

On *Pseudotaberina malabarica* (Carter) (*Foraminiferida*)

F. T. BANNER & J. HIGHTON

British Museum (Natural History), Cromwell Road, London SW7 5BD, U.K.

ABSTRACT—*Pseudotaberina* Eames, 1971, has as its (originally designated) type species *Orbitolites malabarica* Carter, 1853. The taxonomic and nomenclatural history of *P. malabarica* is given, and the diagnoses of both the genus and the species are corrected and emended, following re-examination of the type and other relevant specimens. A lectotype is selected and, with syntypes, strict topotypes and other specimens, is used for redescription of the species. *P. malabarica* is believed to characterise Early to Middle Miocene marine, inner shelf carbonate sediments of Tethys.

INTRODUCTION

In their most comprehensive classification of the foraminifera, Loeblich and Tappan (1988) considered 3,620 validly proposed genera and recognised, by redescription and illustration, 2,455 of them. Only eight generic names were noted which had been recently cited by others, but for which Loeblich and Tappan had failed to find a validating reference (op. cit., p.725). One of these generic names was *Pseudotaberina*, which had been cited by Datta and Bhatia (1977) while describing the part played by *P. malabarica* in the biostratigraphy of the Neogene of the Cambay oil-rich basin, India. This paper seeks to clarify the status of the genus *Pseudotaberina* Eames and of the only described, but internationally biostratigraphically valuable species, *P. malabarica* (Carter).

TAXONOMIC AND NOMENCLATURAL HISTORY

The first valid publication of the genus *Pseudotaberina* was made by F. E. Eames in his revision of the work of his old teacher, A. Morley Davies (1971). Eames (in Davies, 1971, pp.34–38) included this genus in his collection of genera which he believed to be biostratigraphically useful members of the family “Soritidae [Orbitolitidae, Peneroplidae]”; in his text, he wrote (op. cit., p.36):

“*Pseudotaberina* (Fig. 52): lenticular, spiral-involute, becoming flaring pseudevolute, not cyclical; interseptal pillars and primary subepidermal partitions. M. Mio., India, M. East, E. Africa, W. Pac”.

“Figs. 52f(A), f(B), k. *Pseudotaberina malabarica* (Carpenter), M. Mio. Ceylon. T”.

Earlier in his text, Eames had explained that in his figures “T” meant “Type species (of genus or subgenus), “f(A)” and “f(B)” meant “equatorial or median section – (A) of megalospheric, (B) or microspheric forms”, and that “k” was the reference-letter for “megalosphere” (Davies, 1971, pp.11, 19). The Figs. 52 (op. cit., p.37) were very diagrammatic line-drawings,

and were said to be “original” and, therefore, not based upon any previously published work.

The species, in fact, had been first validly proposed by H. J. Carter (1853a, reprinted 1853b); it then was described, figured and named *Orbitolites malabarica*. The species was found to be abundant in “argillaceous limestone . . . about 30' below the surface at Cochin on the Malabar coast”. Specimens of this rock, with its abundant *malabarica*, were labelled “30. Travancore, Malabar Coast” in Carter’s collection; they were given by him to the Geological Society of London, which (about 1932) gave them to the British Museum (Natural History), where they are registered as specimens P.29875-9. The town of Cochin, on the Malabar coast (south-west India) was, in Carter’s time, in the state of Travancore, but state boundaries have been redrawn and territories renamed, so Cochin is now in the state of Kerala.

Carter (1853a, pl. 11A; 1853b, pl. 16B) had published four drawings of his new species, to illustrate its natural size, its centre magnified in equatorial view (like the first, showing the spiral, not annular, chamber arrangement), its periphery in axial view (to show the marginal apertures), and, also in axial view, the interior of a chamber periphery, showing both septal apertures and what were later to be (incorrectly) called “subepidermal partitions”. The properties of the species, as depicted by Carter, agree fully with the description of *Pseudotaberina malabarica* later to be given by Eames (in Davies, 1971). In Carter’s collection, there are five specimens stuck onto a glass slide and labelled “26. *Orbiculina malabarica*. Malabar coast” (now registered BM(NH) P.28587) but, sadly, as their photomicrographs show (Plate 1), they cannot be matched with any certainty with any of Carter’s original four illustrations (1853a, 1853b). The Malabar rock was not re-collected by or for Carter and these specimens are undoubted syntypes (they were probably prised from the original

rock sample by Carter with a needle); from them a lectotype has now been chosen (as noted below, in the emended description of the species).

The generic name *Orbiculina* was first used in revision for *Orbitolites malabarica* by Carpenter (1856, pp.549, 552), and Carter (1857, p.634) was quick to accept this usage. Originally, Carter (1853a, 1853b) had believed that the spiral growth of the chambers in *O. malabarica* showed clearly that d'Orbigny (1852, p.189), in his last classification of the foraminifera, was misled in attributing a "concentricity" to all the rows of chambers in the order *Cyclostègues*. Carpenter (loc. cit.) pointed out that *O. malabarica* was a species of *Orbiculina*, not *Orbitolites*, and belonged, rather, to the order *Helicostègues*; in this revision spiral coiling was normal, and Carpenter (op. cit., pl. 28, figs. 17–22) supported this with fine drawings of specimens of "*Orbiculina (Orbitolites Malabaricus, Carter)*". The source of these specimens was not noted, in these or in subsequent publications, by either Carter or Carpenter, and consequently the syntypy of these specimens cannot be proven. However, Carpenter's (1856) publication explains Eames's *lapsus calamus* (1971) in citing Carpenter, rather than Carter, as author of the species name.

At this time (from July, 1846), Carter was an Assistant Civil Surgeon in Bombay and (from 1847 until he finally left India in 1862) Honorary Secretary to the Bombay Branch of the Royal Asiatic Society. He received foraminiferal and geological specimens, from his friends, from many parts of India. Among these were specimens of a "yellow compact limestone" from "Khattyawar" (now Kathiawar province in Gujarat State), on the coast near the town of "Poorbunder" (Porbandar), about 430km north-west of Bombay; in these samples were specimens which Carter (1861a,

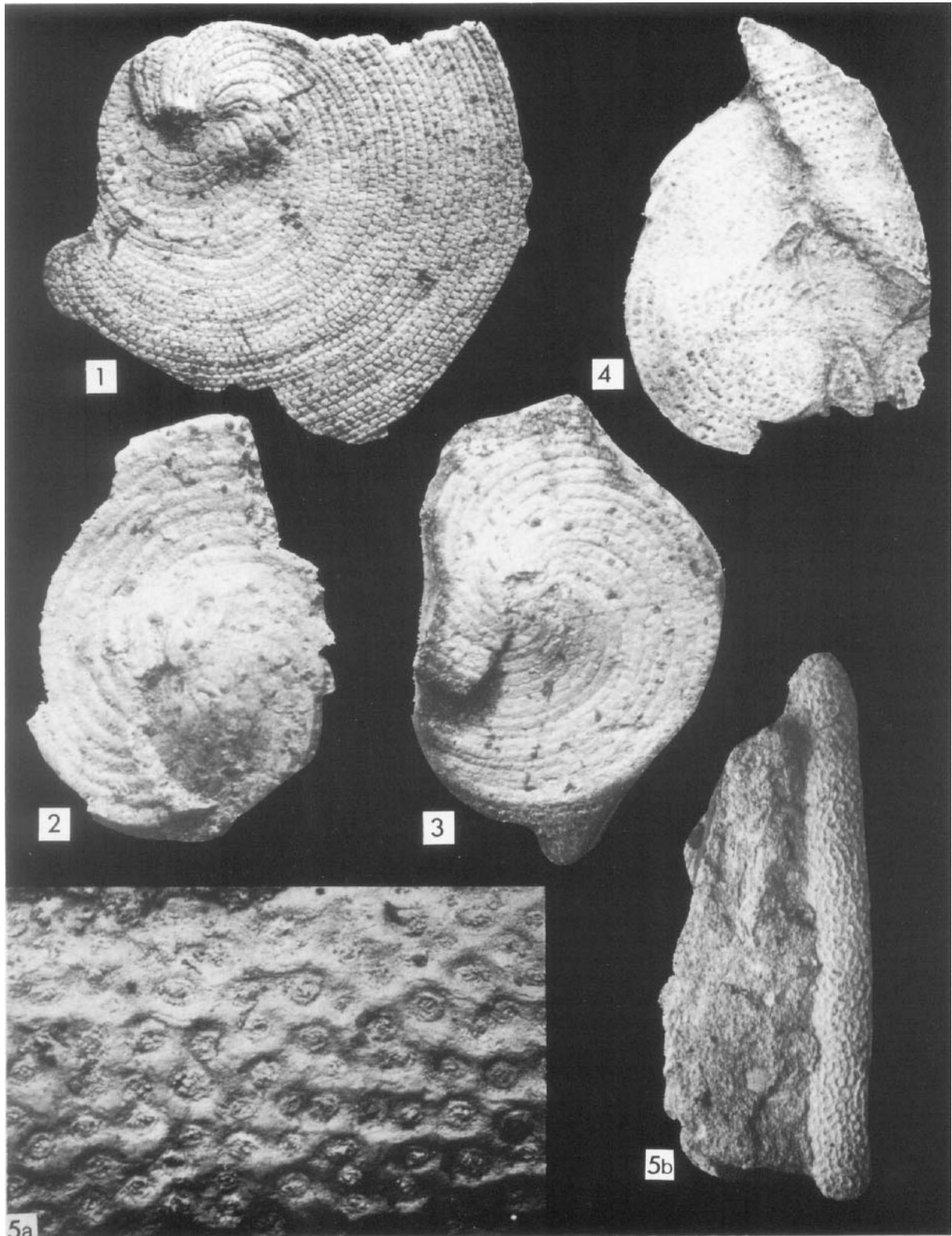
pp.88–89; 1861b, p.462) described as "*Orbiculina malabarica* variety *a*"; he observed that "the only differences between this fossil and the typical form are that the chambers are much smaller in the specimens from Khattyawar". As noted by Adams et al. (1980, p.9), these specimens (the limestone and its contained foraminifera) are deposited in the British Museum (Natural History) and registered as P.29871-29874. All were labelled "29. *Orbiculina*" in Carter's original collection, and were originally labelled "Poorbunder" (P.29871, P.29874), "Khattyawar, West Coast" (P.29873) or "Khattyawar Coast, near Poorbunder" (P.29873).

