

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*, *Cytherura duddukuruensis*, *Hapsicytheridea undulata*, *Krithe bhandarii*, *Paracandona andhraensis*, *Munseyella indica*, *Neomonoceratina paraortlii*, *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 vis à vis of the associated Deccan Traps. Most of the earlier workers until the nineteen seventies considered the Inter-trappean beds as Tertiary in age, ranging from Paleocene to Eocene (Hislop in Hislop *et al.*, 1860; Sahni, 1934; Rao and Rao, 1935, 1937a, 1937b; Rao *et al.*, 1936; Rao, 1956; Sastri, 1961; Bhalla, 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 (Courtilot *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-1 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), Bhalla (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-Kovvur 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 *Costabuntonia* 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 *Cytherella* 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*. Bhalla (1965) recognised 16 ostracode species from Pangadi, Andhra Pradesh. These are: *Brachycythere* sp., *Bythocypris* sp., *Costa* sp., *Cytherella* sp., *Cytheretta* [possibly *C. laticostata* (Reuss)], *Hermanites* sp. A, *H.* sp. B, *Krithe* [provisionally identified as *K. bartonensis* (Jones)], *Leguminocythereis* sp. A, *L.* sp. B, *Neocyprideis* sp., *Occultocythereis* sp., *Quadracythere* sp., *?Schizocythere* sp., *Semicytherura* [provisionally identified as *S. forestensis* (Keij)], and *Xestoleberis* [provisionally identified as *X. subglobosa* (Bosquet)]. Their stratigraphic distribution and paleoecologic significance were given in his subsequent paper (Bhalla, 1967). Bhalla (1979a–c, 1980) described and illustrated the following new species from the Pangadi area: *Hermanites sastryi*, *Loxoconcha singhi*, *Occultocythereis elongatum*, and *Quadracythere tewarii*.

Guha (1970) recorded *Cythereis* cf. *tamulicus*, *Hermanites* cf. *pondicheriensis*, *Paracypris* sp., *Protobuntonia* sp., *Xestoleberis* sp., and the genus *Ovocytheridea*.

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., *Cytherella* sp. cf. *münsteri* (Roemer), *Cytherelloidea* sp. cf. *C. keiji* McKenzie, *?Cytheridea* sp. indet., *Hermanites* sp. cf. *H. cracens* Siddiqui, *Limnocythere* sp. indet., *Loxoconcha* sp. indet., *Quadracythere* (*Hornibrookella*) *subquadrata* Siddiqui, and *?Xestoleberis* sp. indet.

Bhandari (1995) recorded 15 species from the Inter-trappean beds near Duddukuru, Andhra Pradesh. Of these four species — *Cushmanidea bhatiai*, *Cytherella mohani*, *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 Bhalla, *Hermanites* sp., *Hornibrookella tewarii* (Bhalla), *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 Bhalla (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 come 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 Bairdiidae, Candonidae, Cushmanidae, Cytherideidae, Krithidae, Limnocythereidae and Loxoconchidae. An analysis of these 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-Godavari districts, Andhra Pradesh.

Age	Formation
Quaternary	Alluvium
Mio-Pliocene	Rajahmundry Formation
Late Maastrichtian-Early Paleocene	Deccan Trap with Inter-trappean beds
Late Maastrichtian	Infra-trappean Limestone
Late Cretaceous	Tirupati Formation
Early Cretaceous	Raghavapuram Formation
Triassic-Jurassic	Kota Formation (Upper Gondwana)
Permian	Kamthi Formation (Lower Gondwana)
Archean	Khondalite

Table 2. Stratigraphic succession of Section I.

Sample No.	Lithology	Thickness in meters
	Black colored basalt	1.2
	Grey shale	0.45
	Red shale	0.45
I/10-11	Light yellow limestone	2
I/9	Yellowish grey clay	0.15
I/8	Light yellow limestone	0.76
I/6-7	Yellowish grey clay	0.25
I/4-5	Brownish yellow marl	0.3
I/3	Grey clay	0.3
I/2	Greyish white clay	0.25
I/1	Light yellow limestone	2.44
	Black colored basalt	Base not exposed

Table 3. Stratigraphic succession of Section II.

