Ostracodes from the Inter-trappean beds (Early Paleocene) of the east coast of India

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Abstract. Twenty-seven ostracode species from the Inter-trappean beds (Paleocene) of Duddukuru, West Godavari District, Andhra Pradesh, east coast of India are recorded and/or described. Nine species—Cytheromorpha godavariensis, Cytthera duddukuruensis, Hapscytheridea undulata, Kriihe bhandarii, Paramcandana andraensis, Munseyella indica, Neommonoceratina parsoerlii, Semicytherura diluta, and Uroleberis rasilis—are new. The identification of 6 species, previously described from the east coast of India, and also recorded in this work, are revised. The stratigraphic distribution, age and affinity and paleoecology of the ostracode fauna are also discussed.

Key words: Duddukuru, East Coast of India, Inter-trappean beds, Ostracodes, Paleocene

Introduction

The Inter-trappean beds of the east coast of India are a key marker horizon in the stratigraphy of the country. They are of great significance in fixing the age limits of the Deccan Traps, at least those of this part of the peninsula, with which these beds are closely associated. This is because of their unique stratigraphic position (Table 1) and the prolific marine microfauna they contain. There are, however, varied opinions about the age of the Inter-trappean beds and the Tertiary. Most of the earlier workers during the nineteen seventies considered the Inter-trappean beds as Tertiary in age, ranging from Paleocene to Eocene (Hislop et al., 1860; Sahni, 1934; Rao and Rao, 1935, 1937a, 1937b; Rao et al., 1936; Rao, 1956; Sastri, 1961; Bhatta, 1967). However, these views changed markedly in the nineteen eighties during which the Deccan volcanism was demonstrated to be a major Cretaceous-Tertiary boundary (KTB) event (Courtillot et al., 1986, 1988, 1990; Baksi, 1987; Duncan and Pyle, 1988; Hallam, 1988; Sahni and Bajpai, 1988). Govindan (1981) using foraminifera from the Inter-trappean sediments from Narsapur-I well section from Krishna-Godavari (KG) Basin (of which the present area of Duddukuru under study is a part) assigned the Deccan Traps of this well to late Maastrichtian, emplaced between 70–67 Ma. Subsequently, Raju et al. (1991, 1994, 1995), Jaiprakash et al. (1993), Saxena and Mishra (1994), and Mishra et al. (1994) studied foraminifera, calcareous nannoplankton and dinoflagellate cysts from more well sections from the K-G Basin. The data suggest that the volcanism began during 65.5 to 65 Ma (considering KTB at 65 Ma, Sharpton et al., 1992) in the terminal Cretaceous and continued across the KTB into the early Paleocene.

The microfauna of the Inter-trappean beds of the east coast of India comprises mainly foraminifers and ostracodes. A survey of the literatures reveals that important contributions on these foraminifers have been made by Rao and Rao (1937a), Sastri (1961), Bhatta (1967), Govindan (1981), Raju and Dave (1993), and Jaiprakash et al. (1993), while on ostracodes by Jain (1978) and Bhandari (1995).

With the intention of working on the ostracode fauna of the Inter-trappean beds of the east coast of India the authors collected samples of these beds from two sections. The location of the sections is given below and also in Figure 1. Section I is from a limestone quarry, belonging to M/S Facor Ltd., about 1 km south of the village of Duddukuru (17° 2′ 15″ N; 81° 35′ 30″ E) on the Eluru-Kovur Road, West Godavari District, Andhra Pradesh, east coast of India. Section II is from an abandoned quarry about 2 km southeast of Duddukuru. Both sections yielded a prolific, well preserved ostracode fauna much richer than those reported by Jain (1978) and Bhandari (1995). The assemblage comprises a total of 27 species including 9 new ones and a number of species being reported for the first time from the region. This has necessitated revising the ostracode fauna of the Inter-trappean beds of the east coast of India. A new genus Costobuntonia has recently been
proposed for the species previously described as Protobuntonia hartmanni Jain (Khosla, 1999).

Previous work

Among the earlier works on the ostracode fauna from the Inter-trappean beds of the east coast of India, an important contribution was made by Sastri (1961 and 1963) who reported the occurrence of nine species from these beds at Kuntamuru village near Rajahmundry. These species are Cyttherella sp., Cytheropteron sp., ?Eucythere sp., Loxoconcha sp., Bairdia subdeltoidea (Münster), Cythere (?Xestoleberis) ranikotiana Latham, Cythereis bowerbanki Jones, Cythereis cf. mersondaviesi Latham, and Cytherelloidea sp. Of these only the last five species were described and illustrated in his 1963 paper while the specific name Cythere (?Xestoleberis) ranikotiana was modified as Cythere ranikotiana. Bhalha (1965) recognised 16 ostracode species from Pangiadi, Andhra Pradesh. These are: Brachycythere sp., Bythocypris sp., Costa sp., Cyttherella sp., Cytheretta [possibly C. laticostata (Reuss)], Hermanites sp. A, H. sp. B, Krithe [ provisionally identified as K. bartonensis (Jones)], Leguminothecys sp. A, L. sp. B, Neocypridis sp., Occulocythereis sp., Quadracythere sp., ?Schizocythere sp., Semicytherura [ provisionally identified as S. forestensis (Keiji)], and Xestoleberis [ provisionally identified as X. subglobosa (Bosquet)]. Their stratigraphic distribution and paleoecologic significance were given in his subsequent paper (Bhalha, 1967). Bhalha (1979a–c, 1980) described and illustrated the following new species from the Pangiadi area: Hermanites sastryi, Loxoconcha singhi, Occulocythereis elongatum, and Quadracythere tewarii.


Jain (1978) described and illustrated twelve ostracode species from Kateru, Rajahmundry. Of these two species, Ovocytheridea raoi and Protobuntonia hartmanni are new, the other species represented being “Bairdia” sp. indet., ?Bythocypris sp. indet., Cyttherella sp. cf. münstleri (Roemer), Cytherelloidea sp. cf. C. keiji McKenzie, ?“Cytherea” sp. indet., Hermanites sp. cf. H. cracens Siddiqui, Limnocythere sp. indet., Loxoconcha sp. indet., Quadracythere (Hornbrookella) subquadra Siddiqui, and ?Xestoleberis sp. indet.

Bhandari (1995) recorded 15 species from the Inter-trappean beds near Duddukuru, Andhra Pradesh. Of these four species — Cushmanidea bhati, Cytherella mohoni, Cytheridella rajahmundryensis and Palmoconcha rajui are new. The other species reported are Bythocypris? sp., Cytherelloidea sp. cf. C. keiji McKenzie, Cytheridella sp., Gyrocythere sp. cf. G. parvicarinata Siddiqui, Hermanites sastryi Bhalha, Hermanites sp., Hornbrookella tewarii (Bhalha), Nucleolina diluta Al-Furaih, Ovocytheridea raoi Jain, Protobuntonia hartmanni Jain, and Xestoleberis sp.

Stratigraphy

The geology of the region, along with a detailed map, has been adequately described by Bhalha (1967) and this has been followed in this work. The Inter-trappean beds are set of sedimentary strata composed mainly of limestone with shale/claystone intercalations lying in between the Deccan trap. The generalised stratigraphy of the coastal tract of the Krishna-Godavari districts, Andhra Pradesh is summarised in Table 1 (for details see references in Ramam and Murty, 1997).

