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DIVERSITY DYNAMICS OF THE JURASSIC BRACHIOPOD FAUNA OF KACHCHH AND JAISALMER BASINS, INDIA

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ABSTRACT

Brachiopods made their appearance in the newly opened Kachchh and Jaisalmer basins in the Bathonian, being represented by a few terebratulids and rhynchonellids and then thrived nearly throughout, but the abundance and diversity varied widely. A detailed analysis of taxonomic diversity changes of the brachiopod community in the Jurassic of western India, reveals a cyclic pattern with an overall decrease in diversity from the Middle to the Upper Jurassic. The study highlights a sharp decline already by the latest Oxfordian, prior to the Jurassic-Cretaceous mass extinction boundary, indicating that the characteristic Kachchh endemic brachiopod fauna was exterminated much earlier than the mass-extinction event unlike the gastropods and ammonites. Anoxic conditions may have played a role in this biotic crisis, in which the endemic brachiopod taxa were the first to be eliminated. Species diversity dynamics reveal that the number of singleton taxa are much higher during the successive stages in the Middle-Upper Jurassic in the Kachchh and Jaisalmer, whereas the 'range through taxa' are rare. Variation in the brachiopod distribution in the Callovian and Oxfordian along a proximal-distal transect across Jara, Jumara, Keera and Jhura, the latter being nearest to the shoreline, reflects the influence of water depth on brachiopod abundance.

Keywords: Brachiopoda, Jurassic, Kachchh and Jaisalmer basins, diversity dynamics, J-K boundary, mass-extinction

INTRODUCTION

Quantitative assessment of biodiversity is a major tool to recognize evolutionary trends or some major key events like extinction, faunal turnover or radiations (Vörös, 1993; Vörös and Dulai, 2007, Ruban, 2004, 2009; Baeza-Carratalá, 2013). In an exhaustive study of the diversity dynamics pattern of Lower Jurassic brachiopods from Eastern Subbetic Province, Baeza-Carratalá (2013) shows several diversification and decline episodes of brachiopod faunas in the Pliensbachian-Toarcian interval, with replacements and turnovers that reflect the record of both regional and global events in the westernmost Tethys Ocean.

Mesozoic marine biodiversity dynamics provide evidence of a mass extinction at the Jurassic-Cretaceous boundary, when, apart from diversity decrease, number of fossil taxa declined showing strong extinction signal (Bardhan *et al.*, 2007; Raup and Sepkoski, 1984; Sepkoski, 1984). The importance of the J/K mass extinction for the brachiopod fauna was considered of little change for this group (Hallam, 1986). Recently, brachiopod diversity dynamics in the Caucasus region in the Callovian-Albian transition reveal significant fluctuations in the number of taxa, and a crisis at the J/K boundary was suggested by Ruban (2011) after comparative studies of the brachiopod diversity dynamics in the Neo-Tethys and the Alpine Tethys.

The Kachchh and Jaisalmer basins (Fig. 1), in the western part of India, developed as a result of intense tectonic activity associated with Gondwana fragmentation and was inundated by the sea commencing from Bajocian- Bathonian (Singh *et al.*, 1982; Biswas, 1991). The newly formed basin played host to a rich and diverse faunal succession of ammonites, bivalves, gastropods, nautiloids, corals, sponges and brachiopods in the Jurassic. The basin records a general deepening which culminates in the mid. Oxfordian and was followed by a regression in the Kimmeridgian (Fursich *et al.*, 1991). Brachiopods first appear in the Middle Bathonian of Kachchh, represented by the terebratulid genera *Kutchithyris* and *Charltonithyris* and during Early Bathonian of Jaisalmer represented by *Plectoidothyris*; the rhynchonellids *Kutchirhynchia* and *Cryptorhynchia* being present in both the basins. After their arrival during the Early-middle Bathonian in the newly opened basins, brachiopods lived till the end of Jurassic but their number and diversity varied widely.

The J/K boundary mass extinction event is well marked in Kachchh, where the ammonites show a strong extinction signal along with gastropods and bivalves and an extinction percentage of 91% of the ammonite taxa has been described as 'hot-spots' of extinction (Bardhan *et al.*, 2007). According to Bardhan *et al.*, (2013), the J/K extinction in Kachchh is sharp and catastrophic with an overall extinction percentage of 70%, the Tithonian being the extinction phase. Interestingly, brachiopods make only a meagre 3.44 % of the total fauna from the highly fossiliferous oolitic sandstone unit of the Uppermost Tithonian of western Kachchh, though it had a dominating presence during the Bathonian-Callovian.

A detailed analysis of the taxonomic diversity changes in this group from the Bathonian to Tithonian of western India is necessary to understand the causes behind decline of the typical brachiopod fauna of the Kachchh-Jaisalmer basins and if it was a precursor to the J/K boundary mass-extinction event.