Sample No.	Lithology	Thickness in meters
II/6-8	Greyish white limestone	0.81
II/5	Grey clay	0.38
II/1-4	Light yellow limestone	1.22
		Base not exposed

2. Eight species, *Costabuntonia hartmanni* (Jain), *Cushmanidea bhatiai* Bhandari, *Cytherella mohani* Bhandari, *Falsocythere elongata* (Bhalla), *Hermanites sastryi* Bhalla, *Hornibrookella tewarii* (Bhalla), *Neocyprideis raoi* (Jain), and *Palmoconcha rajui* 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), Himachel 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, *Paijenborchellina indica* (Khosla) and *Paracypris khuialaensis* 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, *Holcopocythere bassiporosa* Al-Furaih and *Nucleolina diluta* 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. khuialaensis*, were originally reported from the lower Eocene beds, and two species, *H. bassiporosa* and *N. diluta*, 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), Kakdi 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. diluta* 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 Karimpur Member of the Ghatal Formation of Dhananjapur Well No. 1, West Bengal Basin. In the Karimpur Member ostracodes are associated with a few planktonic foraminifers like *Morozovella pseudobulloides* and smaller benthics like *Protelphidium adamsi*, *Discorbis 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 Inter-trappean beds of the east coast of India.

Horizon	Sample number																		Total	
	Section I											Section II								
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7		8
<i>Bairdia beraguaensis</i> Singh & Tewari																			1	
<i>Costabuntonia hartmanni</i> (Jain)						3	4	2	42	4	2		3					16	6	82
<i>Cushmanidea bhatiai</i> Bhandari											2	1	1	10				4		18
<i>Cytherella mohani</i> Bhandari													3					11	6	20
<i>Cytherella</i> sp. A																		4		4
<i>Cytherella</i> sp. B																		1		1
<i>Cytherelloidea bhatiai</i> Guha & Shukla									1									5	1	7
<i>Cytheromorpha godavariensis</i> sp. nov.						2					1	14	75	35						127
<i>Cytherura duddukuruensis</i> sp. nov.									3	29	9	8	106	136				18		309
<i>Falsocythere elongata</i> (Bhalla)							4					1						35		40
<i>Paijenborchellini</i> gen. et sp. indet. A					2	1														3
<i>Hapsicytheridea undulata</i> sp. nov.						1			2	34	6	37	164	105	4				11	364
<i>Hermanites sastryi</i> Bhalla					6	10			31	3		4	7					38	3	102
<i>Holcopocythere bassiporosa</i> Al-Furaih						18			2				4							24
<i>Hornibrookella tewarii</i> (Bhalla)									16	24			2				4	69	33	148
<i>Krithe bhandarii</i> sp. nov.									4	2	2	25	76	138				17		264
<i>Munseyella indica</i> sp. nov.									1									6		7
<i>Neocyprideis raoi</i> (Jain)				85	203	304	418	38	53	12	10	211	360	130			41	69		1934
<i>Neomonoceratina paraoertlii</i> sp. nov.							1					39	143	92						275
<i>Nucleolina diluta</i> Al-Furaih																		8	10	18
<i>Paijenborchellina indica</i> (Khosla)																		24		24
<i>Palmoconcha rajui</i> Bhandari							5	3		2	51	8	2	6	4				38	119
<i>Paracandona andhraensis</i> sp. nov.				10																10
<i>Paracypris khuialaensis</i> Bhandari													8	4				4		16
<i>Semicytherura diluta</i> sp. nov.													33	63	14					110
<i>Uroleberis rasilis</i> sp. nov.																		3		3
<i>Xestoleberis subglobosa</i> (Bosquet)										3								7		10
TOTAL	0	0	10	85	211	344	430	40	157	162	40	383	1017	664	4	0	45	339	109	4040

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 *Paracandona*. The underlying beds, in ascending order, light yellow limestone (Sample No. 1) and greyish-white clay (Sample No. 2) are devoid of ostracode fauna. *Paracandona* 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 *Neocyprideis*, 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*, *Holcopocythere*, Genus A, *Palmoconcha*, *Cytheromorpha*, *Hapsicytheridea* and *Neomonoceratina*.