The Intra-trappean beds have a gentle dip of 4 to 6 degrees towards the southeast and thickness varying from less than a meter to a little over 9 meters. The samples from which the present ostracode fauna was obtained came from the two sections. The sequence of these sections is given in Tables 2 and 3.

Materials and methods

The samples were broken into small pieces and boiled for 3–4 hours in water to which one or two tablespoons of soda ash were added. The disintegrated material was wet screened through set of sieves of 30, 80, and 150 mesh size. The dried, washed residue was uniformly spread on a picking tray and scanned under a stereozoom microscope. The ostracodes present were hand picked with a fine sable-hair brush and arranged in assemblage slides. The type specimens were photographed on Jeol SEM using ORWO 120, black and white 100 ASA film. A total of 4,040 ostracodes were picked up, counting both complete carapaces and open valves as individual specimens. Their distribution is given in Table 4 and all the species recognized in this work are illustrated in Figures 2–5.

Composition, age and affinity of ostracode fauna

The ostracode fauna of the Inter-trappean beds of Duddukuru comprises 27 species (Table 1). These belong to 13 families, 4 species each to the families Cytherellidae, Cytheridae, and Cytheruridae, 3 species each to the families Hemicytheridae and Trachyleberididae, two species to the family Xestoleberididae, and one species each to the families Bairdidae, Canodontidae, Cushmanidae, Cytheridae, Kritidae, Limnocytheridae and Loxoconchidae. An analysis of this distribution is given below.

1. Three species are left under open nomenclature and nine species are considered new. These are of little use in age interpretation at present.
Table 1. Generalized stratigraphy of the coastal tract of the Krishna-
Goddavari districts, Andhra Pradesh.

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Alluvium</td>
</tr>
<tr>
<td>Mio-Pliocene</td>
<td>Rajahmundry Formation</td>
</tr>
<tr>
<td>Late Maastrichtian-Early</td>
<td>Deccan Trap with Inter-trappean beds</td>
</tr>
<tr>
<td>Paleocene</td>
<td></td>
</tr>
<tr>
<td>Late Maastrichtian</td>
<td>Infra-trappean Limestone</td>
</tr>
<tr>
<td>Late Cretaceous</td>
<td>Tirupati Formation</td>
</tr>
<tr>
<td>Early Cretaceous</td>
<td>Raghavarapam Formation</td>
</tr>
<tr>
<td>Triassic-Jurassic</td>
<td>Kota Formation (Upper Gondwana)</td>
</tr>
<tr>
<td>Permian</td>
<td>Kamthi Formation (Lower Gondwana)</td>
</tr>
<tr>
<td>Archean</td>
<td>Khondalite</td>
</tr>
</tbody>
</table>

Table 2. Stratigraphic succession of Section I.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Lithology</th>
<th>Thickness in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/10-11</td>
<td>Light yellow limestone</td>
<td>2</td>
</tr>
<tr>
<td>I/9</td>
<td>Yellowish grey clay</td>
<td>0.15</td>
</tr>
<tr>
<td>I/8</td>
<td>Light yellow limestone</td>
<td>0.76</td>
</tr>
<tr>
<td>I/6-7</td>
<td>Yellowish grey clay</td>
<td>0.25</td>
</tr>
<tr>
<td>I/4-5</td>
<td>Brownish yellow marl</td>
<td>0.3</td>
</tr>
<tr>
<td>I/3</td>
<td>Grey clay</td>
<td>0.3</td>
</tr>
<tr>
<td>I/2</td>
<td>Greyish white clay</td>
<td>0.25</td>
</tr>
<tr>
<td>I/1</td>
<td>Light yellow limestone</td>
<td>2.44</td>
</tr>
<tr>
<td>I/2</td>
<td>Black colored basalt</td>
<td>Base not exposed</td>
</tr>
</tbody>
</table>

Table 3. Stratigraphic succession of Section II.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Lithology</th>
<th>Thickness in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/6-8</td>
<td>Greyish white limestone</td>
<td>0.81</td>
</tr>
<tr>
<td>I/5</td>
<td>Grey clay</td>
<td>0.38</td>
</tr>
<tr>
<td>I/1-4</td>
<td>Light yellow limestone</td>
<td>1.22</td>
</tr>
<tr>
<td>I/1</td>
<td>Black colored basalt</td>
<td>Base not exposed</td>
</tr>
</tbody>
</table>

2. Eight species, Costabantonia hartmanni (Jain), Cushmanidea bhatiai Bhandari, Cytherella mohani Bhandari, Falsocyclithrella elongata (Bhalla), Hermanites sastryi Bhalla, Hornibrookella tevarii (Bhalla), Neocypriideis raoi (Jain), and Palmoconcha raju Bhandari, have so far been known only from Duddukuru (Jain, 1978; Bhalla, 1979b, c, 1980; Bhandari, 1995).

3. One species, Xestoleberis subglobosa (Bosquet), has been recorded widely from the Eocene beds of France, Belgium, Netherlands (Keij, 1957) and also from the Middle Eocene of Kachchh, western India (Guha, 1968; Khosla and Pant, 1988), Himachal Pradesh, northern India (Mathur, 1969) and the Lower Eocene of Rajasthan, western India (Khosla, 1972).

4. One species, Bairdia beraguaensis Singh and Tewari, has previously been recorded from the Early Eocene beds of Jammu and Kashmir (Tewari and Singh, 1966), Pakistan (Sohn, 1970), Rajasthan (Khosla, 1972), Meghalaya (Singh, 1984) and from the Middle Eocene beds of Assam (Neale and Singh, 1985).

5. Three species, Cytherelloidea bhatiai Guha and Shukla, Pajenbarcheloina indica (Khosla) and Paracypriis kluiaelaensis Bhandari, have been described from the Early Eocene beds, the first from Vridhachalam, Tamilnadu, southern India (Guha and Shukla, 1974), the other two from Rajasthan (Khosla, 1972; and Bhandari, 1996). P. indica has also been reported from Kachchh (Khosla and Pant, 1988).

6. Two species, Holcopocytanthere bassiporosa Al-Furaih and Nucleolina dilata Al-Furaih, have been recorded from the latest Cretaceous and Early Paleocene beds of Saudi Arabia (Al-Furaih, 1980).

From the analyses given above it is apparent that the majority of the ostracodes are either new or have so far been known from the Inter-trappean beds of the east coast of India. One species, X. subglobosa, occurs widely in the Eocene beds. Four species, B. beraguaensis, C. bhatiai, P. indica, and P. kluiaelaensis, were originally reported from the lower Eocene beds, and two species, H. bassiporosa and N. dilata, are characteristic of Early Paleocene age. So far as the Early Eocene species are concerned, it is feared that the stratigraphic horizons from where the occurrences of these species were reported; i.e. Fuller’s Earth at Palana, Bikaner District, Rajasthan (Khosla, 1972), Kaki Stage, Kachchh District (Khosla and Pant, 1988), and subsurface samples from Vridhachalam District (Guha and Shukla, 1974), have not been precisely dated on the basis of planktonic foraminifers and might be of Paleocene age. The presence of H. bassiporosa and N. dilata in the Inter-trappean beds of the east coast of India is suggestive of an Early Paleocene age for the beds.

This is in conformity with the views of Bhandari (1995), who has proposed an Early Paleocene age for these beds on the basis of similarity of their ostracode fauna with the ostracodes of the Karipuram Member of the Ghatal Formation of Dhananjapur Well No. 1, West Bengal Basin. In the Karipuram Member ostracodes are associated with a few planktonic foraminifers like Morozovella pseudobulloides and smaller benthics like Protelphidium adamsi, Discorsis midwayensis var. soldadoensis etc., suggesting an Early Paleocene (Danian) age (= 1PB on Planktic scale).