Four thin-section slides have been cut from samples P.29871 and P.29874 ("variety *a*" of Carter, 1861a, 1861b) and these have been compared with similar thin-sections of the original syntypic rocks (four from P.29875, and two each from P.29876, P.29877 and P.29878); these, with study of the specimens visible on the surface of the rocks (the specimens originally available to Carter, and which must constitute part, at least, of the syntype series) has shown no taxonomic difference between the specimens from Cochin and Khathiawar (Plates 1–8). The only differences are those due to microspheric and megalospheric generations (as noted by Eames, 1971, and as described below) and those due to differences of preservation. The specimens in the rock from Cochin are beautifully preserved; they are filled with clear, sparitic calcite but the walls of the specimens are freshly preserved and resemble those of living Soritidae (Pls. 6–8). In contrast, the specimens in the limestone from Poorbunder (Porbandar) have undergone a degree of recrystallisation and, although the structure of the tests is clear, their microstructure ("ultrastructure") has become obscure (Pl. 6). We have no doubt that the original

Explanation of Plate 1

Pseudotaberina malabarica (Carter)

- Extant syntypes, labelled "*Orbiculina malabarica*. Malabar Coast" in H. J. Carter's handwriting, and numbered "26" in the Carter Collection. All firmly stuck with balsam on one, single slide registered as P.28587 in the British Museum (Natural History). Like the specimens figured on Plates 2–4, they have been imaged by the ISI 63A SEM, using the Environmental Chamber, so that the specimens have not been coated. The specimens of Figs. 1–4 are initially biconvex and therefore megalospheric; the generation of the specimen in Fig. 5 is unknown.
- Fig. 1. Equatorial view; chamber walls have been eroded, displaying the "stalagmitic" structures present at the lateral peripheries of the chambers; specimen here designated as lectotype; $\times 30$.
- Figs. 2, 3. Equatorial views of other, similar specimens; both partly eroded and with balsam adhesive patchily present on displayed sides; fig. 2. $\times 24.3$; fig. 3. $\times 44.5$.
- Fig. 4. Equatorial view of syntype which has been eroded so deeply that the fused "stalactitic" and "stalagmitic" structures inside the chambers are displayed; $\times 33.3$.
- Figs. 5a, 5b. Axial, peripheral views of a fragmentary syntype, still partly embedded in the host limestone, showing the scattered, packed apertures, which are not arranged in parallel rows; each aperture possesses a raised lip, and these, like the inflated areas of the apertural face between the apertures, may link to form an irregular reticulation of ridges; fig. 5a, detail, $\times 120$; fig. 5b, $\times 16.3$.



specimens from Travancore and those subsequently described by Carter from Kathiawar are conspecific.

Understanding of the nature of the species was complicated by the early work of Davies (1923), who studied collections of Miocene (“Vindobonian or later”) fossils from the North-Western Province of Ceylon (now Sri Lanka). He photographed and described specimens which he called *Orbiculina malabarica* (Carter), but stated that they had their “spiral growth restricted to early life . . .” and that there was “perfect cyclical growth” in “the greater part of the disc”. The specimens were deposited in the British Museum (Natural History) in 1923, as part of the E. J. Wayland collection. In this collection is a solid, exceptionally (uniquely?) large microspheric specimen (from Kirimalai, Jaffna Peninsula, P.22325), approximately 21 mm in diameter; this achieves cyclical growth after about 8 mm diameter is reached by helical growth. This is probably the specimen photographed by Davies (1923, pl. 27, fig. 1) and upon which his interpretation was based. His photographs (1923, pl. 27) of thin-sections of megalospheric and microspheric forms, also in the Wayland collection, are of specimens in sections of limestone registered as P.22327 & 22329 (from “Puttalam, Anuradhapura Road”; 1923, pl. 27, fig. 2), P.22330 (from “north of Pomparippu”; 1923, pl. 27, fig. 3) and P.22326 & 22328 (from “Pallai, Jaffna Point”; 1923, pl. 27, fig. 4). These and the other specimens present in the slides are of a species identical with that of the types of *malabarica* from Travancore, but none shows cyclical chamber additions (not even in the microspheric specimen, P.22326). Cyclic chamber additions only occur in the latest growth stages of microspheric forms, and occupy a significant part of the test only in the largest specimens; cyclicity never occurs

in megalospheric specimens. Davies was wrong in his redescription. Also, Davies (1923, p.592) believed that the type locality of *malabarica* had been incorrectly cited by Carter (1853a, 1853b); he stated that the specimens had come from a site called Purappakkara, near Quilon in Travancore, some 120 km south of Cochin. This statement was based on the account by Medlicott (1884) of collections made in Travancore by one General Cullen, and have no apparent relevance. Carter (1853a, 1853b) gave no credit to General Cullen for the Travancore collection he had studied. In their revision of the micropalaeontological biostratigraphy of the Quilon Beds, Rasheed & Ramchandran (1978), recording the presence there of *Archaias malabaricus*, cited a cliff section at Padappakara (*sic*), near Quilon, as its type locality. Pandey (1982, p.120) referred to both Cochin and Purappakkara, the former as the source of Carter’s illustrated material, and the latter as a locality which provided “topotypes”. We must accept that an outcrop (in a pit, below laterite?) probably near Cochin yielded the original syntypes.

The first modern taxonomic reviser of the species was Vaughan (1928), who recognised that *Archaias* de Montfort, 1808, was a senior synonym of *Orbiculina* Lamarck, 1816, and that it was the former generic name which should be used for *malabarica*. The usage of the binomen *Archaias malabaricus* (Carter) was accepted by de Neve (1947) for the large, terminally cyclic form described by Davies (1923). It is possible that de Neve’s own, new Miocene taxon from Borneo, *Archaias vandervlerki* de Neve (1947, pp.14–15, text-figs. 1–4), which was typified by wholly planispiral (but unsectioned) specimens, was merely its megalospheric synonym. However, the sectioned specimens from the Miocene of Saipan, referred to as *A. vandervlerki* by

Explanation of Plate 2

Pseudotaberina malabarica (Carter)

These specimens, like those shown on Plates 3–4, are hypotypes from Kathiawar, collected by A. K. Chatterji and presented by him to the Iraq Petroleum Co. Museum (no. M 8426). They were probably obtained by Chatterji from the Gaj beds, 1½ miles west of Khorasa, Verawal area, Kathiawar (Mohan & Chatterji, 1956). They are now registered in the BM(NH).

