

Moluscan Fauna from the Miocene Sediments of Kachchh – Part 2. Bivalve subgenus *Indoplacuna*

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Three species of *Placuna* (*Indoplacuna*) are reported from Miocene rocks of the Kachchh region of Gujarat, Western India (viz. *Placuna* (*Indoplacuna*) *birmanica* Vredenburg, *P. (I) lamellata* (Dey) and *P. (I) sindiensis* Vredenburg). Species of the subgenus *Indoplacuna* are restricted to the middle part of the Burdigalian Claystone Member of Chhasra Formation. The age of the *Indoplacuna* bearing strata is estimated between 20 and 18.75 Ma. The Quilon Beds of Kerala (India), that contain *P. (I) lamellata* (Dey) are also assigned a Burdigalian age.

KEY WORDS: Miocene, India, Anomiidae.

Introduction

In 1924, Vredenburg erected the subgenus *Indoplacuna* and included species from the Rupelian Padaung Shale, the Aquitanian Koma Clay, both from Myanmar, and a species from the Burdigalian Upper Gaj Beds (Sind Province, Pakistan). *Placuna* (*sensu stricto*), lacks hinge teeth. Instead, the central ligament pit is modified and flanked by a pair of elongate ridges, termed chondrophores or crura, that lie just below the umbo on the interior of right valve.

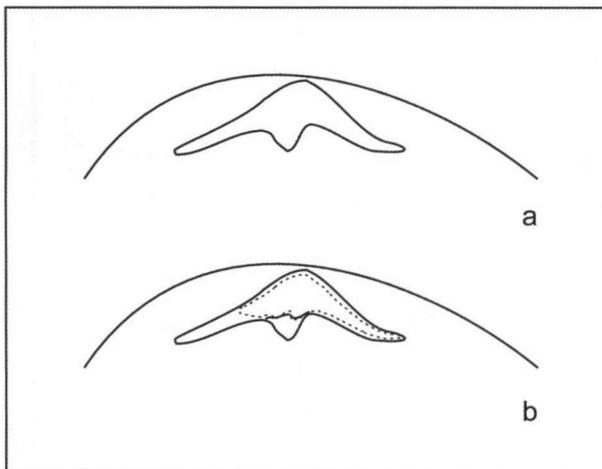


Figure 1.

- (a) Schematic diagram of the hinge of *Indoplacuna* showing the three perceptible crura.
 (b) Essentially there are two pairs of ridges, one superposed (dotted lines) by the other.

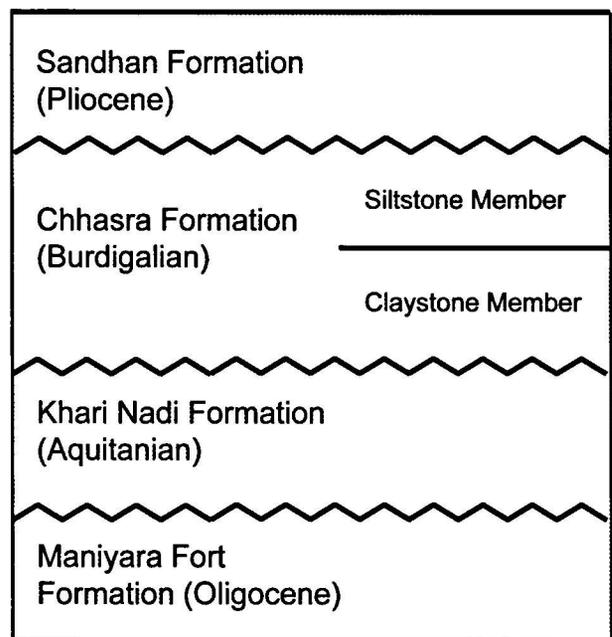


Table 1. Lithostratigraphic classification of Miocene Rocks of Kachchh (after Biswas, 1992).

There are corresponding sockets on the interior of left valve. Furthermore, Vredenburg (1924) noted that the fossil shells at his disposal differed from *Placuna* s.s. by exhibiting a raised platform occupying the interval between the two crura. Moreover, there are two pairs of crura, one being superimposed on the other.