**Paleoenvironments**

The Inter-trappean beds of the Rajahmundry area (as is true of other coastal formations in India) are the result of a marine transgression, which took place in Early Paleocene times. The paleoenvironment of the beds is discussed on the basis of evidence furnished by ostracodes.
Table 4. Distribution of ostracodes in the Inner-trappean beds of the east coast of India.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Sample number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Section I</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4  5  6  7  8  9  10  11</td>
</tr>
<tr>
<td>Bairdia berguerensis Singh &amp; Tewari</td>
<td>1 1 16 6 82</td>
</tr>
<tr>
<td>Costabuntonia hartmanni (Jain)</td>
<td>3 4 2 42 4 2 3</td>
</tr>
<tr>
<td>Cashmanidea bhati Bhandari</td>
<td>2 1 1 10 4 18</td>
</tr>
<tr>
<td>Cytherella mohani Bhandari</td>
<td>3 3 16 6 20</td>
</tr>
<tr>
<td>Cytherella sp. A</td>
<td>4 4 4</td>
</tr>
<tr>
<td>Cytherella sp. B</td>
<td>2 1 1 1</td>
</tr>
<tr>
<td>Cythereleida bhati Guha &amp; Shukla</td>
<td>2 1 14 75 35</td>
</tr>
<tr>
<td>Cytheromorpha godavariensis sp. nov.</td>
<td>2 3 29 9 8 106 136 18 309</td>
</tr>
<tr>
<td>Cytherura ddukarunsensis sp. nov.</td>
<td>4 1 35 40</td>
</tr>
<tr>
<td>Fastacythera elongata (Bhalla)</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Paijanborellini gen. et sp. indet. A</td>
<td>2 1</td>
</tr>
<tr>
<td>Hapsicytheridea undulata sp. nov.</td>
<td>1 2 34 6 37 164 105 4 11 364</td>
</tr>
<tr>
<td>Hermanites sastryi Bhalla</td>
<td>6 10 31 3 4 7 38 3 102</td>
</tr>
<tr>
<td>Holcocythera bassiporosa Al-Furaih</td>
<td>18 2 2 4</td>
</tr>
<tr>
<td>Hornibrookella tevarii (Bhalla)</td>
<td>16 24 2</td>
</tr>
<tr>
<td>Kriithi bhandarii sp. nov.</td>
<td>4 2 2 25 76 138 17 264</td>
</tr>
<tr>
<td>Munseyella indica sp. nov.</td>
<td>4 1 6 7</td>
</tr>
<tr>
<td>Neocyprides raoi (Jain)</td>
<td>85 203 304 418 38 53 12 10 211 360 130 41 69 1934</td>
</tr>
<tr>
<td>Neomonomeratina paraortlii sp. nov.</td>
<td>1 39 143 92</td>
</tr>
<tr>
<td>Nucleolina dilata Al-Furaih</td>
<td>3 4 5</td>
</tr>
<tr>
<td>Paijanborellini indica (Khosla)</td>
<td>24 24</td>
</tr>
<tr>
<td>Palmoconcha rajui Bhandari</td>
<td>10 3 5 1 8 2 6 4 38 19</td>
</tr>
<tr>
<td>Paracanodana andhraensis sp. nov.</td>
<td>10 3 5 1 8 2 6 4 38 19</td>
</tr>
<tr>
<td>Paracypris khulalaensis Bhandari</td>
<td>8 4 4 16 100</td>
</tr>
<tr>
<td>Semicythera dilata sp. nov.</td>
<td>33 63 14</td>
</tr>
<tr>
<td>Uroleberis raziis sp. nov.</td>
<td>3 3 3</td>
</tr>
<tr>
<td>Xestoleberis subglobosa (Bosquet)</td>
<td>3 3 7 10</td>
</tr>
</tbody>
</table>

**TOTAL**

| Section I | 85 203 304 418 38 53 12 10 211 360 130 41 69 1934 | 275 |

**Section I**

In Section I ostracodes make their first appearance in grey clay (Sample No. 3) where they are represented by a solitary species of *Paracanodana*. The underlying beds, in ascending order, light yellow limestone (Sample No. 1) and greyish-white clay (Sample No. 2) are devoid of ostracode fauna. *Paracanodana* is a characteristic freshwater genus. Its occurrence in the grey clay suggests that the bed might have accumulated in a similar environment.

In the succeeding brownish-yellow marl (lower part, Sample No. 4) appears a species of *Neocyprides*, which occurs commonly in it. Soon, however, the species becomes enormously abundant in the overlying beds. In brownish-yellow marl (upper part, Sample No. 5) it constitutes 97% of the entire ostracode assemblage, while in yellowish-grey clay, sample Nos. 6 and 7, it forms 84% and 98% respectively. The other ostracodes present in their order of predominance are *Hermanites, Costabuntonia, Holcocythera, Cytheromorpha, Hapsicytheridea and Neomonomeratina*.

Of these ostracodes, little is known about the ecology of the genera *Costabuntonia, Genus A, Holcocythera* and *Hapsicytheridea* as they do not occur in the present day. The genera *Hermanites* and *Neomonomeratina* are epipelic and the genus *Cytheromorpha* is characteristic of mesohaline to littoral environments (Morkhoven, 1963). A Recent species of *Palmoconcha* has been described by Swain and Gilby (1974) from Station I, Bahia Sebastian Vizcaíno, Baja California at a depth of 59 m. The genus *Neocyprides* is closely related to the living genus *Cyprides*, which probably evolved from it (Morkhoven, 1963). The latter genus inhabits freshwater to hypersaline conditions, but is most abundant in mesohaline salinities and hence is regarded as the most typical brackish-water ostracode. According to Keij (1957), Morkhoven (1963), Oertli (1967), Keen (1977) and Neale (1988), *Neocyprides* also occurs predominantly in brackish-water environments. Keen (1977) records the genus from three brackish-water assemblages, maximum predominance being in assemblage IV of the Upper Eocene beds of the Hampshire Basin, U. K. Assemblage IV is taken to represent salinities of 9.0 to 16.5%. Neale (1988) has observed that minimum di-
versity of species and abundance of individuals and reached in low brackish-water environments. In the present Sample Nos. 4–7 of Section I Neocypriideis constitute a very high proportion of the ostracode assemblages (84 to 100%) and other ostracodes together form small fractions, suggesting that the brownish yellow marl and yellowish-grey clay were deposited in a mesohaline (9 to 16.5%), outer bay environment.

There is a sharp decline both in diversity as well as frequency of ostracode fauna in the overlying light yellow limestone (Sample No. 8). Only two species of Neocyprideis and Costabuntonia are encountered in this bed suggesting a temporary shallowing of the basin, and the bed might have been deposited in the marginal estuarine environments. This view is further corroborated by disappearance of foraminifers except for some Nonion. Megafossils are represented by Ostrea, characteristic of near-shore environments.