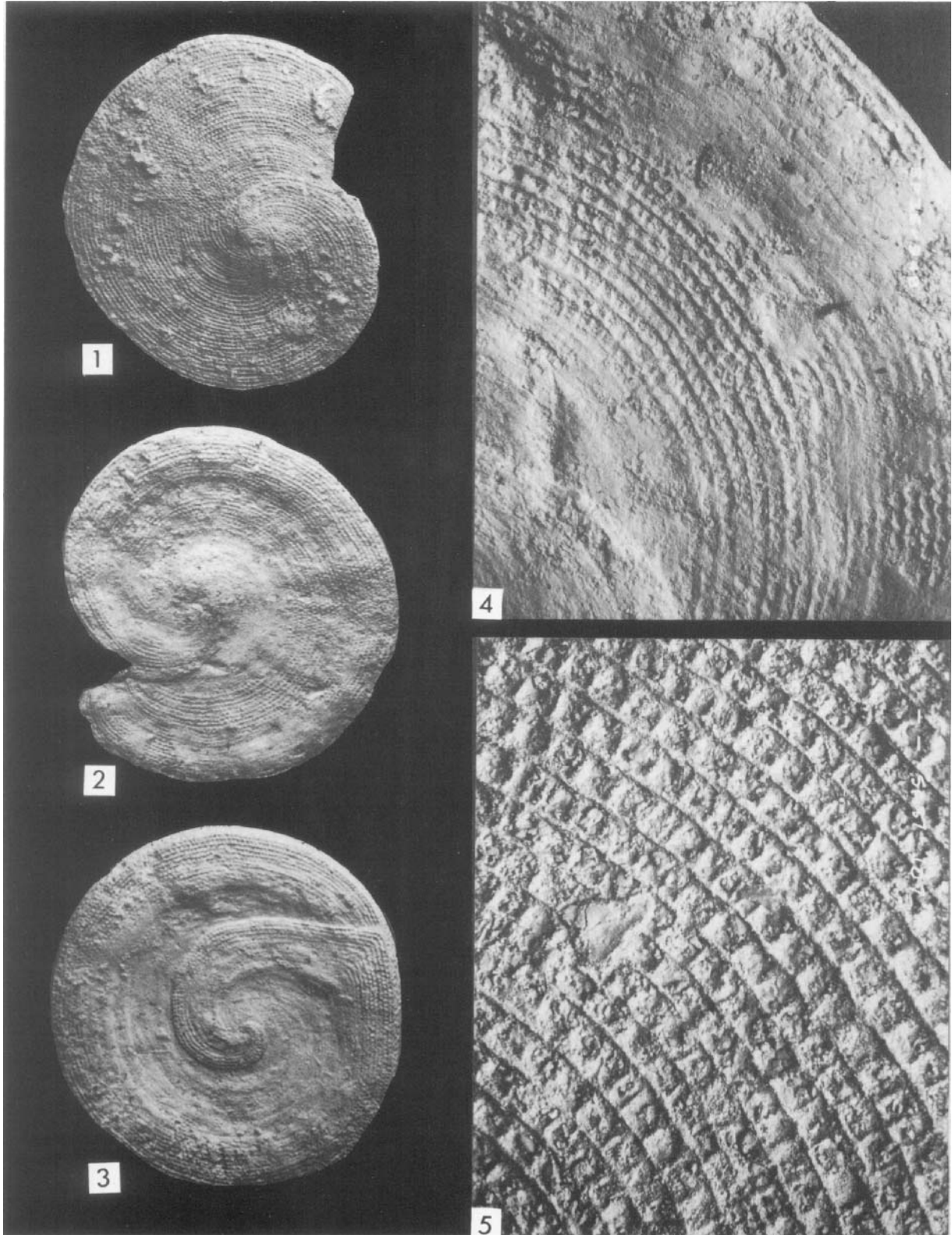
Fig. 1. Initially biconvex, megalospheric specimen, P.52244; archaiasinid planispiral coiling; ×9.8.

Fig. 2. Initially biconvex, megalospheric specimen, P.52242; planispiral coiling in which the last-formed chambers project posteriorly but cyclicity is not attained (achieving a shape called “flabelliform” by Loeblich & Tappan, 1988, for *Archaias*); ×9.2.

Fig. 3. Initially flattened or biconcave, microspheric specimen, P.52245, at the last stage of planispiral growth; the next chamber promises to be cyclic, as the periphery is already virtually circular. Concave areas preserve the outer test wall, which is eroded away in convex areas (as, to a lesser extent, in the less biconcave specimen of Fig. 2); ×9.0.

Fig. 4. Enlarged detail of part of P.52242 (Fig. 2), showing areas in which the outer test wall is preserved and areas in which it is eroded (and where the internal chamber structures are revealed); ×47.

Fig. 5. Enlarged detail of the eroded chamber surfaces of P.52244 (Fig. 1), showing the “stalagmitic” structures of the subepidermal parts of the lateral chamber peripheries (called “subepidermal partitions” by Henson, 1950); ×110.



Cole (1957, p.335, pl. 103, figs. 5–9) seem to be conspecific with *A. hensoni* Smout & Eames (1958, p.219, pls. 40, 41) but this needs further study.

However, Henson (1950, p.50), of the Iraq Petroleum Company, believed that *malabarica* “has alternating sub-epidermal partitions and a central zone of the chambers with numerous interseptal pillars, combining the features of *Archaias* and *Meandropsina*”, and so he placed the species in the genus *Taberina* Keijzer, 1945, which has this structure. The I.P.C. specimens have now been restudied (Plates 2–5), and, with the specimens from Carter’s collection, show that Henson’s statements must be revised. However, Henson also noted (loc. cit.) that the known ages of occurrences of *T. malabarica* were all within the Miocene, and were Middle Miocene in Travancore (Kerala, India), Ceylon, Kafai Island (Persian Gulf), south-west Iran (Lower Fars Limestone) and Syria. Smout and Eames (1958), in their revision of the nature of *Archaias*, agreed that because *malabarica* was supposed to have subepidermal partitions, it could not belong to *Archaias*, but they also doubted the correctness of its assignment to *Taberina* “for the type species of that genus is incompletely described” (1958, op. cit., p.222). The binomen *Taberina malabarica* (Carter) was used, however, not only by Mohan & Chatterji (1956), Smout & Eames (1958) and Bhatia & Mohan (1959), but also by Eames *et al.* (1962) in their review of Oligo-Miocene biostratigraphic correlations in Tethys; the last of these published photographs of thin-sections but they did not redescribe the species. *Taberina* Keijzer, 1945, is a monotypic Danio-Montian genus (*T. cubana* Keijzer), placed by Loeblich and Tappan (1988, p.378) in the subfamily Meandropsinidae Henson. It is not known in Tethys, and it has involute, planispiral coiling followed by rectilinearity in its uncompressed, ovoid test; it is different in appearance and structure, distinct in phylogeny and stratigraphy, and separable at subfamily level from the species *malabarica*. For among these reasons, Eames (1971) proposed for *malabarica* the new genus *Pseudotaberina*.

The new generic name was first used by Clarke & Blow (1969); they were both employed as micropalaeontologists at the BP Research Centre, Sunbury-on-Thames, U.K., where Eames had been (until the end of 1966) Chief Palaeontologist. Consequently, Clarke and

Blow knew of Eames’ work and his intent to publish a valid proposal of the generic name *Pseudotaberina*. Unfortunately, Eames’s work did not see print until later, so, as used by Clarke & Blow (1969), *Pseudotaberina* was *nomen nudum*. The generic name was later and validly used by Datta & Bhatia (1977) and by Adams (1984), but there seems to have been no modern redescription of *Pseudotaberina malabarica* (Carter), except for the notes by Pandey (1982, p.120), prior to our work in this paper.