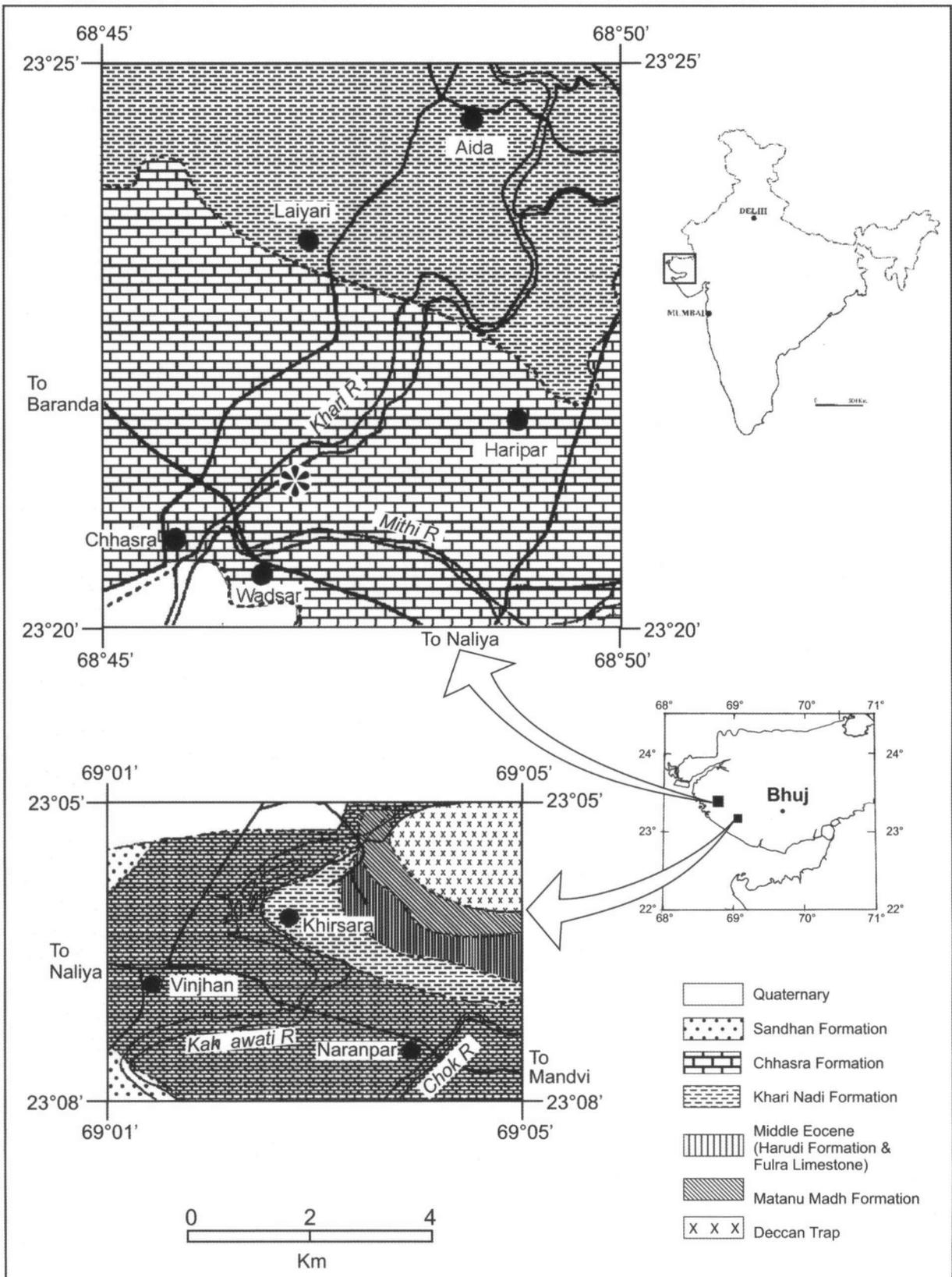


Figure 2. Geological maps of parts of western Kachchh. Exposure of first occurrence of *Indoplacuna* in the Claystone Member, Chhasra Formation, Khari River marked by asterisk.

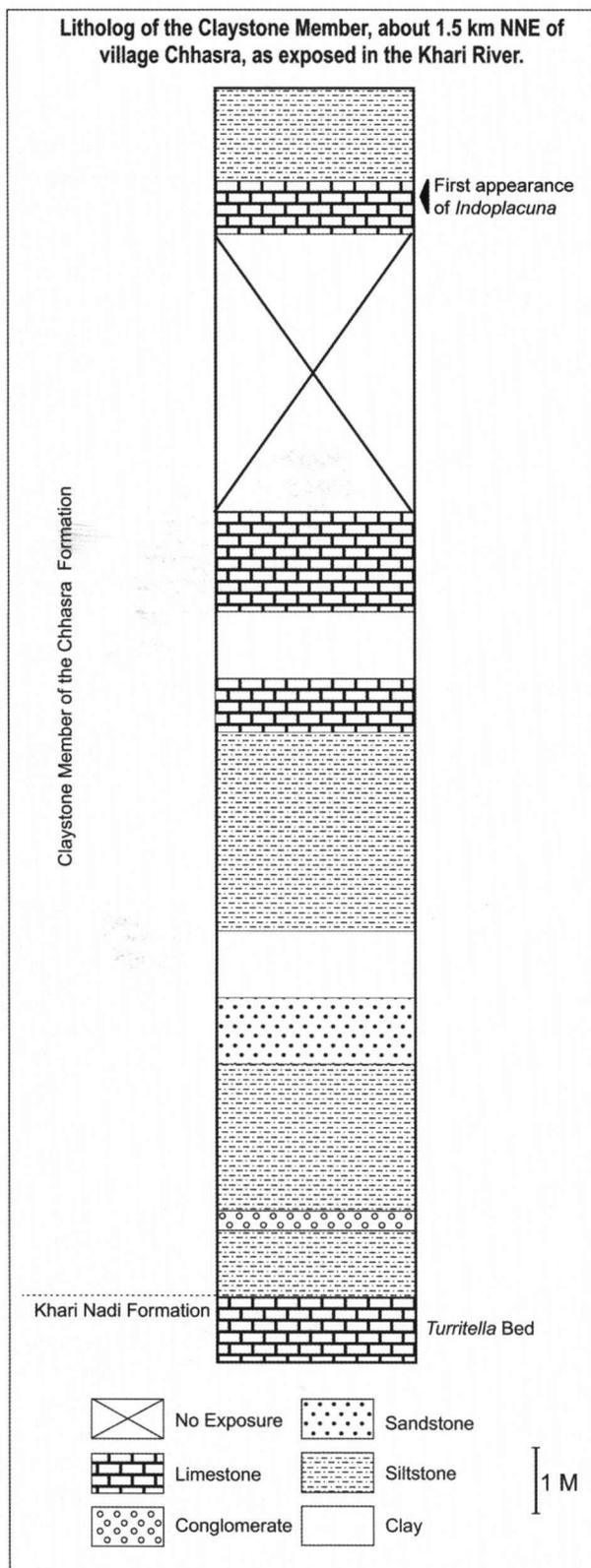


Figure 3. Litholog of the Claystone Member, about 1.5 km NNE of village Chhasra, as exposed in the Khari River.

The underlying pair is less divergent than the overlying pair. The posterior crus of both pairs coincide. This gives a superficial impression that there are three crura arising

from a single point (Figure 1).

Currently, we are reviewing the fossil molluscs from the Miocene rock formations in Kachchh. The oysters have been reported by Borkar *et al.*, (2004). In this paper we review the anomiid bivalves.