MATERIAL AND METHOD

Brachiopod diversity data that have been used in the paper have been compiled mostly from previously published literature (Mukherjee, 2007, 2010a; Mukherjee *et al.*, 2000, 2002, 2003; Ghosh, 1988, 1990) in the Jurassic of Kachchh and Jaisalmer basins (Fig.1 and Fig. 2) and also unpublished but verified work (Ghosh, 1967; Mukherjee, 2002, 2009, 2010b). The material that has been studied by the author has been housed in Palaeontology Repository, Geological Survey of India, Kolkata. The newly recorded genera from Kachchh and Jaisalmer are shown in Plate I.

For a given time unit, the number of taxa confined to the interval (singleton taxa), the number of taxa that cross only the bottom boundary (first appearance), the number of taxa that cross the top boundary (last appearances), the number of taxa that cross both the boundaries (range through taxa) have been recorded to analyse the diversity pattern. Total species quantity, number of appearances, disappearances, number of species restricted within a stage have been calculated for each stage from Bathonian to Tithonian (Table 1) and then plotted against time to analyse the taxonomic diversity dynamics (Fig. 2).

Brachiopod distribution in the Middle-Upper Jurassic of western India

A list of the brachiopods from the two basins are provided in Table 1, to understand the taxonomic diversity from the Bathonian to Tithonian. As can be observed from the table, brachiopods are commonly present in both Jaisalmer and Kachchh from the Bathonian to Oxfordian. The Kimmeridgian units in both Kachchh and Jaisalmer is barren with respect to the brachiopods except for a few fragmentary rhynchonellid specimens which could not be assigned to any genera. Interestingly, in the Tithonian, both the basin hosted identical genera, *Somalithyris* and *Acanthorhynchia* within a brown coloured ooid-bearing sandy limestone.

The vertical distribution of brachiopod taxa in Kachchh and Jaisalmer reveal greater endemicity and species diversity in Kachchh. Facies analysis of the Patcham and Chari Formation (Fig. 2, Mukherjee *et al.*, 2003) revealed that fluctuating sea-levels not only brought about changes in the lithofacies association but also influenced temporal changes in the species diversity of the terebratulid *Kutchithyris* (Mukherjee, 2007). A comparative study of the brachiopod distribution in four localities of Kachchh mainland discussed later, elucidate the influence of depth of water column on brachiopod diversity.

RESULTS

Diversity dynamics

The newly opened Kachchh basin provided abundant supply and ecospace for the biota to flourish and thereby created a diverse fossil record. As many as 19 species belonging to 10 genera appear in the Middle-Upper Bathonian beds of Kachchh and Jaisalmer. It is interesting that the overall brachiopod diversity show a decline from Bathonian to Callovian to Oxfordian (Table 2, Fig. 2) which also coincide with a gradual deepening in the basin (Fürsich *et al*., 1991).

The end Bathonian was marked by the last appearance of 15 of the 19 species and therefore only four of the Bathonian taxa reached the Callovian. The Bathonian-Callovian boundary in Kachchh is also a transgressive phase. The upper part of the Bathonian Patcham Formation is interpreted as representing storm dominated shallow shelf environments and the transition to the overlying Chari Formation is gradual deepening of the basin and it occupied a more offshore position than the underlying Patcham Formation. The deepening of the Kachchh Basin in the Callovian, possibly corresponding to the Callovian eustatic sea-level rise of Haq *et al.* (1987) perhaps affected the brachiopods and so the costate genera like *Cryptorhynchia*, *Flabellothyris* are extinct at the Bathonain-Callovian boundary (Mukherjee *et al*., 2000, 2002). Both the taxa are a dominant component in the cream limestone litho-unit (bed number 4 of Jumara section, fig.2 in Mukherjee *et al*., 2003) but vanish at the next higher bed, i.e., the ferruginous shale-limestone alternating unit (bed number 5, fig.2 in Mukherjee *et al*., 2003) at Jumara.

The Middle and Upper Jurassic sedimentary succession in the Kachchh basin is distinctly cyclic in nature (Fürsich and Pandey, 2003). As a result, the same environments appeared repeatedly and were colonised by taxa of identical generic composition but different species which has been noted in the bivalve diversity pattern (Fürsich and Pandey, 2003) apart from