Of these ostracodes, little is known about the ecology of

the genera *Costabuntonia*, Genus A, *Holcopocythere* and *Hapsicytheridea* as they do not occur in the present day. The genera *Hermanites* and *Neomonoceratina* are epineritic 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 Vizcaino, Baja California at a depth of 59 m. The genus *Neocyprideis* is closely related to the living genus *Cyprideis*, 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), *Neocyprideis* 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-

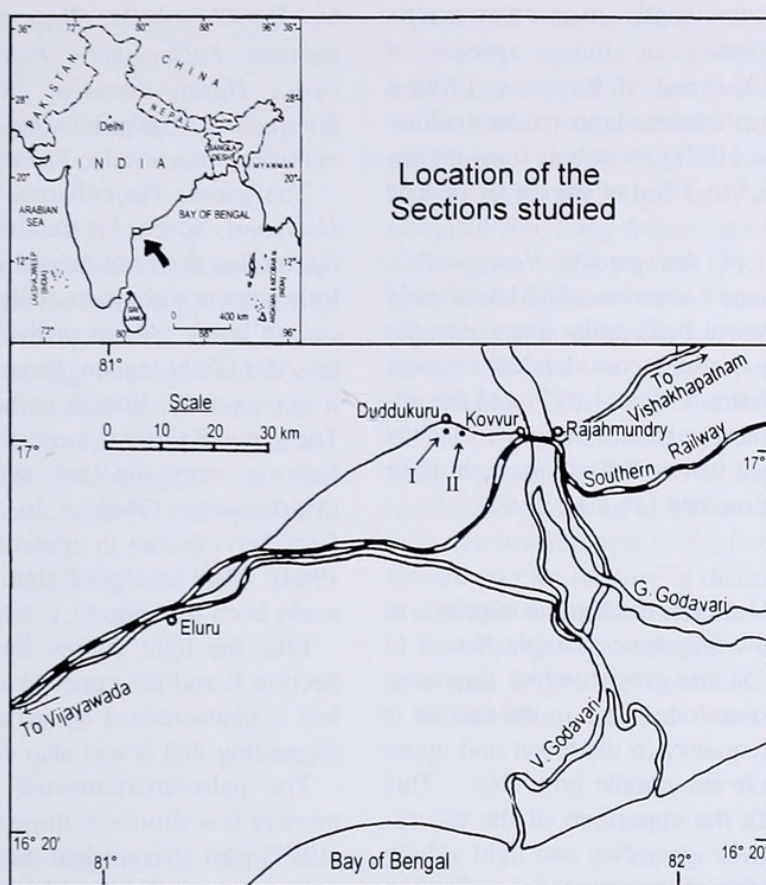


Figure 1. Index map of part of Andhra Pradesh showing locations of the sections studied.

versity of species and abundance of individuals and reached in low brackish-water environments. In the present Sample Nos. 4–7 of Section I *Neocyprideis* 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*, *Hermani-*

tes, *Hapsicytheridea*, *Hornibrookella*, *Krithe*, *Cushmanidea*, *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 infraneritic to bathyal environments. The genus *Munseyella* thrives well in an

epineritic environment predominantly in warmer waters (Morkhoven, 1963). Studies of living species of *Cushmanidea* 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*, *Hapsicytheridea*, *Neomonoceratina*, *Cytherura*, *Krihe*, *Cytheromorpha*, *Semicytherura*, *Costabuntonia*, *Cushmanidea*, *Palmoconcha*, *Hermanites*, *Paracypris*, *Cytherella*, *Falsocythere*, *Holcopocythere* 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*, *Hapsicytheridea*, *Krihe*, *Xestoleberis*, *Paijenborchellina*, *Cytherelloidea*, *Nucleolina*, *Bairdia*, *Cushmanidea*, *Munseyella*, *Paracypris* and *Uroleberis*.

The genera *Paijenborchellina*, *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 *Paijenborchellina* 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 Platycopa
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.

Occurrence.—Section II.

Genus *Cytherelloidea* Alexander, 1929

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

Cytherelloidea bhatiai Guha and Shukla, 1974

Figure 2.5

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

Cytherelloidea sp. cf. *C. keiji* McKenzie. Jain, 1978, p. 52, 53, pl. 1, figs. 2, 3. Bhandari, 1995, p. 94, pl. 1, fig. 3.

