Sonderdruck aus

# Beringeria

Würzburger geowissenschaftliche Mitteilungen

Heft 37
2007

# Miscellanea Wirceburgensis - Franz T. Fürsich zum 60. Geburtstag

Sequence stratigraphic framework of Lower to lower Middle Jurassic sediments of the Jaisalmer Basin, India

DHIRENDRA K. PANDEY & SHIPRA CHOUDHARY 121-131

Würzburg 2007

# Sequence stratigraphic framework of Lower to lower Middle Jurassic sediments of the Jaisalmer Basin, India

DHIRENDRA K. PANDEY & SHIPRA CHOUDHARY

PANDEY, D.K. & CHOUDHARY, S. 2007. Sequence stratigraphic framework of Lower to lower Middle Jurassic sediments of the Jaisalmer Basin, India. – Beringeria **37**: 121-131, 7 text-figs, 1 pl., 1 tab.; Würzburg.

**Abstract**. The Middle Jurassic sea transgressed the Rajasthan shelf simultaneously to the neighbouring Kachchh Basin on the western part of the Indian Craton. Structurally, the part of the Rajasthan shelf which records marine Jurassic sediments has been termed as the Jaisalmer Basin. The sediments in the basin range from non-marine siliciclastics to brackish/marine mixed siliciclastic-carbonate muds. Lithostratigraphically, these sediments have been grouped into the Lathi, Jaisalmer, Baisakhi and Bhadasar formations, in ascending order. Of these, the two older formations represent the first transgressive/regressive cycle ranging from the Lower Jurassic to the Upper Jurassic (Oxfordian). Well cemented, fossiliferous carbonate units represent the peak transgressive events, whereas thick, cross-bedded, non-fossiliferous sandstone units predominantly characterize regressive units. Within the Early Jurassic–Bathonian (Middle Jurassic) time interval, a total of 91 parasequences of fourth order are recognized that have been grouped into 18 sequence cycles of third order. The sequence cycles predominantly consist of transgressive (TST) and highstand systems tracts (HST). The sequence stratigraphic framework reveals that the time interval between the Early and Middle Jurassic (i.e. up to Middle Bajocian) records weak trangressive events which are represented by thin carbonate-rich units, whereas the Late Bajocian time interval, represented by thick rudstone units, documents the first peak of transgression. Similarly, the upper part of the Bathonian records another peak of transgression. A gradual increase in the deepening of the basin and deposition of marine sediments from the Late Bajocian to Late Bathonian is recorded. The character of the sediments deposited during the HST and the absence of any evidence of major change in the tectonic setting in the basin suggest that climatic change has played a main role in the relative sea-level change along with variations in sediment supply.

■ *Lower Jurassic, Middle Jurassic, sequence stratigraphy, Jaisalmer Basin, Lathi Formation, Jaisalmer Formation*

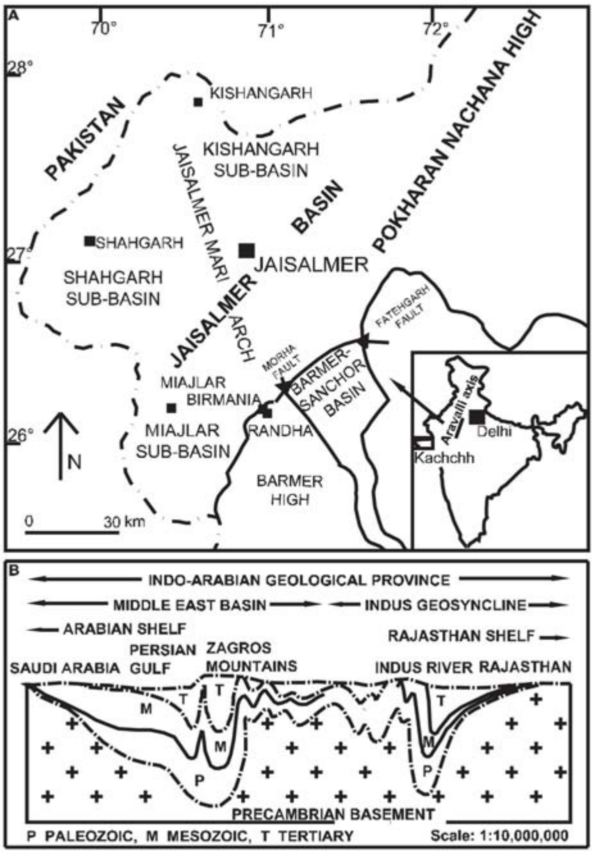
Addresses of the authors: DHIRENDRA K. PANDEY, SHIPRA CHOUDHARY, Department of Geology, University of Rajasthan, Jaipur 302004, Rajasthan, India; <dhirendrap@satyam.net.in>.

## 1 Introduction

The pericratonic Jaisalmer Basin, situated to the west of the Aravalli axis on the western part of the Indian craton, formed the easternmost part of „Indo-Arabean Geological Province“ (Text-fig. 1). The basin has attracted the attention of geologists, palaeontologists and several other non-professionals owing to its rich record of well preserved Jurassic to Tertiary fossils. Recently, the basin has also been proved its potential for fuel oil and gas reserves (ONGC unpublished report 1963, SHRIVASTAVA 1971, DATTA 1983). However, in terms of stratigraphic studies, the basin is still poorly explored, e.g. no sequence stratigraphic framework for the basin is available. The sediments of the basin fill document a prolonged time interval (Jurassic to the Recent) and both, surface and subsurface data offer the potential for resolving several stratigraphic problems, e.g. pertaining to global Jurassic sea-level events and Jurassic-Cretaceous and Cretaceous-Tertiary (K/T) boundary problems.

## 2 Geological framework

The Jurassic sea inundated the basin during the Bajocian simultaneously to the neighbouring Kachchh Basin (SINGH et al. 1982, PANDEY et al. 2006a). However, as evident from gradual lateral change in the character and thickness of the facies, the basin has hitherto been considered a shelf basin in contrast to the neighbouring rift basin of




Text-fig. 1. A. Structural units of the Jaisalmer Basin (modified after Misra et al. 1993). B Geological section across the Indo-Arabian geological province (modified after Gansser 1964, Kaye 1970, Rehman 1963, Shrivastava 1992).

| Formation | Member | Age |
|---|---|---|
| Jaisalmer Formation | Jajiya Member | Callovian to Oxfordian |
| | Kuldhar Member | |
| | Badabag Member | Bajocian to Bathonian |
| | Fort Member | |
| | Joyan Member | |
| | Hamira Member | |
| **Lathi Formation** | Thaiat Member | Lower Jurassic |
| | Odania Member | |

Basement rocks (Proterozoic / Cambrian / Permian–Triassic)

Table 1. Lithostratigraphic classification of Lower Jurassic–Upper Jurassic (Oxfordian) sediments, Jaisalmer Basin, western India.