STRATIGRAPHY

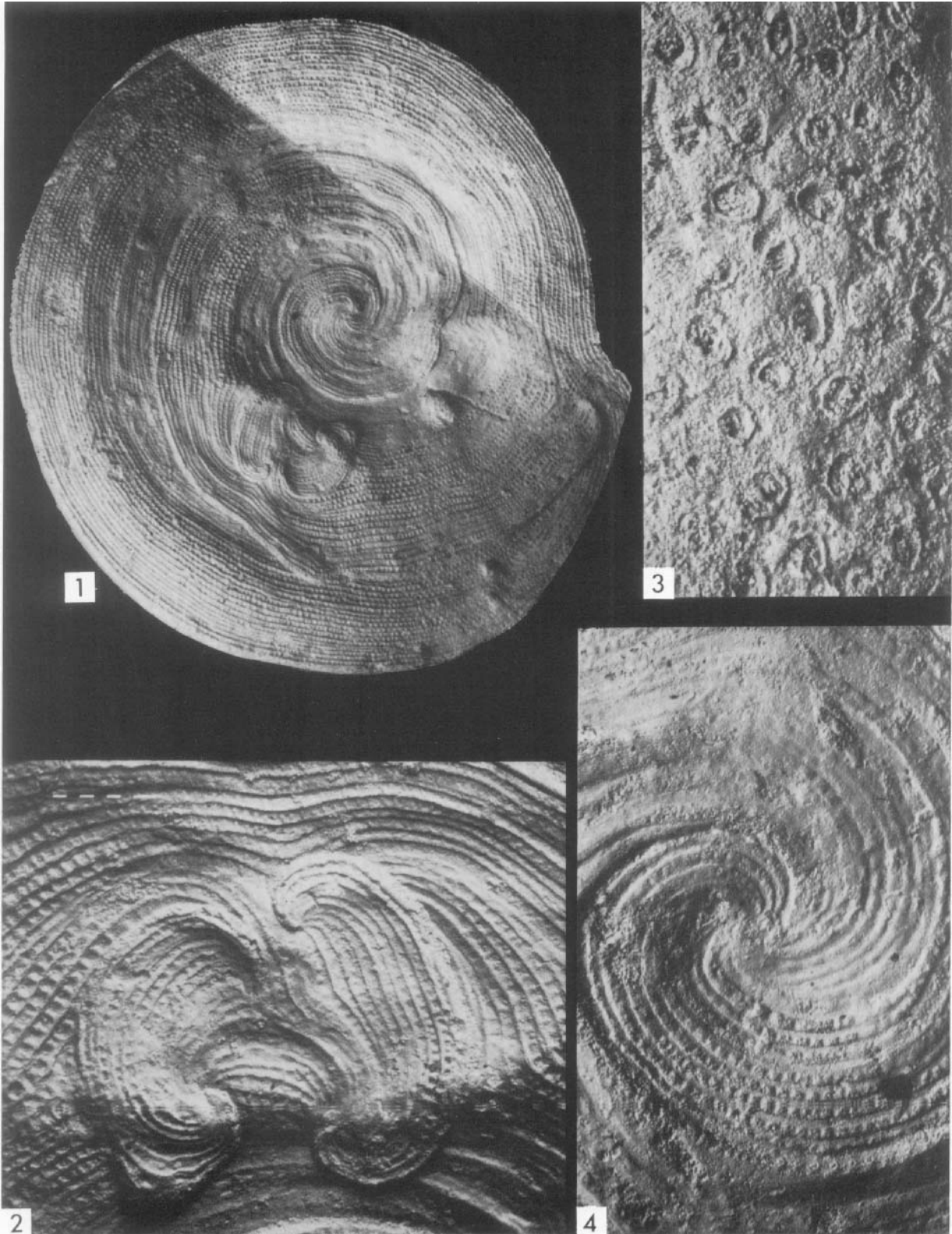
Nine microscope thin-sections have been prepared from Carter’s original specimens (BM(NH) P.29875-8) of the limestones from Cochin, Malabar Coast of India, which contained the syntype specimens of *Pseudotaberina malabarica* (Carter). This rock also contains rare *Miogyopsina* and the codiacean alga *Halimeda*, with abundant *Austrotrillina howchini* (Schlumberger) (photographed by Adams, 1968, pl. 6, figs. 2, 4, 5). This latter species was believed by Adams (1968, pp. 74, 95) to characterise the “Lower Tf (Tf 1–2), Burdigalian” of Tethys, and “within Lower Tf, *Austrotrillina howchini* overlaps with *Orbulina*”. We concur with this, and consider that the overlap of these two species in Tf 1–2 is in the equivalent of planktonic foraminiferal zones N.9–N.12. The provenance of Carter’s (1853a, 1853b) material from Cochin was cited by Pandey (1982), who also referred to Purapakkara, about 10km north-east of Quilon, as an additional source of “topotypes” of the species. In their revision of the foraminiferal biostratigraphy of the Quilon Beds of Kerala State, Rasheed & Ramachandran (1978) used the occurrence of *malabarica* to define and name an upper zone which was immediately subsequent to the *Globigerinatella insueta* zone equivalent; that is, in the Quilon Beds, *P. malabarica* occurs immediately above planktonic foraminiferal zone N.8. This upper interval (zone N.9 and younger) is of Middle Miocene age (possibly referable to the Serravallian or Badenian, but not to the “Burdigalian”, as was once thought).

The Miocene beds of Kathiawar were biostratigraphically reviewed by Mohan & Chatterji (1956), who referred to the “Burdigalian” outcrops of the Gaj beds near Porbander, on the south-western coast, but who described “the richest in well-preserved foraminiferal

Explanation of Plate 3

Pseudotaberina malabarica (Carter)

Figs. 1, 2, 4. Microspheric specimen, P.52247, in equatorial view. Fig. 1, entire specimen, with initially planispiral coiling becoming cyclic in last growth stages, and meandrine septa developing in the planispiral part, $\times 10.3$. Fig. 2, detail of meandrine intercameral septa and meandrine lateral chamber margins of the involute, planispiral test, $\times 40$. Fig. 4, detail of flattened centre of the planispiral coil, with eroded and uneroded chamber walls, $\times 53$. Fig. 3. Axial, peripheral view of the same microspheric specimen P.52247, showing the irregularly packed, lipped areal apertures; $\times 37$.



assemblages [which] contain the well-known species *Taberina malabarica* with *Austrotrillina*, *Miogypsina*, *Lepidosemicyclina*, etc., in the equivalent yellow, argillaceous limestones near Khorasa, south coast. It is probable that this is the locality from which some of the specimens studied here (Pls. 2–5) were obtained by A. K. Chatterji for I.P.C. The same marly limestones were studied by Bhatia & Mohan (1959), who considered that the “*Orbiculina*” Limestone with “*T.*” *malabarica*, at Khorasa, was of “Upper Burdigalian” age as it represented the youngest Miocene horizon present in Kathiawar.

Adams (1984) believed that, in the Indo-West Pacific area, *Pseudotaberina malabarica* was confined to the Tf 1 interval, which he correlated with planktonic foraminiferal zones N.6 to N.9. This contrasts strongly with the N.10–N.11 range given to *P. malabarica* by Clarke & Blow (1969), even though they also believed that species to be confined to the Tf 1–2 interval (equated by Clarke & Blow, 1969, to zones N.10–N.12). Adams (1984) had found no record of *P. malabarica* with Te foraminifera (such as *Eulepidina* and *Spiroclypeus*), and neither had Clarke & Blow (1969), who had access, of course, to all the unpublished records collected by BP. The latter authors did refer to “*Pseudotaberina* sp. aff. *malabarica*” in the highest Te and lowest Tf 1 (correlated by them with the N.8–N.9 zones), but this remains unclarified by further publication.

Pandey (1982), in his synopsis of the studies made on the Tertiary successions drilled off-shore on the western Indian Shelf, concluded that the species *malabarica* was “rather common in shallower, purer limestones of Vinjhanian and Muldwarkian stages”; these stages were correlated by Pandey (1982) with the zonal intervals N.4–N.7 (Lower Miocene) and N.8–N.14 (Middle Miocene), and it was from the lowest to the highest of these zones that *malabarica* was believed, by Pandey, to range. If this conclusion is to be re-assessed, then Pandey’s off-shore material must be restudied, and this cannot be done here.

Pseudotaberina malabarica occurs associated with *Borelis melo* and abundant *Austrotrillina howchini* in Tf 1–2 limestones in Kenya (from various sites near Hadu village, Kenya Coast Province; samples presented to the BM(NH) by the Kenya Geological Survey in 1958, and now registered as P.43944–P.43947). *P. malabarica*

also occurs in limestones with *B. melo* on Kafai Island, Persian Gulf (P.39662) and near Jedraye, Syria (P.39661, P.39663), as shown by samples presented to the BM(NH) by the Iraq Petroleum Co. in 1949.

Eames et al. (1962, p.12) showed *Pseudotaberina malabarica* to characterise the “Burdigalian, Tf 1–2” (*recte* Middle Miocene) of North Africa and the Mediterranean, the Middle East (Upper Asmari Limestone), East Africa, Pakistan and India, and the Netherlands East Indies and New Guinea (Papua) in the Far East. The association of *P. malabarica* and abundant *Miogypsina*, shown by Eames et al. (1962, pl. 7, figs. A, B) to occur in the (lower part of the) Tf 1–2 of the Omati well, Papua New Guinea, is the same association (*P. malabarica* in the “*Miogypsina* spp. biofacies” with *A. howchini*) recorded by Datta and Bhatia (1977) in the Cambay Basin, India, and which was referred by them to the interval of zones N.10–N.11, lower Middle Miocene.

In summary, *Pseudotaberina malabarica* appears to characterise carbonate inner-shelf palaeoenvironments of Tf 1 age in much of Tethys, and this interval has been correlated with planktonic zones N.6–9 (upper Burdigalian to Langhian, latest Early to earliest Middle Miocene, *sensu* Berggren et al., 1985) or with zones N.9–11 (upper Langhian or lower Serravallian, early Middle Miocene, *op. cit.*). Older occurrences have yet to be proved.