Geological setting

The lithostratigraphy of the region has been studied by Biswas (1992), and subdivisions proposed by him are followed here (Table 1). The type sections of the Miocene rock formations are situated in the Abdassa Subdivision of Kachchh District. There, Miocene sediments overlie the Ber Moti Member (Chattian) of the Maniyara Fort Formation (Oligocene) with a minor erosional unconformity. The Miocene rocks are classified in to two formations: the Khari Nadi Formation and the Chhasra Formation. The Chhasra Formation contains two members, viz. the Claystone Member and Siltstone Member. This succession is unconformably overlain by the Pliocene Sandhan Formation (Figure 2).

Raju (1974) identified foraminiferal zones in the Oligocene and Miocene rocks of Kachchh. Within the Claystone Member of the Chhasra Formation three biozones viz., *Miogypsina (Miogypsina) globulina-thecidaeformis* zone, *Miogypsina (Lepidosemicyclina) excentrica* zone and *Miogypsina (Lepidosemicyclina) droogeri* zone were defined.

The Khari Nadi Formation, 65 m thick in the type section, is essentially a sequence of variegated siltstones. The Claystone Member comprises yellowish clayey siltstones with intercalations of gypsiferous shales and fossiliferous limestones. The Siltstone Member, developed only along Kankawati River south of village Vinjhan, consists mainly of greenish yellow silts.

In the Miocene sediments of Kachchh, *Indoplacuna* occurs only in the Claystone Member. No placunids were found in the Khari Nadi Formation or the Siltstone Member of the Chhasra Formation, despite meticulous searches. In the Claystone Member itself, *Indoplacuna* does not occur in the basal 16 m. Three forms reported in this paper, and four more yet to be identified, appear simultaneously in a single horizon (Figure 3). *Indoplacuna* is very common within the bed.

In the exposures in Khari and Mithi Rivers on both sides of the Naliya-Baranda Road, valves of *Indoplacuna* occur in the fossiliferous beds. In the Kankawati River section, between Khirsara and Vinjhan, beds of the Chhasra Formation, younger than those in the Khari River, constitute excellent exposures (Figure 2). All the forms of *Indoplacuna* occurring in the Khari River section are found in these exposures also. Initially, frequency of occurrence matches with that found in the Khari River section. However, it gradually dwindles as one traces occurrence of *Indoplacuna* in succeeding beds. It was noticed that towards higher horizons the frequency is very poor and in the top 20 m of the Claystone Member *Indoplacuna* is totally absent (Figure 4).

Systematic Palaeontology

All material is housed in the Palaeontological Repository of the Agharkar Research Institute bearing registration numbers MACS G 4913 – 4918.

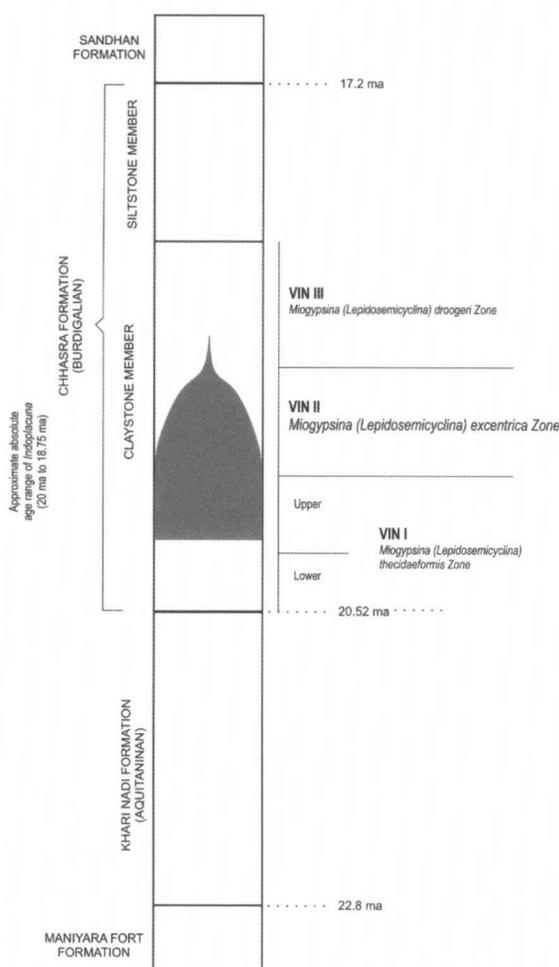


Figure 4. Frequency distribution diagram of the subgenus *Indoplacuna* in the Claystone Member, Chhasra Formation, Kachchh vis-à-vis chronozones proposed by Raju (1991).

Superfamily Anomiacea Rafinesque, 1815
 Family Anomiidae Rafinesque, 1815
 Genus *Placuna* Lightfoot, 1786
 Subgenus *Indoplacuna* Vredenburg, 1924

Type-species — *Indoplacuna sindiensis* Vredenburg, 1924.

Diagnosis — Presence of a raised region occupying part of the interval between the chondrophore ridges and owing to the presence of a more or less distinctly developed subsidiary pair of ridges less divergent than the primary pair (Moore, 1969; Vredenburg, 1924).

Emended diagnosis — Medium to large, concavo-convex, rarely flat, thin shells. Sharply bent resilifer. True teeth absent, but two pairs of crura, one superimposed over the

other in right valve. Crura of superimposed pair usually differ in length and more divergent than those of the underlying pair. Posterior crura of both pairs coincide. Anterior crus of underlying pair appears from below the superimposed crus, giving an impression that the three crura arise from a single point. Corresponding depressions on interior of left valve. Adductor impression sub-central, rather small, circular and shallow. Exterior with numerous fine, delicate yet distinct radiating ribs. Sparse concentric threads give rise to broad, concentric zones of varying widths. Obturated foramen just below umbo on the exterior of right valve.

Placuna (Indoplacuna) sindiensis Vredenburg, 1924
 Figures 5a, 6a

*1924 *Placuna (Indoplacuna) sindiensis* Vredenburg, p. 110- 118, pl. 16, figs 3a– 3c and pl. 17, figs 4 and 5.