There was again an influx of a large number of ostracode species in the succeeding yellowish-grey clay (Sample No. 9) and light yellow limestone (Sample Nos. 10 and 11). The ostracodes in order of predominance are: Neocyprideis, Palmoconcha, Cytherura, Costabuntonia, Hermanites, Hapsicytheridea, Hornibrookella, Krithe, Cushmaniidea, Cytherelloidea, Cytheromorpha, Falsocythere, Holcopocythere, Munseyella and Xestoleberis. Of these, eight genera appear for the first time. Their ecological significance is as follows. The genus Hornibrookella is extinct and therefore little is known about its ecology. The genus Cytherelloidea inhabits shallow, warm marine waters; occasionally it is also 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 temperatures less than 10 °C. The genus Cytherura inhabits mesohaline to littoral environments (Morkhoven, 1963). The genus Falsocythere is a shallow marine form. A living species of the genus has been described from the coastal waters of the Adriatic Seas by Bonaduce et al. (1975) and the Gulf of Aquaba (Red Sea) by Bonaduce et al. (1980). There is some difference of opinion about the ecology of the genus Krithe. According to van den Bold (1960), it occurs in a near-shore as well as an open-shore facies, while Morkhoven (1963) is of the view that the genus is strictly marine and most commonly occurs in infrantryc to bathyal environments. The genus Munseyella thrives well in an
epineritic environment predominantly in warmer waters (Morkhoven, 1963). Studies of living species of Cushmanidae by Ascoli (1964) and McKenzie and Swain (1967) suggest that the genus inhabits lagoonal to shallow-water environments. Keen (1977) records it from the assemblage V (polyhaline, 16.5 to 33%) of the Upper Eocene beds of Hampshire, U.K.

Ecological significance of the genera Neocyprideis, Palmoconcha, Hermanites and Cytheromorpha has already been discussed. In the present beds under discussion the frequency of Neocyprideis declines considerably as compared to underlying beds (Sample Nos. 4 to 7) and the appearance of a number of marine genera suggests that the yellowish-grey clay and light yellow limestone might have been deposited in a polyhaline bay (16.5 to 33%).

**Section II**

The section II is only 2.41 meters thick and comprises, in ascending order, light yellow limestone (Sample Nos. 1 to 4), grey clay (Sample No. 5) and greyish-white limestone (Sample Nos. 6–8). The ostracode fauna in the section is much varied and of high frequency in the lower and upper limestone beds, but absent in the middle grey clay. This succession corresponds with the upper part of the succession in Section I (i.e. yellowish-grey clay and light yellow limestone). The paleoecology of the ostracodes in Section II is discussed below.

The ostracodes in the light yellow limestone (Sample Nos. 1–4) in their order of predominance are Neocyprideis, Hapscytheridea, Neomonomeratina, Cytherura, Krithe, Cytheromorpha, Semicytherura, Costabuntonia, Cashmanidae, Palmoconcha, Hermanites, Paracypris, Cytherella, Falsocythere, Holocypricythere and Hornibrookella.

The genera Cytherella, Paracypris and Semicytherura appear for the first time in this bed. These are essentially marine genera (Morkhoven, 1963). The genus Cytherella occurs at all depths and rarely is also found in brackish-water (mesohaline) environments. The genus Paracypris mainly occurs in deeper water but is very rare in occurrence, and hence may not be of much significance. The genus Semicytherura is epineritic, predominantly littoral. The high diversity of shallow marine genera and presence of Neocyprideis in large numbers suggest that the limestone bed might have accumulated in a polyhaline-bay, brackish-water environment similar to the top two beds of Section I.

The overlying grey clay (Sample No. 5) is devoid of ostracodes. Possibly there was a temporary shallowing of the basin and the bed was deposited in marginal estuarine environments similar to the light yellow limestone (Sample no. 8) of Section I.

The succeeding greyish white limestone is again rich in ostracode fauna. It is represented in order of dominance

by Hornibrookella, Neocyprideis, Costabuntonia, Hermanites, Falsocythere, Palmoconcha, Cytherella, Cytherura, Hapscytheridea, Krithe, Xestoleberis, Pajienborchellina, Cytherelloidea, Nucleolina, Bairdia, Cashmanidae, Munseyella, Paracypris and Uroleberis.

The genera Pajienborchellina, Nucleolina, Bairdia and Uroleberis appear for the first time in this bed. The genus Nucleolina does not extend in the present day. Therefore little is known about its ecological significance. Studies of certain living species of the genus Pajienborchellina from the Abu Dhabi lagoon, Persian Gulf (Bate, 1971) show that it occurs from littoral to near-shore shelf environments. The genus Bairdia is a characteristic marine form occurring both in very shallow as well as very deep waters (Morkhoven, 1963). In the present day the genus Uroleberis occurs in epineritic environments (Morkhoven, 1963). The ecological significance of other genera has already been discussed.

Like the light yellow limestone (Sample Nos.1–4) of Section II and the upper two beds of Section I, the present bed is characterised by varied shallow marine ostracodes, suggesting that it was also deposited in a polyhaline bay.

The paleoenvironmental inferences drawn above are more or less similar to those of Bhalla (1967) and Bhandari (1995) who also worked on the Inter-trappean beds of this region. According to Bhalla (1967), the foraminiferal and ostracode assemblages reflect rhythmic facies changes with alternate brackish-water and normal marine environments of deposition. He also recorded two marine incursions in the area. Bhandari (1995) inferred that the Inter-trappean beds of Duddukuru were deposited in brackish-water to shallow inner neritic conditions around 0–10 m deep with intermittent freshwater conditions.

**Systematic paleontology**

The classification of ostracodes in this paper follows that of Hartmann and Puri (1974). Descriptions of already known and well established species are omitted for the sake of brevity. The illustrated specimens are deposited in the museum of the Department of Geology, Mohan Lal Sukhadia University, Udaipur and catalogued with the prefix SUGDMF.

Order Podocopida
Suborder Platycope
Family Cytherellidae
Genus Cytherella Jones, 1849

*Type species.—Cytherina ovata* Roemer, 1840.
Cytherella sp. A

Figure 2.3

Cytherella sp. cf. muensteri (Roemer). Jain, 1978, p. 52, pl. 1, fig. 1.

Material. — Four carapaces.

Remarks. — The species was recorded as Cytherella sp. cf. muensteri by Jain (1978) from the Inter-trappean beds of Kateru, Rajahmundry. It, however, differs from Cytherella muensteri (Roemer) in having an angulated dorsal margin, the greatest height located near the middle, and a smooth surface. C. muensteri, in contrast, has the greatest height located at the posterior 1/3 of the length, has a pitted surface, and lacks the dorsal angulation. The species is left under open nomenclature.

Dimensions. — A carapace, SUGDMF no. 565, length 0.69 mm, height 0.42 mm, width 0.27 mm.

Occurrence. — Section II.

Cytherella sp. B

Figure 2.4

Material. — One carapace.

Description. — Carapace subrectangular in lateral outline; height equal in anterior and posterior halves; right valve slightly overlaps left valve along dorsal and ventral margins; dorsal margin nearly straight; ventral margin slightly concave, anterior and posterior margins rounded; valve surface smooth.

Remarks. — This species differs from Cytherella mohani Bhandari, 1995 and Cytherella sp. A recorded herein in the lateral outline and degree of overlap. C. mohani is subovate in shape with a pronounced overlap, while Cytherella sp. A is an elongate form having an angulated dorsal margin. The present species is left under open nomenclature.

Dimensions. — A carapace, SUGDMF no. 566, length 0.74 mm, height 0.42 mm, width 0.32 mm.

Occurrence. — Section II.

Genus Cytherelloidea Alexander, 1929

Type species. — Cythere (Cytherella) williamsoniana Jones, 1849.

