

*Prosphaeroidinella*, n. gen.: Probable Ancestral Taxon  
of *Sphaeroidinellopsis* (Foraminifera)

By

**Hiroshi UJIIÉ**

Department of Paleontology, National Science Museum, Tokyo

**Introduction**

In the course of study on planktonic Foraminifera since several years ago, I have recognized a number of taxonomic problems concerning its late Cenozoic taxa, although these have been thought by authors as almost fixed already, through the quantitative analyses of the materials from various places in the western North Pacific region. Some of the problems may be ascribed to local though paleoecologically significant variation, whereas the others might be important for the purpose to refine, to modify somewhat, or to subdivide the so-called world-wide planktonic foraminiferal biostratigraphy.

This article deals with one of the most important examples among the latter cases; namely, a proposal of a new genus whose occurrences, however, were previously reported by many authors under several different and rather well-known specific or subspecific names. These records imply their world-wide distributions and their restricted stratigraphic ranges; therefore, they will be potential as some critical taxa for biostratigraphy if further investigation is made on them.

Prior to such a bibliographic research, nevertheless, I must mention the *raison d'être* of the genus through my own works upon the materials at my hands utilizing an electron microscope (JEOL-S1) and thin-sectioning technique. Among these materials, detailed occurrences of which have been partly reported and published already, most useful and critical ones are from Sites 292 and 296 of Leg 31, Deep Sea Drilling Project.

Hereupon I would like to extend my appreciation to the Deep Sea Drilling Project for affording me the opportunity to participate in the Leg 31 cruise. I am also indebted to Reiko FUSEJIMA of the National Science Museum of Tokyo for reading the manuscript.

**Description**

Family Globigerinidae CARPENTER, PARKER & JONES, 1862

**Genus *Prosphaeroidinella*, n. gen.**

**Type Species:** *Sphaeroidinella disjuncta* FINLAY, 1940

**Description:** Test low trochospiral throughout; chambers 3 per whorl in young stage,

increasing in number up to about 5 at maximum in later stage; wall calcareous, thick, coarsely perforate, provided initially with coarser honey-comb structure than in *Globigerinoides*; honey-comb wall structure often being filled up by secondarily deposited shell substance, even though leaving still rough surface until the final step of wall thickening observed in earlier portion of adult, never forming such smooth surface as seen on "cortex layer" of *Sphaeroidinella* or *Sphaeroidinellopsis*; sutures deeply cut on umbilical side and, in later portion, also on spiral side; aperture interiomarginal, umbilical, rather broad slit to low arched opening; supplementary sutural openings not yet developed, though intercameral sutures deeply cleft.

**Remarks:** Taxonomically this new genus seems to conjugate three planktonic foraminiferal genera such as *Globigerina*, *Globigerinoides* and *Sphaeroidinellopsis* (or *Sphaeroidinella*). *Prosphaeroidinella* has no supplementary apertures like *Globigerina* but, on the other hand, it has very coarsely pitted honey-comb structure on wall like *Globigerinoides*. Honey-comb structure of coarseness comparable to that in *Globigerinoides* can be seen very scarcely among some *Globigerina* species such as *Globigerina woodi* JENKINS which is characteristic in the Middle to upper Lower Miocene of the Pacific region and *Globigerina umbilicata* ORR and ZAITZEFF peculiarly from the Pliocene to Pleistocene beds in the subarctic to cool temperate North Pacific region. Both the species, however, possess a high arched umbilical aperture unlike *Prosphaeroidinella*, n. gen.

In the type species, *Sphaeroidinella disjuncta* FINLAY, honey-comb wall structure becomes considerably obscure at the earlier portion of specimen because of remarkable piling-up of lamellae during the course of growth. Since this type of wall-thickening is accomplished by the outward growth of respective calcite crystals disposed radially against test-surface, the present secondary process does not produce directly such a smooth test-surface as seen in *Sphaeroidinella* or *Sphaeroidinellopsis* but still maintains the rough surface. Moreover, *S. disjuncta* is provided with somewhat more broadly opened aperture than in *Sphaeroidinellopsis*.

