CYTHERELLOIDEA (OSTRACODA) FROM THE UPPER CRETACEOUS BAGH FORMATION OF MADHYA PRADESH, INDIA: ITS AFFINITY AND PALAEOGEOGRAPHIC IMPLICATIONS

MAYA CHAUDHARY, M. L. NAGORI* and NIDHI BHANAT

DEPARTMENT OF GEOLOGY, MOHANLAL SUKHADIA UNIVERSITY
51, SARASWATI MARG, UDAIPUR – 313 002, INDIA
* E-mail: madan.nagori@gmail.com

ABSTRACT

Cytherelloidea is a cosmopolitan Ostracoda genus having worldwide distribution. It occurs commonly in the Cretaceous shallow marine marginal basins of the erstwhile Gondwanaland viz. South America, Africa, Middle East, Madagascar, Australia and India. In the present work eight species of the genus have been recorded from the Bagh Formation (Upper Cretaceous) of Madhya Pradesh, India. Of these, two species—Cytherelloidea awaldaensis and C. rosebaidaensis are new. The other reported species are Cytherelloidea oertelli Singh, C. oudiapurensis Jain, C. raoi Jain, C. subgranulosa Jain, C. thuatiensis Jain, and Cytherelloidea sp. Affinity and palaeogeographic implications of the genus Cytherelloidea are discussed.

Keywords: Madhya Pradesh, Bagh Formation, Upper Cretaceous, Ostracoda, Palaeogeographic implications.

INTRODUCTION

The exposures of Bagh Formation occur as isolated patches, extending about 350 kms. in length from Barwaha (M.P.) in the east to Rajipipla (Gujarat) in the west. This rift/graben basin of central India is roughly ENE-WSW trending, in which marine/fluvialite sediments of Cretaceous ages are deposited (Fig.1). During the course of study of Ostracoda from these beds, present authors came across many species of the genus Cytherelloidea, of which few species are endemic and rest are either common or resembling with other basins of then Gondwanas.

Genus Cytherelloidea was erected by Alexander (1929), which has worldwide distribution from Liassic? to Recent sediments of shallow, warm marine waters; it is occasionally also found in brackish (mesohaline) environments. The species of the genus occur quite abundantly in the Cretaceous marine basins of Peninsular India, particularly Jaisalmer, Narbada and Cauvery. Surprisingly all the basins have their endemic Cytherelloidea species, with some exceptions.

PREVIOUS WORK

Ostracodes from the Bagh Formation were first recorded by Jain (1961), who reported the occurrence of twenty-two species, including ten new. Of these, only the new species were briefly described without any illustration. Subsequently Roy Chowdhury and Sastri (1962) listed four ostracode taxa from the Deola-Chirakhan marl. Thereafter Guha and Ghosh (1970) reported seventeen ostracode taxa, including eight new species and a new variety, without any description and illustration.

The only comprehensive work on this group is by Jain (1975a), who described thirty ostracode taxa, including nine new species. In that paper, Jain described and illustrated five species of the genus Cytherelloidea. Of these, two species: Cytherelloidea kholai and C. oudiapurensis were new, while the other three species were Cytherelloidea raoi Jain, C. subgranulosa Jain, and C. thuatiensis Jain, which were earlier briefly described by Jain (1961). (C. thuatiensis was then designated as C. indica Jain, 1961).


Fig. 1. Outcrops of the Bagh Formation along Narbada Valley (Modified after Jain, 1975)
STRATIGRAPHY

The Bagh Formation has long been known to the Indian geologists. It was initially classified by Blanford (1869) and later on Bose (1884) proposed definite names to its subunits. In subsequent years considerable work has been carried out on the stratigraphy of these beds. Among these, important contributions were made by Rode and Chiplonkar (1935); Roy Chowdhury and Sastri (1962); Sahni and Jain (1966); Sastry and Mamgain (1971); Chiplonkar et al., (1975); Dassarma and Sinha (1975); and Guha (1976). The generalized stratigraphy of the region is given in table 1.