EMENDED DESCRIPTION OF *PSEUDOTABERINA MALABARICA* (CARTER)

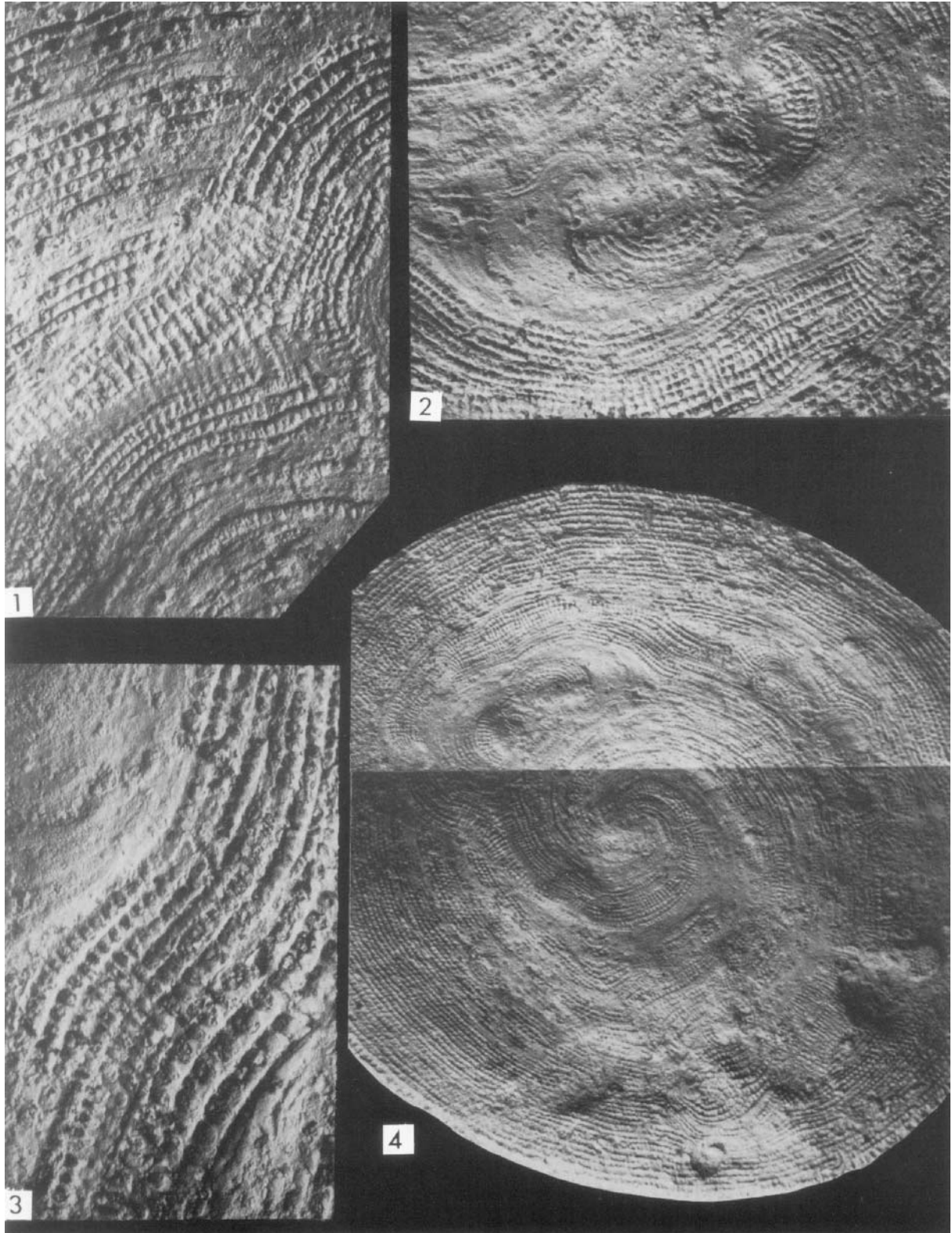
This redescription follows study of all the specimens noted above to be deposited in the British Museum (Natural History), together with those from marls at Kathiawar (Kattyawar) collected by A. K. Chatterji for the Iraq Petroleum Co. museum at its London Office; this collection was presented to the British Museum (Natural History) by F. R. S. Henson, Chief Palaeontologist, I.P.C., and the specimens of *P. malabarica* are now registered as P.52242–52251.

The genus and species are referred to their place in the classification adopted by Loeblich & Tappan (1988) and therefore they may be assumed to possess the characters of the relevant suprageneric taxa as given by Loeblich & Tappan (1988).

Explanation of Plate 4

Pseudotaberina malabarica (Carter)

- Figs. 1–4. Planispiral becoming cyclic, microspheric specimen, P.52246, with meandrine intercameral sutures in both the planispiral and cyclic growth stages. Fig. 1, spiral inter-whorl suture and adjacent intercameral sutures, some of earlier intercameral sutures becoming meandrine, $\times 27$.
 Fig. 2. Meandrine, involute chambers of the planispiral stage (comparable to those of Plate 3, Fig. 2), $\times 27$. Fig. 3, successive chambers with different depths of erosion, $\times 59$. Fig. 4, almost complete equatorial view of this specimen, $\times 10.1$, showing meandrifform chambers developing in parts of the cyclic stage (lower right of photograph).



Suborder Miliolina Delage & Hérouard, 1896
 Superfamily Soritacea Ehrenberg, 1839
 Family Soritidae Ehrenberg, 1839
 Subfamily Archaiasinae Cushman, 1927
 Genus *Pseudotaberina* Eames, 1971, emended

Emended diagnostic description. Test planispiral (becoming cyclical in the latest growth stages of the microspheric form), initially involute, compressed; successive chambers are not embracing; the chambers proximally embrace the earlier whorls but distally (to the earlier whorls) they are pseudevolutive; in shape, the chambers are low but long, with strong posterior curvature so that they cover at least half of the previously formed test, and cover more as growth continues; when the chambers become as long as the circumference of the test, the chambers may become cyclical, so that the test becomes flattened-discoidal and truly evolute with final growth; spaced apart at distances approximately equal to chamber height, the chambers possess pillars which (stalagmitically) arise from each chamber floor (posterior septum) and which, internally to the lateral chamber peripheries, fuse to pillars which (stalactitically) descend from the chamber roof (anterior septum), a descent which is initiated by infolding of that septum between the apertures, but which rapidly leads to thickening of the septa; the pillars fuse discontinuously across the chambers producing discontinuous but regularly spaced chamber divisions, which are clearly seen in equatorial thin-sections; apertures are areal, multiple, scattered over the whole terminal chamber face, occupying most or the whole of the flattened periphery of the test.

Remarks. The "subepidermal partitions", so-called by Eames (1971), are not the radial, peripheral partitions, projecting inwards from the chamber walls, seen in *Taberina* Keijzer; they are not present at the lateral (peripheral) chamber margins, lack lateral continuity and are not true radial chamber partitions at all. The discontinuity of the internal structures also allows rapid distinction of large, microspheric *Pseudotaberina* from discoidal Meandropsinidae like *Larrazetia* Ciry (Loeblich & Tappan, 1988, pp.372–3). Similarly, the Archaiasid *Cyclorbiculina* Silvestri (which becomes cyclic through most of its adult growth in both microspheric and megalospheric forms) possesses true

subepidermal partitions (Loeblich & Tappan, 1988, p.379, pls. 412, 413). However, both the "stalagmitic" and "stalactitic" projections (from the chamber floors and roofs, respectively) discontinuously fuse across the chambers (although not to or at the chamber lateral peripheries, where subepidermal partitions would be situated) producing chamber-subdividing structures, distinct from the separated pillars of *Archaias* de Montfort (Loeblich & Tappan, 1988, pl. 411, figs. 1, 2, 6). Equatorial sections of *Pseudotaberina* clearly display these structures, and axial sections characteristically show their median position in the chambers. The latter also show the thickened septa. The apertures of adult *Archaias* are situated in regular, parallel rows but those of *Pseudotaberina* are scattered over the apertural face; each aperture may be surrounded by a projecting but low lip, as seen in the juvenile, but not the adult, of the type species of *Archaias*.

It is probable that *Pseudotaberina* should be separated from *Archaias* only at subgeneric level.

Pseudotaberina malabarica (Carter) emended
 Pls. 1–8

Orbitolites malabarica Carter, 1853a, 142–144, pl. 2A; 1853b, 425–427, pl. 16B, figs. 1–4.

Orbiculina malabarica (Carter), Carpenter, 1856, 549, 542, pl. 18, figs. 17–22.

Orbiculina malabarica (Carter), Carter, 1857, 634.

Orbiculina malabarica (Carter) var. *a* Carter, 1861a, 88–89; 1861b, 462.

Orbiculina malabarica (Carter), Davies, 1923, 591–592, pl. 28, figs. 1–4.

Archaias malabaricus (Carter), Vaughan, 1928, 302.

Archaias malabaricus (Carter), de Neve, 1947, 14.

?*Archaias vandervlerki* de Neve, 1947, 14–15, text-figs. 1–4.

Taberina [*Archaias*, *Orbiculina*, *Orbitolites*] *malabarica* (Carter), Henson, 1950, 50–51, pl. 3, figs. 7, 11, 12.

Taberina malabarica (Carter), Smout & Eames, 1958, 207, 222.