Material.—Seven carapaces.

Description.—Carapace subrectangular in lateral outline, with height equal in both anterior and posterior halves; valve surface ornamented by elongate punctation; 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 bhatiai* 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) *Keijcyoidea 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;



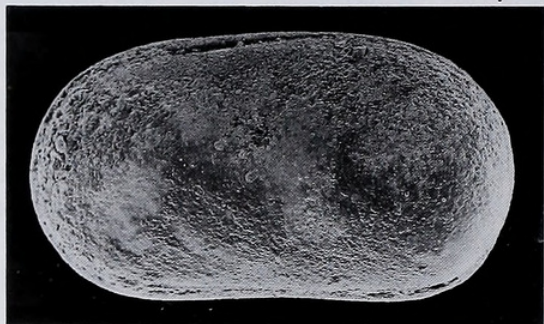
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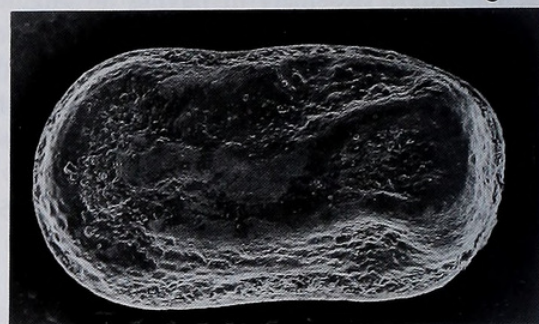
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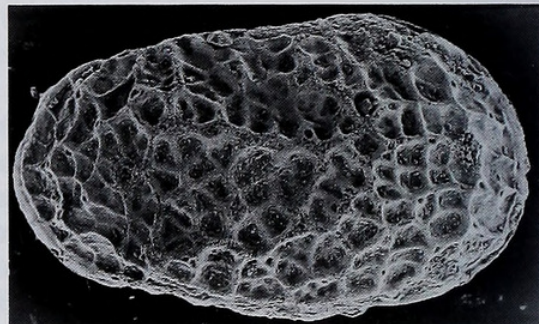
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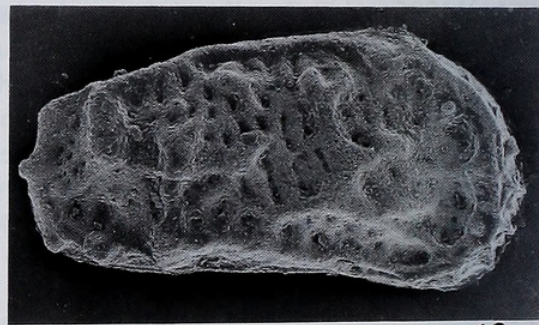
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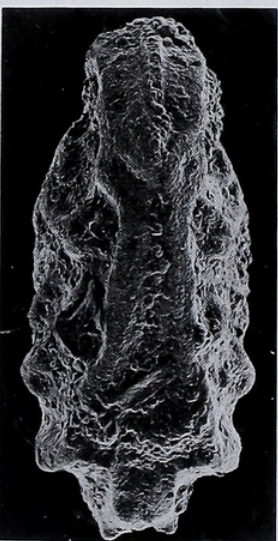
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vestibule present; selvage near outer periphery; normal pores few, widely spaced. Hinge gongyodont; in left valve it consists of an indistinct socket surrounded by a crenulate anterior tooth, which is a continuation of the median crenulate bar and 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 kirtharensis* Guha (1968) described from the Middle Eocene of Kachchh in general appearance. *C. kirtharensis*, however, differs from the present species in having concentrically arranged reticulation and a lack of median transverse ridge. *Cytheromorpha bulla* 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 Pectocytherini

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 posterodorsal region it turns downward forming a thick knob; two short furcating transverse ridges, one in posteromedian-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 Paijenborchellini

Genus *Neomonoceratina* Kingma, 1948

Type species.—*Neomonoceratina columbiformis* Kingma, 1948.

Neomonoceratina paraoertlii sp. nov.