Cytherelloidea bhatiae Guha and Shukla, 1974

Figure 2.5

Cytherelloidea bhatiae Guha and Shukla, 1974, p. 96, 97, pl. 2, fig. 10.


Material. — Seven carapaces.

Description. — Carapace subrectangular in lateral outline, with height equal in both anterior and posterior halves; valve surface ornamented by elongate punctuation; two prominent, sinuate, transverse ridges extending three-fourths of length joined by a posterior vertical ridge; and marginal rim along dorsal, anterior and ventral margins.

Remarks. — The present specimens from Duddukuru are referred to Cytherelloidea bhatiae Guha and Shukla (1974) (species name misspelled as bhatiae) described from the Lower Eocene of Gopurapuram well, Vridhachalam, Tamilnadu. The form described as Cytherelloidea sp. cf. C. keiji from the Inter-trappean beds of the east coast of India by Jain (1978) and Bhandari (1995) belongs to this species. According to McKenzie et al. (1990) Keijyoidae keiji (earlier referred to Cytherelloidea) is a Pleistocene-Recent species ranging in distribution from the southwestern Pacific to northwestern and southern Australia.

Dimensions. — A carapace, SUGDMF no. 567, length 0.48 mm, height 0.29 mm, width 0.21 mm.

Occurrence. — Sections I and II.

Suborder Podocopa
Superfamily Cytheracea
Family Cytheridae
Subfamily Cytherinae
Tribe Cytherini

Genus Cytheromorpha Hirschmann, 1909

Type species. — Cythere fuscata Brady, 1869.

Cytheromorpha godavariensis sp. nov.

Figure 2.7-2.9

Etymology. — After the Indian River Godavari.

Material. — 124 carapaces and 3 valves.

Type locality. — Light yellow limestone (Sample SUGDMF no. 3/II), Inter-trappean beds, Paleocene. Section II.

Diagnosis. — Surface strongly reticulate and with a transverse median ridge.

Description. — Carapace subquadrate in lateral outline, with greatest height at anterior cardinal angle; overlap indistinct; valve inflated ventrally; dorsal margin straight converging posteriorly; ventral margin obscured medially; anterior margin broadly rounded; posterior margin much narrower, subangulate near mid-height; in dorsal view carapace somewhat biconvex, both ends taper, more in posterior than in anterior, maximum width posterior to middle. Valve surface strongly reticulate, edges of reticulation meshes in anterior half raised in low costae; a transverse ridge in median region. Inner lamella moderately wide along anterior and posterior margins and narrows ventrally;
Pleocene ostracodes from India

vestibule present; selvage near outer periphery; normal pores few, widely spaced. Hinge gongylodont; in left valve it consists of an indistinct socket surrounded by a crenulate anterior tooth, which is a continuation of the median crenulate bar and a posterior socket with a distinct tooth at its inner edge.

**Dimensions.**—Holotype, SUGDMF no. 569, a carapace, length 0.30 mm, height 0.19 mm, width 0.14 mm; paratype I, SUGDMF no. 570, a left valve, length 0.32 mm, height 0.19 mm; paratype II, SUGDMF no. 571, a carapace, length 0.30 mm, height 0.18 mm, width 0.16 mm.

**Discussion.**—Cytheromorpha godavariensis sp. nov. resembles Cytheromorpha kirkarensis Guha (1968) described from the Middle Eocene of Kachchh in general appearance. *C. kirkarensis*, however, differs from the present species in having concentrically arranged reticulation and a lack of median transverse ridge. *Cytheromorpha bali* Haskin (1971) described from the Tertiary beds of the Isle of Wight also resembles *C. godavariensis* sp. nov. in overall lateral outline and surface ornamentation but differs in having three distinct vertical ridges in the anterior half.

**Occurrence.**—Sections I and II.

Tribe Pectocysterini
Genus Munseyella van den Bold, 1957

Type species.—Toulminia hyalokystis Munsey, 1953.

**Munseyella indica** sp. nov.

**Figure 2.10, 2.11**

**Etymology.**—After the country of India.

**Material.**—Six carapaces and one valve.

**Type locality.**—Greyish-white limestone (Sample SUGDMF no. 7/II), Inter-trappean beds, Paleocene. Section II.

**Diagnosis.**—Surface ornamented by ridges and vertically arranged pits.

**Description.**—Carapace subquadrate in lateral outline, with greatest height about half of length at anterior cardinal angle; posterior cardinal angle well marked; valves almost equal; dorsal margin nearly straight, sloping down posteriorly; ventral margin concave; anterior margin broadly rounded; posterior straight, nearly perpendicular to ventral margin; anterior margin fringed with 6 or 7 spines and posterior margin with two spines, one at mid-posterior and the other at posteroventral region; in dorsal view carapace rather compressed. Valve surface ornamented by anterior marginal ridge which also continues ventrally slightly above margin; a dorsal ridge extending from anterior cardinal angle backward overhanging margin, in posterdorsal region it turns downward forming a thick knob; two short furcating transverse ridges, one in posteroomedian-median region and the other in ventromedian-anteroventral region; a vertical ridge extending downward from anterodorsal region; vertically arranged deep elongate pits over rest of area.

**Dimensions.**—Holotype, SUGDMF no. 572, a right valve, length 0.38 mm, height 0.21 mm; paratype, SUGDMF no. 573, a carapace, length 0.42 mm, height 0.22 mm, width 0.19 mm.

**Discussion.**—The species closely resembles Munseyella japonica (Hanai, 1957), a Recent species from Kanagawa Prefecture, Japan in overall shape but differs in surface ridge pattern and having vertically arranged, elongate pits.

**Occurrence.**—Sections I and II.

Tribe Pajenborchelli
Genus Neomonoceratina Kingma, 1948

Type species.—Neomonoceratina columbiaformis Kingma, 1948.

**Neomonoceratina paraoertrii** sp. nov.

**Figure 3.1, 3.2**

**Etymology.**—From Greek para, meaning "beside," with reference to its resemblance with *Neomonoceratina oertrii* Guha, 1967.

**Material.**—275 carapaces.

**Type locality.**—Light yellow limestone (Sample SUGDMF no. 3/II), Inter-trappean beds, Paleocene. Section II.

**Diagnosis.**—Surface distinctly reticulate, meshes with 5 or 6 pores, and a depression between ventral ridge and margin.

**Description.**—Carapace elongate, subrectangular in lateral outline, height almost equal in anterior and posterior halves; overlap indistinct; dorsal margin nearly straight.
anteriorly and with a distinct hump posteriorly, obscuring margin; ventral margin straight; anterior margin broadly rounded; posterior margin less so; in dorsal view ends compressed, sides more or less parallel. Eye tubercle present. Valve surface marked by a shallow depression in mid-dorsal and dorsomedian regions; distinct reticulation, meshes mostly quadrangular in shape and with 5 or 6 pores; three feeble longitudinal ridges, median ridge extending from mid-anterior region to posteromedian region, ventral ridges nearly parallel, sloping up and back from mid-ventral region; and a prominent depression between ventral ridge and margin. Internal characters not known.

**Dimensions.**—Holotype, SUGDMF no. 574, a carapace, length 0.42 mm, height 0.19 mm, width 0.18 mm; paratype, SUGDMF no. 575, a carapace, length 0.40 mm, height 0.19 mm, width 0.19 mm.

**Discussion.**—The species very closely resembles *Neomonomeratina oeriltii* Guha (1967) from the Miocene of Saurashtra, Gujarat in lateral outline and overall surface ornamentation. The latter species, however, differs in being much larger in size and having a distinct vertical sulcus.