Table 1. The generalized stratigraphy of the Bagh region:

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uppermost Cretaceous</td>
<td>Lameta Formation</td>
<td>Basalts, Cherty Limestone, Calcareous Sandstone</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>Bagh Formation</td>
<td>Coralline Limestone, Deola-Chirakhan Marl, Nodular Limestone</td>
</tr>
<tr>
<td>Lower Cretaceous</td>
<td>Bijawar Formation</td>
<td>Metamorphics</td>
</tr>
</tbody>
</table>

With the intention of revising the ostracode fauna of the Bagh Formation, authors collected samples from six different localities near Jeerabad village in Man Valley, Dhar District. The locations of these localities are given in the sequel and also in fig. 2. The stratigraphic successions at localities 1 to 6 are given in figs. 3-4.

**Locality 1:** Around 500 mts. SW from Rosebaida village, in a nala section, (N 22°26': E 74°56')

**Locality 2:** Around 2 kms. from Rosebaida village, in a stream section (N 22°26': E 75°05')

**Locality 3:** Near Ratitalai village, 6 kms. SW from Jeerabad Town (N 22°24': E 75°03')

**Locality 4:** Near Hanumanpura village (N 22°22': E 75°04')

**Locality 5:** 1 km SW of Jeerabad village (N 22°05': E 74°54')

**Locality 6:** Near Awalda village

**Repository:** All the described specimens are deposited in the micropaleontology laboratory, Department of Geology, M. L. Sukhadia University, Udaipur and are designated by SUGDMF Nos. 1264-1279.

---

**EXPLANATION OF PLATE I**

1-3. *Cytherelloidea awaldaensis* n.sp. 1, holotype, (SUGDMF No. 1264), a carapace, left valve view, X 166; 2, paratype I (SUGDMF No. 1265), right valve, lateral view, X 142; 3, paratype II (SUGDMF No. 1266), a carapace, dorsal view, X 144. 4. *Cytherelloidea oertelli* Singh. A carapace (SUGDMF No. 1267), left valve view, X 216. 5-6. *Cytherelloidea oudiapurensis* Jain. 5, carapace (SUGDMF No. 1268), left valve view, X 152; 6, carapace (SUGDMF No. 1269), right valve view, X 173. 7-8. *Cytherelloidea raoi* Jain. 7, right valve (SUGDMF No. 1270), lateral view, X 130; 8, carapace (SUGDMF No. 1271), left valve view, X 148.

---

**Fig. 2.** Google earth map showing sampling localities of Sections I-VI
SYSTEMATIC PALAEONTOLOGY

Subclass Ostracoda Latreille, 1806
Order Podocopida Müller, 1894
Suborder Platycopid Sars, 1866
Family Cytherellidae Sars, 1866
Genus Cytherelloidea Alexander, 1929

Cytherelloidea awaldaensis n. sp.

(Pl. I, figs. 1-3)

Name: After village Awalda.

Material: 6 carapaces and 2 valves from locality 6.

Type level and locality: Sample B4/AM1, creamish marl (full of echinoids), Bagh Formation, Upper Cretaceous, Awalda village, Madhya Pradesh, India.

Diagnosis: Carapace elongate-subrectangular in lateral view and nearly wedge-shaped in the dorsal; right valve larger than left valve, overlapping along dorsal and ventral margins, more conspicuously along the latter. Dorsal margin nearly straight; ventral margin concave in middle, anterior margin rounded, and fringed with about 7 denticles; posterior margin truncated in lower half. Maximum length in middle, and height in the anterior.

