www.gondwanags.org.in
Original Article

ISSN : 2455-1953
JGSR
Journal of Geosciences Research
Vol. 7, No.2, July, 2022, pp. 179-185

Depositional Environment of Jurassic Beds of Bela Island, Rann of Kachchh, Gujarat, India Using Ostracodes

Manisha Kumari

Department of Earth Sciences, Pondicherry University, Puducherry-605014(PY), India
(E-mail: drmkumari@gmail.com)

Abstract

The present study focuses on understanding the depositional environment of Jurassic beds of Bela Island, Rann of Kachchh, Gujarat, India which is deduced mainly based on evidence furnished by ostracode fauna. Based on the distribution of 57 ostracode species in Jurassic beds of Bela Island, three biozones, in ascending order, *Cytheropteron micropunctata* Range Zone (early-middle Bathonian), *Progonocythere laeviscula* Range Zone (late Bathonian-early Callovian) and *Habocythere mouwanaensis* Range Zone (early-middle Callovian), have been established. The beds of *lowermost* Zone were deposited in shallow brackish water environment in the initial phase of marine transgression; the beds of middle zone were deposited at moderate rate of sedimentation in shallow sublittoral environment during the transgressive phase of sedimentary cycle; and the beds of *uppermost* zone were deposited in the shallow and brackish water condition in regressive phase of sedimentary cycle.

Keywords: Ostracode, Depositional Environment, Jurassic Beds, Bela Island, Rann of Kachchh

Introduction

Bela Island, standing out prominently amidst the vast plains of the Rann of Kachchh, is an important area because of spectacular development of Bathonian–Callovian succession with rich crop of varied fauna. According to Biswas (1993), the Jurassic outcrops stretch from a little east of the Mouwana Village to west of the Lodrani Village along the northern border of the island. The total thickness of the Jurassic sediments is 376m in Bela Range and 504m in Mouwana Hill. The Bela uplift is a low, narrow rectilinear uplift bounded on north and south by flexures. Bela Flexure, a simple asymmetric anticline, is divisible into two large folds, Lodrani anticline and Mouwana Dome. Both, the outcrops are separated by a tongue of Tertiary and Recent deposits in the saddle between the two structures. The island is affected by a number of faults, dykes and sills. Lodrani anticline, comprises a major part of Bela Range along the northern margin of the island, is a long narrow asymmetric anticline plunging to the east and west. It has a short, steep northern limb (dip ~ 75º - 85º) and a gentle southern limb (dip ~ 8º – 10º). Mouwana Hill, a dome at the eastern end of the island has a steep northern flank dipping ~ 70º and very gentle southern flank, dipping 4º - 6º to the south.

Several workers have discussed the depositional environment of the Jurassic beds of the Bela Island earlier (Agrawal and Kacker, 1978; Singh and Rai, 1980; Biswas, 1991, 1993; Pandey and Fürsich, 2001; Fürsich *et al.,* 2004). The present paper discusses the depositional environment of the Jurassic Beds of Bela Island, deduced mainly based on ostracodes.

Stratigraphy

The Kachchh Basin has been divided into three geological provinces *viz*. Kachchh Mainland, Pachchham Island and Eastern Kachchh based on the lithostratigraphic study (Biswas, 1993; Fig.1). The Mesozoic sediments of the Eastern Kachchh, of which the Bela Island is the part, has been divided into three lithostratigraphic units such as the Khadir Formation, the Washtawa Formation and the Wagad Sandstone (Biswas, 1993). The Khadir Formation represents the oldest unit in the region and is extensively exposed in Khadir, Bela and Chorar Islands. The other two units are exposed in Wagad area. The Khadir Formation in its type area has been further subdivided into following five members in ascending order *i.e.*, the Cheriya Bet Conglomerate Member, the Hadibhadang Shale Member, the Hadibhadang Sandstone Member, the Gadhada Sandstone Member and the Bambhanka/Gangta Member.

As far as the Bela Island is concerned, here only a part of the Khadir Formation is exposed. The Cheriya Bet Conglomerate Member and lower part of the Hadibhadang Shale Member are not exposed, and the succession starts with the upper 91m of the Hadibhadang Shale Member. The highest Jurassic beds here belong to the basal part of the Gadhada Sandstone Member. The Hadibhadang Shales are exposed all along the northern slopes of

(Received : 28 November 2021 ; Revised Form Accepted : 06 April 2022)
https://doi.org/10.56153/g19088-021-0076-11

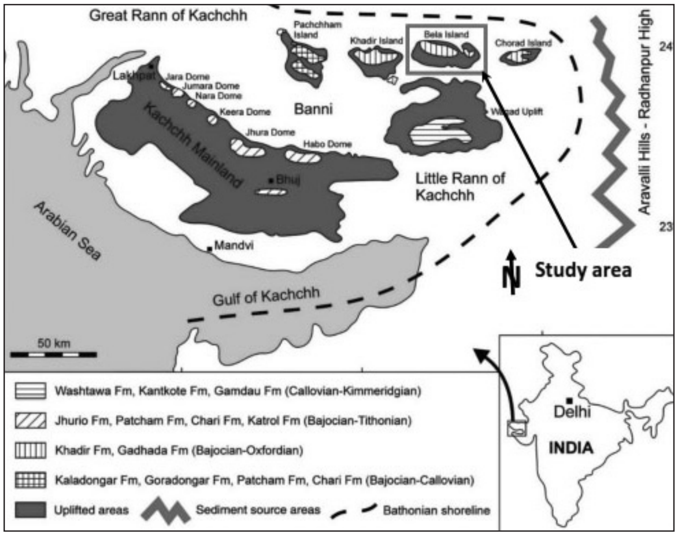

Fig. 1. Geological sketch map of Kachchh Basin (*Modified after* Fursich *et al.,* 2004)