Figure 3.1, 3.2

Etymology.—From Greek *para*, meaning “beside,” with reference to its resemblance with *Neomonoceratina oertlii* Guha, 1967.

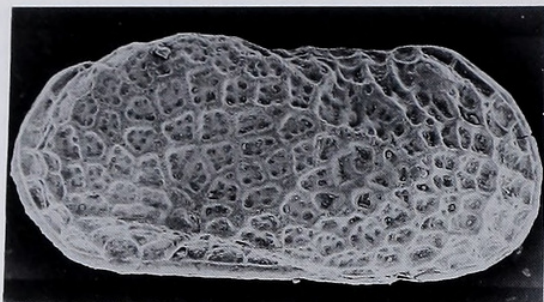
Material.—275 carapaces.

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

← **Figure 2.** 1, 2. *Cytherella mohani* Bhandari. 1, carapace, SUGDMF no. 563, left valve view, $\times 78$; 2, carapace, SUGDMF no. 564, dorsal view, $\times 80$. 3. *Cytherella* sp. A, carapace, SUGDMF no. 565, left valve view, $\times 83$. 4. *Cytherella* sp. B, carapace, SUGDMF no. 566, left valve view, $\times 81$. 5. *Cytherelloidea bhatiai* Guha and Shukla, carapace, SUGDMF no. 567, left valve view, $\times 123$. 6. *Bairdia beraguaensis* Singh and Tewari, carapace, SUGDMF no. 568, right valve view, $\times 76$. 7–9. *Cytheromorpha godavariensis* sp. nov. 7, holotype, SUGDMF no. 569, carapace, right valve view, $\times 210$; 8, paratype I, SUGDMF no. 570, left valve, internal view, $\times 200$; 9, paratype II, SUGDMF no. 571, carapace, dorsal view, $\times 213$. 10, 11. *Munseyella indica* sp. nov. 10, holotype, SUGDMF no. 572, right valve, lateral view, $\times 166$; 11, paratype, SUGDMF no. 573, carapace, dorsal view, $\times 152$. 12, 13. *Neocyprideis raoi* (Jain). 12, carapace, SUGDMF no. 579, right valve view, $\times 80$; 13, left valve, SUGDMF no. 580, internal view, $\times 81$.



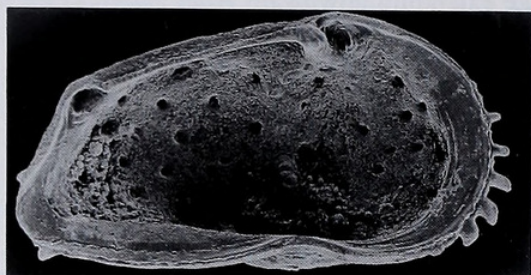
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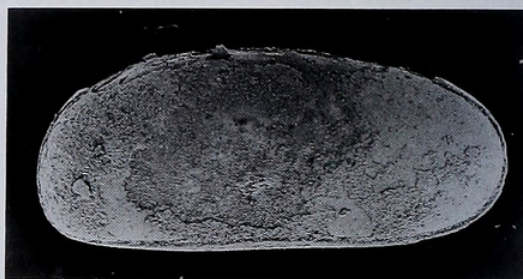
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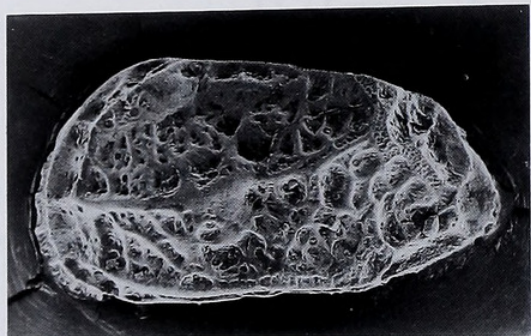
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anteriorly and with a distinct hump posteriorly, obscuring margin; ventral margin straight; anterior margin broadly rounded; posterior margin less so; in dorsal view ends compressed, sides more or less parallel. Eye tubercle present. Valve surface 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 *Neomonoceratina oertlii* 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 two 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 periph-

eral; 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 *Neocyprideis* Apostolescu, 1957

Type species.—*Cyprideis* (*Neocyprideis*) *durocortoris* Apostolescu, 1957.