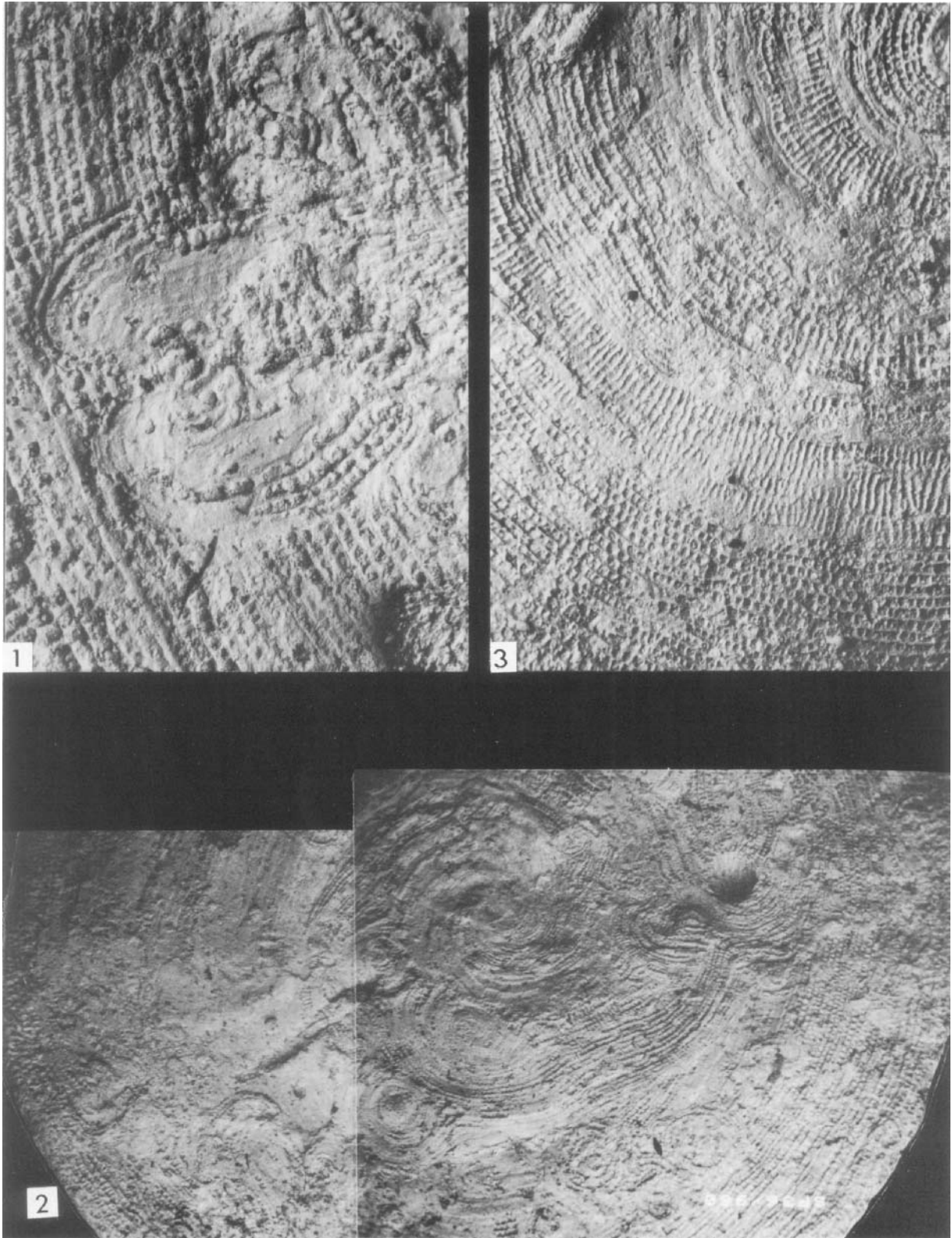
Taberina malabarica (Carter), Eames, Banner, Blow & Clarke, 1962, 11–15, pl. 6, figs. A, B; pl. 7, figs. A, B.

Pseudotaberina malabarica [no authors cited], Clarke & Blow, 1969, 89 [*nomen nudum*; does not satisfy ICZN Art. 13].

Explanation of Plate 5

Pseudotaberina malabarica (Carter)

Figs. 1, 2. Microspheric, flat, exceptionally large, discoid specimen P.52248, with complex meandrine intercameral sutures in both the planispiral and cyclic growth stages. Fig. 1, meandriform chambers (like those of Plate 3, Fig. 2) developed in the early part of the cyclic growth stage, $\times 40$. Fig. 2, almost complete equatorial view, $\times 10.7$. Fig. 3. Part of the equatorial view of the planispiral-cyclical, discoid microspheric specimen P.42250, $\times 22.6$, showing the external, narrow, nearly radial surface ridges visible where the test is clean but uneroded, the chamber walls adjacent to the ridges (smooth probably because of the erosion of the surface ridges), and the chambers with their dividing structures where the chamber walls have been eroded away.



Pseudotaberina malabarica "(Carpenter)" [recte (Carter)], Eames (in Davies), 1971, 36–37, figs. 52. *Archaias malabarica* (Carter), Pandey, 1982, 120, pl. 1, figs. 7–13.

Type specimens. Lectotype (here designated), Pl. 1, fig. 1, specimen on slide P.28587; paralectotypes (here designated), Pl. 1, figs. 2, 3, 4, 5a, 5b, also on slide P.28587; all from "Malabar Coast", probably (according to Carter, 1853a, 1853b) from Cochin, Kerala State (Travancore), India.

Emended diagnostic description. In the megalospheric form, the prolocular chambers consist of an initial, globular protoconch (about 0.2mm in diameter) which is embraced (over about 40% of its surface) by a reniform deuteroconch (about 0.08mm maximum thickness), and these are followed by planispirally coiled chambers, initially about ten in the first whorl, and then increasing in number per whorl as growth increases the test diameter; the chambers of the start of the second whorl are about 0.04mm high in equatorial section, and that is not increased significantly as the test grows. As the whole test enlarges the chambers become longer but not significantly higher. In the microspheric form, planispirality starts immediately around the very small proloculus, initially with about 13 chambers per whorl, but soon (as in the megalospheric form) with many more than this; the chambers are also about 0.4mm in height throughout growth, but become longer until their length is greater than that of the test circumference; at this point, the length of the added chambers becomes equal to the test circumference as the chambers are then added cyclically (this happens when the test diameter has reached about 8mm). The areal, packed, subcircular apertures possess small lips and the apertural face around them is inflated, apparently into irregular, discontinuous, reticulate ridges. The remaining characters are those noted above as diagnostic of the genus *Pseudotaberina*.