Bela (Lodrani anticline) and Mouwana escarpments. The shales are interbedded with siltstones and sandstones. The Hadibhadang Sandstone forms the upper part of the escarpment, the hard limestone bed being at the top. The member becomes more argillaceous towards the east. The middle part is arenaceous in western region, while in Mouwana Hill it becomes argillaceous. The top limestone is thinly bedded and contains hard bands of calcareous conglomerates. Locally lenses of golden-oolite rock occur in the lower part of the limestone bed. The Gadhada Sandstone Member comprises mostly sandstone. The basal shale beds are present and the overlying calcareous beds are represented by thin, flaggy bands, occasionally fossiliferous and separated by silty shales. In Mouwana Hill Section, the calcareous sandstone occurs only at one level, *i.e.* at 63m below the highest exposed beds (Biswas, 1993).

Location of the Sections

The samples were collected from the five lithosections of the Khadir Formation, Bela Island for the study of ostacodes. All the sections have yielded rich and well preserved fauna. The location of these sections is given below:

Bela Anticline: Section I- exposed along Lodrani-Kuda track, north of Lodrani Village (23º 54' 29" N: 70º 37' 25" E); Section II- exposed at about 1 km NW of Gadhada Ruins (23º 54' 17" N: 70º 41' 30" E); Section III- exposed along a stream about 1km northwest of Bela Village (23º 52' 35" N: 70º 48' 13" E); Section IV- exposed along a north-south trending stream, northern escarpment of Bela Range, near Bela Village. Mouwana Hill: Section V- exposed along northern and southern escarpments of Mouwana Hill (23º 49' 50" N: 70º 52' 03" E).

A total of 35 samples were collected from the Section I (Fig. 2). Of these, 2 samples (SI/1-2) come from the basal grey shales, 7 samples (SI/3-9) from the *Corbula lyrata*rich reddish-brown shale, which is traversed by a prominent E-W trending dolerite dyke, and 2 samples (SI/10-11) from the successively overlying shales of the Hadibhadang Shale Member. Three samples (SI/ 12-14) were from the lower part of the Hadibhadang Sandstone Member and 13 samples from the upper part of the member (Raimalro Limestone). Eight samples (SI/28-35) were from the Coralline Limestone of the Gadhada Sandstone Member. In Section II, 8 samples (SII/1-8) were collected from the part of the Gadhada Sandstone Member overlying the Coralline Limestone horizon. In Sections III, 12 samples (SIII/1-12) were collected from the Raimalro Limestone of the Hadibhadang Sandstone Member. In Section IV, 13 samples (SIV/1-13) were collected from the Hadibhadang Sandstone Member. In all 17 samples were collected from the Section V (Fig.

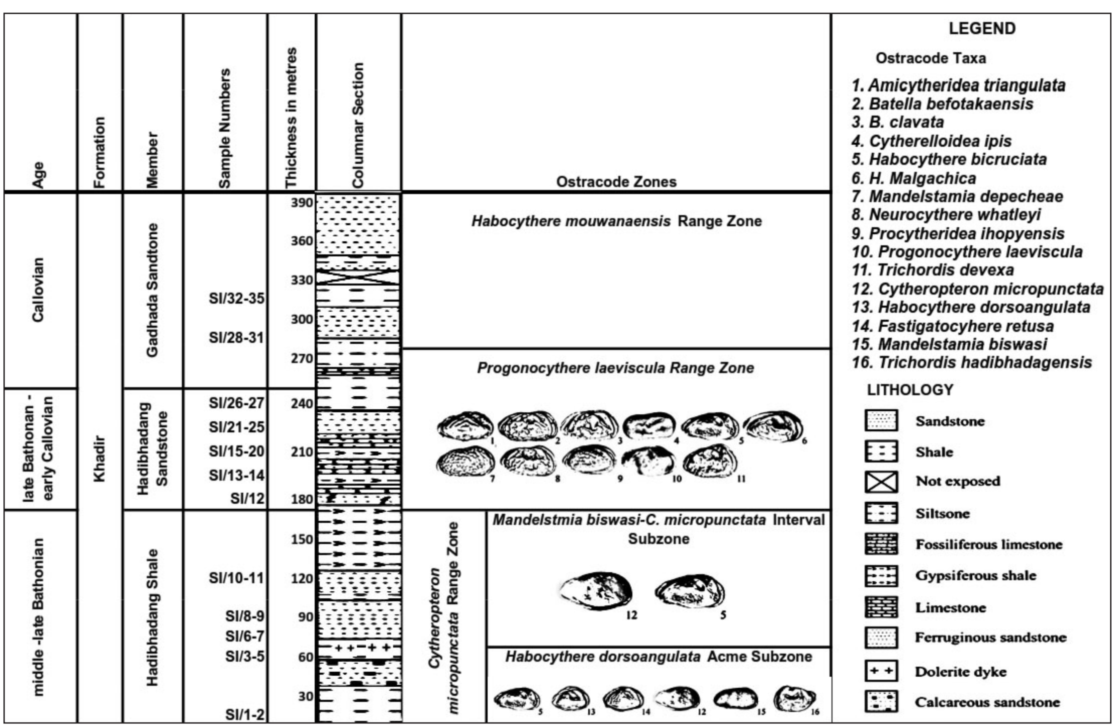

Fig. 2. Stratigraphical succession of Section I, north of Lodrani Village (*Modified after* Biswas, 1993).