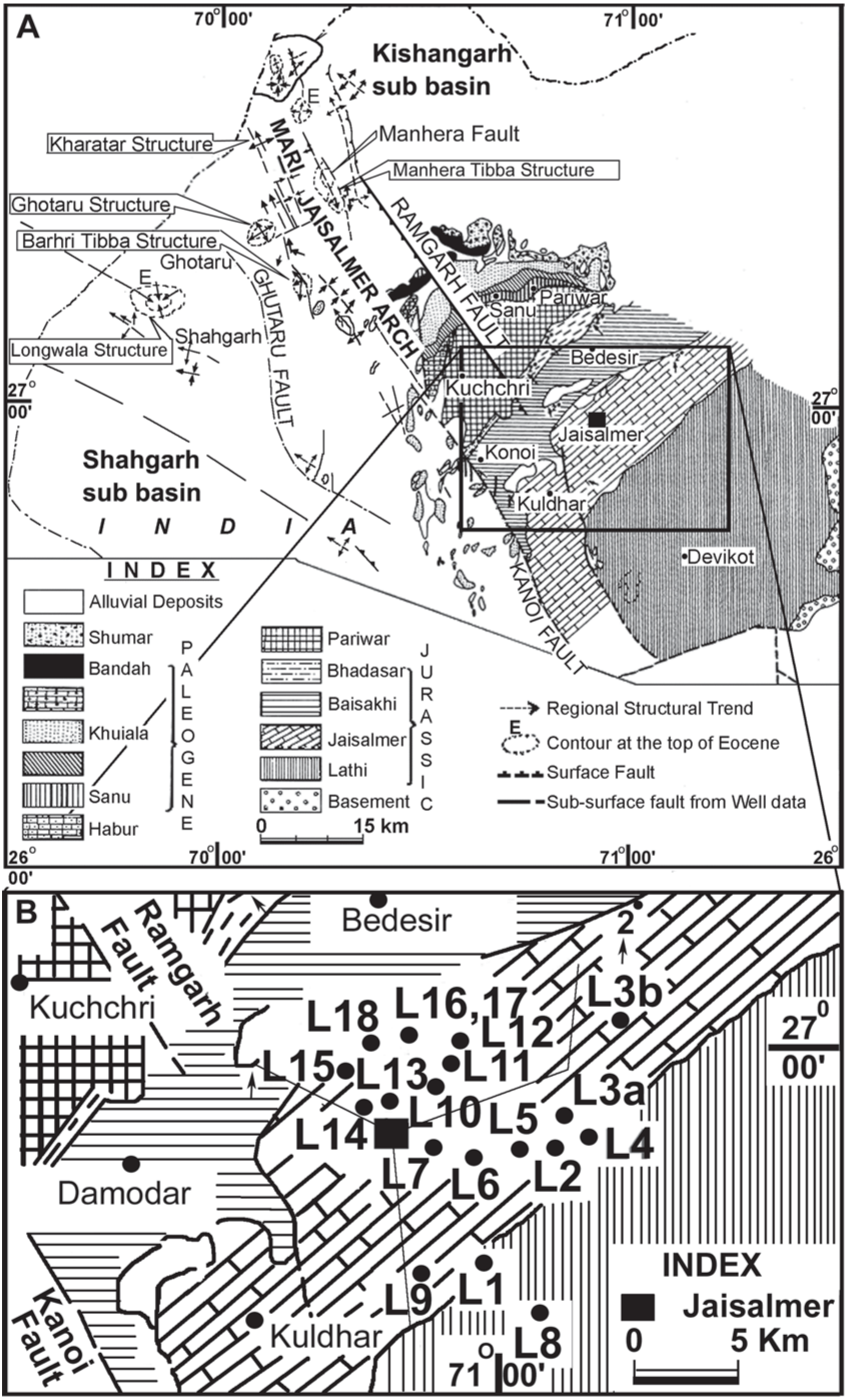
Kachchh (Biswas 1982, 1991, Fürsich et al. 2001). The sediments of the Jaisalmer Basin range from non-marine sandstones and conglomerates to nearshore, littoral, brackish to marine sands, silts, clays and carbonates. Structurally, the basin has been subdivided into four units (Text-fig. 1) as revealed by geophysical investigations conducted by the Oil and Natural Gas Commission (Raghavendra Rao 1972, Sinha et al. 1993, Singh et al. 2005). The Jurassic sediments are best exposed on the southeastern part of the raised Mari-Jaisalmer Arch extending through the central part of the basin.

Lithostratigraphically, the strata have been grouped into the Lathi, Jaisalmer, Baisakhi, and Bhadasar formations in ascending order (Tab. 1, Text-fig. 2, Das Gupta 1975, Pandey et al. 2005, 2006a, b). The thickness of individual formations ranges from 70-1000 m (Swaminathan et al. 1959, Das Gupta 1975, Pareek 1984). The two older formations represent the first transgressive/regressive megacycle ranging from the Lower to the Upper Jurassic (i.e. up to the Oxfordian). These sediments comprise non-marine siliciclastics to brackish-marine, mixed siliciclastic-carbonate muds. The general dip of the beds is gentle of about 2° towards the northwest. There are a few post-Mesozoic faults cross cutting each other.

## 3 Methods

The lithological sections studied in the field were interpreted in terms of sedimentary facies and sequence stratigraphy. The most significant features which were used for the recognition of parasequences and the different systems tracts include observations regarding the geometry of rock units and their bounding surfaces, lateral variations in microfacies, sedimentary structures, biodiversity, degree of bioturbation, ichnofabrics and taphonomy. Also biogenic hardparts which, usually, carry a wealth of ecological and taphonomic information, are of potential use for identifying sequence stratigraphic boundaries and units (e.g. Fürsich & Pandey 2003). Distribution, orientation, diversity and relationships of trace fossils with respect to stratal surfaces are of great importance in the understanding of several environmental parameters of the depositional environment such as oxygen availability, salinity, substrate consistency, bottom water energy, rate of deposition, sediment supply, type of organic matter and erosional surfaces. Bioturbated beds, in most cases, suggest deposition below fair weather wave base with low rate of sediment influx.

In all 18 investigated sections (L1-L18, see Text-fig. 2B) through Lower to the Upper Jurassic (i.e. up to the Oxfordian) Lathi and Jaisalmer formations, exposed on the southeastern part of the raised Mari-Jaisalmer Arch on the east and southeast as well as north and northeast of Jaisalmer, have been measured bed-by-bed and lithological characters, sedimentary structures and fossil con-




Text-fig. 2. A. Geological map of the Jaisalmer Basin (after Das Gupta 1975). B. Locations of the sections measured in the Bajocian–Bathonian Lathi and Jaisalmer formations.

tents have been recorded systematically. The majority of the sequences has been measured along cliff sections (height up to 30 m), only in a few cases long-distance transects have been taken. Laterally, these cliffs can be traced for a few kilometers. Since the dip of the beds is not very large, several opportunities to observe the top bedding surfaces of cap-rocks (mostly well cemented pack- to rudstones) were available. In some cases it was difficult to trace beds laterally for more than a few meters either due to poor cementation or because they were covered with scree material.