**Occurrence.**—Sections I and II.

Paijenborchellini gen. et sp. indet. A

Figure 3.3–3.5

**Material.**—One carapace and two valves.

**Description.**—Carapace elongate, subtrapezoidal in lateral outline, with greatest height about half of length at anterior cardinal angle; left valve slightly overlaps right valve along anterodorsal and posteroventral margins; valves somewhat inflated ventrally, overhanging margin in median and anteroventral region; dorsal margin straight, converging backward; posterior cardinal angle well marked; anterior margin broad, obliquely rounded and fringed with 5 large, downwardly curved spines; posterior margin drawn out ventrally and fringed with 2 spines; in dorsal view carapace sagittate, distinctly compressed near anterior and posterior ends. Valve surface strongly tuberculate, superimposed by punctuation, and marked by a row of about 10 tubercles extending from mid-anterior to mid-ventral region, with a subcentral swelling and a vertical sulcus posterior to it. Inner lamella moderately wide; line of concrescence and inner margin coincide; selvage peripheral; normal pore widely scattered; central muscle scars comprise a vertical row of four scars, lowest being largest, frontal scar not known. Hinge schizodont; in left valve it consists of an anterior socket with two loculi, a postadjacent bilobate anteromedian tooth, a long crenulate posteromedian bar and a large posterior socket, open interiorly; hinge complementary in right valve, anterior tooth bilobate, posterior tooth indistinctly crenulate.

**Remarks.**—The species probably belongs to a new genus but no name is proposed because of insufficient material.

**Dimensions.**—A carapace, SUGDMF no. 576, length 0.62 mm, height 0.32 mm, width 0.27 mm; a left valve, SUGDMF no. 577, length 0.62 mm, height 0.32 mm; a right valve, SUGDMF no. 578, length 0.61 mm, height 0.32 mm.

**Occurrence.**—Section I.

Family Cytherideidae
Subfamily Cytherideinae
Genus *Neocypredia* Apostolescu, 1957

Type species.—*Cyprideis (Neocypredia) durocortorien-sis* Apostolescu, 1957.

**Neocypredia raoid (Jain, 1978)**

Figure 2.12, 2.13

*Ovocyttheridea raoi* Jain, 1978, p. 53, pl. 1, figs. 7–10; Bhandari, 1995, p. 95, 96, pl. 2, figs. 1, 2.

**Material.**—1134 carapaces and 800 valves.

**Remarks.**—The species has previously been described as *Ovocyttheridea raoi* Jain (1978) from the Inter-trappean beds of Katrau, Rajahmundry and from Duddukur, West Godavari District, Andhra Pradesh (Bhandari, 1995). This is the most abundant species in our collection and in certain samples it constitutes up to 90 percent of the total ostracode population.

*Ovocyttheridea* is essentially a Cretaceous genus and the majority of the described species of the genus have a trianguloid lateral outline, strongly convex dorsal margin, posterior margin steeply down-sloping and narrowly ventrally rounded, generally smooth valve surface, narrow median hinge element, distinct accommodation groove, and frontal scars that comprise two closely spaced scars. In

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*Figure 3.* 1. *Neomonomeratina paraoeriltii* sp. nov. 1, holotype. SUGDMF no. 574, carapace, right valve view, x157; 2, paratype. SUGDMF no. 575, carapace, dorsal view, x152. 3–5. Paijenborchellini gen. et sp. indet. A. 3, carapace, SUGDMF no. 576, right valve view, x102; 4, left valve, SUGDMF no. 577, internal view, x100; 5, right valve, SUGDMF no. 578, dorsal view, x105. 6. Cashmariidea bhutaian Bhandari, carapace, SUGDMF no. 581, right valve view, x72. 7. 8. Krihee bhandarei sp. nov. 7, holotype. SUGDMF no. 582, male carapace, right valve view, x142; 8, paratype. SUGDMF no. 583, female carapace, right valve view, x147. 9. 11. Holocypocrythei barrassus Al-Furath. 9, left valve, SUGDMF no. 584, lateral view, x111; 10, right valve, SUGDMF no. 585, internal view, x113; 11, carapace, SUGDMF no. 586, dorsal view, x120. 12. 13. Cos-tubantonia hartmanni (Jain). 12, female carapace, SUGDMF no. 554, right valve view, x90; 13, male carapace, SUGDMF no. 557, right valve view, x87.
contrast to this pattern the present species has an elongate and subovate lateral outline, the greatest height slightly anterior to the middle, dorsal margin arched, anterior and posterior margins evenly rounded, median hinge element quite wide, accommodation groove almost lacking, and frontal scar typically v-shaped.

The species is very similar to *Neocypriides bhupendri* Singh and Mishra (1968) from the Lower Eocene of Rajasthan in all the essential carapace characters (see also Khosla, 1972). This species is also recorded from the Middle Eocene of Kachchh by Khosla and Pant (1988) and the Middle Eocene of Meghalaya by Bhandari (1992). Restudy of the type material of *N. bhupendri* is required to clarify the identity with the present species. The species also closely resembles *Neocypriides simplex* Siddiqui (2000) from the Lower Eocene of Pakistan in lateral outline and ornamentation. On the basis of the characters given above the present species is transferred to the genus *Neocypriides*.

**Dimensions.** — A carapace, SUGDMF no. 579, length 0.75 mm, height 0.48 mm, width 0.40 mm; a left valve, SUGDMF no. 580, length 0.75 mm, height 0.50 mm.

**Occurrence.** — Sections I and II.

**Family Krithidae**

Genus *Krith* Brady, Crosskey and Robertson, 1874

**Type species.** — Ilyobates praetexta Sars, 1866.

*Krith bhandari* sp. nov.

Figure 3.7, 3.8

**Etymology.** — The species is named in honor of Dr. Anil Bhandari, Chief Geologist, Micropaleontology Laboratory, KDMIPE, ONGC Ltd., Dehradun, India.

**Material.** — 264 carapaces.

**Type locality.** — Light yellow limestone (Sample SUGDMF no. 3/II), Inter-trappean beds, Paleocene. Section II.

**Diagnosis.** — Carapace elongate, with greatest height posterior to middle; ventral margin concave anteriorly; posterior margin forming obtuse angle with ventral margin.

**Description.** — Sexual dimorphism distinct, males being more elongate, less high and wide than females. Carapace elongate, subrectangular in lateral outline, with greatest height almost half of length posterior to middle; left valve overlaps right valve along dorsal, anterior and mid-ventral margins; dorsal margin asymmetrically convex, merges gradually with anterior margin, and steeply sloping downward from posterior 2/5 of length; ventral margin with a distinct concavity anterior to middle; anterior margin narrow, evenly rounded; posterior obliquely rounded forming obtuse angle with ventral margin; in dorsal view carapace compressed with maximum width near middle. Valve surface smooth.

**Dimensions.** — Holotype, SUGDMF no. 582, a male carapace, length 0.43 mm, height 0.22 mm, width 0.19 mm; paratype, SUGDMF no. 583, a female carapace, length 0.40 mm, height 0.24 mm, width 0.19 mm.

**Discussion.** — *Krith bhandari* sp. nov. resembles *Krith oryza* Neale and Singh (1985) and *Krith* cf. *K. oryza* from the Middle Eocene of Assam in having a vaulted dorsal margin but is readily differentiated in having a distinct concavity along the ventral margin and different outline of the posterior margin.