Another species also belonging to *Prosphaeroidinella*, *P. parkerae*, n. sp., shows much more widely spaced framework of honey-comb structure. The frame is distinctly larger than that of normal species of *Globigerinoides* and solely comparable sized frame can be recognized at the outer face of an inner layer (Layer 2 designated in later paragraph; p. 15) of wall in *Sphaeroidinellopsis* or *Sphaeroidinella*. The outer layer (Layer 3) is so-called cortex layer, whose outer surface is quite smooth paved by the calcite basal planes. This smoothness corresponds to that at the inner surface of wall. These facts imply some essential difference in genesis between the two types of layer. As will be discussed and inferred in Remarks on the species, the inner layer may be a fundamental constituent of wall in *Sphaeroidinellopsis* or *Sphaeroidinella*, while the outer cortex layer may be secondary but advanced component characteristic to the genera. Therefore, I suppose that the wall structure peculiar to *P. parkerae*, n. sp. may not have been resulted from such a peeling-out of outer Layer 2 of *Sphaeroidinellopsis* or *Sphaeroidinella* through certain chemical dissolution or physical process (e.g.,

some vibration effect during the maceration of sediment samples) as PARKER (1967) thought previously, but it may represent a kind of atavism. In this respect, the species must belong to the genus *Prosphaeroidinella*, although there is necessity to consider the phylogenetic difference between *P. parkerae*, n. sp. and *P. disjuncta* (FINLAY).

The present supposition from taxonomic views of the two species seems to be substantiated by their stratigraphic occurrences. Last appearance of *P. disjuncta* is followed immediately by the initial appearance of rather primitive but real *Sphaeroidinellopsis* species at the boundary between the N. 12 and N. 13 of BLOW's (1969) zones, whereas *P. parkerae*, n. sp. occurs concurrently with well-developed *Sphaeroidinellopsis* and with Pliocene species of *Sphaeroidinella*.

### *Prosphaeroidinella disjuncta* (FINLAY)

(Pl. 1, figs. 1-3; pl. 2, figs. 1-3; pl. 3, figs. 1-3; pl. 10, fig. 4; pl. 11, figs. 1-3; pl. 12, figs. 1-3)

*Sphaeroidinella disjuncta* FINLAY, 1940, Trans. Roy. Soc. New Zealand, vol. 69, pt. 4, p. 467, pl. 67, figs. 224-228, — HORNIBROOK, 1958, Micropaleontology, vol. 4, no. 1, p. 34, pl. 1, fig. 15, — JENKINS, 1971, New Zealand Geol. Surv., Paleont. Bull., 42, pp. 171, 172, pl. 17, figs. 536-538. *Sphaeroidinella rutschi* CUSHMAN and RENZ, 1941, Contr. Cushman Lab. Foram. Res., vol. 17, pt. 1, p. 25, pl. 4, fig. 5, — RENZ, 1948, Geol. Soc. Amer., Mem. 32, p. 167, pl. 10, fig. 1. *Sphaeroidinella grimsdalei* KEIJZER, 1945 (*fide* ELLIS and MESSINA, 1940 *et seq.*) *Prosphaeroidinella philippinensis* UJIIÉ (MS), 1975, Bull. Natn. Sci. Mus., ser. C, p. 85 (list). Cf. *Sphaeroidinella grimsdalei*, BOLLI (not KEIJZER, 1945), 1957, U.S. Nat. Mus. Bull., 215, p. 114, pl. 26, fig. 13.

**Remarks:** FINLAY (1940) mentioned about this species as follows: "In many respects half-way between *Globigerina* and *Sphaeroidinella*, lacking the polish, pore appearance and compactness of [*Sphaeroidinella*] *dehiscens*, but less like *Globigerina* in chamber attachment and deeply cleft sutures." These features were well re-illustrated by HORNIBROOK (1958) based upon the holotype from New Zealand Lower Miocene. Therefore, the "cortex layer" which characterizes the wall structure of *Sphaeroidinella* and *Sphaeroidinellopsis* is regarded as distinctly absent in "*S.*" *disjuncta*, indicating its critical difference from the latter two genera at generic level. On the other hand, this species has such "deeply cleft sutures" as seen typically in *Sphaeroidinella* and *Sphaeroidinellopsis*, suggesting a very close relationship. As will be shown later, the species was alive prior to and extinct just before the initial appearances of *Sphaeroidinellopsis subdehiscens subdehiscens* and of true *S. seminulina* (s.l.). In other words, *S. disjuncta* represents a seemingly ancestral taxon of *Sphaeroidinellopsis* so that a new genus *Prosphaeroidinella* was proposed primarily based on the species as its type.

