CORRESPONDENCE

δ¹³C Variations in Late Jurassic Carbonates, Jaisalmer Formation, Western India

Anil Maheshwari ¹*, A.N. Sial², S.C. Mathur³ and R.P. Tripathi⁴

¹ Department of Geology, University of Rajasthan, Jaipur - 4, India
² NEG-LABISE, Department of Geology, UFPE, Recife, Brazil
³ Department of Geology, J.N.V. University, Jodhpur, India
⁴ Department of Physics, University of Jodhpur, Jodhpur, India

* Corresponding author

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Abstract

The carbon isotope measurements, carried out on subsurface carbonate samples from Oxfordian Jaisalmer Formation, western India, yield positive δ¹³C values up to +3.17‰. The most positive Oxfordian C-isotope value corresponds to the carbon isotope excursion measured in samples from other late Jurassic basins of the world. The latest Oxfordian C-isotope values fluctuate around 2‰ while the C-isotope values of 1.50‰ mark the base of Kimmeridgian. The Oxfordian C-isotope excursion appears to correspond to a time of overall increased organic carbon burial triggered by increased nutrient transfer from continents to oceans during a time of rising global sea level.

Key words: Carbon isotopes, Oxfordian Jaisalmer Formation, palaeoenvironment, carbonates, Ghotaru.

Introduction

The history of atmospheric CO₂ levels and of the global carbon cycle is mirrored in marine carbonate carbon isotope curves. Fluctuations in δ¹³C can be explained by variable Cₑₐ₉/Cₑ₉ export ratios into the marine sedimentary carbon reservoir (Schidlowski, 1987). Times of intensified biological carbon pumping and of high C org burial rates are commonly linked to perturbations of the atmospheric carbon reservoir and to greenhouse climate. Positive δ¹³C-excursions may be regarded as response signals of perturbations of global climate linked to fluctuations in atmospheric carbon dioxide concentrations (Weissert, 1989).

The late Jurassic was not only a time of increased organic carbon burial but it was also a time which was favourable for reef growth and for increased accumulation of carbonate carbon (Budyko et al., 1987). The late Jurassic carbonate carbon isotope record mirrors the response of the marine organic and carbonate carbon pumps to changing climate. The excessive burial of organic carbon at times of high carbonate accumulation rates was triggered by a greenhouse climate combined with a monsoonal rainfall pattern controlled by the break-up of the pangea supercontinent during the late Jurassic (Parrish, 1993). Intensified seafloor spreading and volcanic activity impacted Jurassic climate through the increased flux of volcanic CO₂ to the atmosphere, as suggested by a number of GCM-palæoclimatic models (Moore et al., 1992) and by geochemical models (Berner, 1994).

The Jaisalmer Formation in western India consists of a thick sequence of cream, buff and brown-coloured, commonly fossil-bearing limestone along with oolitic limestone and greyish brown sandstone. The formation occurs extensively on the surface and is also encountered in the subsurface. The thickness of the Jaisalmer Formation ranges between 120 m to 170 m. The subsurface data however, indicate more thickness. In the subsurface the formation has two distinct lithounits. The upper carbonate unit comprises grey to buff limestone, oolitic near top. The intercalation of shale and oolitic bands are frequent within this sequence. The lower unit mainly comprises calcareous sandstone and shale with thin limestone.
intercalation. The limestone beds are generally horizontal or nearly horizontal.

The Jaisalmer Formation is divided into five members, which are named after the localities of their best development namely Kuldhar, Badabagh, Fort, Hamira and Joyan Members. Rich fossil assemblage has been reported from the top most Kuldhar Member which includes *Reineckeria* sp., *Indosphinctes* sp. and *Dhosaites aff. D. otoibides*, etc. Dave and Chatterjee (1996) have recognised three foraminiferal and five Ammonoite zones suggesting Callovian to Oxfordian age. The Jaisalmer Formation is the most fossiliferous Jurassic formation in the region. A shallow marine environment of deposition of the Jaisalmer formation is indicated by the development of fossil bearing limestone-arenaceous limestone sequence without shale beds (Singh, 1996). Marine depositional environment is also indicated by the fair distribution of conifer pollens and the presence of *Hystrochosphaeridium* within the formation.

**Isotopic Data and Discussion**

Bulk subsurface samples were chosen from Ghotaru bore hole section (Fig. 1) for the establishment of a C isotope stratigraphy of the late Jurassic Jaisalmer Formation. A total of 12 carbonate samples were selected. CO$_2$ was extracted from carbonates in a high vacuum line after reaction with phosphoric acid at 25°C, and cryogenically cleaned, according to the method described by Craig (1957). CO$_2$ gas released by this method was analyzed for O and C isotopes in a double inlet, triple collector V.G. ISOTECH mass spectrometer, using the reference gas BSC (Borborema Skarn Calcite) that is calibrated against NBS-18, NBS-19 and NBS-20, has a δ$^{18}$O value of $-11.28\pm0.004\%$ PDB and δ$^{13}$C = $-8.58\pm0.02\%$ PDB. The results are expressed in the δ-notation in parts per thousand in relation to international PDB scale.