**Occurrence.** — Sections I and II.

**Family Hemicytheridae**

**Subfamily Ortonininae**

Genus *Falsocythere* Ruggieri, 1972

**Type species.** — *Falsocythere macagnoi* (Ciampo, 1972) Ruggieri, 1972.

*Falsocythere elongata* (Bhalla, 1979)

Figure 4.5, 4.6

**Occalocythereis elongata** Bhalla, 1979c, p.146–148, figs. A–D.

**Material.** — 40 carapaces.

**Description.** — Carapace elongate subquadrate in lateral outline, with greatest height about half of length at anterior cardinal angle and greatest length at ventral one-third of height; dorsal margin partly obscured due to overhanging ridge, otherwise straight, sloping down posteriorly; ventral margin slightly concave; anterior margin broadly rounded; posterior margin much narrowed, drawn out ventrally, distinctly concave in upper part and obliquely truncated in lower part; anterior and posterior margins denticate;
valve surface ornamented by a high anterior marginal rim which also continues along ventral and posterior margins; an arched dorsal ridge starting from mid-dorsal region overhangs posterodorsal margin and sharply turns forming a U-shaped bend and then continues as a diagonal ridge to anteromedian region; a low vertical ridge extends downwards from the U-shaped bend; area along marginal rim laterally compressed and smooth; faint reticulation over rest of surface

Remarks:—*Occultocythereis elongatum* was described by Bhalla (1979c) from the Inter-trappean beds of Dudhukuru. The specimens he illustrated are internal moulds, so that they lack surface reticulation and marginal denticles. The well preserved specimens we newly collected from the type locality allow us to reconsider the generic position of this species.

The lateral outline and surface ornamentation of the species differ from those of the genus *Occultocythereis*. Species of the latter genus generally have a subquadrature lateral outline and a subangular or rounded posterior margin. In addition, they have a valve surface ornamented by 1) a prominent angular massive tubercle at the posterodorsal cardinal angle and a ridge extending from it along the dorsal margin, 2) a prominent anterior rim, 3) a small posteroventral winglike projection with a short vertical ridge posteriorly, and 4) denticles at anterior and posterior margins. Except for having a ventrally drawn-out posterior margin, the present species closely resembles *Falsocythere indica* Khosla and Nagori, 1989, a Lower Miocene species of Kerala, and *F. maccagnoi* (Ciampo, 1972), a Recent species, in overall lateral outline and surface ornamentation. On this basis the species is herein transferred to the genus *Falsocythere*. The difference in the shape of the posterior margin of the present species might be due to the range of variation within the genus.

Dimensions.—A carapace, SUGDMF no. 591, length 0.56 mm, height 0.27 mm, width 0.19 mm; a carapace, SUGDMF no. 592, length 0.53 mm, height 0.27 mm, width 0.19 mm.

Occurrence.—Sections I and II.

Family Loxoconchidae
Genus *Paloconcha* Swain and Gilby, 1974

Type species.—*Paloconcha laevimarginata* Swain and Gilby, 1974.

*Paloconcha raju* Bhandari, 1995

Figure 4.7

*Loxoconcha* sp. Jain, 1978, p. 56, pl. 2, figs. 6, 7.

*Paloconcha raju* Bhandari, 1995, p. 96, 97, pl. 4, figs. 1–4.

Material.—84 carapaces and 35 valves.

Remarks.—The present species was described from the Paleocene Inter-trappean beds of Dudhukuru by Bhandari (1995). It is based on closed carapaces and its generic assignment is highly questionable. The genus *Paloconcha* is characterised by the presence of flattened, flange-like terminal marginal areas, a gongylodont hinge, a broad vestibule, and numerous closely spaced short marginal pore canals. In contrast, the present species has an anti-merodont hinge structure; in the left valve the hinge comprises loculate terminal sockets that are connected by a finely crenulate median bar, and in the right valve it is complementary, has a few widely spaced, straight, marginal pore canals and lacks flange-like terminal areas and vestibule. Probably a new generic name is required to accommodate this species, but it is deferred unless additional species are found.

Dimensions.—A carapace, SUGDMF no. 593, length 0.51 mm, height 0.29 mm, width 0.29 mm.

Occurrence.—Sections I and II.

Family Cytheruridae
Genus *Hapsicytheridea* Al-Furaih, 1980

Type species.—*Hapsicytheridea binodosa* Al-Furaih, 1980.

*Hapsicytheridea undulata* sp. nov.

Figure 4.8–4.10

Cytheridella sp. Bhandari, 1995, p. 95, pl. 1, fig. 4.

Etymology.—From Latin, meaning wavy, referring to sinuous venter surface.

Material.—346 carapaces and 18 valves.

Type locality.—Light yellow limestone (Sample SUGDMF no. 8/1), Inter-trappean beds, Paleocene.
Section I.

*Diagnosis.*—Surface marked by a prominent groove in posteroventral region, an arcuate carina near posterior margin in right valve, and broad shallow reticulation.

*Description.*—Carapace elongate, subquadrate in lateral view, with greatest height about half of length, at anterior cardinal angle; left valve larger than right valve, overlapping distinctly along anterior and posterodorsal margins; dorsal margin nearly straight; ventral margin sinuate; anterior margin broadly rounded; posterior margin subangulate near mid-height; in dorsal view carapace somewhat inflated, maximum width half of length posteriorly, anterior end narrow, posterior region laterally compressed. Eye tubercle distinct. Valve surface marked by a prominent groove in posteroventral region; a depression posterior to eye tubercle; arcuate carina near posterior margin in right valve; anterior marginal area compressed and smooth; rest of the area ornamented by broad shallow reticulations, arranged in concentric pattern. Inner lamella narrow; line of concrescence and inner margin coincident; selvage distinct near inner periphery; normal pores widely spaced. Hinge antimerodont; in right valve it comprises 8 anterior and 6 or 7 posterior terminal teeth and loculate median groove.

*Dimensions.*—Holotype, SUGDMF no. 594, a carapace, length 0.53 mm, height 0.26 mm, width 0.27 mm; paratype I, SUGDMF no. 595, a carapace, length 0.53 mm, height 0.26 mm, width 0.26 mm; paratype II, SUGDMF no. 596, a right valve, length 0.51 mm, height 0.26 mm.

*Discussion.*—The species was originally described as *Cytheridella* sp. by Bhandari (1995) from the Intertrappean beds of Duddukuru. However, unlike the genus *Cytheridella*, which is characterised by an adont hinge, the new species has a distinct antimerodont hinge structure.

The present species resembles *Hapsicytheridea binodosa* Al- Furaih (1980) from the Lower Paleocene of Saudi Arabia in overall outline and surface ornamentation but differs in the absence of two nodes in the posterolateral region and other ornamental details. The species also lacks a clear caudal process along the posterior margin.

*Occurrence.*—Sections I and II.

Subfamily Cytherurinae

Genus *Cytherea* Sars, 1866

*Type species.*—Cythere gibba O. F. Müller, 1785.

*Cytherea duddukuruensis* sp. nov.

Figure 4.11-4.13

*Etymology.*—After the village of Duddukuru.

*Material.*—309 carapaces.

*Type locality.*—Light yellow limestone (Sample SUGDMF no. 3/II), Inter-trappean beds, Paleocene.

Section II.

*Diagnosis.*—Carapace pear-shaped in lateral outline; surface ornamented by dense fine punctuation.