Meanwhile JENKINS (1971) investigated in detail the morphology and stratigraphic range of "*Sphaeroidinella*" *disjuncta* by examining the type specimens and his own materials from New Zealand. Against FINLAY (1940) and HORNIBROOK (1958), he emphasized not so much coarsely pitted wall in the species as noticed by the both authors. At the same time, JENKINS (op. cit.) found that the largest pores are observed on the thinner-walled final chamber, that the wall of the species is thicker than in

*Globigerinoides trilobus*, and that the pores of "*S.*" *disjuncta* are cone-shaped becoming larger inwards in fractured section of wall like those of *Sphaeroidinellopsis subdehiscens*. When these data are compiled, it tells us that the originally very coarsely pitted wall of *P. disjuncta* becomes remarkably coated by the secondary outward growth of wall. As can be judged from JENKINS' (1971) illustration of his specimen, nevertheless, this secondary filling-up does not appear to produce such smoothly finished outer surface as recognized in *Sphaeroidinellopsis* or *Sphaeroidinella*.

Wall structure of *P. disjuncta* was examined on a number of specimens identified here as the species, employing the scanning electron microscope and thin-sectioning technique. The results are illustrated by examples in plates and then summarized as follows: In these specimens, secondary thickening of wall is ascribed to outward growth of calcite crystals constituting wall-lamellae, each lamella piled upon the previous one as a new chamber is added, which is the usual case of "bilamellar Foraminifera" in REISS' (1957) sense. And such crystal growth occurs extensively on the ridges of honey-comb structure of wall. As the ridges seem to be formed of a combination of rhombohedral or euhedral pyramids of calcite crystals, the outward growth of the ridges would maintain their pyramidal faces even though the original honey-comb frames may be largely masked by irregularly grown crystals at different points on ridges. Moreover, the crystal growth could result in an overhanging state so that the space of frames and even the size of pores would be reduced more effectively. At any rate, it can be expected that the secondary thickening of wall in *Prosphaeroidinella disjuncta* never forms a smooth outer surface of wall as seen in *Sphaeroidinella* or *Sphaeroidinellopsis*. The smooth surface is produced by mere secretion of the so-called cortex layer, whose formation may be carried out in an entirely different way as will be shown in Remarks on *Prosphaeroidinella parkerae*, n. sp.

Species synonymous to *P. disjuncta* may be *Sphaeroidinella rutschi* CUSHMAN and RENZ, 1941 and *S. grimsdalei* KEIJZER, 1945, both in strict sense. This opinion will be supported by their wall structure without obvious cortex layer but with rough surface throughout, and by their stratigraphic occurrence restricted in the middle to lower Miocene, although there is room for confirmation by re-examining the type specimens or topotypes. From the present viewpoints, many subsequent records of the two species, particularly from the upper Miocene and the Pliocene, become questionable and thus their taxa would be *Sphaeroidinellopsis seminulina* [= *Globigerina seminulina* SCHWAGER, 1866], to which *Globigerina kochi* CAUDRI, 1934, *Sphaeroidinella multilobata* LEROY, 1944, or often *Sphaeroidinellopsis subdehiscens* subdehiscens of authors (not BLOW, 1959) should be included as its variety or younger synonym. In the same sense, the two taxa of *Sphaeroidinellopsis* should not include *Prosphaeroidinella disjuncta*, "*Sphaeroidinella rutschi*", nor "*Sphaeroidinella grimsdalei*" as their synonyms; this might be different from current opinions of other authors (e.g., BLOW, 1969).

*Sphaeroidinella grimsdalei* reported from Trinidad by BOLLI (1957) was once redesignated by BLOW (1969) as either *Sphaeroidinellopsis seminulina seminulina* (figs. 6



and 7 in BOLLI's Pl. 26) or *S. seminulina kochi* (fig. 12). According to my observation of BOLLI's illustration, however, all the three figures indicate a wall surface different from those of "*Sphaeroidinella rutschi*" and of "*S. cf. grimsdalei*" shown in the same plate; in the latter two taxa the wall has the aspect typically seen in true *Sphaeroidinellopsis* or *Sphaeroidinella*, while BOLLI's "*S. grimsdalei*" shows somewhat rough surface of wall without any lustre resembling a filled-up honey-comb structure. Besides, it is noteworthy that this "*S. grimsdalei*" was obtained from the *Globorotalia fohsi fohsi* Zone (for figs. 8–11) or *Globorotalia mayeri* zone (for fig. 12) of BOLLI's (1957) zones, i.e., both of lower Middle Miocene below N. 12 of BLOW's (1969) zones, whereas BOLLI's "*S. rutschi*" and "*S. cf. grimsdalei*" came from the *Globorotalia menardii* Zone of the upper Middle Miocene, probably corresponding to N. 15. Thereby, BLOW's redesignation (1969) could be rejected and BOLLI's "*S. grimsdalei*" from the lower Middle Miocene of Trinidad would come to represent *Prosphaeroidinella disjuncta*.