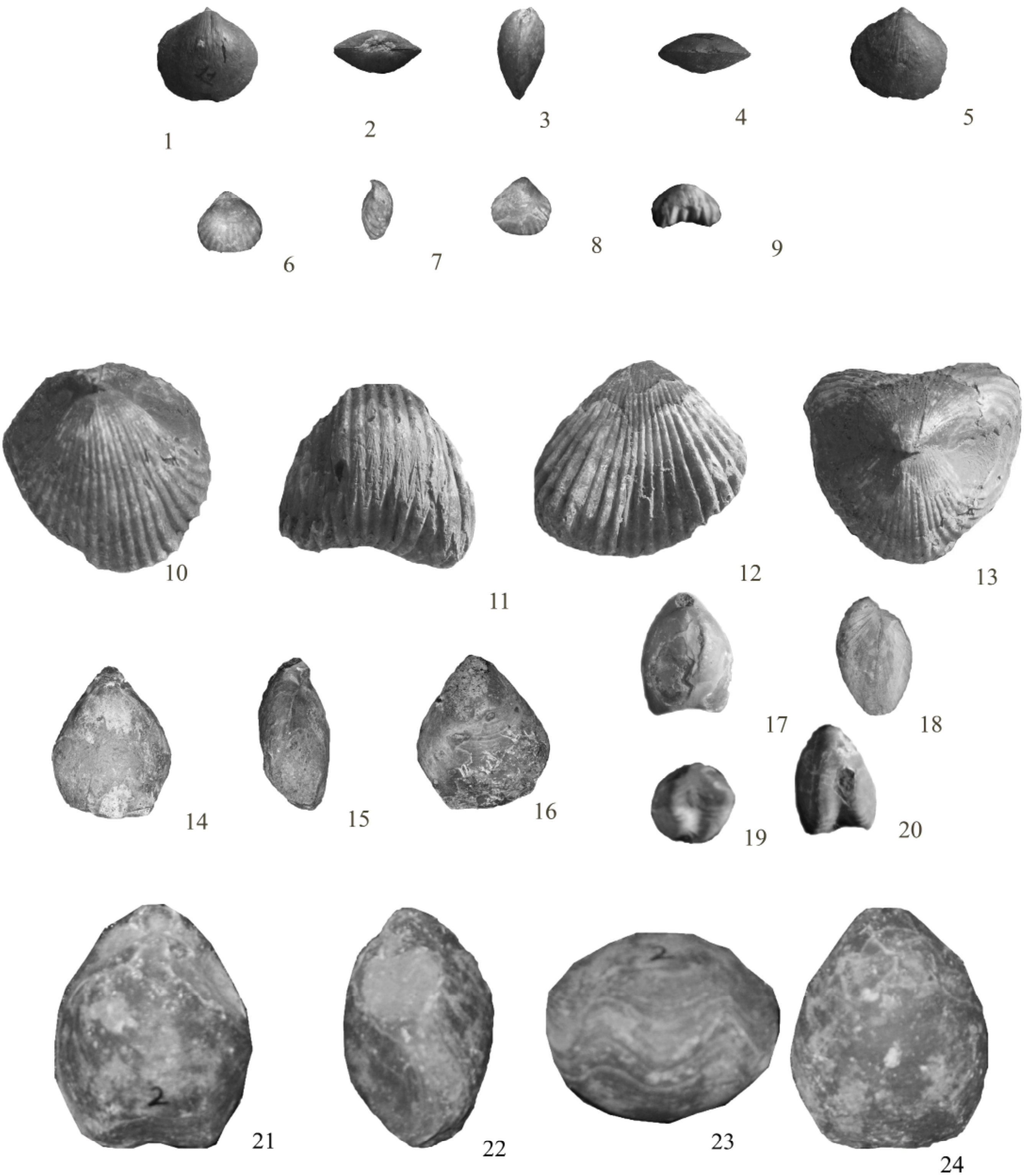
Table 1: Distribution of brachiopods in the Kachchh and Jaisalmer basins during the Jurassic.

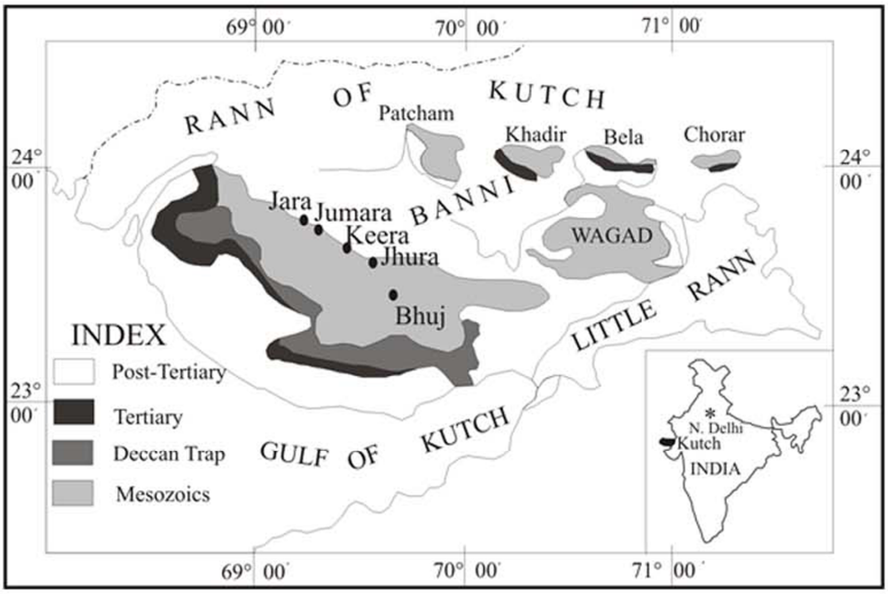
AGE	KACHCHH	JAISALMER
Tithonian	*Acanthorhynchia sp., Somalithyris sp.*	*Acanthorhynchia sp., Somalithyris sp.*
Kimmeridgian	-	-
Oxfordian	*Dienope sp., Kutchithyris dhosaensis, K. euryptycha, K. ingluviosa, K. jooraensis, K. pyroidea, Rhynchonelloidella brevicostata, Somalirhynchia* sp., *Sphenorhynchia asymmetrica.*	*Bihenithyris* sp., *K. jooraensis*, *Sphenorhynchia asymmetrica*, *Septirhynchia nobilis*, *Rhynchonelloidella* sp.
Callovian	*Kutchithyris breviplicata, K. dhosaensis, K. euryptycha, K. ingluviosa, K. mitra, K. propinqua, Kutchirhynchia* sp., *Septirhynchia nobilis, Sphenorhynchia asymmetrica, Rhactorhynchia pseudoinconstans Rhynchonelloidella* sp., *Aulacothyris* sp *A*	*Bihenithyris* sp., *Kutcithyris breviplicata*, *K. mitra*, *K. ingluviosa*, *K. dhosaensis*, *Bihendulirhynchia* sp., *Kutchirhynchia* sp., *Rhynchonelloidella* sp., *Septirhynchia nobilis*, *Sphenorhynchia asymmetrica*, *Aulacothyris* sp. *A*, *A. pala*
Bathonian	*Charltonithyris* sp., *Kutchithyris acutiplicata*, *K. euryptycha*, *K. katametopa*, *K.planiconvexa*, *K. propinqua*, *Sphaeroidothyris* sp., *Cryptorhynchia jooraensis, C. karuna, C. pulcherrima, C.rugosa*, *Kutchirhynchia kutchchensis*, *Rhactorhynchia pseudoinconstans*, *Eudesia multicostata, Flabellothyris dichotoma*	*Plectoidothyris jaisalmerensis*, *Cryptorhynchia* sp. *A*, *C.* sp. *B*., *C. pulcherrima*, *C.rugosa*