Surface of each valve marked with a prominent anterior and a posterior marginal rib; three prominent longitudinal ribs; dorsal rib obliquely disposed in posterodorsal and middorsal area, not joining anterior or median ribs; median rib more prominent and linked to posterior rib at posterodorsal margin, runs forward for a short distance and in median region it takes a curve, convex towards the venter, rising slightly up again and dying out in dorsomedian area; ventral rib linked to posterior rib at posteroventral margin and at 1/4 length it takes a curve, convex towards the dorsal, runs slightly down and then parallel to median rib.

Dimensions (mm):

| Holotype (SUGDMF No.1264), carapace | 0.51 | 0.28 | 0.19 |
| Paratype I (SUGDMF No.1265), Right valve | 0.57 | 0.32 | - |
| Paratype II(SUGDMF No.1266), carapace | 0.56 | 0.32 | 0.20 |

Remarks: This species closely resembles with the Cytherelloidea agyroides Dingle, 1969 originally described from Neocomian of South Africa and later on by Brenner and Oertli, 1976 from Algoa Basin, South Africa in over all shape and rib pattern. However, in C. agyroides posterior rib is situated slightly away from the margin, median rib having a gentle curve, convex towards the venter, and a more or less straight ventral rib. The present species also differs with Cytherelloidea sp. 1 described by Piovesan et al., (2013) from the Upper Albian of Santos Basin, Brazil. In the latter species dorsal oblique rib is short and median rib nearly straight and parallel to ventral rib.

Cytherelloidea oertlii Singh

(Pl. I, fig. 4)

Cytherelloidea oertlii Singh, 1997, pp. 23-24, pl. 14, figs. 8-9, 13-14, 16, 20-22. – Andreu et al., 2007, pl. 2, figs. 3-7. - Babinot et al., 2009, pp. 6-7, pl. 1, figs. 9-14.

Material: One carapace from locality 5.

Dimensions (mm):

| A carapace (SUGDMF No.1267) | 0.37 | 0.24 | 0.07 |

Remarks: The species has so far been recorded from the Parth Formation, Turonian– Coniacian, (Upper Cretaceous) of Manhera Tibba well-I, Jaisalmer, Rajasthan by Singh (1997), Coniacian-Santonian of subsurface of Jaisalmer Basin by Andreu et al., (2007), and from Albian-Turonian of the Antsiranana region, Northern Madagascar by Babinot et al., (2009). The present specimen is identical with C. oertlii Singh. Surface ornamentation of the species comprises a thin rib running all along the margin, and a curved, comma-shaped median rib, its posterior end is thick, whereas anterior end is thin.

Cytherelloidea oudiapurensis Jain

(Pl. I, figs. 5-6)

Cytherelloidea oudiapurensis Jain, 1975a, pp. 193-194, pl. 1, figs. 6 a-b; text-fig. 1.

Material: 48 carapaces and 18 valves from localities 1, 2, 3, 4 and 5.

Dimensions (mm):

| A carapace (SUGDMF No.1268) | 0.54 | 0.31 | 0.18 |
| A carapace (SUGDMF No.1269) | 0.53 | 0.29 | 0.17 |

Remarks: The present specimens are identical with the Cytherelloidea oudiapurensis Jain (1975a) described from the Coraline Limestone (Coniacian), Oudiapur, Dhar District.

The species is ornamented by a strong anterior and a posterior rib; posterodorsally the posterior rib continues into an inner sinuate rib below the dorsal margin, this inner rib makes a hair pin bend somewhat behind the anterior rib slightly above the mid height and a very short rib from the dorsal part of the inner loop bends downwards; one more short, thick longitudinal rib present in between the ventral part of the inner loop and the ventral margin.

Cytherelloidea raoi Jain

(Pl. I, figs. 7-8)

Cytherelloidea raoi Jain, 1961, p. 342. – Jain, 1975a, pp. 194-195, pl. 1, figs. 3a-b; text-fig. 2.