Neocyprideis raoi (Jain, 1978)

Figure 2.12, 2.13

Ovocytheridea 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 *Ovocytheridea raoi* Jain (1978) from the Inter-trappean beds of Kateru, Rajahmundry and from Duddukuru, 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.

Ovocytheridea 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

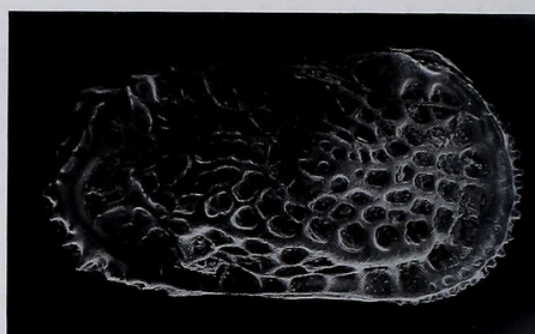
← **Figure 3.** 1, 2. *Neomonoceratina paraoertlii* sp. nov. 1, holotype, SUGDMF no. 574, carapace, right valve view, $\times 157$; 2, paratype, SUGDMF no. 575, carapace, dorsal view, $\times 152$. 3–5. *Paijenborchellini* gen. et sp. indet. A. 3, carapace, SUGDMF no. 576, right valve view, $\times 102$; 4, left valve, SUGDMF no. 577, internal view, $\times 100$; 5, right valve, SUGDMF no. 578, dorsal view, $\times 105$. 6. *Cushmanidea bhatiai* Bhandari, carapace, SUGDMF no. 581, right valve view, $\times 72$. 7, 8. *Krithe bhandarii* sp. nov. 7, holotype, SUGDMF no. 582, male carapace, right valve view, $\times 142$; 8, paratype, SUGDMF no. 583, female carapace, right valve view, $\times 147$. 9–11. *Holcopocythere bassiporosa* Al-Furaih. 9, left valve, SUGDMF no. 584, lateral view, $\times 111$; 10, right valve, SUGDMF no. 585, internal view, $\times 113$; 11, carapace, SUGDMF no. 586, dorsal view, $\times 120$. 12, 13. *Cos-taburtonia hartmanni* (Jain). 12, female carapace, SUGDMF no. 554, right valve view, $\times 90$; 13, male carapace, SUGDMF no. 557, right valve view, $\times 87$.



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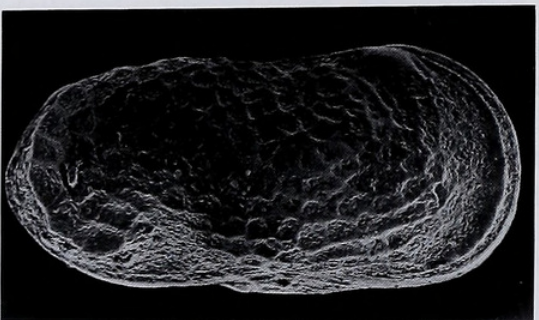
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contrast to this pattern the present species has an elongate and subovate lateral outline, the greatest height slightly anterior to the middle, dorsal margin arched, anterior and posterior margins evenly rounded, median hinge element quite wide, accommodation groove almost lacking, and frontal scar typically v-shaped.

The species is very similar to *Neocyprideis 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 *Neocyprideis 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 *Neocyprideis*.

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 *Krithe* Brady, Crosskey and Robertson, 1874

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

Krithe bhandarii 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., Deharadun, 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.—*Krithe bhandarii* sp. nov. resembles *Krithe oryza* Neale and Singh (1985) and *Krithe* 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 Orionininae

Genus *Falsocythere* Ruggieri, 1972

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

Falsocythere elongata (Bhalla, 1979)

Figure 4.5, 4.6

Occultocythereis elongatum 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 denticulate;