**Stratigraphic Range:** As far as the materials from DSDP Sites 292 and 296 are concerned, the latest occurrence of *P. disjuncta* is within the uppermost part of N. 12 of BLOW's (1969) planktonic foraminiferal zones, very probably beneath the top of N. 12. On the top, *Sphaeroidinellopsis subdehiscens subdehiscens* appears first and then thrives thereafter, suggesting that the species is a direct descendant of *P. disjuncta*.

Identical or quite similar stratigraphic occurrences of *P. disjuncta* or its equivalents and *Sphaeroidinellopsis* species will be expected as a world-wide event, if the comments shown in Remarks are recollected.

TODD (1964) pointed out, though rather vaguely, that her "*Sphaeroidinella disjuncta*" may be a useful Miocene indicator. Unfortunately, however, her own specimens from deep-sea cores off Eniwetok Atoll seem to be not *Prosphaeroidinella disjuncta* but *P. parkerae*, n. sp. which is a geologically younger component of the genus. In addition, almost all the cases referred by her as "*Sphaeroidinella*" *disjuncta* in the same paper appear to be not true *disjuncta* as will be discussed further in Remarks on *P. parkerae*, n. sp.

Contrary to the rather definite upper limit of the occurrence of *P. disjuncta*, the lower limit is not yet fixed at present. At least in N. 7 at Site 296, rather typical specimens were encountered. If it is accepted that the part of range below the base of N. 13 shown by BLOW (1969) for his *Sphaeroidinellopsis seminulina seminulina* is the entire range of *P. disjuncta*, then the initial appearance must be expected within the lower part of N. 6.

In a synthetic work on New Zealand Cenozoic planktonic Foraminifera, JENKINS (1971) showed the stratigraphic range of *Prosphaeroidinella disjuncta* which appeared first near the base of the Altonian and disappeared within the Lillburian, to be replaced by the appearance of his *Sphaeroidinella cf. grimsdalei*. According to BERGGREN and AMDURER (1973), the Altonian seems to be correlated with N. 6 to N. 7 of BLOW's (1969) zones, and the Lillburian with N. 9 to N. 13. Although the extinction datum of *P. disjuncta* in New Zealand is not definite, JENKINS' *S. cf. grimsdalei* seems to have appeared first at the top of his *Orbulina suturalis* zone, correlatable with the N. 12

and N. 13 boundary. And the present *S. cf. grimsdalei* can be regarded as some primitive *Sphaeroidinellopsis subdehiscens subdehiscens*, at least judging from his description and illustration. Such "small spines" on "slightly pointed terminal end of the final chamber" as emphasized by JENKINS (op. cit.) for his *S. cf. grimsdalei* are not of taxonomically valuable character, being merely ornamentation of inner layer (Layer 2) which is still uncovered by outer "cortex" layer (Layer 3). The true figure will be revealed in scanning electron micrographs (Pl. 6, figs. 1,2; Pl. 12, fig. 4b) and in a thin section (Pl. 12, fig. 4a) of similar examples from N. 13 at DSDP Site 296. From the same viewpoint, any taxonomic validity can not be considered about *Sphaeroidinella spinulosa* SUBBOTINA, 1958 (in BYKOVA et al., 1958) from the pre-Carpathian Miocene or about *Sphaeroidinellopsis grimsdalei* forma *reticulata* of REISS and GVIRTZMAN (1966) from the Israeli Middle Miocene. Both the two "taxa" were once referred to "*Sphaeroidinella cf. grimsdalei*" by JENKINS (1971).

Summarizing the foregoing discussion I would like to suggest the range of *Prosphaeroidinella disjuncta* from N. 6 to the top of N. 12. And at the boundary between N. 12 and N. 13 within Middle Miocene, we can expect, as an important and probably world-wide event, the extinction datum of the species to be followed immediately by the initial appearance of true *Sphaeroidinellopsis*.