3). Of these, 3 samples (SV/1-3) were collected from the upper part of the Hadibhadang Shale Member. Three samples (SV/4-7) were from the lower part of the Hadibhadang Sandstone Member and 2 samples (SV/8-9) from the upper part of the member (Raimalro Limestone). Eight samples (SV/10-17) were from the Gadhada Sandstone Member.

Results and Discussion

The ostracode fauna of the Khadir Formation, Bela Island comprises 57 species belonging to 28 genera and 11 families. 22 species belong to the family Progonocytheridae (39%), 7 species each to the families Cytherellidae (12.5%) and Cytheruridae (12.5%), 4 species each to the families Bairdiidae (7%) and Loxoconchidae (7%), 3 species each to the families Schulerideidae (5%), Trachyleberididae (5%) and Paracyprididae (5%), 2 species to the family Bythocytheridae (3%), 1 species each to the families Protocytheridae (2%) and Darwinulidae (2%). The important taxa used to deduce the depositional are provided herewith (Fig.4).

The Jurassic Beds of the Bela Island have been categorized into three ostracode biozones in ascending order such as *Cytheropteron micropunctata* Range Zone (early-middle Bathonian), *Progonocythere laeviscula* Range Zone (late Bathonian-early Callovian) and *Habocythere mouwanaensis* Range Zone (early-middle Callovian). *Cytheropteron micropunctata* Range Zone is further subdivided into two subzones, *Habocythere dorsoangulata* Acme Subzone and *Mandelstamia biswasi - Cytheropteron micropunctata* Interval Subzone (Khosla *et al.,* 2005; Fig. 2-3).

Of five sections, the lower part of Section I belongs to *Cytheropteron micropunctata* Range Zone, the upper part of Section I and Sections III, IV and the middle part of Section V belong to *Progonocythere laeviscula* Range Zone, while Section II and the upper part of Section V belong to *Habocythere mouwanaensis* Range Zone. According to earlier workers the beds were largely deposited in a marine transgressive phase during Bathonian-early Callovian time and partially in a marine regressive phase during succeeding middle Callovian time (Agrawal and Kacker, 1978; Biswas, 1991, 1993; Pandey and Fürsich, 2001). An integrated coral and ostracode biostratigraphy is given in Table 1.

Herein, the depositional environment of the Jurassic Beds, Bela Island is deduced mainly based on evidence furnished by ostracode fauna. However, the other significant invertebrates like bivalves and corals, which occur abundantly at certain stratigraphic levels were used to discuss the past ecological conditions. A lot of work on the ostracodes has been carried out worldwide to generate the ecological data, which was used to interpret the depositional environment (Kronicker, 1963; Morkhoven, 1963; Sohn, 1964; Pokorný, 1971; Andreev and Mandelstam, 1971; Oertli, 1971; Bonaduce *et al.,* 1976; Bate, 1978; Kilenyi, 1978, Dépêche, 1985, Dépêche in Dépêche *et al.,* 1986; Dingle, 1985; Neale, 1988; Mannikeri, 1996; Khosla *et al.*, 1997; Nazeer *et al.*, 2021). The majority of Jurassic ostracode genera are extinct and only a few genera occur in the present-day sea. Hence, the paleoecological interpretation provides a generalized picture.

Cytheropteron micropunctata Range Zone

This zone covers the lower part of the Hadibhadang Shale Member. It is composed mainly of yellowish-brown gypsiferous *Corbula lyrata* bearing shales and sandstones. The Samples S I/6-11 in which ostracode fauna occurs come from these *C. lyrata* bearing shales.

The ostracodes of this zone, in order of their abundance, are: *Habocythere, Mandelstamia, Cytheropteron, Fastigatocythere, Neurocythere, Citrella, Lophocythere, Paracypris* and *Darwinula*.