EXPLANATION OF PLATE I

Fig. 1-24. Middle-Upper Jurassic brachiopods from Kachchh and Jaisalmer. 1-5: ***Acanthorhynchia*** sp. from the Tithonian of Lakhapar, Kutch, all X1; 1-Dorsal view, 2-Posterior view to show the very short beak, 3- Lateral view, 4-Anterior view. 5- Ventral view. 6-9: ***Bihendulirhynchia*** sp. from the Upper Callovian Kuldhar Member of Jaisalmer, all X 1; 6-Dorsal view, 7-Lateral view, 8- Ventral view, 9-Anterior view. 10-13: ***Septirhynchia*** sp. from the Upper Callovian Kuldhar Member of Jaisalmer, Kuldhara, all X 0.5; 10-Dorsal view, 11-Anterior view, 12- Ventral view, 13-Posterior view showing the stout, incurved beak. 14-16. ***Somalithyris*** sp. from the Tithonian of Lakhapar, Kachchh, 14- Dorsal view, 15-Lateral view, 16-Ventral view, all X1 ; 17-20: ***Dienope*** sp. from the Dhosa oolite of Mandvi road, Kachchh all X1. 17- Dorsal view, 18-Lateral view, 19-Anterior view, 20-Ventral view; 21-24: ***Bihenithyris*** sp. from the Kuldhar Member, Jaisalmer Formation, Kuldhara nala section, Jaisalmer all X1. 21- Dorsal view, 22-Lateral view, 23 -Anterior view, 24-Ventral view.

Plate I





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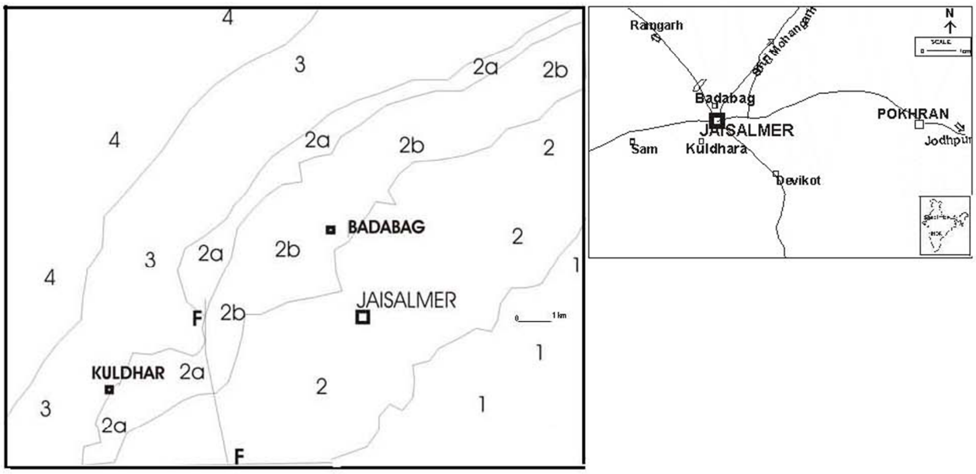


B

Fig. 1. (A) Studied area and distribution of the Mesozoic rocks in the Kachchh basin. (B) Geological map and field localities of Jaisalmer area, Rajasthan. 1. Lathi Formation, 2. Jaisalmer Formation, 2a: Kuldhar Member, 2b: Badabag Member, 3. Baisakhi Formation, 4. Bhadasar Formation (modified from Mukherjee, 2010b and Pre-Quarternary interpretative map of north-western Rajasthan).

the brachiopods. The *Kutchithyris* species diversity elucidates this very well – the genus continued from the Middle Bathonian to Oxfordian but different species assemblages are confined to different stages (Mukherjee, 2007, fig.2).