***Prosphaeroidinella parkerae*, n. gen. et n. sp.**

(Pl. 3, fig. 4; pl. 4, figs. 1, 2, 4; pl. 5, figs. 1-4; pl. 12, fig. 5; pl. 13, fig. 1)

*Sphaeroidinella disjuncta*, TODD (not FINLAY, 1940), 1964, U.S. Geol. Surv., Prof. Paper 260-CC, p. 1089, pl. 290, figs. 2, 4.

*Sphaeroidinella seminulina*, PARKER (not SCHWAGER, 1866), 1967, Bull. Amer. Paleont., vol. 52, no. 235, pp. 161-162, pl. 23, figs. 3, 5 (not 1, 2, 4), — KENNETT & VELLA, (not SCHWAGER, 1866), 1975, Init. Rep. D.S.D.P., vol. 29, p. 772, pl. 8, fig. 7.

**Description:** Test free, low trochospiral; periphery equatorially lobulate to a considerable extent, transversely rounded; wall calcareous, thick, coarsely perforate with very coarsely and regularly pitted honey-comb structure, each frame of which measures 0.03 mm in diameter even for the latest chambers of juvenile specimens; chambers globular, 2 per whorl in young to 5 in full grown adult, increasing in size rather rapidly at three-chambered stage but slowly afterward so that the final chamber becomes often smaller than the penultimate one; sutures on umbilical side radial, deeply cut; sutures on spiral side radial to slightly curved, depressed or, in some places of final whorl, deeply cut in connection with fissured spiral suture, but never opened to leave supplementary aperture; umbilicus narrowly but deeply opened at a junction of deeply cleft sutures; aperture interiomarginal, umbilical, sometimes with small lip in adult. Diameter, up to 0.7 mm; thickness, up to 0.4 mm.

**Holotype:** Pl. 4, fig. 1; **Paratypes:** Pl. 4, fig. 4; pl. 3, fig. 4; pl. 5, fig. 3; pl. 13, fig. 1.

**Remarks:** This new species differs from the type species of *Prosphaeroidinella*, in

showing less degree of masking the honey-comb wall structure at the earlier stage by secondary thickening of wall and in suggesting certainly different genetical origin. While *P. disjuncta* represents very probably a direct ancestor of *Sphaeroidinellopsis* as mentioned already, *P. parkerae*, n. sp. has its occurrence range considerably concurrent with those of *Sphaeroidinellopsis* and *Sphaeroidinella*. Aside from the morphologic affinity, the two species are considered congeneric for the reason that *P. parkerae*, n. sp. is inferred to represent an atavism of *Sphaeroidinellopsis*.

Before extending the above inference, we must review first such a peculiar wall structure of *Sphaeroidinella* as mentioned by RHUMBLER (1911) in the early days of foraminiferal investigation. After RHUMBLER noticed the flask-shaped pores piercing through the thick wall of *Sphaeroidinella dehiscens*, many authors (e.g., BÉ, 1965; BÉ and VAN DONK, 1971; HOFKER, 1972) have illustrated the same features in thin sections but without paying any special attention. Giving critical significance to the wall structure in the taxonomy of *Sphaeroidinella* and *Sphaeroidinellopsis*, BANNER and BLOW (1959) and BLOW (1969) nevertheless misjudged the structure as being composed of homogeneously thickened main layer which is rather superficially coated with thin veneer of "cortex layer". Such a veneer of "cortex" could never mask completely the very coarsely pitted surface of underlying layer and its formation should be found only at the final stage of ontogenetic growth of shells, conflicting with the fact that even very young specimens are already provided with smoothly finished surface of shells.