The C isotope data are provided in Table 1. The isotope data are graphically summarized in figure 2. The sedimentary rocks carrying the Oxfordian C-isotope signal are preserved in the Jaisalmer Formation of western India. The measured carbon isotope record starts with a positive shift starting within the Oxfordian. The most positive Oxfordian values fall within a range of $+2.9\%$ to $+3.1\%$ which corresponds to a synchronous carbon isotope excursion measured in samples from the Swiss Jura Mountains (Bill et al., 1995). The oxygen isotope values fluctuate between $-3.0\%$ and $-4.23\%$ in the carbonates from the Jaisalmer Formation. Heydari et al. (1993) analysed late Oxfordian sediments from the Smackover Formation and they report C-isotope compositions reaching values of up to δ$^{13}$C = $+3\%$ to 6‰.

Jenkyns (1995) identified a prominent C-isotope excursion falling within the *transversarium* zone and reaching carbon isotope values of more than $+3\%$ in sections from the southern Tethyan margin. The observed variations in the late Jurassic carbonate carbon isotope record may reflect changes in Jurassic marine carbon cycle. Times marked with more positive C-isotope compositions should correspond to times of a higher organic carbonate/carbon burial ratio (Schidlowski, 1987). The long-term oceanic carbon isotope budget should reach a balance if average river carbon input is balanced by carbon and carbonate export into the sedimentary sink. The measured carbon isotope values fluctuates around $2\%$ in the latest Oxfordian and the early Kimmeridgian represented by Baisakhi Shales in Jaisalmer Basin is represented by lower C-isotope values $\sim 1.5\%$.

Globally, the major organic carbon-rich deposits show major peaks in the late Oxfordian, the Kimmeridgian and in the early Tithonian. Major sinks for organic-rich sediments were the cratonic Siberian basin (Oxfordian and Volgian/Tithonian age, Nesterov et al., 1990), the North American Gulf Coast (Smackover Formation, late Oxfordian; Failes, 1990) and the Arabian shield. The widespread occurrence of organic carbon-rich sediments can be explained as a result of high productivity and/or limited deep water renewal and widespread low oxygen conditions and/or elevated sedimentation rates with improved preservation of marine and terrestrial organic carbon.
samples from Oxfordian Jaisalmer Formation, western India, yield positive δ¹³C values up to +3.17‰. The most positive Oxfordian C-isotope value corresponds to the carbon isotope excursion measured in samples from other late Jurassic basins of world. The latest Oxfordian C-isotope values of Jaisalmer Basin fluctuate around 2‰ while the C-isotope values of 1.50‰ mark the base of Kimmeridgian. The Oxfordian C-isotope excursion appears to correspond to a time of overall increased organic carbon burial triggered by increased nutrient transfer from continents to oceans during a time of rising global sea level.

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References


Deolapar area has attracted attention of Precambrian geologists of India for report of a nappe structure by West (1936), mainly on the basis of stratigraphic omissions and inversions in the Sausar Group. In a recently published paper, Chattopadhyay et al. (2003) have tried to solve the problem of nappe controversy by remapping the area around Deolapar. However, when we compare the map published by West (1936) on a scale larger than that of Chattopadhyay et al. (2003), it becomes clear that some of the metasedimentary units (Chorbaoli Formation and Junewani Formation) mapped by West (1936) show westward closures between Kadbikhera and Khapa, but these have been regrouped as Tirodi Gneiss by Chattopadhyay et al. (2003) without any closures. No explanation is available for this change. In addition, the paper by Chattopadhyay et al. (2003) has the following lacunae, which require clarification.

Evidence of Thrusting

The authors have stated that the basement block shows evidence of shearing (p. 109, col. 2, 5th line from the bottom), but neither attempt was made to decipher the sense of shearing from the foliated fabric nor the orientation of any lineation related to shearing is reported. Subsequently the authors have stated that typical fault shear zone rocks are absent in the area (p. 115, col. 2, line 1-4). The only evidence of thrusting is mentioned to be a ‘fibrolite-biotite schist’, mapped at the contact of the Tirodi Gneiss (basement block) and the adjacent supracrustal rocks (Sausar Group). The authors considered that the granitic rocks of the basement were considerably modified by fluid flow during thrusting to give rise to aluminum-rich protoliths, which were modified to give the fibrolite biotite schists. However, alternative explanation (cf. Mohanty, 1993) for the development of such aluminum-rich protoliths by weathering and leaching of the granitic basement rocks (development of palaeosol) before the deposition of the Sausar Group is possible. This alternative explanation would explain the absence of any shear zone rocks along the contact of the basement and cover rocks. The authors have not given any reason against such a possibility.

Evidence for Unconformable Relation

Chattopadhyay et al. (2003a) state that “Typical