EXPLANATION OF PLATE II

1-3. Cytherelloidea rosebaidaensis n.sp. 1, holotype, (SUGDMF No. 1272), a carapace, left valve view, X 134 ; 2, paratype I (SUGDMF No. 1273), carapace, right valve view, X 132 ; 3, paratype II (SUGDMF No. 1274), a carapace, dorsal view, X 134. 4-5. Cytherelloidea subgranulosa Jain. 4, left valve (SUGDMF No. 1275), lateral view, X 124 ; 5, carapace (SUGDMF No. 1276), right valve view, X 118 . 6-7. Cytherelloidea thuatiensis Jain. 6, carapace (SUGDMF No. 1277), right valve view, X 128 ; 7, carapace (SUGDMF No. 1278), left valve view, X 128. 8. Cytherelloidea sp. A. Carapace (SUGDMF No. 1279), left valve view, X 125.
Plate II

CHAUDHARY, NAGORI AND BHANAT
Material: 78 carapaces and 116 valves from localities 1, 2, 3, 4, 5 and 6.

Dimensions (mm):

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>A right valve</td>
<td>0.63</td>
<td>0.39</td>
<td>–</td>
</tr>
<tr>
<td>A Carapace</td>
<td>0.56</td>
<td>0.35</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Remarks: The specimens recorded herein are identical with the Cytherelloidea raoi described by Jain (1961 & 1975a) from the Coralline Limestone (Coniacian), Thuati, Dhar District. In C. raoi surface ornamentation consists of a thick anterior rib, two nodes in posterior region, joined posteriorly by a vertical rib, a thickened dorsal rib inside the dorsal margin which is joined posteriorly by a posterodorsal node and anteriorly curves round, another short but thick longitudinal rib is present in the ventral part above the main upturned part of the ventral margin, ventral rib is not joined with poteroventral node. Surface smooth/finely reticulate.

Cytherelloidea rosebaidaensis n. sp.
(Pl. II, figs. 1-3)

Name: After village Rosebaida.

Material: 50 carapaces and 55 valves from localities 1, 2, 3, 4, 5 and 6.

Type level and locality: Sample No. RB 1/5, Nodular Limestone, Bagh Formation, Upper Cretaceous. Rosebaida, Madhya Pradesh, India.

Diagnosis: Carapace elongate-subrectangular in lateral outline; dorsal margin nearly straight, ventral margin concave in middle; anterior margin broadly rounded; posterior margin less so; right valve larger than left valve, overlapping all along margin, more pronounced along the dorsal. Maximum length in the middle, height at anterodorsal corner. Surface marked by a prominent anterior and a posterior marginal rib; besides, two more longitudinal ribs; dorsal rib more pronounced and linked to posterior rib at posterodorsal corner, runs a short distance and takes a down curve and up again and continued in the back of anterior rib; ventral rib short, horizontal to curved, somewhat comma shaped, situated in ventromedian region. Rest of valve surface smooth.

Dimensions (mm):

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holotype</td>
<td>0.61</td>
<td>0.35</td>
<td>0.21</td>
</tr>
<tr>
<td>Paratype I</td>
<td>0.62</td>
<td>0.35</td>
<td>0.20</td>
</tr>
<tr>
<td>Paratype II</td>
<td>0.61</td>
<td>0.34</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Remarks: Cytherelloidea rosebaidaensis n. sp. closely resembles Cytherelloidea oudiapurensis Jain 1975a, described from Oudiapur, Dhar District. However in the latter species posterodorsally the dorsal rib continues into an inner sinuate rib below the dorsal margin, this inner rib makes a hair pin bend somewhat behind the anterior rib, above midheight and a short sinuate rib, from dorsal part of the inner loop bends downward and continued upwardly. Present new species also resembles with C. raoi Jain, 1975a, in overall shape. However in latter species two nodes in posterior region, joined posteriorly by a vertical rib and a very thick dorsal rib. Present species also resembles with C. austinenesis Sexton, 1951 in overall shape and to some extent surface rib pattern. However in C. austinenensis dorsal rib is nearly straight and parallel to dorsal margin.