Material — Five right valves including MACS G 4913 (plesiotype) and MACS G 4914 (paratype)

Dimensions — Specimens are fragmentary. However, MACS G 4913 and MACS G 4914 are a bit larger fragments. Judging from these two specimens, length attained by this species was over 9 cm.

Description — The valves show a gentle curvature and are externally slightly convex. The external surface is ornamented with very fine, slender yet distinct, numerous radiating ribs. The concentric ornamentation consists of rather sparse threads, giving rise to broad concentric zones of varying widths, probably representing growth spurts. The hinge consists of two pairs of conspicuous crura just beneath the umbo of the right valve. One pair superimposes the other. The underlying pair borders the internal surface of the valve.

It is difficult to comment on the length of crura of the superimposed pair as their distal ends are not intact. However, in MACS G 4913, the anterior crus is entirely preserved and is slightly but clearly shorter than the posterior crus. Both the crura are broadest just beneath the umbo, from where they diverge, and taper to rather sharp points to their distal ends. The course of the crura is slightly curved, convexity in both crura being towards anterior. The anterior crus of the superimposed pair is attached to its counter part of the underlying pair for only half of its length, the distal half is detached. In case of the posterior crus, only the distal, sharp end is detached. Due to tapering nature and curvature of crura of the superimposed pair, the angle subtended between them varies according to places where it is measured. Between edges towards umbo it is about 65° while that between edges away from umbo is about 104° (Figure 5a). In the underlying pair, the crura are shorter than those of the overlying pair; that is precisely the reason for the distal portion of both the crura in superimposed pair appearing detached. The dorsal edges of the underlying crura coincide with those of superimposed pair.

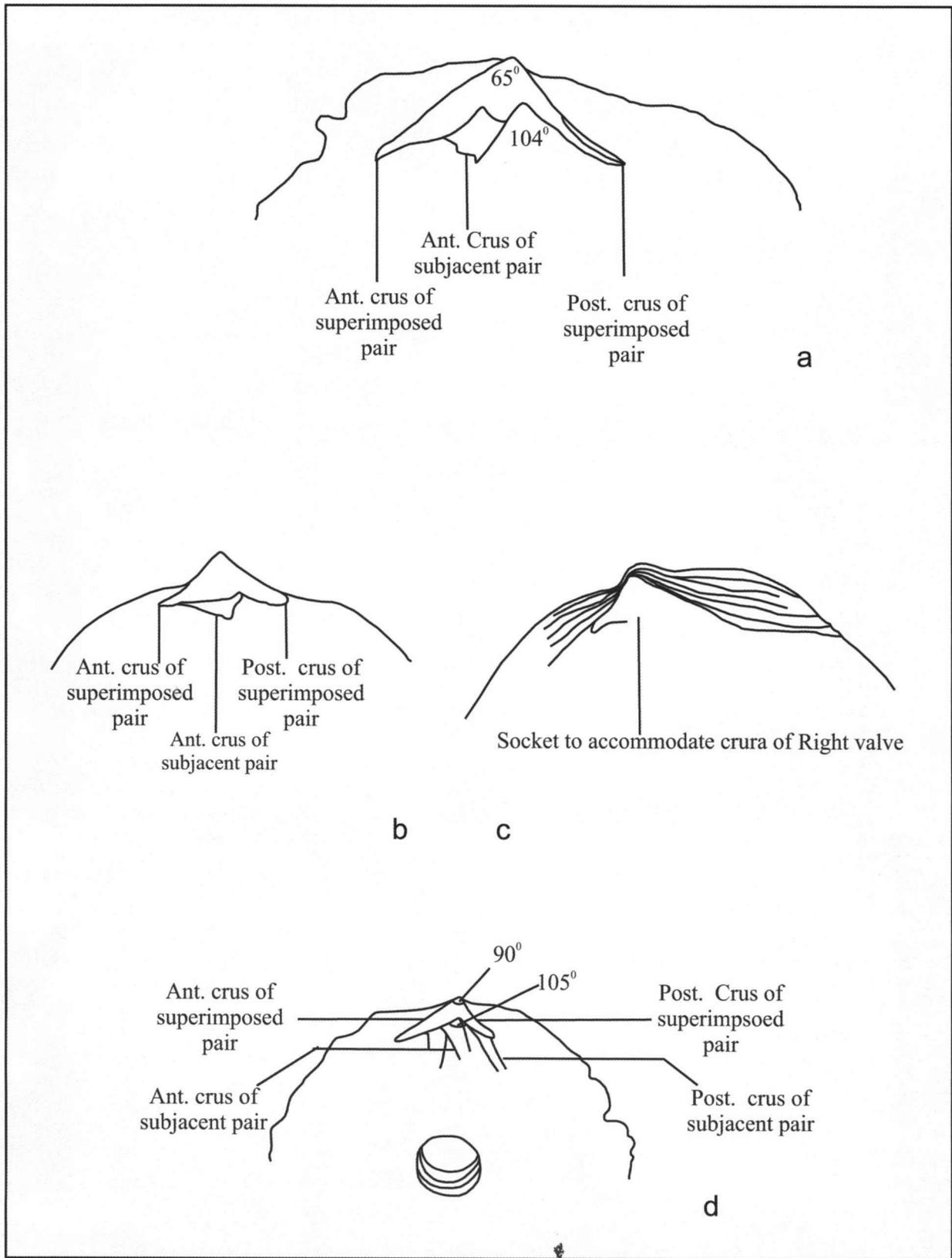


Figure 5. Line drawings (all original size) of *Indoplacuna* depicting disposition of the crura and their angles of divergence. a) *Placuna (Indoplacuna) sindiensis*, b) *Placuna (Indoplacuna) lamellata* (RV), c) *Placuna (Indoplacuna) lamellata* (LV), d) *Placuna (Indoplacuna) birmanica*.