The most significant and conspicuous sedimentary features recorded during the investigation are non-marine followed by marine sequences (Pl. 1B, see also Text-fig. 4, PANDEY et al. 2006a, b), erosive surfaces (Pl. 1C, PANDEY et al. 2006b), hardground surfaces (PANDEY et al. 2007), sedimentary structures including hummocky cross-beds (PANDEY et al. 2007), shallowing hemicycles, alternating bioturbated (Pl. 1D, G, H) and cross-bedded units (Pl. 1E, F), alternating poorly cemented siliciclastic and well cemented carbonate units (Pl. 1A, PANDEY et al. 2006a) and alternating richly and poorly fossiliferous units. In total, 13 sedimentary facies within the Lower–Middle Jurassic (up to Bathonian) sequence have been recognized. The lateral continuity of the sedimentary facies is shown in Text-figs. 4-7. These facies boundaries facilitated the correlation of parasequences and sedimentary sequence cycles.

In total, 91 parasequences of fourth order and 18 sequence cycles of third order have been recognized. Out of the four systems tracts constituting complete depositional sequences, the falling stage systems tract (FSST) and the lowstand systems tract (LST) were not recognized in the sequences studied here. The possibility of preserving lowstand deposits is generally low in a shallow water shelf basin. The recognition of parasequence of the FSST seems to be difficult due to limitation of the outcrops. Thus, the transgressive systems tract (TST) and highstand systems tract (HST) are the building blocks of the studied sequences.

## 4 Sequence stratigraphy

The Jurassic outcrops of the Lathi and Jaisalmer formations have been broadly subdivided into three sub-areas, based on comparable sequences and continuity of outcrops (Text-fig. 2). For two of these areas, i.e. east/southeast and north/northeast of Jaisalmer, comparable sequence sets have been illustrated in Text-figs. 4-7. The sequence stratigraphic framework and the correlation of individual systems tracts within each comparable succession are given below.

### 4.1 Sequence stratigraphic framework of the Jurassic east and southeast of Jaisalmer

These sections correspond to the Thaiat Member of the Lathi Formation and Hamira and Joyan members of the Jaisalmer Formation (Tab. 1, Text-figs. 4, 5). They represent the Early to Middle Jurassic (up to the Late Bajocian) time interval (KACHHARA & JODHAWAT 1981, PANDEY & FÜRSICH 1994) in the Jaisalmer Basin and expose the complete Thaiat Member and the greater part of the Joyan

## EXPLANATION OF PLATE 1

Fig. A. Panoramic view of a rudstone unit representing the TST of sequence cycle 9 (Bathonian) exposed at Bara bagh. Note Bara bagh cenotaphs in the background.

Fig. B. Fort section exposed 3 km northeast of Jaisalmer Fort representing at least five sequence cycles (section L11 in Text-fig. 6). The basal non-marine sandstone (HST) is overlain by fully marine sequences.

Fig. C. Close-up view of well cemented alternating mud- to packstone overlain by a rudstone with erosional surfaces (TST) exposed 11 km south of Jaisalmer, uppermost part Joyan Member, Jaisalmer Formation.

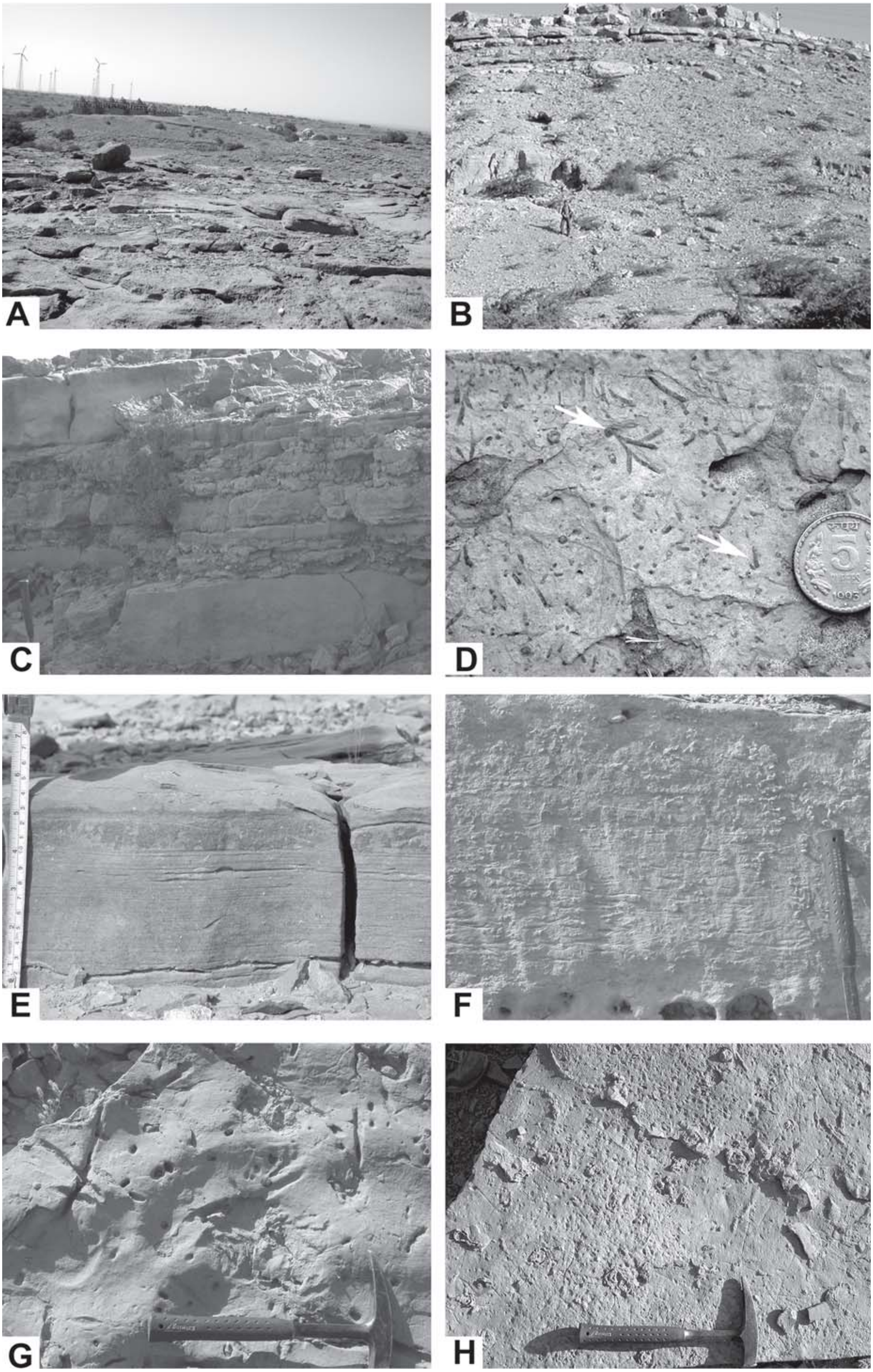
Fig. D. Close-up view of *Chondrites* and *Rhizocorallium irregulare* on the upper surface of bioturbated calcareous mudstone, exposed 11.5 km southeast of Jaisalmer, Joyan Member, Jaisalmer Formation.