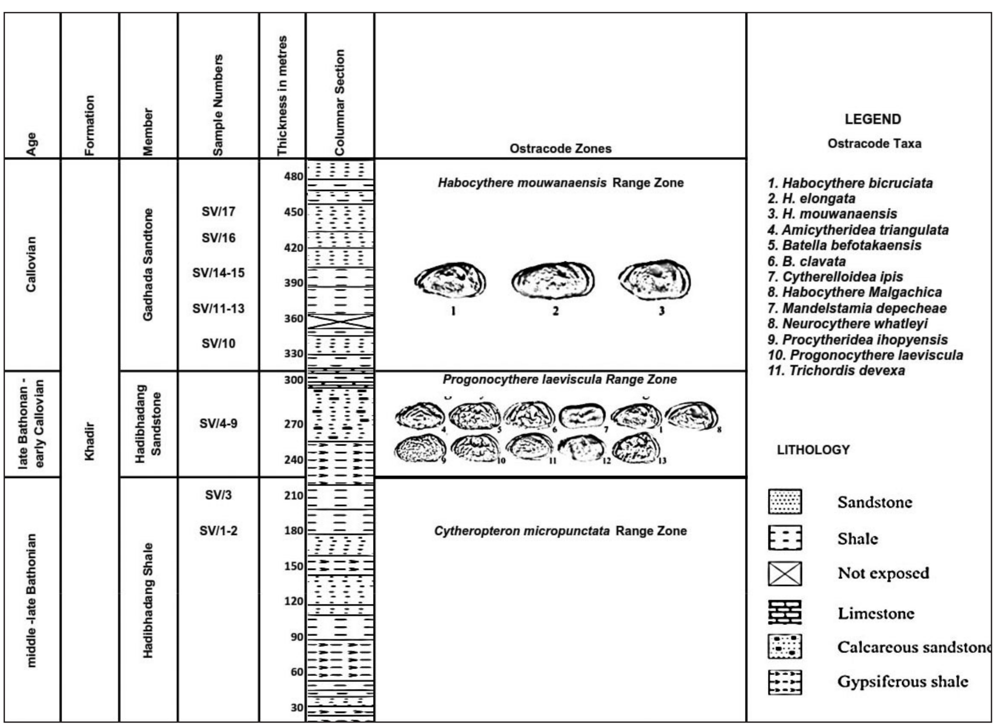

Fig. 3. Stratigraphical succession of Section V, near Mouwana Village (*Modified after* Biswas, 1993).