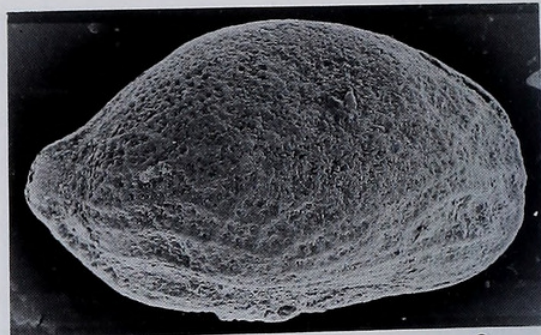
Figure 4. 1. *Nucleolina diluta* Al-Furaih, carapace, SUGDMF no. 587, right valve view, $\times 84$. 2, 3. *Hermanites sastryi* Bhalla. 2, carapace, SUGDMF no. 588, right valve view, $\times 64$; 3, right valve, juvenile, SUGDMF no. 589, lateral view, $\times 80$. 4. *Hornibrookella tewarii* (Bhalla), carapace, SUGDMF no. 590, right valve view, $\times 86$. 5–6. *Falsocythere elongata* (Bhalla). 5, carapace, SUGDMF no. 591, right valve view, $\times 110$; 6, carapace, SUGDMF no. 592, dorsal view, $\times 119$. 7. *Palmoconcha rajui* Bhandari, carapace, SUGDMF no. 593, right valve view, $\times 122$. 8–10. *Hapsicytheridea undulata* sp. nov. 8, holotype, SUGDMF no. 594, carapace, right valve view, $\times 121$; 9, paratype I, SUGDMF no. 595, carapace, dorsal view, $\times 123$; 10, paratype II, SUGDMF no. 596, right valve, internal view, $\times 122$. 11–13. *Cytherura duddukuruensis* sp. nov. 11, holotype, SUGDMF no. 597, female carapace, right valve view, $\times 157$; 12, paratype I, SUGDMF no. 598, female carapace, dorsal view, $\times 155$; 13, paratype II, SUGDMF no. 599, male carapace, right valve view, $\times 155$.



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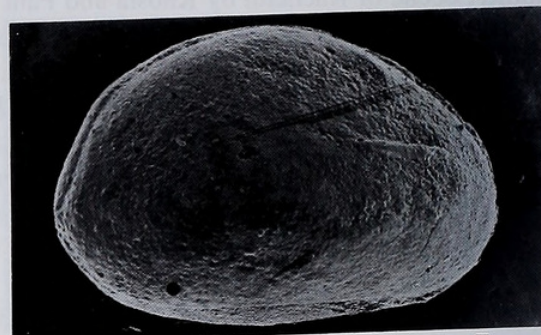
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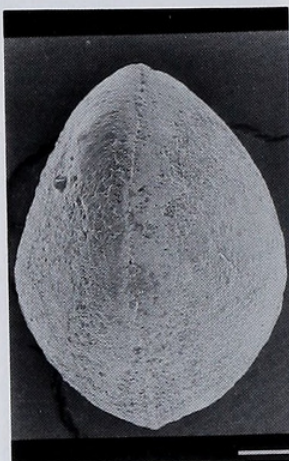
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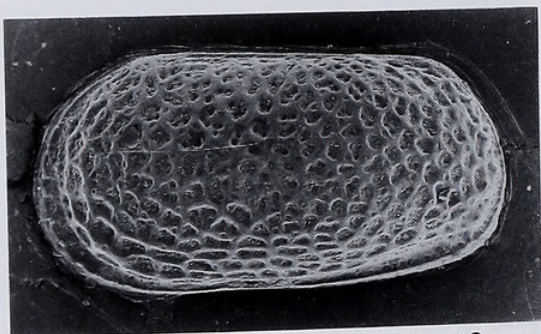
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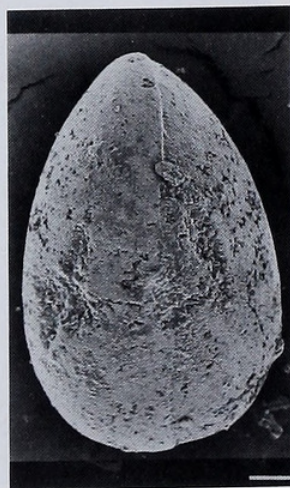
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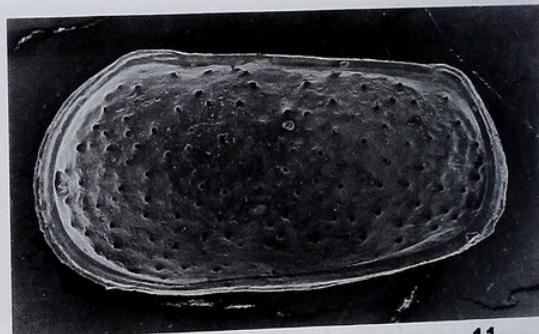
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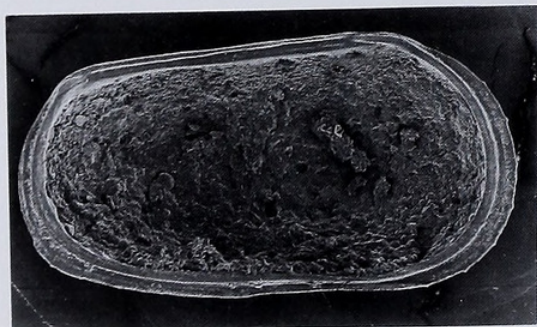
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valve surface ornamented by a high anterior marginal rim which also continues along ventral and posterior margins; an arched dorsal ridge starting from mid-dorsal region overhangs posterodorsal margin and sharply turns forming a U-shaped bend and then 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 Duddukuru. 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 subquadrate 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 *Palmoconcha* Swain and Gilby, 1974