Cytherelloidea subgranulosa Jain
(Pl. II, figs. 4-5)

Cytherelloidea subgranulosa Jain, 1961, p. 341. – Jain, 1975a, pp. 195-196, figs. 4ab, 5; text-fig. 3.

Material: 9 carapaces and 6 valves from localities 1, 4, and 6.

Dimensions (mm):

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>A left valve</td>
<td>0.69</td>
<td>0.39</td>
<td>–</td>
</tr>
<tr>
<td>A carapace</td>
<td>0.70</td>
<td>0.45</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Remarks: Specimens recorded herein are identical with Cytherelloidea subgranulosa described by Jain (1961 & 1975a) from the Coralline Limestone (Coniacian), Thuati, Dhar District. Cytherelloidea subgranulosa species characterized by a discontinuous marginal rib; the posterior part of the rib is thick and prominent; the anterior part of the rib is thinner than the posterior; a short oblique rib in dorsomedian region; rest of the valve surface ornamented with 14-16 granules.

Cytherelloidea thuatiensis Jain
(Pl. II, figs. 6-7)


Cytherelloidea thuatiensis Jain, 1975a, p. 196, pl. 1, figs. 10a-c, text-fig.4.

Material: 110 carapaces and 41 valves from localities 1, 2, 3, 4, and 5.

Dimensions (mm):

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>A carapace</td>
<td>0.66</td>
<td>0.35</td>
<td>0.20</td>
</tr>
<tr>
<td>A carapace</td>
<td>0.67</td>
<td>0.35</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Remarks: The present specimens are identical with Cytherelloidea thuatiensis described by Jain (1961 & 1975a), from the Coralline Limestone (Coniacian), Thuati, Dhar District. The species has following characteristics: valve surface ornamented with a spiral rib with nearly equally strong anterior, ventral and posterior parts of the outer loop and dorsal and ventral parts of the inner loop; the rib starts from the anterodorsal margin.
**Cytherelloidea sp.**  
(Pl. II, fig. 8)

**Material:** 3 carapaces from locality 1.  
**Remarks:** Carapace elongate-subrectangular in lateral outline; dorsal margin straight; ventral margin sinuate in the middle; anterior and posterior margins subrounded; surface ornamented with an anterior and a high posterior marginal rib, posterior rib in lower part curves anteriorly and continue parallel to ventral margin at half the distance. Rest of the surface area smooth. The species is left under open nomenclature for want of more material.

**Dimensions (mm):**

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>A carapace (SUGDMF No.1279)</td>
<td>0.64</td>
<td>0.33</td>
<td>0.27</td>
</tr>
</tbody>
</table>

**AFFINITY AND PALAEOGEOGRAPHIC IMPLICATION**

Rifting of India and Madagascar from Africa initiated in the Late Jurassic (about 155 Ma); the movement was almost directly south and nearly parallel to the African coastline, so genetic communication was still possible in the shallow marine environment until at least the earliest Cenomanian (about 100 Ma).

This timing is important because there are ostracodes that occur in Madagascar and India quite early in their evolutionary history, early Cenomanian (Babinot et al., 2009) and shallow water migration pathways must have been open.

Rifting ceased after only a few million years, it again initiated about 130 Ma and resulted in the movement of India, Madagascar and Africa away from Antarctica. During the next 50 Ma (until about 82 Ma), India remained close to Madagascar, but during the Campanian, sea floor spreading initiated between India and Madagascar via the Carlsberg ridge, resulting in rapid movement of India away from Madagascar (Puckett et al., 2016).