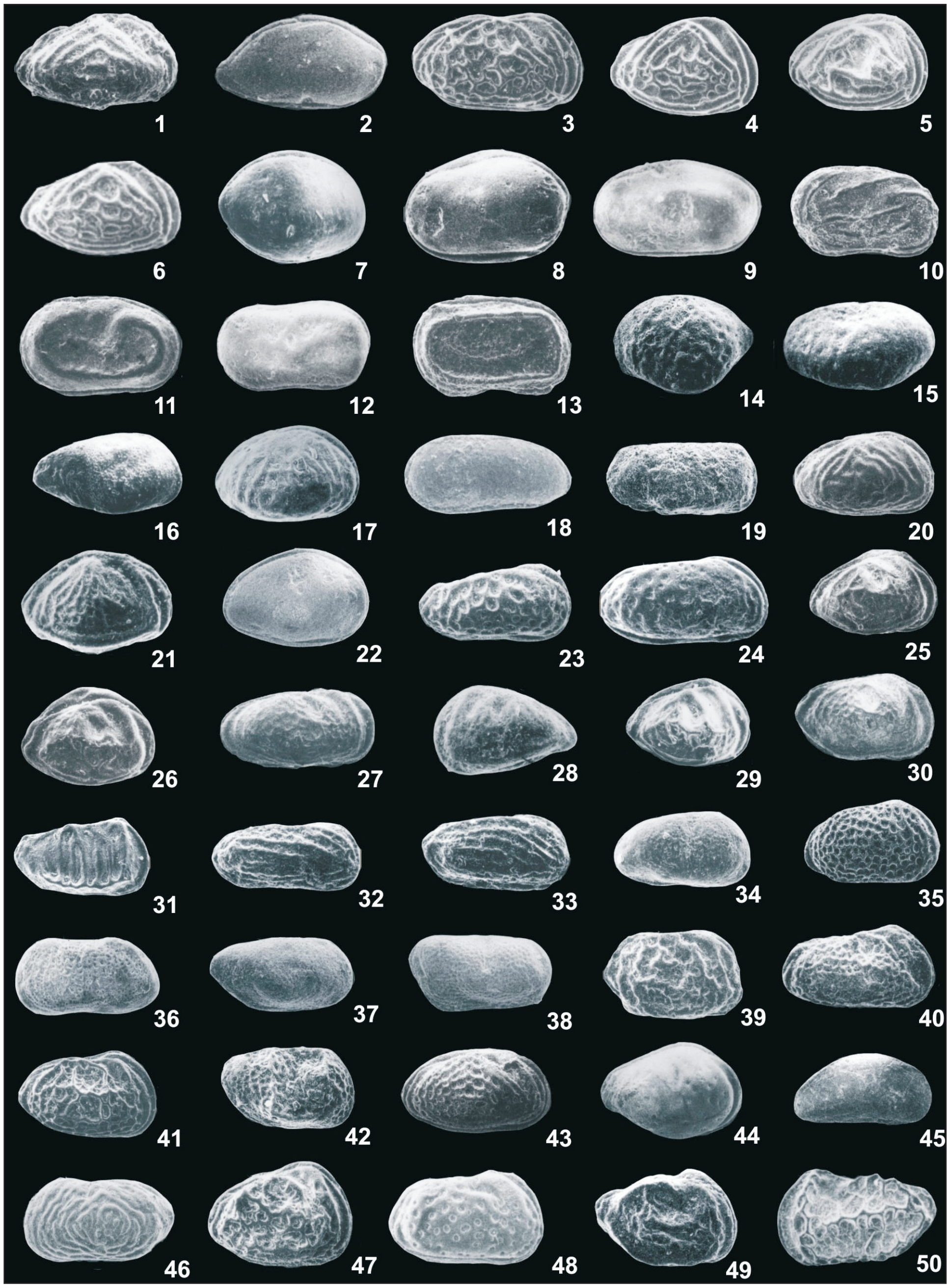

Fig. 4. *1. Amicytheridea triangulata* Bate, carapace (SUGDMF No. 686), RVV, l. 0.60mm, h. 0.35mm; 2. *Bairdoppilata* sp. E, carapace (SUGDMF No. 742), RVV,l. 0.61mm, h. 0.30mm; 3. *Balella befotakaensis* (Grekoff), male carapace (SUGDMF No. 792), RVV, l. 0.66mm, h. 0.36mm; 4. *B. belaensis* (Khosla and Manisha Kumari), right valve (SUGDMF No. 793), LtV, l. 0.51mm, h. 0.32mm; 5. *B. clavata* Khosla *et al.*, female carapace (SUGDMF No. 688), RVV, l. 0.56mm, h. 0.37mm; 6. *B. depressa* Khosla *et al.*, carapace (SUGDMF No. 689),RVV, l. 0.57mm, h. 0.36mm; 7. *Citrella belaensis* Khosla *et al.*, male carapace (SUGDMF No. 771), RVV, l. 0.41mm, h. 0.28mm; 8. *Cytherella disjuncta* Lyubimova and Mohan, female carapace (SUGDMF No. 678), LVV, l. 0.88mm, h. 0.57mm; 9. *C. obscura* Lyubimova & Mohan, carapace (SUGDMF No. 830), LVV, l. 0.64 mm, h. 0.36 mm; 10. *Cytherelloidea badiensis* Khosla *et al.*, carapace (SUGDMF No. 682); LVV, l. 0.61mm, h. 0.32mm; 11. *C. dhrangensis* Khosla and Jakhar, carapace (SUGDMF No. 831), LVV, l. 0.68mm, h. 0.39mm; 12. *C. ipis* Grekoff, carapace (SUGDMF No. 683), LVV, l. 0.63mm; 13. *C. paradifficila* Khosla *et al.*, carapace (SUGDMF No. 684), LVV, l. 0.57mm, h. 0.33mm; *14. Cytheropteron devai* (Khosla *et al.*), left valve (SUGDMF No. 774), LtV, l. 0.46mm, h. 0.32mm; 15. *C. kutchensis* Neale and Singh, carapace (SUGDMF No. 775), RVV, l. 0.51mm, h. 0.28mm; 16. *C. micropunctata* Khosla *et al.*, male carapace (SUGDMF No. 778), RVV, l. 0.46mm, h. 0.24mm; 17. *C. pandeyi* (Khosla *et al.*), carapace (SUGDMF No. 780), RVV, l. 0.43mm, h. 0.28mm; *18. Darwinula* sp., carapace (SUGDMF No. 749), RVV, l. 0.69mm, h. 0.29mm; *19. Eucytherura* sp., carapace (SUGDMF No. 770), RVV, l. 0.41mm, h. 0.19mm; *20. Fastigatocythere indica* Khosla and Manisha Kumari, male carapace (SUGDMF No. 801), RVV, l. 0.72mm, h. 0.39mm; *21. F. retusa* (Grekoff), female carapace (SUGDMF No. 812), RVV, l. 0.66mm, h. 0.40mm; *22. Galliaecytheridea lodraniensis* Khosla and Manisha Kumari, female carapace (SUGDMF No. 756), RVV, l. 0.52mm, h. 0.33mm; *23. Glabellacythere hussaini* Khosla *et al.*, carapace (SUGDMF No. 761), RVV, l. 0.60mm, h. 0.25mm; *24. G.mathuri* (Khosla *et al.*), carapace (SUGDMF No. 764), RVV, l. 0.77mm, h. 0.37mm; *25. Habocythere bicruciata* (Grekoff), female carapace (SUGDMF No. 690), RVV, l. 0.61mm, h. 0.38mm; *26. H. dorsoangulata* (Grekoff), carapace (SUGDMF No. 796), RVV, l. 0.41mm, h. 0.30mm; *27. H. elongata* (Khosla and Manisha Kumari), carapace (SUGDMF No. 797), RVV, l. 0.62mm, h. 0.29 mm; *28. H. jakhari* (Khosla *et al.*), left valve (SUGDMF No. 694), LtV, l. 0.54mm, h. 0.32mm; *29. H. malgachica* (Grekoff), female carapace (SUGDMF No. 692), RVV, l.0.41mm, h. 0.28mm; *30. H. mouwanaensis* (Khosla and Manisha Kumari), carapace (SUGDMF No. 807), RVV, l. 0.56mm, h. 0.32mm; 31. *Lophocythere vertipolycostata* Khosla & Manisha Kumari, carapace (SUGDMF No. 708), RVV, l. 0.67mm, h. 0.35mm; *32. Mandawacythere kachchhensis* Khosla *et al.*, carapace (SUGDMF No. 824), RVV, l. 0.51mm, h. 0.20mm; *33. M. multicostata* Khosla and Manisha Kumari, carapace (SUGDMF No. 826), RVV, l. 0.54mm, h. 0.26mm; 34. *Mandelstamia biswasi* Khosla *et al.*, carapace (SUGDMF No. 786), RVV, l. 0.56mm, h. 0.38mm; 35. *M. depecheae* Khosla *et al.*, right valve (SUGDMF No. 704), LtV, l. 0.59mm, h. 0.30mm; 36. *M. kachchhensis* Khosla *et al.*, carapace (SUGDMF No. 788), LVV, l. 0.57mm, h. 0.27mm; 37. *Monoceratina mouwanaensis*

Table 1: Integrated coral and ostracode biostratigraphy of the Khadir Formation, Bela island, Kachchh.