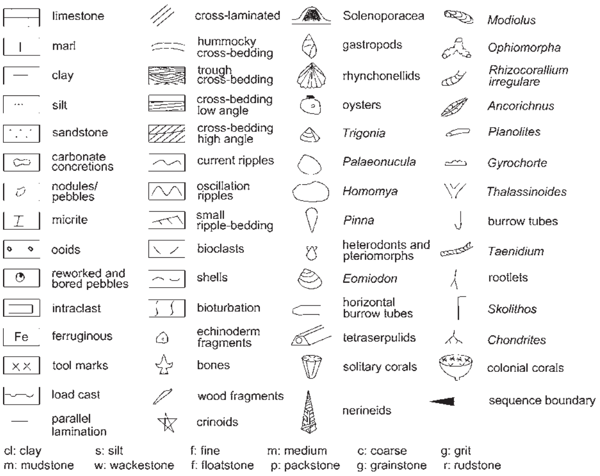
Fig. E. Close-up view of low angle trough cross-lamination in well cemented fine-grained calcareous sandstone, exposed 11.5 km southeast of Jaisalmer, Joyan Member, Jaisalmer Formation.

Fig. F. Close-up view of low angle cross-bedding in the upper part of the fine-grained calcareous sandstone, exposed 11.5 km southeast of Jaisalmer, Joyan Member, Jaisalmer Formation.

Fig. G. *Rhizocorallium* sp. on the lower undulated surface of a fine-grained calcareous sandstone, Joyan Member, Jaisalmer Formation, Jaisalmer.

Fig. H. *Rosselia* sp. on the lower surface of a fine-grained calcareous sandstone, Joyan Member, Jaisalmer Formation, Jaisalmer.

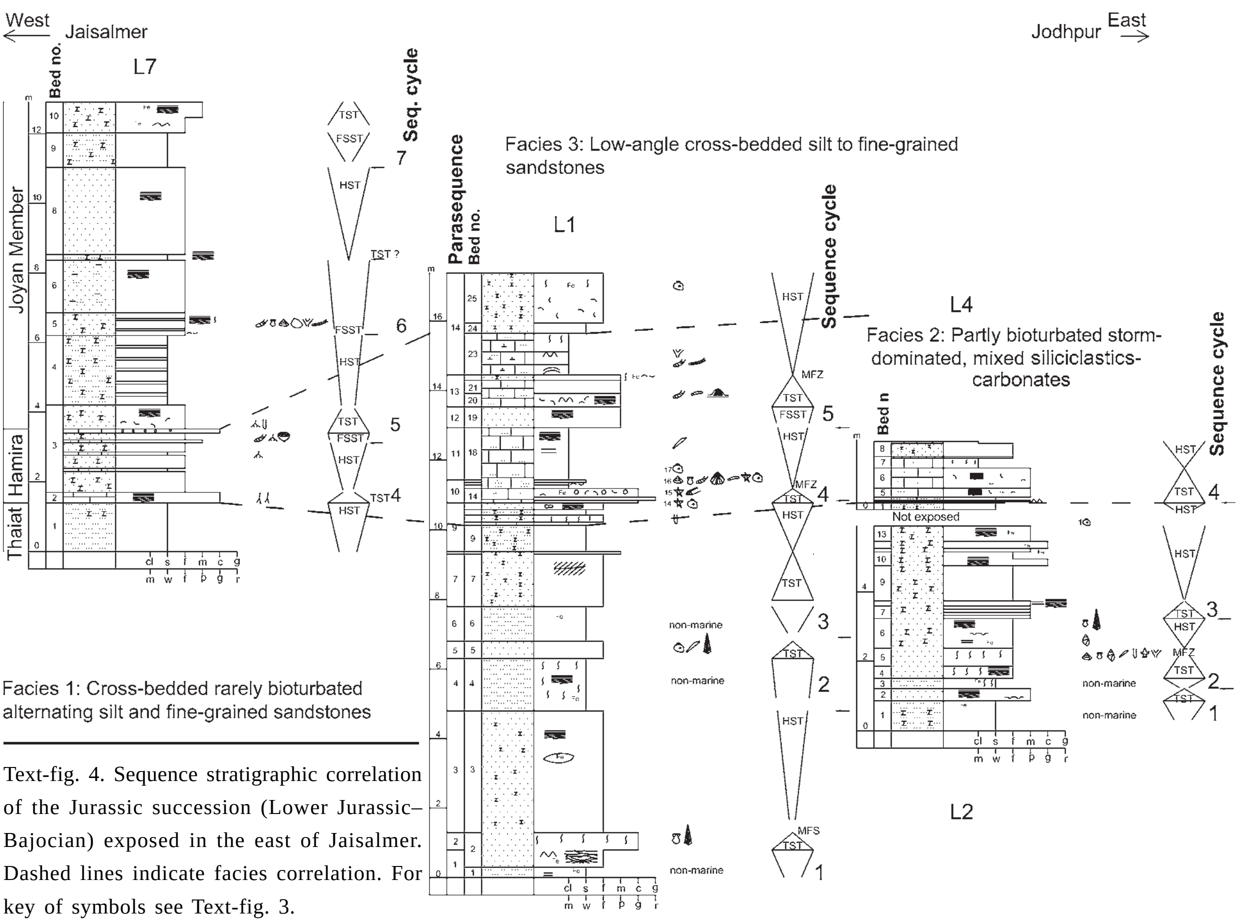

A
B
C
D
E
F
G
H




Text-fig. 3. Key of symbols for Text-figs. 4-7.

Member (consisting of siliciclastic sediments) as well as the major parts of the Hamira Member and topmost part of the Joyan Member (consisting of carbonate sediments). Based on maximum thickness and excellent outcrops, the sections L1 and L7-L9 (Text-fig. 2B) have been chosen as reference sections for sequence stratigraphic classification. In all, 42 parasequences and 9 sequence cycles have been recognized (Text-figs. 4, 5). Parasequences have been delineated on the basis of flooding surfaces or maximum flooding surfaces (mfs), rapid shallowing events and sequence boundaries (SB).

