Palaeogeography, Palaeoclimatology, Palaeoecology 433 (2015) 20–48

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Deciphering the history of climate and sea level in the Kimmeridgian deposits of Bure (eastern Paris Basin)

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ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form 6 May 2015
Accepted 19 May 2015
Available online 27 May 2015

Keywords:
Jurassic
Kimmeridgian
Sea level
Climate
Palaeoenvironment
Paris Basin

ABSTRACT

An integrated stratigraphic study was conducted on a Kimmeridgian succession of 3rd-order cycles including marls and limestones in a shelf context at Bure (Paris Basin). The study was possible due to the exceptional opportunity provided by well-boring activities related to the construction of an underground laboratory of the French National Agency for Radioactive Waste Management (ANDRA). Studies of macrofossils, microfossils, sedimentology, clay mineralogy, isotopic composition (C, O) of shells and organic molecular geochemistry lead to a detailed description of the stratigraphic column, which allows us to address the history of sea-level and climate changes. Six transgressive–regressive cycles are recognised in the studied Kimmeridgian succession. In these 3rd-order cycles, the deepest environments are systematically represented by marls and organic-rich sediments whilst the shallowest are represented by limestones. These cycles do not correspond to changes in temperatures or carbonate production rates at a regional or global scale. On the contrary, long-term palaeontological, sedimentological, and geochemical changes during the Early Kimmeridgian are interpreted as climatically induced. These climatic changes are considered as responsible for bringing significant granular carbonate production to an end, in contrast to carbonate mud that was deposited in alternation with marls throughout the Late Kimmeridgian.

1. Introduction

To build an underground scientific research laboratory at Bure (Lorraine, France), the French National Agency for Radioactive Waste Management (ANDRA) has created two wide shafts (5 m in diameter), connecting the surface to underground facilities at an approximate depth of 490 m. Mining operations have provided large amounts of fossiliferous rocks from Early Oxfordian to Early Tithonian age, which were analysed in a multidisciplinary study. The sinking of this shaft offered a unique opportunity to compare and confront data from macroscopic rock analyses (e.g., macrofossils, sedimentary structures) with well data (e.g., well logging, organic geochemistry). Furthermore, it is impossible to find a 500-m-high outcrop of a single vertical section anywhere in the Paris Basin that crosscuts the all Kimmeridgian and Oxfordian stages; this complete succession of marls and limestones can only be logged at the Bure underground laboratory site.

This exceptional situation was used to test various issues of wide interest in palaeoenvironmental sciences. The main target of the present study is to understand the palaeoecological and sequential significance of claystones in the context of a carbonate platform. Do these deposits record periods of low sea level during which the erosion of emergent land areas increased (e.g., Meng et al., 1997; Saltzman, 1999)? Or were these clays deposited during periods when the sea level was so high that the carbonate factory could not function (e.g., Szulczewski et al., 1996; Kindler et al., 2006). Another possibility is that alternating clays and carbonates result from climatic shifts in temperature and humidity. Thus, changes in seawater surface temperature as well as nutrient input, which is often associated to clay input inhibiting carbonate production, could be the main factors controlling clay/carbonate

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http://dx.doi.org/10.1016/j.palaeo.2015.05.007
0031-0182/

sedimentation rather than significant variations in relative sea level (e.g., Droxler et al., 1998; Wilmsen, 2000; Mutti and Hallock, 2003; John and Mutti, 2005; Coffey and Read, 2007). On the contrary, should intercalated carbonates be considered as resulting from higher skeletal productivity on the platform during high sea-level stands (e.g., Ehrenberg et al., 2006) or does the production of carbonate stem from a shallowing of the platform in the carbonate window (e.g., Brachert et al., 2003; Kindler et al., 2006)?

2. Geological setting

The village of Bure is located in the eastern part of the Paris Basin, 100 km south–west of Nancy. The surface facilities of the laboratory are built on the basal Tithonian limestones belonging to an extensive outcrop belt of Late Jurassic deposits (Fig. 1). The Paris Basin is usually considered as an intracratonic basin formed during a regime of decreased thermal subsidence, and the Kimmeridgian stage corresponds to a period of rapid creation of accommodation space (Guillocheau et al., 2000). The laboratory is sited in an area forming part of the Saxo-Thuringian zone of the Hercynian orogenic belt, within a stable compartment bounded by the Gondrecourt Graben and by the Marne Faults. The activation of these inherited structures is classically attributed to the Oligocene, but an older heritage should be considered at least for the Marne Faults (André, 2003). Some evidence of Jurassic movements has been recorded (André et al., 2004). Nevertheless, compared to the underlying Oxfordian stage, the Kimmeridgian stratigraphic record obtained from well logging data in the Paris Basin is remarkably constant over large areas. However, Hantzpergue (1985) has documented variations in thicknesses over wide distances, which can be inferred as being due to weak deformation at the scale of the basin.