Formation	Member	Coral Assembalage (Pandey and Fursich, 2001)	Ostracode Biozone (current work)
Khadir	Gadhada Sandstone	*Amphiastraea piriformis* assemblage	*Habocythere mouwanaensis* Range Zone
	Hadibhadang Sandstone	*Amphiastraea piriformis- Montlivaltia cornutiformis* assemblage	*Progonocythere laeviscula* Range Zone
	Hadibhadang Shale	*Amphiastraea-Isastraea* assemblage	*Cytheropteron micropunctata* Range Zone

Except for *Paracypris and Darwinula* none of the other genera occur in the present day. The genus *Paracypris* inhabits in deeper (infra-neritic to bathyl) water and polyhaline conditions, while *Darwinula* is a fresh water form and occasionally occurs in the oligo-mesohaline waters (Morkhoven, 1963). The genera *Lophocythere* and *Mandelstamia,* according to Morkhoven (1963) and Andreev and Mandelstam (1971) are marine forms. The species of genera *Cytheropteron, Neurocythere, Mandelstamia, Lophocythere* and *Citrella* occur widely in the marine Jurassic beds of England and France (Kilenyi, 1978; Dépêche, 1985). The genus *Fastigatocythere* has been described from the marine Jurassic Beds of the Jaisalmer Formation, Jaisalmer (Mannikeri, 1996). The genus *Habocythere* has so far been described from the Jurassic beds of Kachchh. In the present zone under discussion constitutes 87% of the total ostracode fauna, being represented by 726 specimens out of the total 841. The remaining ostracodes are represented by only 13%. The ostracode assemblages having low diversity but high frequency are generally characteristic of brackish water environment (Neale, 1988).

The overall evidence suggests that the beds of *C. micropunctata* Range Zone were deposited in shallow brackish water environment in the initial phase of marine transgression during the Bathonian period. This inference is also supported by the abundant occurrence of the bivalve genera like *Corbula* and *Eomiodon,* which are characteristic of brackish water environment (Agrawal and Kacker, 1980).

***Progonocythere laeviscula* Range Zone**

This zone comprises the Hadibhadang Sandstone Member and basal part of the Gadhada Sandstone Member and contains mainly sandstone, siltstone, partings of flaggy limestone, coralline limestone, calcareous marl, alternate band of fossiliferous, yellow gypsiferous shale and hard siltstone.

Ostracode fauna of this zone shows greatest diversity both at generic as well as at specific level. The fauna is represented by following genera, in order of their abundance: *Progonocythere, Trichordis, Batella, Procytheridea, Cytherella, Galliacytheridea*, *Glabellacythere*, *Habocythere, Pirileberis, Fastigatocythere, Neurocythere, Cytherelloidea, Mandelstamia, Mandawacythere, Paracypris, Morkhovenicythereis, Amicytheridea, Bairdopillata, Eucytherura, Cytheropteron* and *Monoceratina.* The ecological significance of the genera *Habocythere, Mandelstamia, Nophrecythere* and *Paracypris* has already been discussed. The genus *Cytherella* occurs in various temperature and depth ranges in marine environments (Morkhoven, 1963). The genus *Cytherelloidea* occurs in shallow, warm marine waters, occasionally found in brackish-water (mesohaline) environments (Morkhoven, 1963). According to Sohn (1964), the genus is a good paleotemperature indicator and in the present-day seas it does not survive in temperature less than 10ºC. Species of the family Cytherellidae are abundant in the shallow shelf, warm water condition (Kronicker, 1963). The genus *Bairdopillata* is a characteristic of marine environment and occurs in very shallow as well as in very deep waters (Morkhoven, 1963). Bonaduce, Ciampo and Masoli (1975) recorded the species of the genus at the depth between 10m-125m from the near-shore condition. The genera *Cytheropteron, Eucytherura* and *Monoceratina* occur in marine environment and the former two occur mostly at all depths of the present-day seas (Morkhoven, 1963). Bonaduce *et al.* (1975), who have studied the ostracode fauna of the Adriatic Sea, recorded the representatives of the genera *Cytheropteron, Eucytherura* and *Monoceratina* from a depth of 30-210m, 30-170m and 70-210m, respectively, at average salinity between 38-40‰ and average temperature between 10-17º C. The genera *Amicytheridea, Batella, Fastigatocythere, Mandawacythere, Galliaecytheridea*, *Glabellacythere*, *Morkhovenicythereis, Pirileberis, Procytheridea, Progonocythere* and *Trichordis* do not occur in the present day oceans but the associated fossils with them indicate their marine affinity.

The genus *Batella* has so far been described from the Jurassic of Kachchh (Khosla *et al.*, 1997) and the genus *Fastigatocythere* from the Jurassic of Central Saudi Arabia (Dépêche 1985 in Dépêche *et al.,* 1986). The genera *Morkhovenicythere* is and *Progonocythere* occur in the marine Jurassic beds of England and France (Bate, 1978; Dépêche, 1985). According to Morkhoven (1963), the genera *Procytheridea* and *Progonocythere* occur in marine environment. Dingle (1985), who discussed the marine ostracode provinces in Southern Gondwanaland, shows that the genera *Amicytheridea, Pirileberis* and *Progonocythere* occur in the marine provinces of the Southern Gondwanaland.

Rich assemblages, viewed individually as well as specifically, are limited to shallower waters, perhaps upto 200-300m depths (Pokorný, 1971). Different species of Ostracoda reacts