The parasequences recognized in the sections are stacked in progradational and retrogradational parasequence sets, occasionally capped by sequence boundaries. In most cases the parasequence sets could be laterally correlated. The parasequences in the lower half of the reference section „L1“ can be easily confused with the normal TST and HST sequence cycles. The unfossiliferous ferruginous siltstone units representing parasequences 4 and 6, overlying fine-grained, occasionally fossiliferous sandstone units of either the HST or TST (parasequences 3 and 5) are suggested to have been deposited in a non-marine, protected basin in the backshore zone of the continental shelf during lowstand of sea-level. Therefore, they are deposited after the SB and correspond to the next consecutive sequence cycles. Hence, the parasequence 6 overlying 5 does not belong to same sequence cycle. The corresponding parasequences in the comparable section „L2“ show a similar sequence. Parasequences 9 and 10, in fact, can be further divided into three parasequences each. However, based

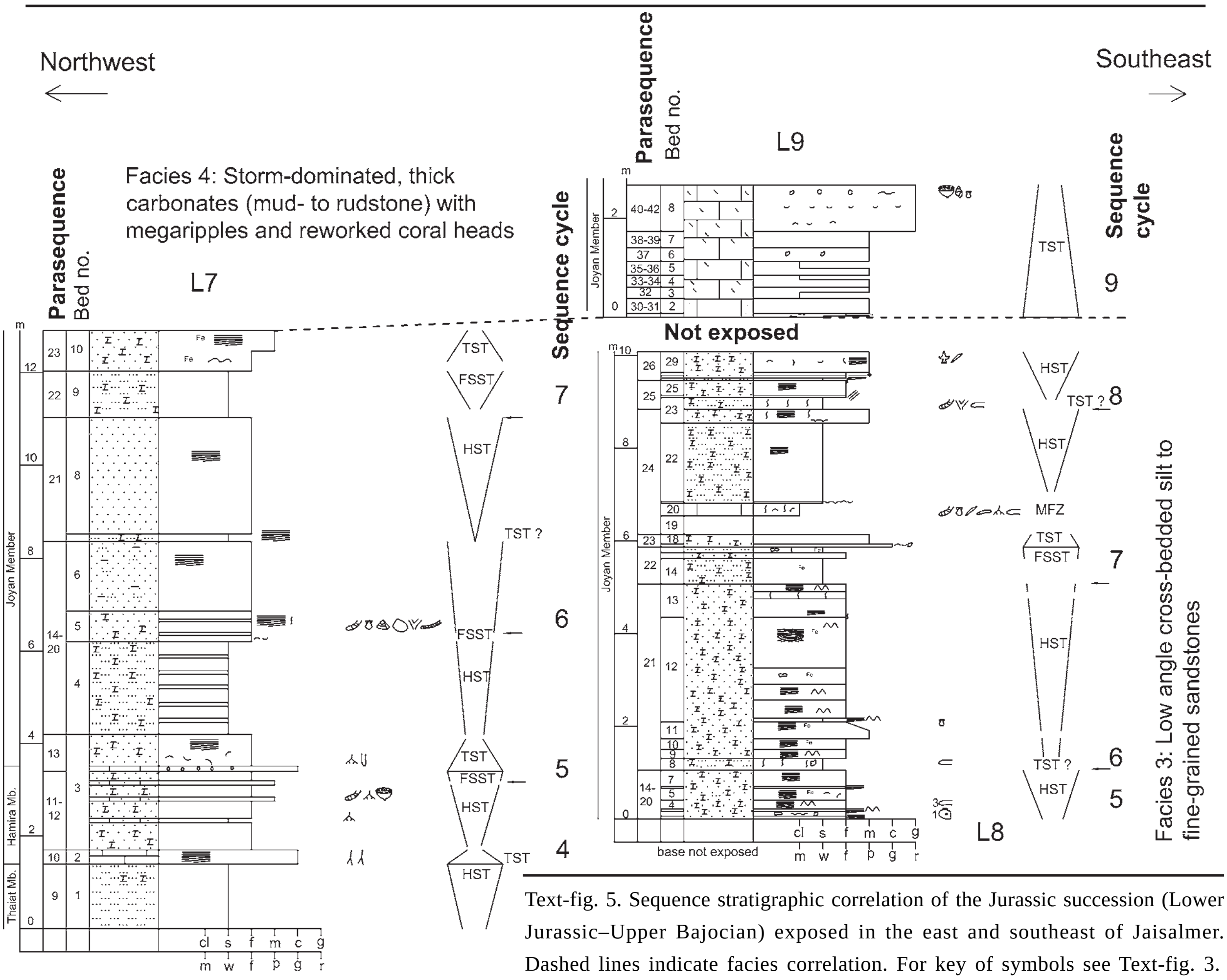



Text-fig. 4. Sequence stratigraphic correlation of the Jurassic succession (Lower Jurassic–Bajocian) exposed in the east of Jaisalmer. Dashed lines indicate facies correlation. For key of symbols see Text-fig. 3.

on limited thickness and outcrop conditions, and pending more evidences, these units have been combined. The rapid change in the depositional environment such as a sudden decrease or increase of energy levels or rate of influx of sediments or terrestrial influence is evident from rapid change in individual or a combination of sedimentary characters such as colour, primary sedimentary structures including geometry of sedimentary bodies, degree of bioturbation and erosional surfaces, degree of cementation, grain size, fossils, and taphonomic features.

The sequence stratigraphic correlation of the Jurassic sequences exposed in this area suggests that the sediments were deposited on the continental shelf between backshore and foreshore zones. A gradual increase in the intensity of the transgressive events and the deposition of the marine sediments is recorded. In nine sequence cycles only seven TSTs could be recorded, of which parasequence no. 8 is only 8 cm thick. The TST units are either well cemented limestones or at least calcareous sandstones. Wood fragments, *Rhizocorallium*, *Planolites*, *Chondrites* and *Thalassinoides* are common (trace) fossils. The units representing HST are exclusively siliciclastic. Wood fragments, *Rhizocorallium*, *Planolites*, *Chondrites*, *Taenidium*, *Thalassinoides* and indeterminate burrow tubes are common. Bivalves, gastropods, vertebrate bone fossils and oyster fragments occur rarely.

The topmost unit of the area, comprising pack- to rudstones with coral heads, high-spired gastropods and a few bivalves (bed nos. 1-8 of L9), represents the TST of sequence cycle 9. Lithostratigraphically, this is the youngest unit of the Joyan Member. This is one of the most indurated and distinct units in the entire Bajocian–Oxfordian sequence of the Jaisalmer Basin. The unit shows several erosional surfaces (each unit between two erosional surfaces is a parasequence) and was deposited during the first peak of marine transgression. The fossil record (Pandey & Fürsich 1994) suggests that this first peak of marine transgression inundating the Jaisalmer Basin was contemporary to the Late Bajocian transgressive event in the neighbouring rift basin of Kachchh (Singh et al. 1982).