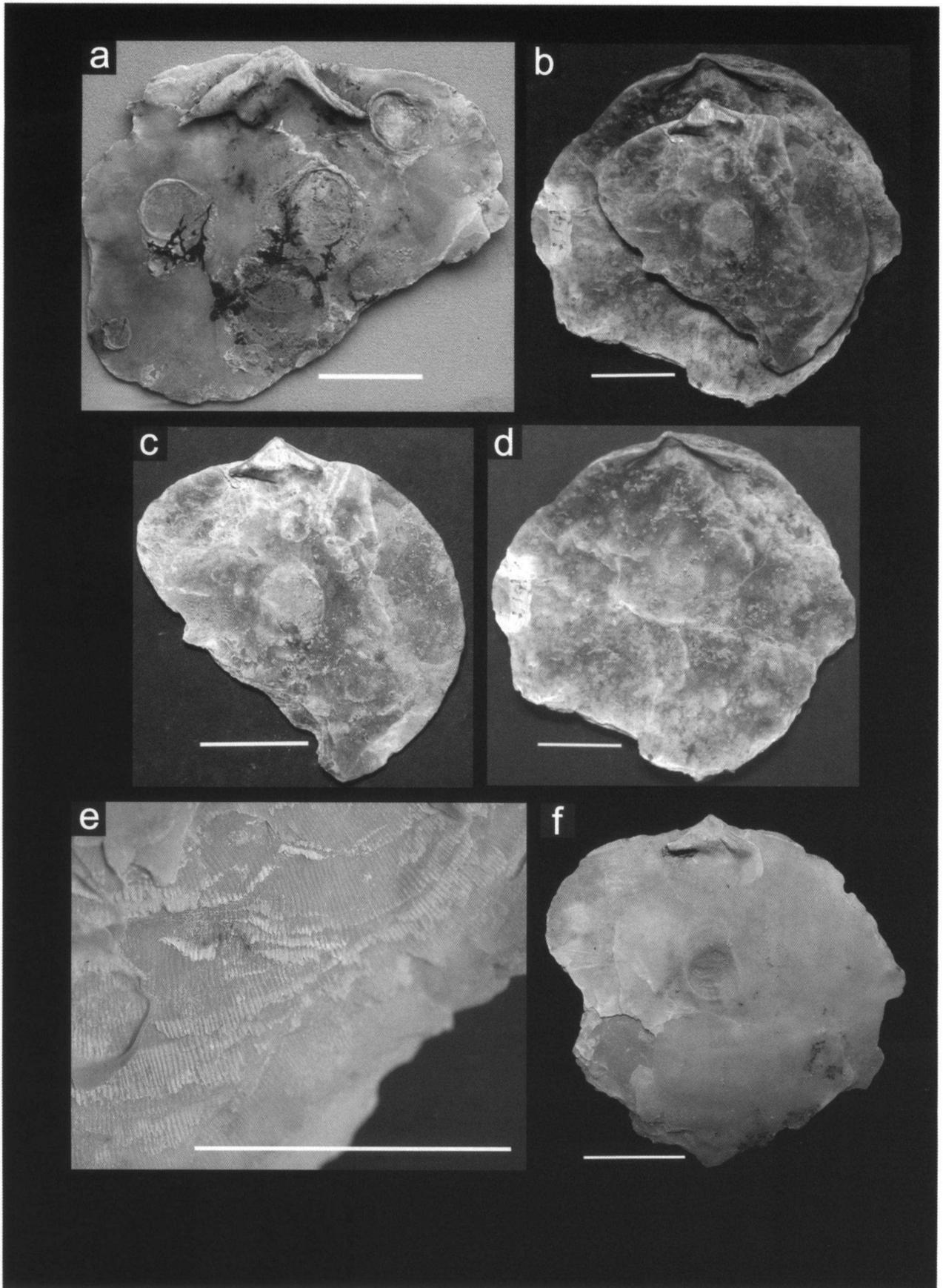


Figure 6.

Figure 6. (scale bar 20 mm).

- (a) *Placuna (Indoplacuna) sindiensis* Vredenburg, RV (MACS G 4913), internal view. Note unequal, tapering and curved nature of crura of superimposed pair and broad anterior crus of subjacent pair.
- (b) *Placuna (Indoplacuna) lamellata* (Dey), both valves of the same shell (MACS G 4915).
- (c) *Placuna (Indoplacuna) lamellata* (Dey), RV (MACS G 4915), internal view.
- (d) *Placuna (Indoplacuna) lamellata* (Dey) LV (MACS G 4915), internal view. Note triangular depression bounded by two radiating ridges.
- (e) Detail same specimen, external view. Note the fine radiating ribs and occasional concentric ribs characteristic of the subgenus.
- (f) *Placuna (Indoplacuna) lamellata* (Dey) RV (MACS G 5916), internal view. Sub-centrally placed, well rounded, small adductor impression is distinct.