During the Kimmeridgian, the Paris Basin corresponded to a wide and flat platform mostly oscillating between infralittoral and circalittoral environments (Cecca et al., 1993; Thierry, 2000). This platform corresponds to an intermediate biogeographical area between the Subboreal and Submediterrenean bioprovinces (Hantzpergue, 1989). Detailed analysis shows that ammonite faunas in this area show alternately Tethyan and Boreal influences, and sometimes the episodic development of short-lived endemic lineages (Hantzpergue, 1995).

The lithostratigraphic framework of the Kimmeridgian in the eastern Paris Basin is given in Fig. 2, which also takes new palaeontological observations from Bure into account.

3. Material, methods and results

The data of this study are derived mainly from the rocks extracted during the sinking of the shafts from 2001 to 2006. Most of the samples come from the principal access shaft (labelled PPA, with samples numbered from PPA1021 to PPA1076). The auxiliary shaft (PAX) situated at about 80 m from the principal access shaft provided additional material (referred to here as samples PAX 1009 to PAX 1020). The samples were taken with a vertical resolution of 2–3 m corresponding to the steps of the sinking carried out by explosives. Some samples for studying palynology, clays and organic matter were collected with higher resolution

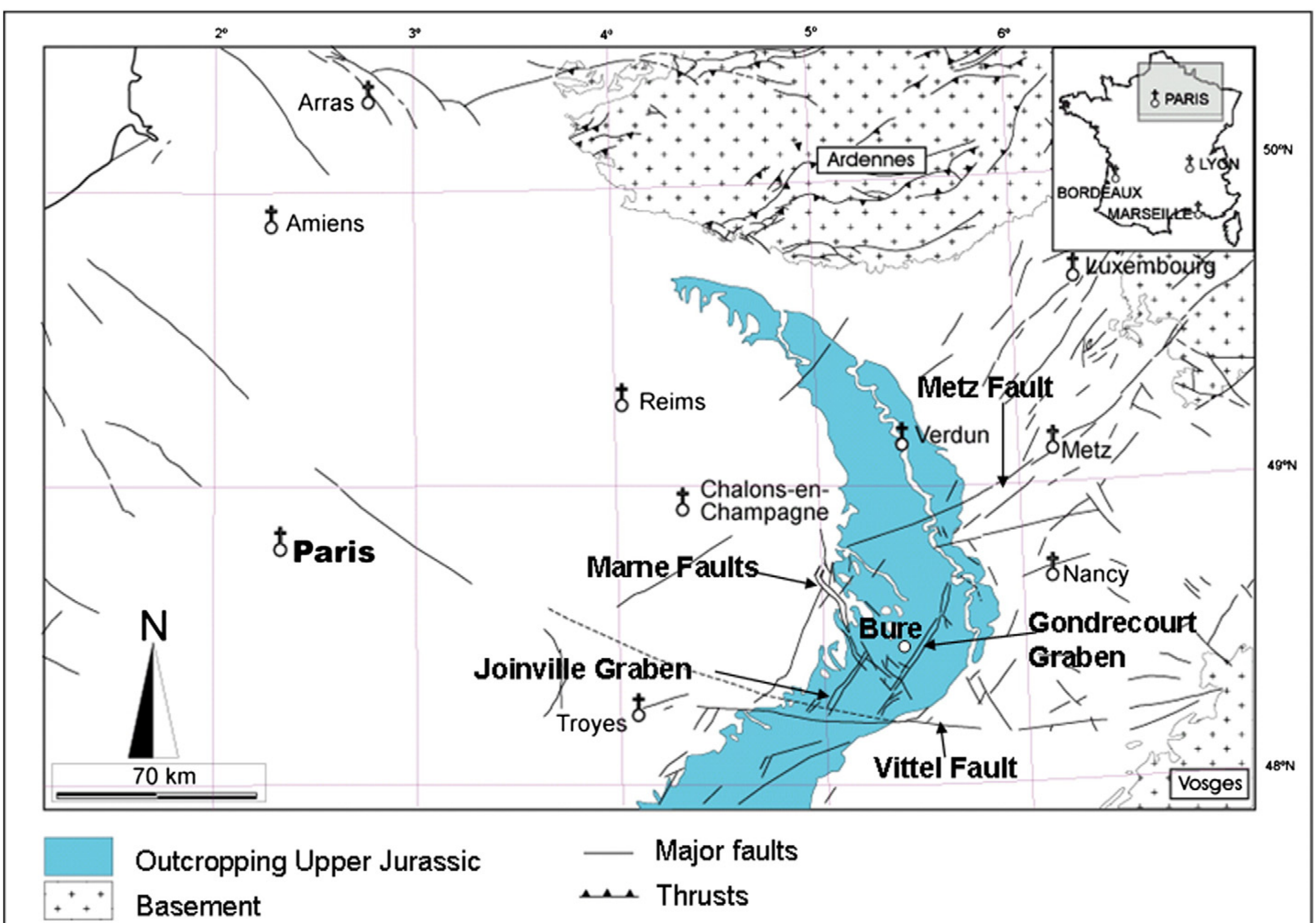

Fig. 1. Geological setting of Bure (France).