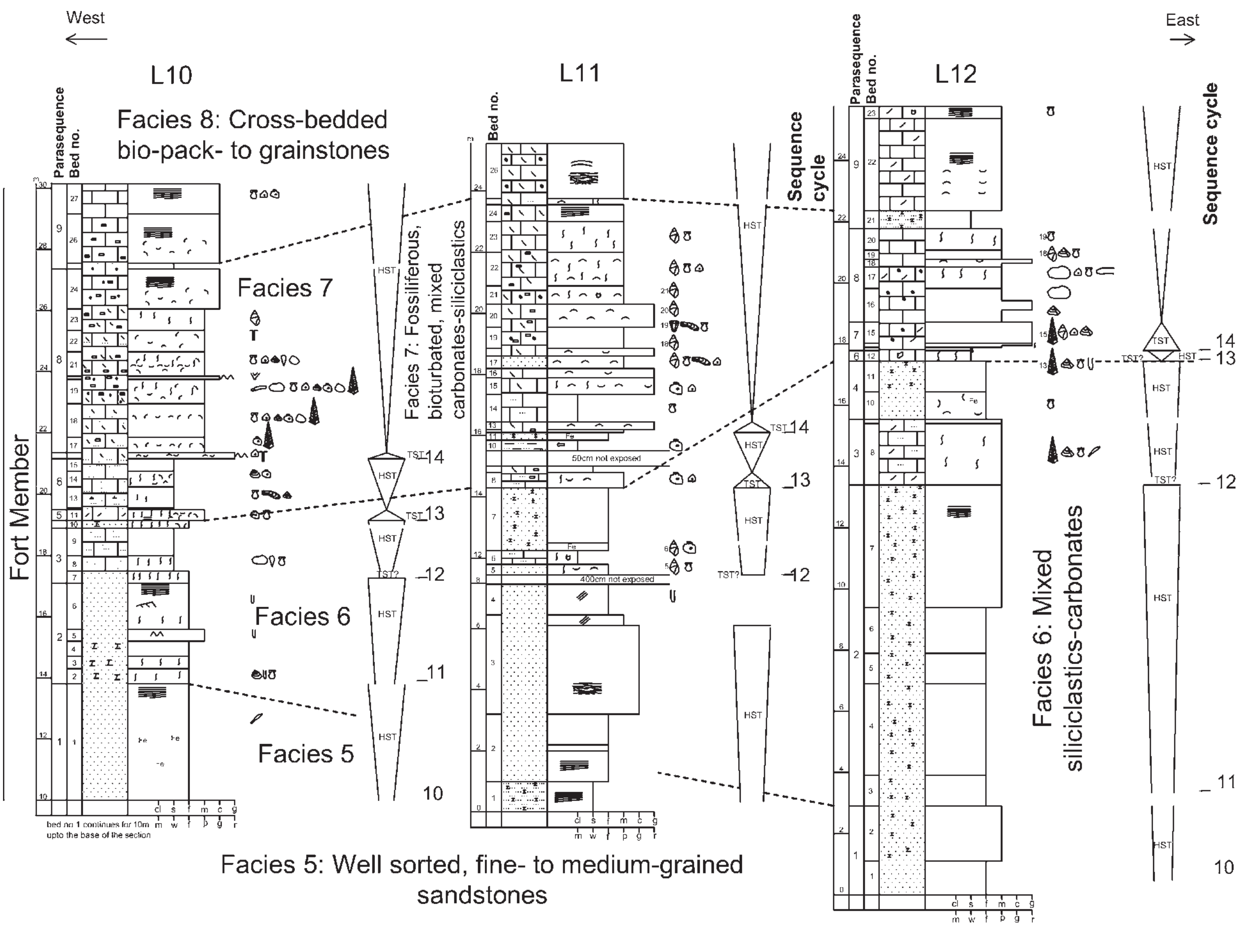

Text-fig. 5. Sequence stratigraphic correlation of the Jurassic succession (Lower Jurassic–Upper Bajocian) exposed in the east and southeast of Jaisalmer. Dashed lines indicate facies correlation. For key of symbols see Text-fig. 3.

## 4.2 Sequence stratigraphic framework of the Jurassic north and northeast of Jaisalmer

The sections correspond to the Fort and Badabag members of the Jaisalmer Formation (Tab. 1, Text-figs. 6-7). They represent the Late Bajocian–Bathonian time interval in the Jaisalmer Basin. The sediments following above the TST of the last sequence cycle (no. 9, see above), are exposed only at the base of the Fort section north and northeast of the city. They are characterized by pinkish, grayish-white, poorly to moderately cemented, well sorted, fine-grained sandstones at the base, and poorly sorted silt- to medium-grained calcareous sandstones, weathering to concretions (silcrete), in the upper part (bed nos. 1 and 2 in L12, Text-fig. 6). The sediments show strong terrestrial influence and there is no (faunal) element present which suggests marine influence. On the other hand, in the view of the underlying transgressive units (TST), representing the peak of the Late Bajocian transgression, it is difficult to imagine a sudden fall of sea level. These sediments either belong to the upper part of the HST (with strong fluvial influence) or were deposited during a following FSST. In the latter case, the sediments mark the beginning of a new sequence cycle.

The overlying sequence cycles can be broadly subdivided into two major transgressive events following nonmarine-brackish water conditions. Brackish conditions are evident by the occurrence of the bivalve genus *Eomiodon*. Consequently, the sequence stratigraphic framework of the Jurassic sequence exposed in the north and northeast of Jaisalmer is shown separately (Text-figs. 6-7). In total, 49 parasequences and nine sequence cycles have been recognized in the Upper Bajocian–Bathonian of this area.

The transgressive systems tracts of the older transgressive cycle exposed in the Fort section (L10-L14, Text-fig. 2) are not always represented. When present, they are only characterized by thin cross-bedded, shelly to fossiliferous pack- to rudstone units, whereas highstand systems tracts are thick and generally characterized by coarsening-upward successions. HST beds show fairly




Text-fig. 6. Sequence stratigraphic correlation of the Middle Jurassic succession (Upper Bajocian–Bathonian) exposed in the north and northeast of Jaisalmer Fort. Dashed lines indicate facies correlation. For key of symbols see Text-fig. 3.