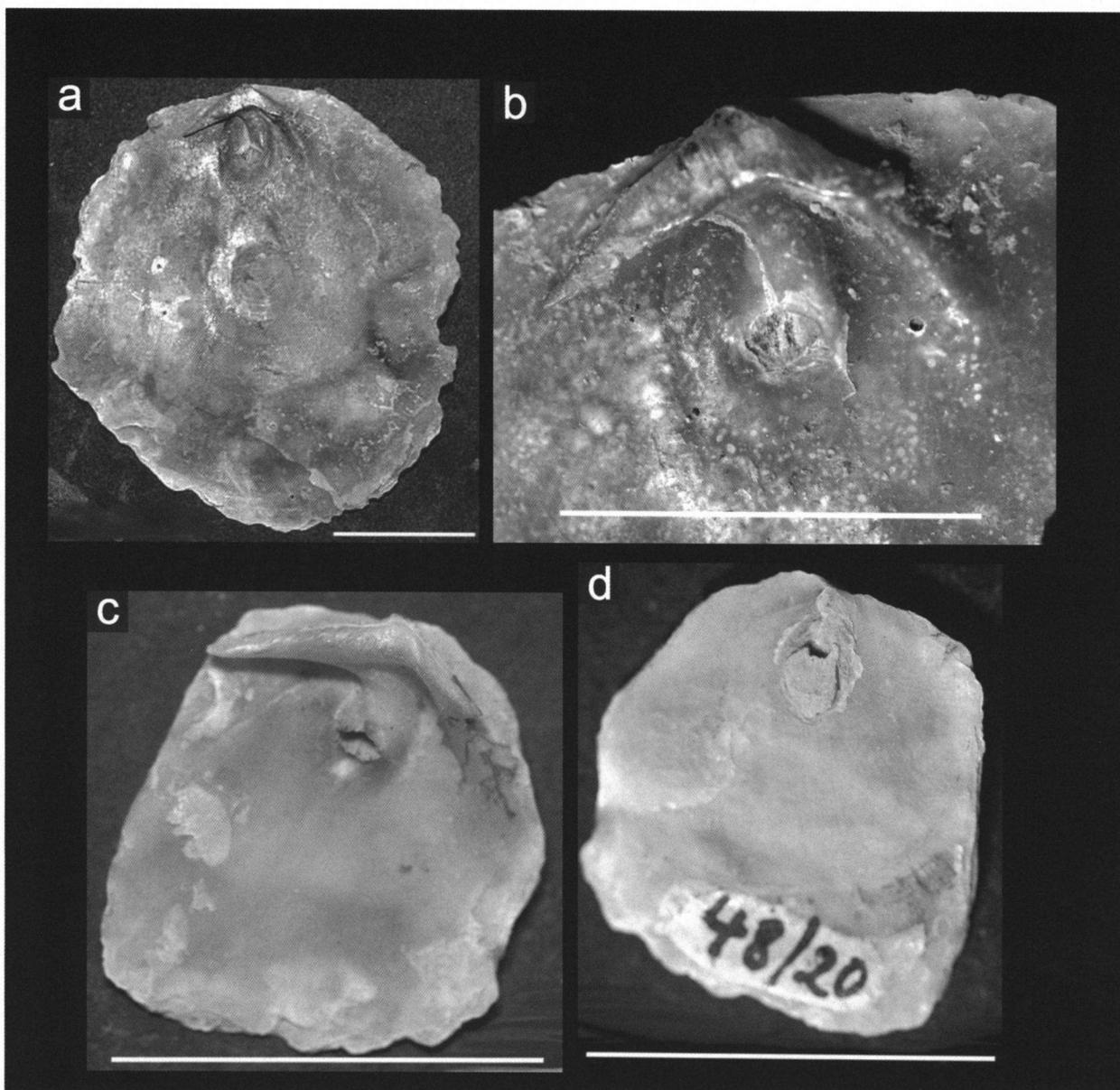


Figure 7. *Placuna (Indoplacuna) birmanica* Vredenburg (scale bar 20 mm).

- (a) RV (MACS G 4017), internal view. Note the two pairs of crura, with a longer posterior ridge of the underlying pair.
- (b) Close up of part of the specimen in (a), showing swellings on either side protecting the foramen.
- (c) RV (MACS G 4918), internal view. Oblique disposition of foramen distinct.
- (d) Close up of part of the specimen in (c), external view. Note obturated (sealed) foramen.

However, the anterior crus is very broad and spreads from beneath its counterpart of the superimposed pair on the side, away from umbo giving an appearance of a small plat-

form between the crura of superimposed pair. This platform is wider away from umbo and width reduces as it is traced towards posterior crura of both the pairs. Finally it

merges into the posterior crus.

Thus, superficially it appears that the dentition consists of three crura (Figure 6a). The distal portion of the platform between the anterior crus is slightly marginally detached from the margin of the valve's interior. The shape of this platform is variable.

The dorsal margin of the posterior crus of the underlying pair also coincides with the dorsal margin of the posterior crus of the superimposed pair. Its margin on the abapical side is slightly sloping and slowly merges into the shell surface. In two of the specimens a small circular adductor impression was observed, that is shallow and subcentrally located.

Remarks — The present specimens are identical with the type specimens of *Placuna (Indoplacuna) sindiensis* from the Miocene of Gaj Beds, Sind, Pakistan (Vredenburg, 1924, p. 115; pl. 16, figs 3a – c, pl. 17, figs 4 and 5) in all essential characteristics, especially the angle of divergence subtended by the crura of superimposed as well as that by the crura of the underlying pair.

According to Vredenburg (1924), *Placuna miocenica* Fuchs, from the Miocene of Egypt, is probably closely related to the above described species and the Egyptian form (Fuchs, 1882, p. 26, pl. 8, figs 1-4) can be distinguished by the straight nature of the posterior crus of the superimposed pair, which is concave towards posterior in *P. (I.) sindiensis* from Kachchh and Sind.

Distribution — Burdigalian: Gaj Beds of Sind, Pakistan; Chhasra Formation, Kachchh District, India.

***Placuna (Indoplacuna) lamellata* (Dey, 1962)**

Figures 5b, c; 6b-f

*1962 *Placenta lamellata* Dey, p. 42, pl. 3, figs 2, 6.

Material — Four specimens including MACS G 4915 (plesiotype) and MACS G 4916 (paratype).

Dimensions — MACS G 4915: L 86.9 mm, H 83.2 mm, timidity 8.4 mm; MACS G 4916: L 71.5 mm, H 69.9 mm, valve thickness 3.8 mm; n.n.: L 77.6 mm, 73.4 mm, valve thickness 3.2 mm.