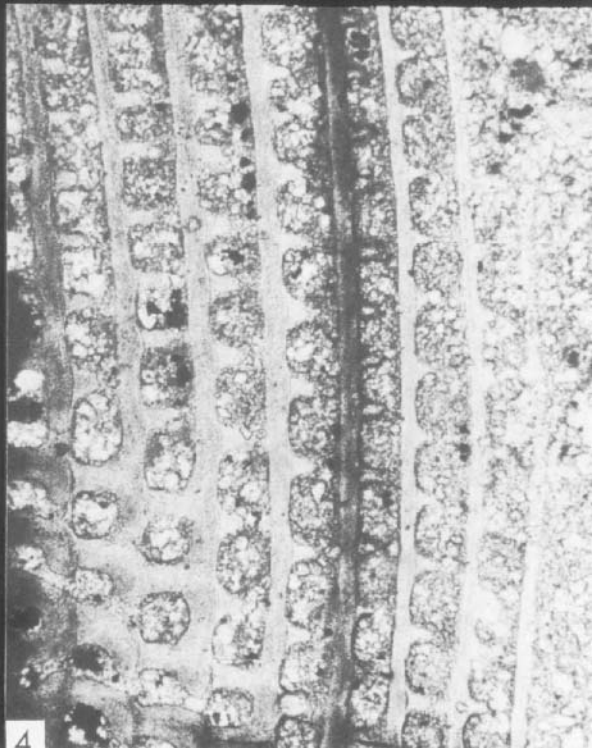
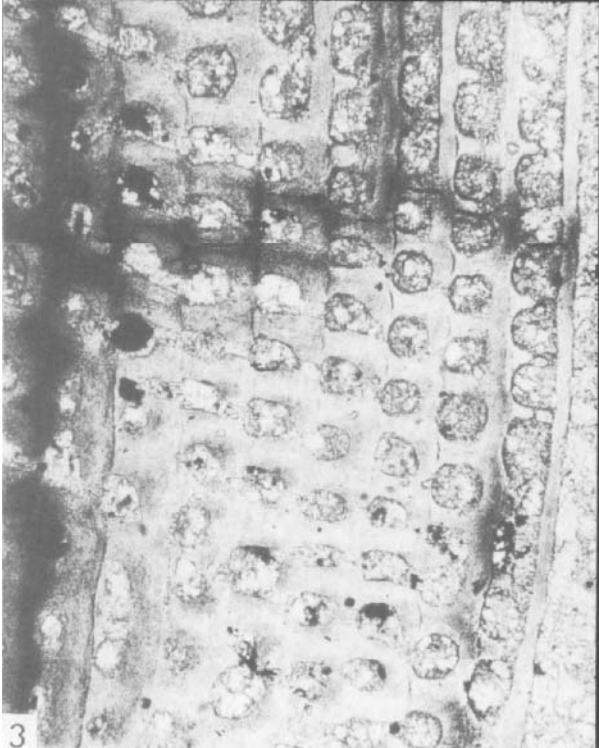
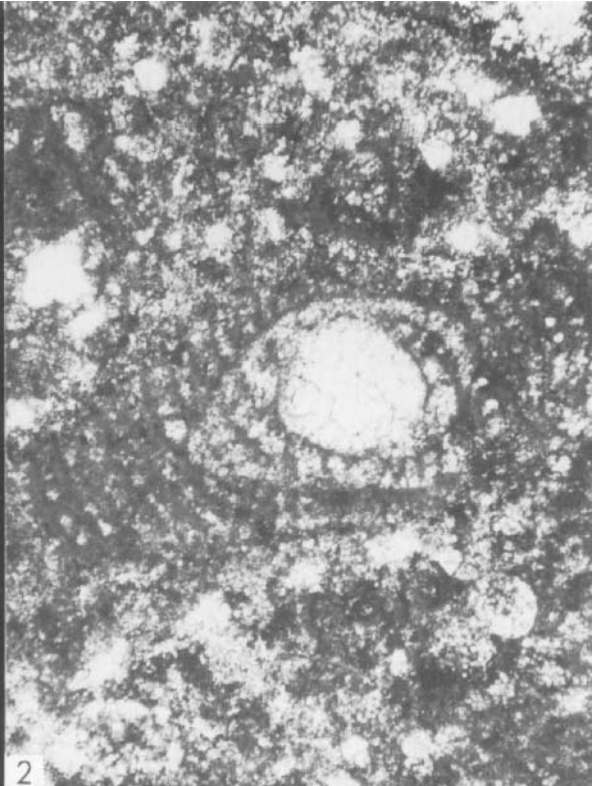
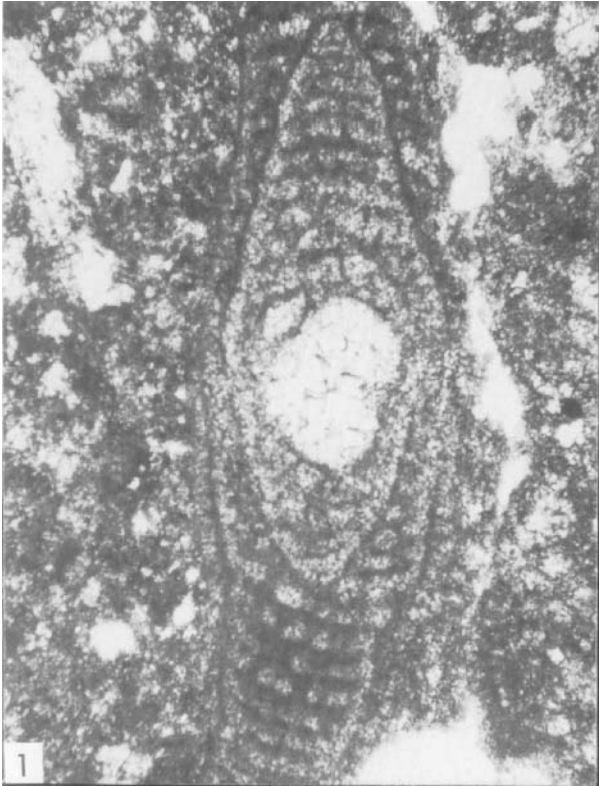
Remarks. The initial biconvexity of the megalospheric forms (Plate 2, figs. 1, 2) contrasts with the initial flatness or even biconcavity of the microspheric forms (Plate 2, fig. 3; Plates 3–5). The megalospheric forms, in their later stages of growth, add chambers which are increasingly long but which do not, posteriorly, touch the earlier parts of the whorl, even though they may project backwards (Plate 2, fig. 2); in contrast, in the microspheric forms the later, longer chambers form a discoid test (Plate 2, fig. 3) even before cyclicality is begun.

Although we have not seen it in the megalospheric forms, the microspheric forms can develop meandrine intercameral sutures as the chambers themselves become, in part, meandriform. The meandrine sutures may be confined to the planispiral growth stage (Plate 3, fig. 1) but they may occur in both the planispiral and cyclic stages (Plates 4, 5). The meandrine sutures may become so convoluted (Plate 3, fig. 2) that they give the illusory impression that the test is budding! Such meandrine shapes can only develop when successive chambers are embracing – i.e., are involute; the involute parts of the chambers, proximal to the test centre, are extremely thin (Plate 6, fig. 1; Plate 7, fig. 1) and in these thinly developed parts of the chambers the intercameral sutures become irregularly curved and meandrine. If the successive chambers do not embrace (partially at least) there can be no meandriform shapes. Therefore, in the latest growth stages of those specimens which have become cyclic, the presence of meandriform chambers (Plate 5, figs. 1, 2) shows that there, at least, there is partial involution of successive chambers. The meandrine sutures can give the appearance that "buds" have become almost circular – but this can only be an effect in the thin, laterally embracing parts of the otherwise cyclic, unembracing chambers. Partial erosion of these thin meandriform chamber-extensions make such structures exceptionally difficult to interpret (compare Plate 5, fig. 1, with Plate 3, fig. 2!).

Explanation of Plate 6

Pseudotaberina malabarica (Carter)

- Figs. 1, 2. Thin-sections from yellowish, compact limestone sample P.29871, labelled "29", "Poorbunder. *Orbiculina*" in the H. J. Carter collection; these are strict topotypes for *Orbiculina malabarica* (Carter) var. *a* Carter, 1861. Fig. 1, axial section $\times 55$; fig. 2, oblique-axial section $\times 47.5$.
- Figs. 3, 4. Details of equatorial section (same specimen as on Plate 8, figs. 1, 2) of the successive chambers of a microspheric form cut from argillaceous limestone sample P.29875, labelled "30", "Malabar Coast, Travancore" in the H. J. Carter collection; these are strict topotypes for *Orbitolites malabarica* Carter, 1853. Both are $\times 120$; both are cut slightly obliquely, cutting just below the surface of the lateral chamber walls on the right-hand side of each photograph, but cutting to deeper levels, further within the chambers, towards the left-hand sides. On the right of each photograph, the peripheral part of the septum has no pillars or other structures built upon it; deeper in the chamber, "stalagmitic" structures are built regularly upon the septa; still deeper, the "stalagmitic" structures fuse to equally-spaced "stalactitic" ones; apertures (intercameral foramina) appear in the deeper cuts on the left-side of each photograph.



Specimens which preserve their outer chamber walls may show the presence of radial, thin outer ridges, which are continuous from chamber to successive chamber (with coalescence or bifurcation, to give "Y"-shapes), spaced at smaller distances than those between the internal chamber dividing-structures (Plate 5, fig. 3). These superficial ridges are not visible in thin-sections, but they must have had the ability to channel extrathalamous cytoplasm to and from the peripheral apertures.

ACKNOWLEDGEMENTS

We thank C. G. Adams and J. E. P. Whittaker for useful discussions and R. L. Hodgkinson for preparing the thin-sections and for his helpful notes on the biography of H. J. Carter. We also thank BP International Ltd. for financial support, and the Manager, Stratigraphy Branch, BP Research Centre, for use of the optical photomicroscope.