On the other hand, HOFKER (1972) distinguished correctly three layered structure in wall of *Sphaeroidinella* and *Sphaeroidinellopsis*; namely, thin basal layer (his "lamella 1") probably originated from embryonic apparatus, coarsely pitted middle layer ("lamella 2"), and outer layer with smooth surface ("lamella 3"). But I prefer to use the terms Layers 1, 2, and 3 for these lamellae, since a lamella in bilamellar Foraminifera means a sheet of shell substance piling upon the previous wall surface as a new chamber is added. Whereas the nature and genesis of Layers 1 and 2 are almost the same as in *Globigerinoides* except for distinctly coarser honey-comb structure in the former, Layer 3 is quite unique in *Sphaeroidinella* and *Sphaeroidinellopsis*; that is, a real cortex layer. As could be inferred from many thin sections (for examples, Pl. 13, figs. 2 and 3; pl. 14, figs. 1 and 2 of this paper; BÉ and VAN DONK, 1971; BÉ, 1965) and particularly from some electron micrographs of mechanically dissected specimens (Pl. 7, figs. 2 and 3; pl. 8, figs. 1 and 2; pl. 10, figs. 1 to 3), crystal growth of calcites constituting Layer 3 would commence from ridges of honey-comb structure of Layer 2 and progress always in directing its rhombohedral or euhedral pyramid inward and its flat basal plane outward as a new chamber is added. Therefore, the outer surface of Layer 3 would be paved with flat basal planes of calcite crystals. Mosaic pattern on the surface closely resembles that on the inner surface of wall, where pavement with basal planes of calcite crystals must be expected as to constitute the base of Layer 1 (compare pl. 8, fig. 4 with pl. 9, fig. 4 as an example). All crystals composing Layer 2 may also grow up from their flat basal planes, whose mosaic aggregation may be also analogous to that on the inner surface of Layer 1, in developing their rhombohedral

to euhedral pyramid planes outwards. If such a contrasting mode of crystal growth between Layers 2 and 3 were just as interpreted here, it would be a logical consequence that the pores sealed by the two layers become flask-shaped. Moreover, the growth mode of Layer 3 (real "cortex layer") should inevitably result in diminution of pore-diameter (Fig. 1).

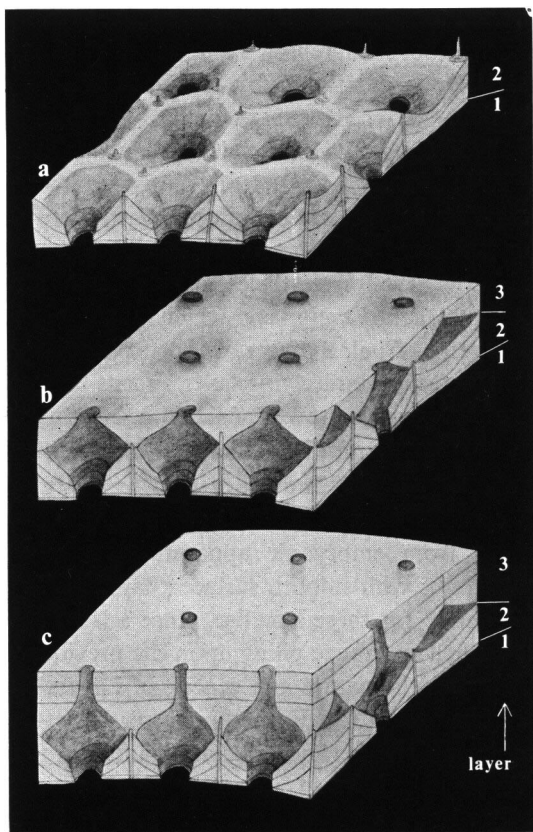


Fig. 1. Schematic diagrams showing the development of wall structure in *Sphaeroidinella*  
a: *Prosphaeroidinella* stage; b: primitive *Sphaeroidinellopsis* stage; c: advanced *Sphaeroidinellopsis* and *Sphaeroidinella* stage.

Since the boundary between Layers 2 and 3 is a junction of outwardly and inwardly pointed pyramids of crystals, the boundary is most susceptible to chemical dissolution and mechanical damage. For instances, Pl. 8, figs. 1 and 2 suggest such a selective dissolution around the boundary, while Pl. 8, fig. 3 and Pl. 7, figs. 2 and 3 show that Layer 2 was peeled off, because of mechanical action that took place at the boundary, probably caused by the ultrasonic vibrator in the course of maceration of sediment samples containing specimens. It is especially noteworthy that the honey-

comb structure of Layer 2 exposed in such a way is very coarsely pitted just like in *Prosphaeroidinella parkerae*, n. sp.

Previously PARKER (1967) found this similarity and then she concluded that the specimens shown in her Pl. 23, figs. 3 and 5 under the name of *Sphaeroidinella seminulina* represent merely peeled-out specimens of the species, probably due to selective dissolution worked on the outer cortex layer; she thought the cortex layer to be most susceptible. Contrary to her presumption, however, *Sphaeroidinella dehiscens* with typical cortex layer is one of the most resistant taxa against the chemical dissolution among 15 to 22 species of Recent planktonic Foraminifera according to BERGER's (1968, 1970) experiment and observation. Besides, every *Globigerinoides* species with coarsely pitted wall is most susceptible to the dissolution so that Layer 2 of *Sphaeroidinella* or *Sphaeroidinellopsis* with much coarser pits must be dissolved much easier than Layer 3.