It has been observed that the brachiopods are generally a dominant component of the shelly macro-fauna during the transgressive episodes. Evolution in the terebratulid genus *Kutchithyris* reflects a 'burst of speciation' in three stages which coincided with the major transgressive events in the basin (Mukherjee, 2007). Fürsich *et al*. (1991) explained an increase in benthics during transgression because of availability of hard substrate in plenty which in return resulted in the colonisation of the suspension-feeding epifauna. As little sedimentation has taken place, reworking is common and results in concentration of biogenic hard parts forming the hard substrate favoured by the brachiopods.

The Callovian-Oxfordian boundary in the Kachchh mainland is characterised by a shift from argillaceous silt in the uppermost Callovian to a coarser clastic dominated lithology in the Oxfordian (Dhosa oolite Member, see Fürsich *et al*., 1991; Alberti *et al*., 2012a) which is reflected in the brachiopod community. The Late Callovian has low brachiopod fauna, especially in Jumara and Keera but again an increase is noticed in the Early Oxfordian. Of the total 16 species in the Callovian of Kachchh and Jaisalmer, 8 species disappear by mid-Callovian;

Table 2: Diversity dynamics of Brachiopod taxa in the Jurassic of western India

Time Interval	Duration (in m.y)	First Appea-rance	Last Appea-rance	Range through taxa	Singleton taxa
Tithonian	5.3	2	2	0	2
Kimmeridgian	4.8	0	0	0	0
Oxfordian	5.6	4	12	0	4
Callovian	3.5	12	8	1	5
Bathonian	3.0	19	15	?	15

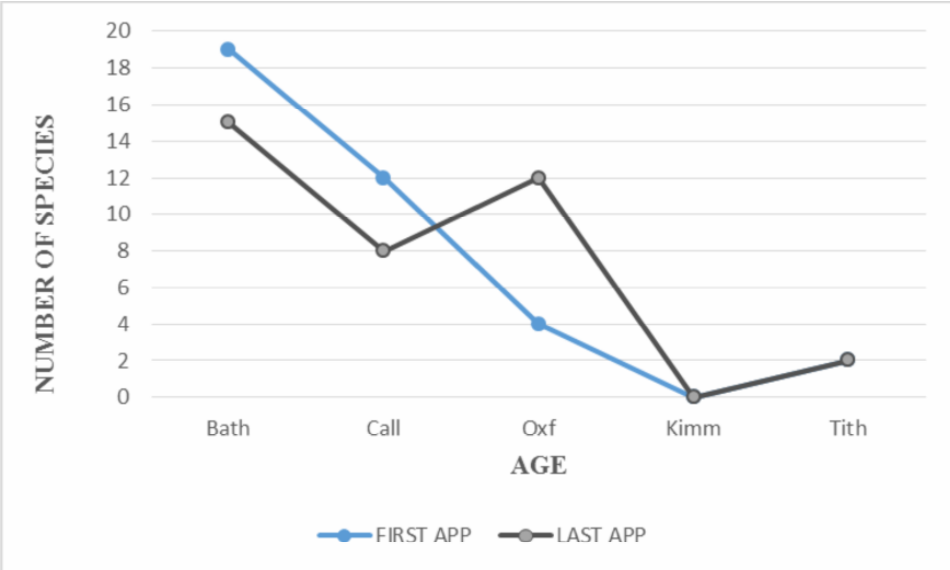


Fig. 2. Changes in total diversity, rate of first appearance and last appearance of the brachiopod species during the Jurassic in Kachchh and Jaisalmer, western India.

again 4 new species appear in the Oxfordian, therefore showing a total species diversity of 12 in the Oxfordian, but all of these become extinct at the Oxfordian–Kimmeridgian boundary (Table 2). As a result of this, brachiopods are not recorded in the Kimmeridgian of western India, neither in the Katrol Formation of Kachchh nor the Baisakhi Formation of the Jaisalmer basin. In the Late Tithonian, two brachiopod genera again appeared in both Kachchh and Jaislamer in a oolite-shale alternation sequence, the brachiopods being restricted in the oolites. But the two genera are cosmopolitan taxa, new to Kachchh, one of them, *Somalithyris*, is known from the Ethiopian realm: Somalia (MuirWood, 1935), Saudi Arabia (Cooper, 1989) and also Iran (Mukherjee and Fursich, 2014). *Acanthorhynchia*, has a widespread distribution and occurs throughout the French and German Jura and also in Normandy, Poland and England from the Upper Bajocian to the Tithonian (Childs, 1969 among others). The two taxa come to Kachchh in the latest Jurassic (Tithonian) and are present in large numbers in both Kachchh and Jaisalmer, in the westernmost part of Kachchh, i.e. near the palaeoshoreline but both disappear soon after and are not found afterwards in Kachchh or globally and therefore must be the victims of the J/K mass-extinction event.