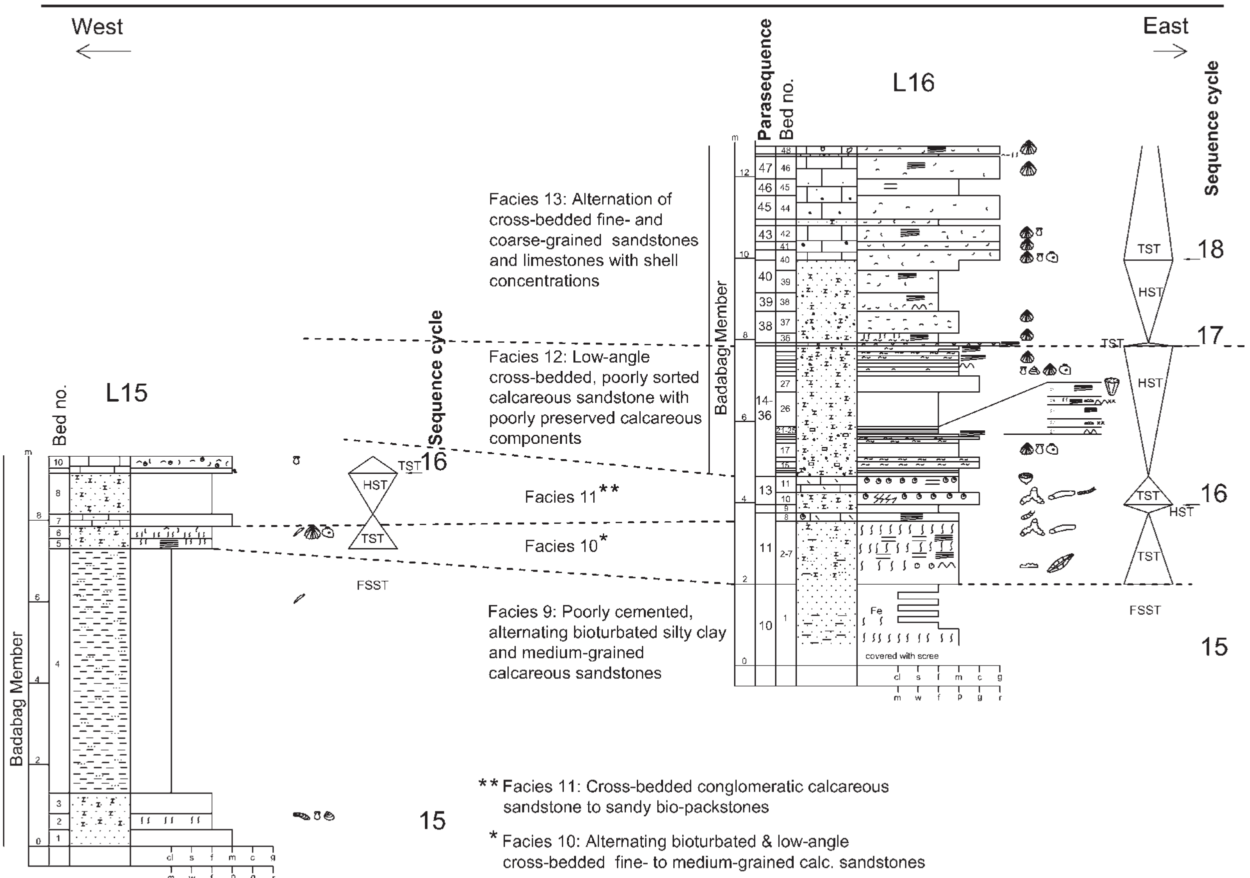
diverse depositional conditions consisting of mixed carbonate and siliciclastic sediments; bioturbated units are followed by cross-bedded units, alternating bioturbated and cross-bedded units, or are represented by only cross-bedded units. The bioturbated units are invariably richly fossiliferous, the fauna consisting of fully marine bivalves and echinoids. *Thalassinoides* and *Planolites* are the most common trace fossils.

The transgressive systems tracts of the younger transgressive cycle exposed at Bara bagh section (L15-L18, Text-fig. 2) are characterized by often thick (thickness more than 2 m), cross-bedded, well cemented sandstones, conglomerates and shelly to fossiliferous pack- to rudstones. In a few cases, their upper part is bioturbated. *Gyrochorte*, *Ophiomorpha*, *Rhizocorallium*, *Taenidium* and *Planolites* are the most common trace fossils. Rhynchonellids are very common brachiopods. The units representing highstand systems tracts are thinner in comparison to the older transgressive cycle (see above), exclusively siliciclastic, occasionally fossiliferous, bioturbated (predominant trace fossil *Gyrochorte*) and followed by cross-bedded units. Erosional surfaces are common features in these sequence cycles.

## 5 Conclusions

The Lower–Middle Jurassic (up to the Bathonian) succession of the Jaisalmer Basin examined in the present study displays in general shallowing-upward sedimentary hemicycles. The sediments demonstrate alternating low-energy and high-energy depositional environments. The units deposited in low-energy settings are invariably fine-grained and bioturbated, whereas those of high-energy environments are coarser grained and cross-bedded. The rapid change in microfacies and taphonomic features is explained mainly as the result of a change in the depositional environment due to changes in relative sea-level and climatic conditions.

The absence of any index fossil from the Lower–Middle Jurassic succession (up to Middle Bajocian) of the Jaisalmer Basin (Lukose 1972, Pandey et al. 2006b) does not allow for precise chronostratigraphic correlation.




Text-fig. 7. Sequence stratigraphic correlation of the Bathonian exposed at Bara bagh, north of Jaisalmer. Dashed lines indicate facies correlation. For key of symbols see Text-fig. 3.

The earliest near-to-precise age which can be taken into consideration is Late Bajocian, based on the occurrence of the coral *Isastraea bernardiana* (PANDEY & FÜRSICH 1994) for the parasequence 42 of sequence cycle 9. Furthermore, the sedimentary succession ranging from the Upper Bajocian to the Upper Bathonian yielded the index ammonite genus *Clydoniceras* BLAKE (PRASAD et al. 2007) of Middle to Late Bathonian age.

Consequently, within the sediments ranging from Lower–Middle Jurassic (up to the Bathonian) of the Jaisalmer Basin, 91 parasequences and 18 sequence cycles can be identified. It is difficult to locate the Bajocian–Bathonian boundary. However, assuming an eustatic control and counting five sequence cycles in the Bathonian (HARDENBOL et al. 1998) it can be suggested that the Bajocian–Bathonian boundary lies just above sequence cycle 13 (Text-fig. 6). The parasequences recognized in these sections include stacking pattern of progradational and retrogradational parasequence sets. The compilation of information from sedimentary facies, depositional environment and sequence stratigraphy suggests that highstand sediments in the Lower–Middle Jurassic (up to the Upper Bajocian) were deposited mostly in a protected basin on the continental shelf between backshore and foreshore zones with salinity ranging from non-marine to brackish water. The units are either non- or poorly fossiliferous. In the Bathonian, the highstand deposits are thinner, represented by fossiliferous, mixed carbonate-siliciclastic to exclusively siliciclastic sediments deposited in protected to open marine settings between the nearshore to upper offshore transition zones. The transgressive systems tract (TST) units are always well cemented and consist of thin, fossiliferous, cross-bedded pack- to grain- and rudstones with erosional bedding surfaces. In case of complete sequences, the TST grades into a richly fossiliferous maximum flooding zone followed by the high-stand systems tract (HST) showing an upward-coarsening or increasing energy levels as evident from sedimentary structures. A gradual deepening of the basin and deposition of increasingly marine sediments from the Late Bajocian to Late Bathonian is recorded. The frequent occurrence of erosional surfaces and in most cases absence of falling stage (FSST) and lowstand parts (LST) of the sequence cycles suggests that the sedimentary record of the Lower Jurassic to Bathonian (Middle Jurassic) of the Jaisalmer Basin is considerably incomplete.

## Acknowledgement

Field and laboratory work was financially supported by the Department of Science and Technology, New Delhi (Project no. SR/S4/ES-41/2003). We discussed with Prof. F.T. FÜRSICH (Würzburg) both in the field and laboratory on several issues related to sedimentary basin analysis. The observations and comments given by M. WILMSEN (Würzburg) during editing the manuscript were very useful. The authors are extremely thankful to him. We are thankful to A. SHAH and D. KASHYAP (Jaipur) for assistance in the field and R. KASHYAP (Jaisalmer) for logistic support. Administrative support by the Department of Geology, University of Rajasthan, is gratefully acknowledged.

## References

BISWAS, S.K. 1982. Rift basins in western margin of India and their hydrocarbon prospects with special reference to Kutch basin. – American Association of Petroleum Geologists Bulletin **66** (10): 1497-1513.