Description — The specimens are fairly well preserved. Though three of the specimens are isolated right valves, the fourth (MACS G 4915) contains both valves of a single pair. This species is fairly large and distinctly orbicular. The valves are moderately thick and foliaceous. The shell as a whole is, however, feebly tumid. The right valve is externally concave while the left is externally convex, imparting a concavo-convex aspect to this form. An entirely sealed foramen is located just below the umbo. The external surface shows numerous, very fine, slender, well delimited radiating ribs (Figure 6e). The concentric ornamentation consists of sparse threads constituting broad concentric growth zones of varying widths. The interior of right valve

shows two pairs of diverging crura, just below the umbo, one superimposing the other (Figure 5b). The point of divergence is just beneath the umbo. The posterior crus of the overlying pair coincides with the posterior crus of the underlying. This is not the case with the anterior crus, since the divergence angle of the underlying pair is less. The divergence subtended by the dorsal margins of crura of superimposed pair is more or less a right angle. Anterior crus of this pair is very wide beneath the umbo and tapers to a sharp point distally. Therefore, this crus has almost a triangular shape. The proximal part of this crus is attached to its counterpart of the other pair, and hence the distal tapering end appears detached from the valve. The posterior crus of the superimposed pair is shorter than the anterior one, has uniform width and is narrower than the anterior crus (Figure 6c, f).

A small, flattish process from the anterior crus of the underlying pair extends from below the anterior crus of the superimposed pair and is bent towards the posterior. Its width varies between different specimens and the extent of tapering is also variable. Ultimately, this process merges into the internal surface of the valve. Though the posterior crus of this pair coincides with the posterior crus of superimposed pair it is a bit longer. The four crura together superficially appear as three crura only. The small and circular adductor impression is sub-centrally placed (Figure 6f). The interior of the left valve shows a 'V'-shaped depression beneath the umbo to accommodate the crura in the right valve (Figures 5c, 6b, d). A careful examination shows that this depression includes perfect replica of the crura of the superimposed pair (Figure 6d). This depression is flanked on antero-dorsal and postero-dorsal sides by ridges consisting of several lamellae.

Remarks — The Kachchh material was compared with holotype of *Placenta lamellata* (No. 16417, right valve and 16418, left valve; Central Fossil Repository, G.S.I., Kolkata; Dey, 1962, p. 42, pl. 3, figs 2, 6), from the Quilon Beds of Kerala. Dey (1962) had attributed this specimen to the genus *Placenta*. He mentioned that the area between the ridges was occupied by "an irregular platform" and remarked that it was a feature pointing to an advanced stage of evolution of *Placenta*. While discussing on the Quilon fauna at length he emphasized presence of "*Placenta lamellata*", stating that this species was unlike any species of *Placenta* and that the taxon constituted a link between *Placenta* and the extinct subgenus *Indoplacuna* (Dey, 1962, p. 6). However, a close examination of Dey's type specimens revealed that the right valve contains two distinct pairs of crura like the other species of *Indoplacuna*. The Kachchh specimen resembles the Quilon specimens in all essential aspects, including the foliated nature of the shell, and short crura of the superimposed pair. Even the extension of anterior crus in the form of an irregular platform is clearly seen. The left valve of the plesiotype (MACS G 4915) procured along with the corresponding right valve is the only well preserved left valve of *Indoplacuna* in the collection of the present authors. The moderately broad ridges on the two sides of 'V'-shaped depression, meant to accommodate the

crura in right valve, consist of flat foliaceous expanses formed by the superposed terminations of the successive shell layers. This feature has also been noticed by Dey (*op cit.*) in the Quilon specimens. Vredenburg (1924) had observed this feature in *P. (I.) birmanica* and commented that it is analogous to similar structures frequently observed in the corresponding umbonal portion of oyster shells.

Distribution — Chhasra Formation, Kachchh District, and Quilon Beds of Kerala, India (Miocene, Burdigalian).

Placuna (Indoplacuna) birmanica Vredenburg, 1924
Figures 5d, 7a-d

*1924 *Placuna (Indoplacuna) birmanica* Vredenburg, p. 110, pl. 14, figs 1a-c; pl. 15, fig. 1d, e.

Material — Six isolated right valves, including MACS G 4917 (plesiotype) and MACS G 4918 (paratype).

Dimensions — MACS G 4917: L 68.3 mm, H 68.0 mm, valve thickness 3.4 mm; MACS G 4918: L 69.9 mm, H 69.9 mm, valve thickness 3.5 mm.

Description — Two of the six right valves are well preserved, while the remaining are fragmentary. This form is moderately large. Subgeneric characters such as orbicular shape, concavo-convex nature of the shell, numerous, fine radiating ribs and frill-like concentric ornamentation are seen. The RV interior contains two pairs of crura just below the umbo. The two crura of the superimposed pair diverge from below the umbo. They are short, wide and taper in the direction away from umbo. The anterior crus is longer than the posterior one. Distal ends of these crura are detached. Length of detached portion is greater in anterior crus. The angle subtended by their dorsal edges is slightly more than 90° while that by ventral edges is about 105° (Figure 5d). The crura of the underlying pair are longer, less prominent and distally merge into internal surface of the valve. The angle between these crura is slightly less than 40°, thereby anterior crus extends from below anterior crus of the superimposed pair. The posterior crus coincides with and is longer than its counterpart of the superimposed pair, hence extends from below it. The foramen below the crural pairs is distinct in some of the specimens of this form (Figures 7b, c). The foramen is not at right angle to the thickness of the valve, but has an inclination parallel to height and towards ventral side. Internally, opening of the foramen is protected on anterior and posterior side by small swellings on the surface of the valve (Figures 7b, c). Externally it is sealed (Figure 7d).

Remarks — The Kachchh specimens compare well with the holotype of *Placuna (Indoplacuna) birmanica* from the Padaung Shale (Rupelian) from near Mindegyi, Myanmar (Holotype Nos. 12680 and 12681; Central Fossil Repository, G.S.I., Kolkata; Vredenburg, 1924, p. 110; pl. 14, figs 1a-c; pl. 15, figs 1d-e) and therefore identified as such. The

small swellings on both sides of the foramen are distinctly discernible in the holotype of this species.