Puckett et al. (2016) stated that “As Africa and South America rifted away from each other, continental–scale stresses caused rifting in the North Africa Rift Zone (creating the Trans–Sahara Seaway), the Central African Shear Zone, and several fracture zones in South America. During the Late Cenomanian, the combination of down drop due to rifting in the North African Rift Zone and high sea level due to the high production of oceanic crust in the south Atlantic caused a shallow seaway to form connecting the Benue Trough region to the northern margin of Gondwana and the Tethyan seaway (Trans–Saharan Seaway). This brief seaway enabled ostracode species to migrate to large regions in North and West Africa and Arabia; when sea level dropped in the early Turonian, these faunas were cutoff and evolved separately”.

Singh (1997) recorded five new species of the genus *Cytherelloidea* viz. *C. ghotaruensis*, *C. monomediocostata*, *C. onkareshwarensis*, *C. oertelii* and *C. reniformata* from Jaisalmer Basin. While from Bagh Basin Jain (1961, 1975a) had earlier recorded another five new species viz. *C. khola*., *C. oudiapurensis*, *C. raoi*, *C. subgranulosa* and *C. thuatensis*, further present authors have now recorded two more new species and *C. oertelii* Singh from this basin. Both the basins have their own endemic *Cytherelloidea* species, except for *Cytherelloidea oertelii* which was originally described from the lower part of Cenomanian, Manhera Tibba Well-I, Jaisalmer, Rajasthan, India. This species has also been reported by Andreu et al. (2007) from subsurface of Jaisalmer Basin, Rajasthan, India and by Babinot et al. (2009) from Albian–Middle Turonian of Antsiranana region (Northern Madagascar).

Similarly *C. ghotaruensis* Singh originally recorded from upper member (Cenomanian), Goru Formation, Manhera Tibba Well-I, Jaisalmer, India, Andreu et al. (2007), also recorded it from same basin and Babinot et al. (2009) from Albain-Cenomanian of Madagascar.

*Cytherelloidea awaldaensis* n. sp. shows close affinity with *C. agyroides*, initially described by Dingle, (1969) from Neocomian of South Africa. *C. tigignitensis* Andreu et al., 1998 described from Coniacian-Santonian of Essaouira basin, Atlantic Atlas, Morocco, C. sp. 1 described by Piovesan et al. (2013) from Upper Albian of Santos Basin, Brazil, *Cytherelloidea* sp. C. by Jain 1(975b) and ? *Cytherelloidea* sp. described by Sastry et al. (1972) from Ariyalur Formation, Upper Cretaceous of South India.

*Cytherelloidea oudiapurensis* Jain 1975a originally described from Bagh Formation shows affinity with *C. sp. 1* described by Rosenfeld and Raab (1974) from Judea group (Upper Cenomanian) of Israel, similarly *C. raoi* Jain 1975a shows close affinity with *C. cf. C. bicoastata* Crane from the equivalent horizon of Israel. It is evident from above that at least few species migrated from one basin to another via shallow sea route.

From above distribution of ostracodes it is concluded that during rifting of South America from Africa and Madagascar and India from Africa, a new oceanic crust emerges, with opening of South part of Atlantic ocean and similarly northern part of Africa via Israel and Saudi Arabia and northern part of Madagascar with Jaisalmer and Narbada Basins of India has at least shallow sea for movement of ostracode species. That is the reason many *Cytherelloidea* species shows close affinity with Brazil, Morocco, Israel, South Africa, Tanzania, Madagascar and to some extent with South India.
ACKNOWLEDGEMENTS

The authors are grateful to Head and Coordinator, SAP, Department of Geology, Mohanlal Sukhadia University, Udaipur for the financial support to carryout field work and for extending laboratory and library facilities. The authors also acknowledge the reviewer for his valuable comments and kind suggestions for the improvement of the paper. Thanks to Centre director and director of UGC-DAE-CSIR for allowing us for utilizing the SEM facility. Thanks to Dr. D.M. Phase for allocating the time slot for performing the SEM experiment and to V. K. Ahire for performing SEM experiment and providing us SEM data.

REFERENCES


Manuscript received December 2016
Revised Manuscript accepted April 2017