Type species.—*Palmoconcha laevimarginata* Swain and

Gilby, 1974.

Palmoconcha rajui Bhandari, 1995

Figure 4.7

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

Palmoconcha rajui 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 Duddukuru by Bhandari (1995). It is based on closed carapaces and its generic assignment is highly questionable. The genus *Palmoconcha* is characterised by the presence of flattened, flangelike terminal marginal areas, a gongyodont 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 flangelike 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/I), Inter-trappean beds, Paleocene.

← **Figure 5.** 1. *Paijenborchellina indica* (Khosla), carapace, SUGDMF no. 600, right valve view, $\times 105$. 2–4. *Semicytherura diluta* sp. nov. 2, holotype, SUGDMF no. 601, female carapace, right valve view, $\times 150$; 3, paratype I, SUGDMF no. 602, male carapace, right valve view, $\times 137$; 4, paratype II, SUGDMF no. 603, female carapace, dorsal view, $\times 146$. 5, 6. *Uroleberis rasilis* sp. nov. 5, holotype, SUGDMF no. 604, carapace, right valve view, $\times 124$; 6, paratype, SUGDMF no. 605, carapace, dorsal view, $\times 100$. 7, 8. *Xestoleberis subglobosa* (Bosquet). 7, carapace, SUGDMF no. 606, left valve view, $\times 164$; 8, carapace, SUGDMF no. 607, dorsal view, $\times 135$. 9. *Paracypris khuialaensis* Bhandari, carapace, SUGDMF no. 608, right valve view, $\times 71$. 10–13. *Paracandona andhraensis* sp. nov. 10, holotype, SUGDMF no. 609, left valve, lateral view, $\times 129$; 11, paratype I, SUGDMF no. 610, right valve, internal view, $\times 131$; 12, paratype II, SUGDMF no. 611, left valve, internal view, $\times 144$; 13, paratype III, SUGDMF no. 612, right valve, dorsal view, $\times 151$.

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 coincide; 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 Inter-trappean 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 *Cytherura* Sars, 1866

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

Cytherura 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 punctation.

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 medially; 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 punctation. 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.—*Cytherura duddukuruensis* sp. nov. resembles *Cytherura 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 *Semicytherura* Wagner, 1957

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

Semicytherura 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 punctation 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 Khuiala 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 rasilis sp. nov.

Figure 5.5, 5.6

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

Material.—Three carapaces.

Type locality.—Greyish-white limestone (Sample SUGDMF no. 7/II), 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. 1* 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 Candoninae Kaufmann, 1900
Genus *Paracandona* Hartwig, 1899

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

Paracandona andhraensis sp. nov.

Figure 5.10–5.13

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 posteroventral 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 posteroventral margins.

Occurrence.—Section I.

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