Instead of chemical reaction, some mechanical exfoliation might be expected for these cases. But it may be impossible that such a process peels away Layer 3 over its whole surface of a specimen. In addition to this logic, I have found a number of specimens including juveniles from various places in the western North Pacific region; i.e., from a piston core in the Philippine Sea (UJIIÉ and MIURA, 1971), from Miyakojima of the Ryukyu Islands (UJIIÉ and OKI, 1974), from the Sagara Group in central Japan (UJIIÉ and HARIU, 1975), under the name of "Naked *Sphaeroidinella* or *Sphaeroidinellopsis*" species, and from DSDP Sites 292 and 296 (UJIIÉ, 1975a). The universality of occurrence may deny that *P. parkerae*, n. sp. resulted from *Sphaeroidinella* or *Sphaeroidinellopsis* through some accidental peeling of its Layer 3.

From the comparative analysis of wall structures shown heretofore, I would like to conclude that *P. parkerae*, n. sp. is independent from any species belonging to *Sphaeroidinellopsis* or *Sphaeroidinella*, probably having undergone atavism, particularly of *Sphaeroidinellopsis seminulina* (s.l.). In other words, the new species failed to develop Layer 3 (cortex layer). In the respect of evolutionary trend, *P. parkerae*, n. sp. must belong to *Prosphaeroidinella*.

Although TODD (1964) mentioned first the presence of the species, she unfortunately regarded it as *Sphaeroidinella disjuncta* FINLAY, 1940. Her illustrated specimens from deep-sea cores off Eniwetok Atoll are completely conspecific to the new species. TODD (op. cit.) also referred several specimens of other authors to her "*S. disjuncta*"; they are *S. disjuncta* from New Zealand (FINLAY, 1940; HORNIBROOK, 1958) and from some North Atlantic deep-sea cores (PHLEGER et al., 1953), *Sphaeroidinella rutschi* from the Donni Formation of Saipan (TODD, 1957), *Globigerina* sp. B from Eniwetok Atoll (TODD and LOW, 1960), and *Sphaeroidinella multilobata* from Sylvania Guyot (HAMILTON and REX, 1959). Excluding the New Zealand specimens from consideration these referred taxa may be not *disjuncta* but *parkerae*, according to their morphology illustrated in plates and their stratigraphic occurrence distinctly younger than that of *disjuncta*. Different from TODD's (1964) opinion, I estimate the age as Pliocene rather than Miocene for the North Atlantic specimens from Core 234 since they are associated

with *Sphaeroidinella dehiscens*, *Globorotalia* (s.s.) *multicamerata*, *Candeina nitida*, etc., for the specimens from the Donni Formation of Saipan which was lately assigned to N. 19 to N. 17 by BLOW (1959), and also for the Sylvania Guyot samples mixed with *Globigerinoides fistulosus*.

As well as considered by many authors (e.g., TODD, 1964; PARKER, 1967; JENKINS, 1971), I am inclined to doubt the validity of *Sphaeroidinellopsis* as a genus independent from *Sphaeroidinella*, because juvenile or young specimen of *Sphaeroidina dehiscens* PARKER and JONES, 1865 (type species of *Sphaeroidinella*) is often devoid of supplementary apertures on spiral side just like *Sphaeroidinellopsis subdehiscens* (s.s.), type species of the genus. The other morphologic characters than the supplementary aperture are essentially the same between the two type species. Nevertheless, *Sphaeroidinellopsis subdehiscens* (s.s.) has not been associated with any typical *Sphaeroidinella* as pointed out by BLOW (1969), for a considerably long period prior to the appearance of the latter genus; in other words, during the period from the beginning of N. 13 to the end of N. 18. In order to emphasize this biostratigraphic significance, therefore, the genus *Sphaeroidinellopsis* might be used for convenience sake, although the biological meaning of such taxonomic procedure may be open to discussion.