It is noteworthy therefore, that the characteristic Kachchh brachiopod fauna with a lot of endemic species was exterminated in the Oxfordian, much earlier than the mass extinction event, highlighting a special feature of their evolution. What could be the probable causes for this sudden demise of the endemic Jurassic brachiopod fauna of western India remains to be explored.

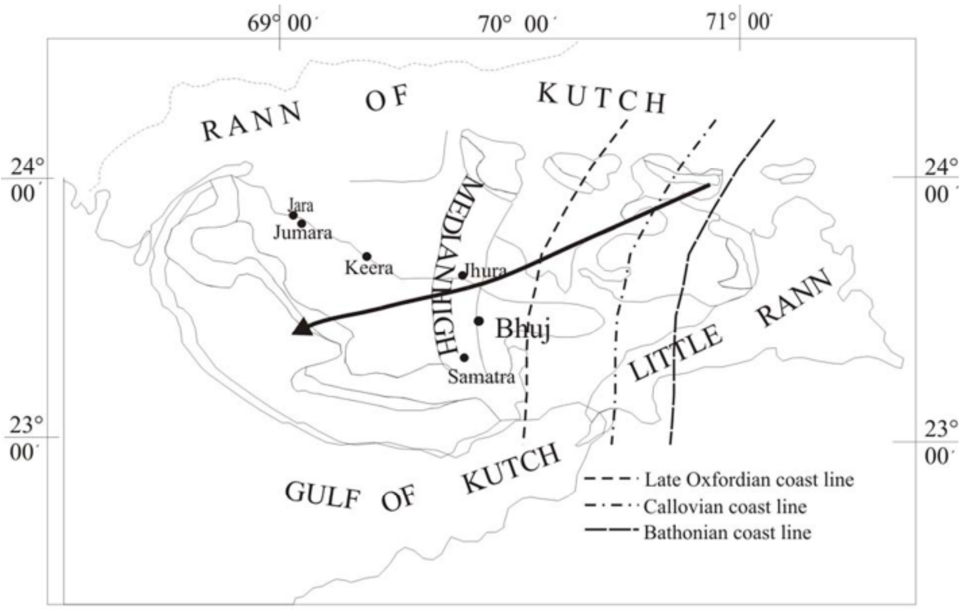
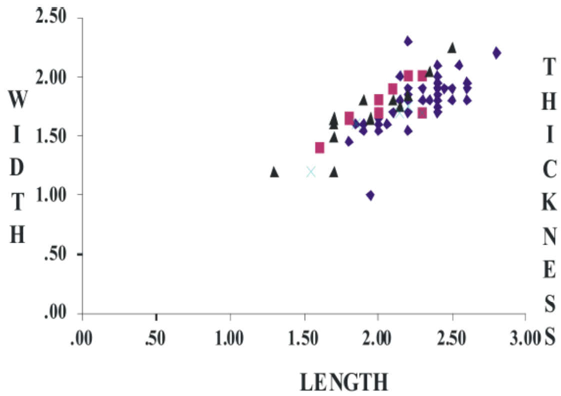


Fig. 3. The four domes, Jara, Jumara, Keera and Jhura in the Kachchh Mainland with the trends of palaeo-coastline and palaeo-slope direction. The position of Jara is farthest and Jhura is nearest to the shoreline. (Figure modified after Shome, 2009; Biswas, 1987).

	Jhura	Samatra	Jumara	Jara
N	45	5	13	8
$L\pm\delta_L$	2.29±0.36	2.01±0.14	1.92±0.09	2.04±0.09
S_L	0.24	0.31	0.33	0.25
$W\pm\delta_W$	1.81± 0.032	1.59± 0.10	1.69±0.08	1.77±0.07
S_W	0.22	0.22	0.29	0.2
$T\pm\delta_T$	1.21± 0.35	1.02±0.06	0.9±0.04	0.91±0.04
S_T	0.24	0.14	0.15	0.12



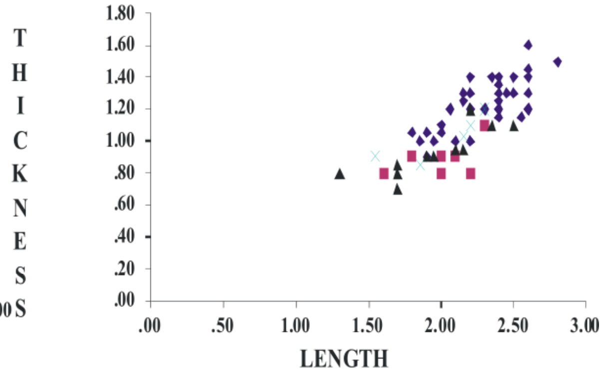


Fig. 4. Bivariate plots of size parameters, length, width and thickness of *Kutchithyris euryptycha* from Jara (square), Jumara (triangle), Jhura (rhomb) and Samatra (cross) and univariate statistics of the three size parameters, length, width and thickness of the *Kutchithyris euryptycha* from the areas showing number of specimens (N), mean (L) (W) (T), standard error (δ_L, δ_W, δ_T) and standard deviation (S_L, S_W, S_T).