Distribution — Chhasra Formation, Kachchh District, India (Miocene, Burdigalian) and Padaung Shale near Mindegyi, Myanmar (Oligocene, Rupelian).

Discussion

Extensive information about the fossil molluscs from the Miocene rocks of Kachchh became available through the work of Vredenburg (1925, 1928). He referred to these sediments as 'The Gaj Beds of Kachchh'. He noticed the close relationship and strong affinity between the faunas of the Lower Gaj and Upper Gaj Beds of the Indian subcontinent and that of the Rembang and Njalingdung Series of the Tertiary Sequence of Java, Indonesia, described by Martin (1879), who had assigned Aquitanian and Burdigalian ages respectively to these formations. Therefore, Vredenburg assigned an Early Miocene age to the Gaj Beds, their lower and upper divisions approximately corresponding to Aquitanian and Burdigalian epochs. Biswas (1992), on the basis of foraminiferal studies by Raju (1974a, 1974b, 1991), also assigned Aquitanian and Burdigalian ages to his Khari Nadi and Chhasra Formations, corresponding to Lower and Upper Gaj Beds based on the occurrence of *Miogypsina tani* in the Khari Nadi Formation and that of *Archaias malabaricus* and *Miogypsina droogeri* in the Chhasra Formation, which are decisive in this regard. Thus, it is evident that *Indoplacuna* makes its first appearance and becomes extinct within the Burdigalian in the Indian subcontinent.

When Vredenburg (1924) erected the genus *Indoplacuna*, its distribution was known from Stampian (=Rupelian) and Aquitanian deposits of Myanmar and Burdigalian of Sind (Pakistan), when Vredenburg (1924) instituted this subgenus. Now it is known to occur in the Miocene rocks of Myanmar, India, Egypt, Asia Minor, Portugal and N. Africa (Moore, 1969; Davies, 1971). Only *P. (I.) birmanica* has an Oligocene (Rupelian) occurrence (Padaung Clays, Myanmar). However, the solitary specimen on which Vredenburg erected this species was stray and its exact horizon and locality are uncertain (Vredenburg, 1924). Therefore, range of *Indoplacuna* is generally considered to be Aquitanian to Burdigalian.

As the stratigraphic range of subgenus *Indoplacuna* is very short, it was imperative to note its vertical distribution in Kachchh carefully. It was discovered in the field that its first occurrence is in a laminated clayey limestone bed, 16 m above the base of the Claystone Member exposed in the Khari River, about 1.5 km NE of village Chhasra. This bed can be easily identified by the presence of abundant barnacles, oysters (especially *Ostrea angulata* and *O. latimarginata*), and the bivalve *Glans quilonensis*. A study of foraminifera revealed that the bed roughly corresponds to upper part of *M. globulina-thecidaeformis* zone proposed by Raju (1974). From about the same spot in the Khari

River section along with *Miogypsina* spp., *Archaias malabaricus* and *Austrorillina howchini* also occur (Prof. P.K. Saraswati, personal communication).

Raju and Ramesh (2002) and Raju (2004) have tied up the foraminiferal biozones with the standard stages and geochronological dates. The contact between Khari Nadi Formation and Claystone Member has an estimated age of 20.52 Ma. The Vinjhanian Stage of the time-stratigraphic classification, which more or less corresponds to the Chhasra Formation, is subdivided into three chronozones viz., VIN-I, VIN-II and VIN-III. They consecutively correspond to (i) *Miogypsina* (*Lepidosemicyclina*) *thecidaeformis* Zone, (ii) *M. (L.) excentrica* Zone and (iii) *M. (L.) droogeri* Zone; and have estimated ages of 20.5 Ma, 19.5 Ma and 17.2 Ma respectively. The occurrence of *Indoplacuna* in Miocene sediments of Kachchh is restricted approximately in the sequence from Upper VIN- I to Lower VIN-III (Figure 4). It is estimated therefore that the first appearance of *Indoplacuna* on the Indian subcontinent has an age of circa 20 Ma. This subgenus survived here for 1.25 Ma and became extinct circa 18.75 Ma.

The Quilon Beds of Kerala (Langhian-Tortonian) and the Jaffna Beds as well as the Kudremalai Beds of Sri Lanka were assigned a Vindobonian (Langian-Tortonian) age by Davies (1923) on the basis of gastropod and bivalve fauna. However, Eames (1950) dealt at length with the age after restudying the collection. He concluded that these faunas were of a Burdigalian age, in view of affinity they show to the molluscan forms from the Gaj Beds of Sind (Pakistan) and Kathiawar (western India). Eames considered the occurrence of the foraminifer *Archaias malabaricus* in the Miocene rocks of Kerala and Sri Lanka as a confirmatory evidence for Burdigalian age.

Despite the arguments put forward by Eames, Dey (1962), during a thorough revision of bivalves and gastropods from the Quilon Beds, favoured a Vindobonian age. He emphasised on the occurrence of *Placenta lamellata* in the Quilon Beds and suggested that it was a more advanced form of *Indoplacuna*, and therefore younger. Thus, he interpreted occurrence of *P. lamellata* to be in support of Vindobonian age. However, study of the type specimen of this species led to infer that, in reality, it is an *Indoplacuna*. Moreover, *Placuna* (*Indoplacuna*) *lamellata* has now been recorded from the Chhasra Formation as well. In view of this, and occurrence of *A. malabaricus* in the Quilon Beds of Kerala as well as in the Jaffna and Kudremalai Beds of Sri Lanka (Eames, 1950), it is suggested here that all the three rock formations should be assigned a Burdigalian age.

Lately, Khosla and Nagori (1989) also pointed to a Burdigalian age for the Quilon Beds, based on ostracods. On the basis of planktic foraminifera from the Quilon Beds, Singh (1998) suggested age ranging from Late Burdigalian to Early Langhian.

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