*Description.*—Sexual dimorphism distinct, males being more elongate, less high and less wide than females; carapace pear-shaped in lateral outline, with greatest height at anterior cardinal angle; valves strongly compressed posteroventrally; overlap indistinct; dorsal margin straight, converging posteriorly; ventral margin distinctly sinuate medi ally; anterior margin broad and obliquely rounded; posterior margin with a caudal process at mid-height; in dorsal view, carapace biconvex with maximum width near middle, ends compressed. Valve surface ornamented by dense, fine punctuation. Internal characters not known.

*Dimensions.*—Holotype, SUGDMF no. 597, a female carapace, length 0.40 mm, height 0.24 mm, width 0.16 mm; paratype I, SUGDMF no. 598, a female carapace, length 0.40 mm, height 0.24 mm, width 0.18 mm; paratype II, SUGDMF no. 599, a male carapace, length 0.42 mm, height 0.21 mm, width 0.14 mm.

*Discussion.*—*Cytherea duddukuruensis* sp. nov. resembles *Cytherea interposita* Lyubimova and Guha in Lyubimova et al. (1960) from the Miocene of Kachchh in overall shape. The latter species, however, differs from the present species in having an oblong lateral outline, a shallow vertical sulcus and reticulation, and meshes enclosing two or more punctae.

*Occurrence.*—Sections I and II.

Genus *Semicytherea* Wagner, 1957

*Type species.*—Cythere nigrescens Baird, 1838.

*Semicytherea diluta* sp. nov.

Figure 5.2-5.4

*Etymology.*—From Latin *diluta* meaning weakened or thinned; with reference to the faint ornamentation.

*Material.*—110 carapaces.

*Type locality.*—Light yellow limestone (Sample SUGDMF no. 1/II), Inter-trappean beds, Paleocene.

*Section II.*

*Diagnosis.*—Surface ornamented by feeble transverse ridges and reticulation in ventral half.

*Description.*—Sexual dimorphism distinct, males being more elongate, less high and more wide than females; carapace subovate in lateral outline, with greatest height near middle and greatest length below mid-height; overlap indistinct; dorsal margin strongly convex in females and arched in males; ventral margin concave anteriorly but convex posteriorly; anterior margin narrowly rounded; posterior drawn out in a caudal process slightly below mid-height; in dorsal view carapace biconvex, posterior end compressed.
maximum width near middle in females, posterior in males. Valve surface ornamented by feeble transverse ridges in ventral half, lowermost ridge continuous from anteroventral to posteroventral region, other ridges intersecting each other in ventromedian region forming weak reticulation; fine punctuation over rest of area.

**Dimensions.**—Holotype, SUGDMF no. 601, a female carapace, length 0.42 mm, height 0.26 mm, width 0.22 mm; paratype I, SUGDMF no. 602, a male carapace, length 0.46 mm, height 0.24 mm, width 0.22 mm; paratype II, SUGDMF no. 603, a female carapace, length 0.43 mm, height 0.26 mm, width 0.22 mm.

**Discussion.**—*Semicytherura diluta* sp. nov. closely resembles *Semicytherura indica*? subspecies described by Neale and Singh (1985, pl. 46, fig. 2) in overall outline and ornamentation. *S. indica*? subspecies is based on a single specimen and inadequately described. It differs from *S. diluta* in having feeble transverse ridges all over the valve surface and a nearly straight ventral margin.

*Semicytherura longilinea* Bhandari (1995) from the Lower Eocene Khuaiala Formation of Jaisalmer resembles *S. diluta* in appearance. However, it differs in having 9 or 10 transverse ridges that extend nearly the entire length of the carapace.

**Occurrence.**—Section II.

Family Xestoleberididae
Genus *Uroleberis* Triebel, 1958

**Type species.**—*Eocytheropteron parnensis* Apostolescu, 1955.

*Uroleberis rasiliis* sp. nov.

![Figure 5.5, 5.6](image)

**Etymology.**—From Latin *rasiliis*, meaning smoothed; with reference to smooth surface.

**Material.**—Three carapaces.

**Type locality.**—Greyish-white limestone (Sample SUGDMF no. 7/I), Inter-trappean beds, Paleocene. Section II.

**Diagnosis.**—Carapace ovate in lateral outline; posterior margin with an indistinct caudal process.

**Description.**—Carapace ovate in lateral outline, with greatest height near middle; left valve slightly overlaps right valve along dorsal and posterior margins; dorsal margin arched; ventral margin nearly straight; anterior margin narrowly rounded; posterior margin slightly concave in upper part, rounded in lower part and with indistinct caudal process; in dorsal view carapace biconvex, ends narrowed, maximum width slightly posterior to middle. Valve surface smooth.

**Dimensions.**—Holotype, SUGDMF no. 604, a carapace, length 0.45 mm, height 0.30 mm, width 0.30 mm; paratype, SUGDMF no. 605, a carapace, length 0.45 mm, height 0.32 mm, width 0.32 mm.

**Discussion.**—The species resembles *Uroleberis* sp. aff. *U. sp. I* described by van den Bold (1988) from the Upper Miocene-Pliocene of the Dominican Republic in lateral outline but differs in the absence of transverse ridges in the ventral region.

**Occurrence.**—Section II.

Superfamily Cypridacea Baird, 1845
Family Candonidae Kaufmann, 1900
Subfamily Candoninidae Kaufmann, 1900
Genus *Paracandona* Hartwig, 1899

**Type species.**—*Candona euclectella* Brady and Norman, 1889.

*Paracandona andhraensis* sp. nov.

![Figure 5.10-5.13](image)

**Etymology.**—After the Indian state of Andhra Pradesh.

**Material.**—Ten valves.

**Type locality.**—Light yellow limestone (Sample SUGDMF no. 3/I), Inter-trappean beds, Paleocene. Section I.

**Diagnosis.**—Valve surface marked by dense reticulation, meshes enclosing 3 or 4 punctae.

**Description.**—Valve subrectangular in lateral outline, with greatest height a little over half of length near anterior cardinal angle; dorsal margin straight; ventral margin slightly concave anterior to middle; anterior margin broad and evenly rounded; posterior margin slightly narrow, sloping down in upper half and rounded in lower; posterior cardinal angle distinct; in dorsal view valve nearly convex, flat medially. Valve surface ornamented by dense reticulation, arranged concentrically, meshes enclosing 3 or 4 punctae; anterior and posteroverentral regions laterally compressed. Inner lamella narrow; line of concrescence and inner margin coincide; selvage well developed, near inner periphery. Hinge modified adont; in right valve it consists of a smooth ridge, selvage at its terminal ends raised giving socketlike appearance; hinge complementary in left valve. Central muscle scars not known.

**Dimensions.**—Holotype, SUGDMF no. 609, a left valve, length 0.45 mm, height 0.24 mm; paratype I, SUGDMF no. 610, a right valve, length 0.45 mm, height 0.22 mm; paratype II, SUGDMF no. 611, a left valve, length 0.43 mm, height 0.22 mm; paratype III, SUGDMF no. 612, a right valve, length 0.42 mm, height 0.22 mm.

**Discussion.**—The species resembles *Paracandona* aff. *belgica* Tambareau, 1984, described from the Thanetian of the Paris Basin in subrectangular lateral outline and reticu-
lated ornamentation. *Paracandona* aff. *belgica*, unlike the present species, has fine, hexagonal reticules and lacks laterally compressed anterior and posteroverentral margins.

**Occurrence.**—Section I.

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