Spatial change in brachiopod distribution during Callovian-Oxfordian: the four domes in Kachchh mainland

The Patcham and Chari formations in the Kachchh mainland spanning the Bathonian-Oxfordian are the main brachiopod-bearing unit and can be studied at Jumara, Jara, Keera and Jhura (Fig. 3). The Jurassic rocks of the Kachchh Basin were essentially deposited in an inner to middle shelf setting but there was no significant temperature gradient in the water column (Fürsich *et al*., 2005). While the rocks actually reflect a slight deepening towards the west (e.g., common cross-bedding in the east versus finer sediment and extensive oncoid formation in the west), belemnites, brachiopods, and oysters do not record any distinct temperature trends as seen in the stable oxygen isotopic data (Alberti *et al*., 2012b). But brachiopods, which are known to be sensitive to the water depth, record a change in their diversity pattern when compared in the four domes from West to East, Jara, Jumara, Keera and Jhura. In the Bathonian and Callovian, the brachiopods are much diverse and abundant in Jumara, Keera but in the Jhura dome they become prolific and diverse only during the Late Callovian and Oxfordian (Mukherjee, 2007, fig. 2).

Tectonically, the basin has a characteristic feature, a meridional high in the middle, trending NNE-SSW, and this controlled the facies and thickness of the sediments (Biswas, 1987). Jara and Jumara had a more offshore position and Jhura were much near the coast in the Jurassic and therefore during the Late Callovian sea-level highstand, the basin were probably deeper in Jara, Jumara and Keera which inhibited the brachiopods. Jhura being shallower shows a proliferation of the brachiopods, particularly the terebratulid *Kutchithyris*, with six of its species being abundant in the uppermost Callovian and Oxfordian. According to Biswas (1987), to the west of the high, the basin is deeper with thicker accumulation of sediments and therefore shows a change of facies from shallow to deeper shelf. At the east of the high, the basement is shallow with less thickness of sediments and the facies vary from shallow marine to littoral and fluvial. However, this is more pronounced in the Upper Jurassic. The Middle Jurassic facies show more or less uniform thickness and therefore, the depth of sea-level was controlled mainly by transgression/regression cycles.

The basal part of the Upper Jurassic in Kachchh has the distinctive Dhosa Oolite Member which is a regional marker stratigraphic horizon. The brachiopods are prolific in this horizon. The Dhosa oolite from Jara, Jumara and Keera records mostly *Kutchithyris euryptycha* and *Rhynchonelloidella* sp., in Jhura and Habo dome, *K. dhosaensis, K. hypsogonia K. ingluviosa*, *K. jooraensis*, *K. pyroidea*, has been recorded other than *K. euryptycha* together with the rhynchonellids *Rhynchonelloidella* sp., *Somalirhynchia* sp., *Sphenorhynchia* sp. The Dhosa Oolite Member from the Charwar Hills also revealed the terebratulid *Dienope* sp. which has not been recorded earlier in the Indo-Madagascan palaeo-biogeographic Province.

The terebratulid *Kutchithyris euryptycha* occurs as a diagnostic element in the Dhosa oolite. Bivariate size-plot of *K.euryptycha* from different sections, reflect no major change or morphologic variation related to the position from the shoreline – except for a decrease in number and shell size in Jara and Jumara than Jhura which can be seen from the univariate statistics of the size parameters (Fig. 4). Jumara and Jara being farthest from the palaeoshoreline, were deeper than Jhura (near shore) during the trangressive episodes. Mesozoic brachiopods were dominantly shallow water dwellers (e.g. see Ager, 1986; Ruban, 2009). Thus both number and size increase of *K. euryptycha* probably elucidate that depth variation also had a potential control on brachiopod diversity in Kachchh.

DISCUSSION

In a detailed study of the Jurassic brachiopod diversity dynamics of the Caucasus region, Ruban (2011) noted fluctuating trends from the Callovian which finally decreased significantly in the Berriasian remaining low till the end of early Cretaceous and he postulated the overall collapse due to an acceleration in disappearance rate and a drop in appearance rate which was a result of change in basin depth. Brachiopod species associated with the Tithonian reefal limestone in southern Europe were affected by the end Jurassic marine regression and as many as 50 species, both endemic and geographically widespread, became extinct, which has been related to severe habitat restriction as a result of marine regression (Sandy, 1988). The overall demise of the Jurassic brachiopods of western India, during the entire middle-upper Jurassic interval, differed from the diversity dynamics of other fossil groups like ammonites, gastropods which were not affected until the Tithonian (Bardhan *et al*., 2007; Das, 2008). All ammonite genera including leiostracans suffered regional extermination and it so happened that the genera also became extinct globally and it is perhaps due to the reason that the Kachchh sea harboured shallow water faunas which suffered most during the extinction (Bardhan *et al*., 2007).