Khosla and Manisha Kumari, carapace (SUGDMF No. 750), RVV, l. 0.48mm, h. 0.24mm; 38. *M. rannensis* Khosla and Manisha Kumari, carapace (SUGDMF No. 752), RVV, l. 0.60mm, h. 0.29mm; 39. *Morkhovenicythere isrectangularis* Khosla *et al.*, carapace (SUGDMF No. 766), RVV, l. 0.43mm, h. 0.28mm; *40. Neurocythere kachchhensis* Khosla and Manisha Kumari, male carapace (SUGDMF No. 813), RVV, l. 0.48mm, h. 0.24mm; *41. N. whatleyi* Khosla and Jakhar, female carapace (SUGDMF No. 815), RVV, l. 0.37mm, h. 0.23mm; *42. Paracypris mohani* Khosla *et al.*, carapace (SUGDMF No. 746); RVV, l. 0.75mm, h. 0.36mm; 43. *Paranotacythere* sp., carapace (SUGDMF No. 781), RVV, l. 0.36mm, h. 0.22mm; *44. Procytheridea ihopyensis* Grekoff, male carapace (SUGDMF No. 769), RVV, l. 0.83mm, h. 0.41mm; *45. Progonocythere laeviscula* Lyubimova & Mohan, female right valve (SUGDMF No. 698), LtV, l. 0.67mm, h. 0.44mm; 46. *Pseudoperissocytheridea concentrica* Khosla *et al.*, left valve (SUGDMF No. 828), LtV, l. 0.56mm, h. 0.27mm; 47. *Trichordis devexa* (Grekoff), carapace (SUGDMF No. 699), RVV, l. 0.54mm, h. 0.33mm; 48. *T. gujaratensis* Khosla *et al.*, female carapace (SUGDMF No. 819), RVV, l. 0.73mm, h.0.40mm; *49. T. hadibhadangensis* Khosla *et al.*, female carapace (SUGDMF No. 820), RVV, l. 0.78mm, h. 0.49mm; 50. *T. jaisalmerensis* (Kulshreshtha *et al.*), male carapace ((SUGDMF No. 823), LVV, l. 0.80mm, h. 0.36mm. (Abbreviations: RVV – right valve view; LtV – lateral view; LVV – left valve view; l. – length; h. – height.)

differently to environmental changes for survival and there are changes in morphological characters within the various specimens those found at different depths (Nazeer *et al*., 2021).The present zone under discussion has abundant and highly diverse ostracode fauna. Most of the individuals have different sizes, thick shells and varied surface ornamentations. The overall preservation of the fauna is good and the ratio of carapace and open valves is almost equal (1620 carapaces and 1634 valves). These indicate that the beds of the zone were deposited at moderate rate of sedimentation in shallow sublittoral environment during the transgressive phase of sedimentary cycle.

Habocythere mouwanaensis Range Zone

This zone covers middle part of Gadhada Sandstone Member comprising buff coloured, medium to coarse-grained sandstones and grey, fossiliferous shales. The samples S II/2 and 5, and S VI/7, in which ostracode fauna occurs, come from the middle part of the member.

Habocythere is the most dominant genus present in the zone. It constitutes 94% (247 specimens out of 264) of the total ostracode fauna. *Lophocythere, Citrella, Paracypris, Trichordis* and *Paranotacythere are* other associated genera, which form 6% of the assemblage. Except for *Paranotacythere,* which is a marine form (Bassiouni, 1974),the ecological significance of all other genera has already been discussed.

The reduction of diversity during regressive phase of sedimentary cycles is a common phenomenon. A sharp decline both in diversity as well as frequency of ostracode fauna is suggestive a temporary shallowing of the basin. The fauna are poorly preserved and having smaller size. These features indicate that the environment changed greatly during the deposition of the beds of the present zone, the basin water becoming shallow, turbid and unsuitable for the ostracode fauna. In addition, a very high carapace-valve ratio (264 carapaces and 2 valves) indicates an accelerated rate of sedimentation, which would be consistent with the presumed high turbidity.

On the basis of above observations, it is inferred that the beds of the zone were deposited in the shallow and brackish water condition in regressive phase of sedimentary cycle.

Conclusions

Jurassic Beds of the Bela Island have been grouped as three ostracode biozones. The overall evidence furnished by the fauna suggests that there were fluctuations in the sea level persisted within the basin during early Bathonian-middle Callovian periods. Majority of the genera depicts a picture of shallow marine and brackish water conditions and suggests moderate to low energy deposition under the littoral to sub-littoral environment. The lowermost *C. micropunctata* Range Zone was deposited in shallow brackish water environment in the initial phase of marine transgression, while the middle *P. laeviscula* Range Zone was formed in shallow sublittoral environment under the transgressive phase and the uppermost *H. mouwanaenis* Range Zone was evident of reappearance of the shallow and brackish water condition under the regressive phase of sea.

Conflict of Interest

Author declares no conflict of Interest.

Acknowledgements

The paper forms part of the study carried out by the author for her Ph.D. thesis. The author owes a debt of gratitude and regard to her revered supervisor Dr. S. C. Khosla, Retired Professor, Department of Geology, Mohanlal Sukhadia University, Udaipur for his invaluable guidance, expertise suggestions and constant inspiration throughout the course of the study.

References

Agrawal, S.K. and Kacker, A.K. (1978). Succession and fossil molluscs of the Jurassic rocks near Mouwana, Eastern Bela Island, District Kutch, Gujarat. Recent Researches in Geology, Chiplonkar Commemorative Volume, Hindustan Publishing Corporation (I), Delhi, v. 4, pp. 482-492.

Andreev, Yu.N. and Mandelstam, M.I. (1971). Biogeographical associations of Cretaceous Ostracods in the USSR, pp. 615-629, table 1, figs. 1-5. *In:* Oertli, H.J. (*Ed.*), Paléoécologie des Ostracodes, Bull. du Cent. des Res. Pau-SNPA, suppl. 5.

Bassiouni, M.E.A.A. (1974). *Paranotacythere* n. g. (Ostracoda) aus dem Zeitraum Oberjura bis Unterkreide (Kimmeridgium bis Albium) von Westeuropa. Geologisches Jahrbuch, Reihe A, v.17, pp. 3-111.