BISWAS, S.K. 1991. Stratigraphy and sedimentary evolution of the Mesozoic Basin of Kutch, West India. – In: TONDON, S.K., PANT, C.C. & CASSHYAP, S.M. (eds). Sedimentary Basins of India: Tectonic Context: 74-103; Nainital (Gyanodaya Prakashan).

DAS GUPTA, S.K. 1975. A revision of the Mesozoic- Tertiary stratigraphy of the Jaisalmer Basin, Rajasthan. – Indian Journal of Earth Sciences **2** (1): 77-94.

DATTA, A.K. 1983. Geological evolution and hydrocarbon prospects of Rajasthan Basin. – Petroleum Asia Journal, Oil and Natural Gas Commission **6** (4): 93-100.

FÜRSICH, F.T. & PANDEY, D.K. 2003. Sequence stratigraphic significance of sedimentary cycles and shell concentrations in the Upper Jurassic-Lower Cretaceous of Kachchh, western India. – Palaeogeography, Palaeoclimatology, Palaeoecology **193**: 287-309.

FÜRSICH, F.T., PANDEY, D.K., CALLOMON, J.H. JAITLY, A.K. & SINGH, I.B. 2001. Marker beds in the Jurassic of the Kachchh Basin, western India: their depositional environment and sequence-stratigraphic significance. – Journal of the Palaeontological Society of India **46**: 176-198.

GANSSER, A. 1964. Geology of Himalayas. – 289 pp.; London (John Wiley and Sons Ltd.).

HARDENBOL, J., THIERRY, J., FARLEY, M.B., JACQUIN, T., DE GRACIANSKY, P.C. & VAIL, P.R. 1998. Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins. – In: DE GRACIANSKY, P.C., HARDENBOL, J., JACQUIN, T. & VAIL, P.R., (eds.), Mesozoic and Cenozoic Sequence Stratigraphy of European basins. SEPM (Society for Sedimentary Geology) Special Publication **60**: 3-13.

KAYE, M.K. 1970. Geology and productivity of Persian Gulf Synclinorium. – American Association of Petroleum Geologists Bulletin **54** (12): 2371-2394.

KACHHARA, R.P. & JODHAWAT, R.L. 1981. On the age of Jaisalmer Formation, Rajasthan, India. – Proceedings of IX Indian Colloquium on Micropalaeontology and Stratigraphy: 235-247.

LUKOSE, N.G. 1972. Palynological evidence on the age of Lathi Formation, Western Rajasthan, India. – Proceeding of Seminar on Palaeopalynology and Indian Stratigraphy (1971): 155-159.

MISRA, P.C., SINGH, N.P., SHARMA, D.C., KAKAROO, A.K., UPADHYAY, H. & SAINI, M L. 1993. Lithostratigraphy of Indian Petroliferous Basins. Document II West Rajasthan Basins. – Unpublished report Keshva Dev Malaviya Institute of Petroleum Exploration, Oil and Natural Gas Commission, Dehradun: 1-123.

PANDEY, D.K. & FÜRSICH, F.T. 1994. Bajocian (Mid-Jurassic) age of the lower Jaisalmer Formation of Rajasthan, Western India. – Newsletter on Stratigraphy **30**: 75 - 81.

PANDEY, D.K., KASHYAP, D. & CHOUDHARY, S. 2005. Microfacies and depositional environment of the Gharoi River section (upper Jaisalmer Formation), west of Baisakhi Village, Jaisalmer Basin, Rajasthan. – Proceedings of the National Seminar on Oil, Gas & Lignite Scenario with special Reference to Rajasthan, Jaipur: 117-130.

PANDEY, D.K., SHA, J. & CHOUDHARY, S. 2006a. Depositional environment of Bathonian sediments of the Jaisalmer Basin, Rajasthan, western India. – Progress in Natural Science (Special issue of IGCP 506 on the Jurassic Boundary Events) **16**: 163-175.

PANDEY, D.K., SHA, J. & CHOUDHARY, S. 2006b. Depositional history of the early part of the Jurassic succession on the Rajasthan Shelf, western India. – Progress in Natural Science (Special issue of IGCP 506 on the Jurassic Boundary Events) **16**: 176-185.

PANDEY, D.K., SHA, J. & CHOUDHARY, S. 2007. Sedimentary cycles in the Callovian-Oxfordian of the Jaisalmer Basin, Rajasthan, western India. – Volumina Jurassica. [Accepted]

PAREEK, H.S. 1984. Pre-Quaternary Geology and Mineral Resources of northwestern Rajasthan. – Memoirs Geological Survey of India **115**: 1-99.

PRASAD, S., JAIN, R.L. & SRIVASTAVA, M.S. 2007. Record of Middle Jurassic (Bathonian) ammonite genus *Clydoniceras* BLAKE from Jaisalmer Basin, western Rajasthan. – Journal of the Geological Society of India **69**: 53-56.

RAGHAVENDRA RAO, V. 1972. Subsurface stratigraphy, tectonic setting and petroleum prospects of the Jaisalmer area, Rajasthan, India. – Proceedings of the IV Symposium of Development in Petroleum Resources of Asia and Far Canberra, Australia, series 41, **1**: 366-371.

REHMAN, H. 1963. Geology of Petroleum in Pakistan. – World Petroleum Congress. Section 1, Paper **31**, PD-3: 659-674.

SHRIVASTAVA, B.P. 1971. Rock stratigraphic nomenculture for the sedimentaries of West Central Rajasthan. – Bulletin of Geology, Mining & Metallurgical Society of India **40**: 1-19.

SHRIVASTAVA, B.P. 1992. Significant fourth-dimensional stratigraphic markers in Palaeozoic sediments of west central Rajasthan - palaeogeographic implication. – Petroleum Habitat **1** (2): 224-244.

SINGH, C.S.P., JAITLY, A.K. & PANDEY, D.K. 1982. First report of some Bajocian-Bathonian (Middle Jurassic) ammonoids and the age of the oldest sediments from Kachchh, Western India. – Newsletters on Stratigraphy **11** (1): 37-40.

SINGH, A.K., SETHI, J.R., RAI, A.K., KUMAR, S., KUNDU, J. & GOEL, S.M. 2005. An overview of exploration and exploitation strategy for hydrocarbons in ONGC acreages of Jaisalmer Basin, Rajasthan. – Proceedings of the National Seminar on Oil, Gas & Lignite Scenario with special Reference to Rajasthan, Jaipur: 53-68.

SINHA, A.K., YADAV, R.K. & QURESHI, S.M. 1993. Status of exploration in South Shahgarh Subbasin of Jaisalmer Basin, Rajasthan. – In: BISWAS, S.K, DAVE, A., GARG, P., PANDEY, J., MAITHANI, A. & THOMAS, N.J. (eds.), Proceedings of second seminar on petroliferous basins of India, Indian Petroleum Publishers, **2**: 285-333.

SWAMINATHAN, J., KRINSHNAMURTHY, J.G., VERMA K.K. & CHANDIAK, G.J. 1959. General geology of Jaisalmer area, Rajasthan. – Proceedings of the Symposium on the Development of Petroleum Resources of Asia and the Far East, Mineral Resources Development Series **10**: 154-155.