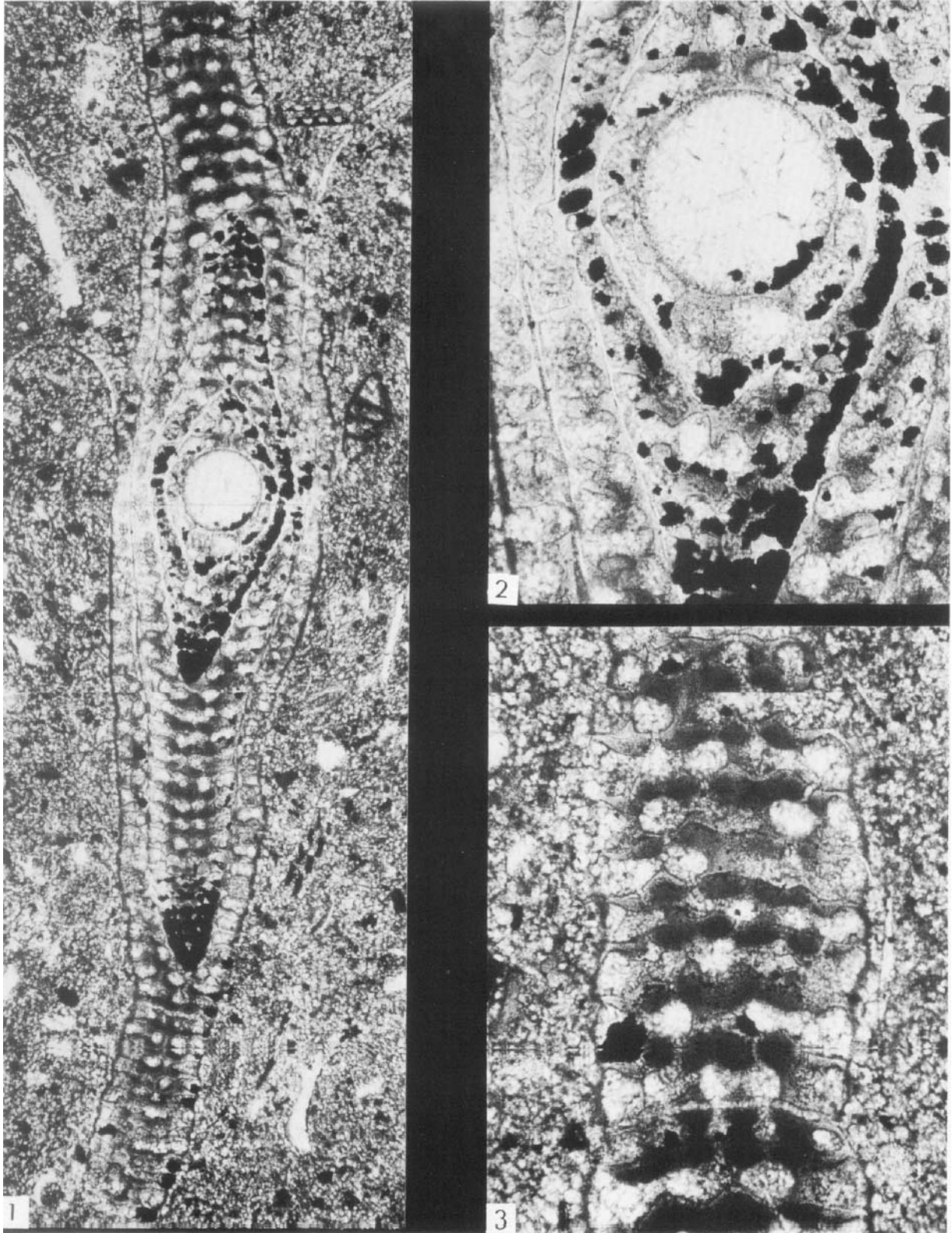
REFERENCES

- Adams, C. G., 1968. A revision of the Foraminiferal genus *Austrotrillina* Parr. *Bull. Br. Mus. nat. Hist. (Geol.)*, **16** (2), 73–97. pls. 1–6.
- Adams, C. G., 1984. Neogene larger foraminifera, evolutionary and geological events in the context of datum planes. In: Ikebe, N., & R. Tsuchi (eds.), *Pacific Neogene Datum Plane*, Univ. Tokyo Press, 47–67.
- Adams, C. G., Harrison, C. A. & Hodgkinson, R. L., 1980. Some primary type specimens of foraminifera in the British Museum (Natural History), *Micropaleontology*, **26** (1), 1–16.
- Berggren, W. A., Kent, D. V., Flynn, J. F. & van Couvering, J. A., 1985. Cenozoic geochronology. *Geol. Soc. America Bull.*, **96**, 1407–1418.
- Bhatia, S. B. [incorrectly given as "S. R."] & Mohan, K., 1959. Miocene (Burdigalian) Foraminifera from Kathiawar, Western India. *Journal of Paleontology*, **33**(4), 641–661.
- Carpenter, W. B., 1856. Researches on the Foraminifera. Part II. On the genera *Orbiculina*, *Alveolina*, *Cycloclypeus*, and *Heterostegina*. *Phil. Trans. Roy. Soc., London*, **146**, 547–569. pls. 28–31.
- Carter, H. J., 1853a. A description of *Orbitolites malabarica*, illustrative of the spiral and not concentric arrangement of chambers in d'Orbigny's order Cyclostègues. *Journal, Bombay Branch, Royal Asiatic Society*, **5**, 142–144, pl. 2.
- Carter, H. J., 1853b. A description of *Orbitolites malabarica* (H.J.C.), illustrative of the spiral and not concentric arrangement of chambers in d'Orbigny's order Cyclostègues. *Annals & Magazine of Natural History*, (2) **11**, 425–427, pl.16B.
- Carter, H. J., 1857. On contributions to the geology of central and western India. *Journal, Bombay Branch, Royal Asiatic Society*, **5**, 614–638.
- Carter, H. J., 1861a. Further observations on the structure of foraminifera and on the larger fossilized forms of Scinde, etc., including a new genus and species. *Journal, Bombay Branch, Royal Asiatic Society*, **6**, 31–96.
- Carter, H. J., 1861b. Further observations on the structure of foraminifera and on the larger fossilized forms of Scinde, etc., including a new genus and species. *Annals & Magazine of Natural History*, (3)**8**, 311–353, 366–382, 446–470, pls. 15–17.
- Clarke, W. J. & Blow, W. H., 1969. The inter-relationships of some Late Eocene, Oligocene and Miocene larger foraminifera and planktonic biostratigraphic indices. In: Brönnimann, P. & Renz, H. H. (Eds.), *Proceedings of the First International Conference on Planktonic Microfossils, Geneva, 1967*, **2**, 82–97.
- Cole, W. S., 1957. Larger foraminifera, *Geology of Saipan, Mariana Islands*, U.S. Geol. Surv. Profess. Paper **280-1**, 319–360, pl. 94–118.
- Datta, A. K. & Bhatia, M. L., 1977. Foraminiferal biostratigraphy of the Neogene and Quaternary sequences of the Cambay Basin. *Proceedings, IV Colloquium on Indian Micropalaeontology and Stratigraphy, 1975–75*. Dehra Dun, 59–61.
- Davies, A. M., 1923. The Faunas of the Miocene of Ceylon. *Quart. J. Geol. Soc. London*, **79**, 584–602, pls. 28–29.
- Davies, A. M., 1971. *Tertiary Faunas. A Text-book for Oilfield Palaeontologists and Students of Geology*. Vol. 1: *The Composition of Tertiary Faunas*. Revised and brought up to date by F. E. Eames. 2nd ed. George Allen & Unwin Ltd., London. 571 pp.
- Eames, F. E. Banner, F. T. Blow, W. H. & Clarke, W. J., 1962. *Fundamentals of Mid-Tertiary Stratigraphical Correlation*. Cambridge University Press. 163 pp., 27 pls.
- Henson, F. R. S., 1950. *Middle Eastern Tertiary Peneroplidae (Foraminifera) with remarks on the phylogeny and taxonomy of the family*. West Yorkshire Printing Company, Wakefield.
- Loeblich, A. R. Jr. & Tappan, H., 1988. *Foraminiferal genera and their classification*, **1-2**, 1–970. 847 pls. Van Nostrand Reinhold, New York.

Explanation of Plate 7

Pseudotaberina malabarica (Carter)

Fig. 1–3. Axial section of megalospheric, strict topotype of *Orbitolites malabarica* (Carter) from limestone sample P.29875 (as in Plate 6, figs. 3, 4). Fig. 1, $\times 70$; fig. 2, details of initial (proximal) part of same section, $\times 175$; fig. 3, detail of distal part of same section, $\times 175$, showing the evolute (anterior) parts of the chambers, with the vertical fusion of the "stalagmitic" and "stalactitic" processes to form pillars and the discontinuous lateral fusion of these pillars to form partial chamber-subdivisions. In Fig. 3, the thickening of the septa and their hummocky convexities between intercameral foramina (apertures) may be seen.



- Medlicott, H. B., 1884. Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1883. *Records of the Geological Survey of India*, **17**, 1–11.
- Mohan, K. & Chatterji, A. K., 1956. Stratigraphy of the Miocene beds of Kathiawar, western India. *Micropaleontology*, **2**, 349–356.
- Neve, G. A. de, 1947. A new *Archaias* species from east Borneo. Dutch East Indies. *Dienst. Mijnb., Bull. Bur. Mines & Geol. Survey Indonesia, Bandoeng*, **1** (1), 13–16.
- d'Orbigny, A. D., 1852. *Cours élémentaire de paléontologie et de géologie stratigraphiques*. Masson, Paris, **2** (1 & 2), 841 pp.
- Pandey, J., 1982. Chronostratigraphic correlation of the Neogene sedimentaries of the western Indian shelf, Himalayas and Upper Assam. *The Palaeontological Society of India, Spec. Publ.* **1**, 95–129.
- Rasheed, D. A. & Ramachandran, K. K., 1978. Foraminiferal biostratigraphy of the Quilon Beds of Kerala State, India. In: Rasheed, D. A. (Ed.), *VII Indian Colloquium on Micropalaeontology and Stratigraphy*, Univ. Madras, 299–320, pls. 1–3.
- Smout, A. H. & Eames, F. E., 1958, the genus *Archaias* (Foraminifera) and its stratigraphical distribution. *Palaeontology*, **1** (3), 207–225, pls. 39–42.
- Vaughan, T. W., 1928. Notes on the types of *Lepidocyclina mantelli* (Morton) Gumbel and on topotypes of *Nummulites floridanus* Conrad. *Proc. Acad. Nat. Sci. Philadelphia*, **79**, 299–303, pl. 23.

Explanation of Plate 8

Pseudotaberina malabarica (Carter)

Figs. 1–4. Equatorial sections of strict topotypes of *Orbitolites malabarica* Carter, 1853, from limestone sample P.29875 (as on Plate 6, figs. 3, 4, and Plate 7); figs. 1, 2, microspheric form; figs. 3, 4, megalospheric form. Fig. 1, ×52.6; fig. 2, detail of same specimen, ×124. Fig. 3, ×65; fig. 4, detail of same specimen, ×155.

