resulting in an improved understanding of depositional processes and palaeoenvironmental changes.

2. Geological framework

The Upper Jurassic of southern Germany is subdivided by a well-defined framework of lithostratigraphy (Quenstedt, 1858; Gygi, 2000a,b), biostratigraphy (Hantzpergue et al., 1998; Gygi, 2000a,b; Schweigert, 2000; Baier and Schweigert, 2001) and sequence stratigraphy (Hardenbol et al., 1998; Sharland et al., 2001; Taylor et al., 2001; Colombié, 2002; Hug, 2003; Pawellek and Aigner, 2003a). This study covers the Late Jurassic Transversarium to Pseudomutabilis (lower part) ammonite zones (Fig. 1). In the submediterranean realm the Pseudomutabilis zone covers the same time interval as the Eudoxus zone. However, according to Baier and Schweigert (2001), the top of the Eudoxus zone in southern Germany does not correspond to the top of the Eudoxus zone in Great Britain and France. Instead, the uppermost part of the British and French Eudoxus zone correlates with the lower part of the Tethyan/submediterranean Beckeri zone. To avoid confusion, Baier and Schweigert (2001) suggest to replace the term Eudoxus zone by Pseudomutabilis zone in the Tethyan/submediterranean realm.

The lithostratigraphic subdivision for southern Germany dating back to Quenstedt (1858) is used here because it proved to be very practicable in outcrop, core and gamma-ray log analysis. Furthermore in the Swabian Basin the lithostratigraphic boundaries defined by Quenstedt (1858) correlate with biostratigraphic boundaries (Schweigert, personal communication 2004). To achieve the best fit between lithostratigraphic and biostratigraphic zonations Schweigert (personal communication, 2004) suggests to use the Mutabilis zone instead of the Acanthicum zone as the Mutabilis zone is more sharply defined. The Divisum and Mutabilis zones cover a time-span of about 1.1 Ma (Hardenbol et al., 1998; Fig. 1). This time-span was used to determine the duration of the identified sequences.

During the Late Jurassic, the study area was located in the deeper part of a gently inclined carbonate ramp, below and up to storm wave base (Pawellek and Aigner, 2003b). It was inundated by an epicontinental shelf sea marginal to the Tethys Ocean in the South (Meyer and Schmidt-Kaler, 1989; Ziegler, 1990). Towards the North, it was separated from the boreal realm by the Rhenish and the London–Brabant Massifs. Two shallow-water platforms flanked the study area: the Swiss Platform in the Southwest and the Franconian Platform in the East (Fig. 2). Between these two platforms the more basinal Swabian facies developed. The Swabian realm is characterized by two main lithofacies types: (1) well-bedded limestones alternating with marls and (2) sponge–microbial bioherms or mounds (Gwinner, 1976; Ziegler, 1977). Clastic input was mainly