One of the most distinct changes within the basin, in terms of facies pattern, is the change from a carbonate-dominated sedimentary milieu in the Bathonian to a siliciclastic regime in the Callovian. The highest brachiopod diversity in the Bathonian (Fig. 2), is probably a result of several factors such as opening of new ecospace, bathymetry and climate. A distinct feature of the Bathonian in Kachchh is the presence of high diversity (more than 60 taxa) coral meadows (Fürsich *et al*., 1994, 2004), gastropods (Das, 2008), bivalves, diverse sponges occurring as sponge meadows (Mehl and Fürsich, 1997). The Bathonian of Kachchh, according to Fürsich *et al*. (2004) was characterised by low nutrient supply and a warm, tropical water temperature. Rapid evolution in some brachiopod genera played a decisive role in resulting in the diversity increase, e.g., evolution in the dominant Kachchh genera, *Kutchithyris* (5 species in the Bathonian) and *Cryptorhynchia* (4 species) have been governed by heterochrony, especially paedomorphosis (Mukherjee, 2007; Mukherjee *et al*., 2002). In the Bathonian rhynchonellid *Cryptorhynchia*, progenesis was the heterochronic mechanism, where the descendant is the scaled down version of the ancestor. Progenesis is considered to be an adaptive strategy for r-selected regimes and is associated with unstable environments (Mckinney, 1986).The disappearance of the vast majority of brachiopod species at the Bathonian-Callovian boundary is related to the sudden change in environmental parameters from the Late Bathonian to the Early Callovian as inferred from the change in sedimentary regime from carbonate ramp to siliciclastic ramp setting which affected the overall faunal diversity (Fürsich *et al*., 2004). The almost absence of ‘range through taxa’ and dominance of ‘singleton taxa’ (Table 2), that characterises the Jurassic brachiopod faunal diversity of western India also indicate that the distribution pattern was governed by subtle differences in environmental parameters.

Recent sedimentological analyses of the Oxfordian Dhosa Oolite Member by Alberti *et al*. (2012a) gives evidence of at least two phases of sub-aerial exposure (palaeokarst and corroded surfaces) of the Kachchh Mainland and thereby points to considerable changes in relative sea-level. The formation of the Dhosa Conglomerate Bed was concurrent with a phase of strong tectonic activity in the Kachchh Basin, which might be responsible for the sometimes strong sea-level fluctuations during the Middle and early Late Oxfordian.

The last appearance of all 12 Oxfordian taxa by the end Oxfordian and absence of any other brachiopod in the Kimmeridgian is worth probing. Recently, Arora *et al*. (2015) recorded black shales within the Middle Kimmeridgian – Tithonian of the Kachchh Basin and therefore intermittent anoxia related to Late Jurassic Oceanic anoxic event was suggested from the presence of pyrite framboids and V, Ni and Co concentrations of the black shales which indicated sub-oxic to anoxic depositional settings. Thus, bottom anoxia was probably the major factor responsible for the near absence of benthics in the Kimmeridgian. Oxygen deficiency is frequently discussed as a main trigger of brachiopod extinction in the Palaeozoic and Mesozoic (Racki, 1998; Ruban, 2004). The fast changing bathymetric conditions in the Kachchh-Jaisalmer sea along with the stressed environment due to the presence of anoxia, perhaps became detrimental for the brachiopods and they could not recover after the end—Oxfordian extinction phase. Thus, the end Jurassic biotic crisis was perhaps felt by the brachiopods first and so the Kachchh endemic fauna got diminished much before the main extinction phase in the Tithonian. During the Tithonian, only two cosmopolitan brachiopod genera entered the Kachchh and Jaisalmer basins, and they became extinct at the latest Tithonian along with many gastropods, ammonites taxa probably due to the Late Jurassic oceanic anoxic event.

CONCLUSIONS

The study of the Jurassic brachiopod fauna in western India, revealed that the diversity was highest in the Bathonian and then decreased in the Callovian and Oxfordian. The endemic Kachchh-Jaisalmer brachiopod fauna was extinct by the end Oxfordian and after that the Tithonian cosmopolitan taxa were the victims of the mass-extinction at the J/K boundary.

The cyclic pattern of the species diversity dynamics observed by the high appearance rate at the beginning of each stage boundary and high extinction at the close of the stage boundary, predominance of singleton taxa and very few range-through taxa is probably due to the cyclic sedimentation pattern in the Middle–Upper Jurassic of Kachchh and Jaisalmer as a result of which the same environments appeared again and again and were colonised by taxa of identical generic composition but different species.

Though the lithofacies served as the major control for the distribution but the diversity dynamics of the Middle-Upper Jurassic brachiopods of western India reveal a control of the depth of water column and therefore also the transgression-regression cycles. The distribution pattern was governed by subtle differences in environmental parameters.

Study of the diversity from Bathonian to Tithonian reflect changes in the brachiopod communities which indicate they were stressed much before the J/K mass extinction. The changing bathymetry coupled with environmental stress posed by intermittent anoxia as revealed by recent sedimentological studies of the Upper Jurassic of Kachchh proved detrimental for the endemic brachiopod taxa and they could not recover after the Late Oxfordian extinction phase. In the Late Tithonian, two cosmopolitan taxa found their way into the basin and were exterminated at the J/K boundary.

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