Bate, R.H. (1978). The Jurassic Part 2 (Aalenian to Bathonian). *In:* R.H. Bate and E. Robinson (*Eds.*), A Stratigraphical Index of British Ostracoda. Geol. Jour. Special Issue, No. 8, pp. 213-258.

Biswas, S.K. (1991). Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, western India. *In:* S.K. Tondon (*Ed.*), Stratigraphy and Sedimentary Evolution of Western India, Delhi, pp. 74-103.

Biswas, S.K. (1993). Geology of Kutch. Keshava Dev Malviya Institute of Petroleum Exploration, DehraDun, v. 1-2, pp. 1- 450.

Bonaduce, G., Ciampo, G. and Masoli, M. (1975). Distribution of ostracode in the Adriatic Sea. Pubblicazioni della Stazione Zoologica di Napoli, v. 40(1), pp. 1-154.

Dépêche, F. (1985). Liassupérieur, Dogger, Malm. *In:* Oertli, H.J. (*Ed.*). Atlas des Ostracodes de France (Paleozoique – Actuel). Bull. des Centr. de Rech. Explor. – Prod. Elf.-Aquit. Mém., v. 9, pp. 119-145.

Dépêche, F., Nindre, Y., Manivit, J. and Vaslet, D. (1986). Les ostracodes du Jurassiqued' Arabie Saoudite centrale: Systématique, Répartition Stratigraphique et Paléogéographique. Geobios, Mem. Spec. no. 9, pp. 221-275.

Dingle, R.V. (1985). Turonian, Coniacian and Santonian Ostracoda from south-east Africa. Annal. South Afric. Mus., v. 96(5), pp. 123-239.

Fùrsich, F.T., Callomon, J.H., Pandey, D.K., Jaitly, A.K. (2004). Environments and faunal patterns in the Kachchh rift basin, western India, during the Jurassic. *Riv. Italiana di Pal. e Strat*., v. 110, pp. 181-190.

Khosla, S.C., Jakhar, S.R. and Mohammed, M.H. (1997). Ostracodes from the Jurassic beds of Habo Hill Kachchh, Gujarat. Micropaleontology, v. 43(1), pp. 1-39.

Khosla, S.C., Manisha Kumari, Darwin Felix, A., Jakhar, S.R. and Nagori, M.L. (2005). Middle Jurassic Ostracoda from the Northern Island Belt, Rann of Kachchh, Gujarat, India. Jour. Pal. Soc. India, v. 50(1), pp. 17-64.

Kilenyi, T.I. (1978). The Jurassic, Part 3: Callovian – Portlandian. *In:* Bate, R.H. and Robinson, E. (*Eds.*), A Stratigraphical Index of British Ostracoda. Geol. Jour. Spec. Issue, v. 8, pp. 259-298.

Kronicker, L.S. (1963). Ecology and classification of Bahamian

Cytherellidae (Ostracode). Micropaleontology, v. 9, pp. 61-70.

Mannikeri, M.S. (1996). Two new ostracode genera *Jainiana* (Family: Progonocytheridea) and *Bhatiana* (Family :Trachyleberididae) from the Middle Jurassic of Jaisalmer, Western Rajasthan, India. *In:* Pandey, J., Azmi, R.J., Bhandari, A. and Dave, A. (*Eds.*) Indian Colloquium on Micropalaentology and Stratigraphy, DehraDun. pp. 397-406.

Morkhoven, F.P.C.M.Van (1963). Post-Palaeozoic Ostracoda. Amsterdam: Elsevier Publishing Company, v. 2, pp. 1-478.

Nazeer, M.N., Hussain, S.M., Salaj, S.S., Razi Sadath and Nishath, N.M. (2021). Ostracoda Morphometry in Deciphering the Paleoenvironment of Epipelagic to Bathypelagic Zone, off Visakhapatnam, Bay of Bengal. Jour. Geosci. Res., v. 6 (1), pp. 87-93.

Neale, J.W. (1988) Ostracodes and palaeosalinity reconstruction. pp. 125-155. *In:* Deckker, P., De Colin, J.-P. and Peypouquet, J.P. (*Eds.*), Ostracoda in the Earth Sciences, Elsevier, The Netherlands.

Oertli, H.J. (1971). The aspects of ostracode fauna – a possible new tool in petroleum Sedimentology, pp. 137-151, figs. 1-7, pls. 1-2. *In:* Oertli, H.J. (*Ed.*), Paléoécologie des Ostracodes, Bull. du Centr. des Res. Pau-SNPA, suppl. 5.

Pandey, D.K. and Fürsich, F.T. (2001). Environmental Distribution of Scleractinian Corals in the Jurassic of Kachchh, Western India. Jour. Geol. Soc. India, v. 57(6), pp. 479-495.

Pokorný, V. (1971). The diversity of fossil ostracode communities as an indicator of palaeogeographic conditions, pp. 45-61, figs. 1-4, tables 1-2. *In*: Oertli, H.J. (*Ed.*), Paléoécologie des Ostracodes, Bull. du Centr. des Res. Pau-SNPA, suppl. 5.

Singh, C.S.P. and Rai, J.N. (1980). Bathonian-Callovian fauna of Western Bela Island (Kutch): Pt. 1 – Bivalve families Cardiidae, Neomiodontidae and Corbulidae. Jour. Pal. Soc. India, v. 23-24, pp. 71-80.

Sohn, I.G. (1964). The Ostracoda genus *Cytherelloidea,* a possible indicator of paleotemprature. Publ. Staz. Zool. Napoli, v. 33 suppl., pp. 529-534.