*Prosphaeroidinella parkerae*, n. sp. has been recognized generally in part lower than N. 21 of Upper Pliocene, where *Sphaeroidinellopsis seminulina* (s.l.) almost disappears together with *P. parkerae*, n. sp., so that this new species might reflect a kind of atavism of *S. seminulina* (s.l.), for the additional reason that the two species resemble each other in the general morphology (e.g., number of chambers per whorl, shell-outline, etc.). Although UJIIÉ and OKI (1974) once noticed the scarce but continuous occurrence of *P. parkerae*, n. sp. up to the lowermost Pleistocene (lower N. 22 of BLOW's zones) in Miyako-jima, Ryukyu Islands, by the name of "Naked *Sphaeroidinellopsis*" species, there was also an exceptional? occurrence of *S. seminulina* (s.l.) extending up to lower N. 22 (see Pl. 1, fig. 12, of UJIIÉ and OKI, op. cit.).

Since 1965, BÉ has contended that *Sphaeroidinella dehiscens* may be merely a phenotypic variation of *Globigerinoides sacculifer* which reflects some adaptation to changing water depth of habitat in the course of individual growth. BÉ and his collaborators (BÉ, 1965; BÉ and HEMLEBEN, 1970; BÉ and VAN DONK, 1971) presumed that the outer "cortex" layer (Layer 3 of this paper) of wall characteristic in *Sphaeroidinella* may be a result of incrustation over *Globigerinoides*-type shells as their habitat become deeper with the ontogenetic growth of shell as observed well in many other planktonic foraminiferal taxa.

However, such incrustation never produces the peculiar wall structure of Layer 3 in *Sphaeroidinella*, but would cause disorderly thickening of wall as exemplified by ORR (1969) with *Globigerinoides ruber*. As evidence in favor of their argument, BÉ and HEMLEBEN (1970) showed many beautiful scanning electron micrographs of "specimens which they considered as showing gradational change from *Globigerinoides sacculifer* to *Sphaeroidinella dehiscens*". Despite of their words, their "intermediate or transitional specimens" illustrated in Plates 27 and 32 seem to be only the heavily

encrusted *G. sacculifer*. Between these and the specimens at their "medium and late *dehiscens* stages", which are real *S. dehiscens*, there ought to be a clear break if we notice the smoothly finished surface at the interpore space in the latter specimens (particularly see, Pl. 28, figs. 2 and 3; pl. 29, fig. 2; pl. 30, figs. 2, 4 and 5); these smooth faces are never seen in Plates 27 and 32.

Secondly, Layer 3 of *Sphaeroidinella* is developed enough in specimens smaller than ordinary sized individuals of *Globigerinoides*. This fact evidently conflicts with the opinion of BÉ and his collaborators who regarded "*Sphaeroidinella*-stage" as to be added to "*Globigerinoides*-stage" in the course of ontogenesis. And it seems that Layer 3 in *Sphaeroidinellopsis* and particularly *Sphaeroidinella* increases its thickness by piling one lamella upon another as a new chamber is added (see Plates 13 and 14, respectively), while Layer 2 seemingly ceases its thickening at a much earlier stage.

Thirdly, any sutural supplementary opening has not been found on the reticulate surface of Layer 2 in *Sphaeroidinella*, unlike the test surface of *Globigerinoides* but like that of *Prosphaeroidinella*. Moreover, the mesh-size of the reticulate wall is distinctly coarser (usually about twice) than that in *Globigerinoides sacculifer*.

Finally, as suggested or pointed out by the other authors somewhere else, BÉ's argument should have taken more account of biostratigraphic ranges of *Sphaeroidinella* species and related taxa, although he is a most distinguished researcher of living or Recent planktonic Foraminifera. Prior to the appearance of *Sphaeroidinella* and *Sphaeroidinellopsis*, a number of *Globigerinoides* species alone lived for a long period of geologic time without producing "*Sphaeroidinella* stage", even though some of the species might have had potential to do so, like "Recent *G. sacculifer*".

**Stratigraphic Range:** So far as my own experiences are concerned, the earliest occurrence of *Prosphaeroidinella parkerae*, n. sp. is in the lower part of N. 15 of BLOW's (1969) zones, i.e., upper Middle Miocene, in the Sagara Group on the Pacific coast of central Japan (UJIIÉ and HARIU, 1975), and the latest occurrence is in the lowermost part of N. 22, lowermost Pleistocene, in the Shimajiri Group of Miyako-jima, Ryukyu Islands (UJIIÉ and OKI, 1974). However, the upper and lower limits need to be defined more precisely by further study.

At any rate, very popular occurrence of the species has been recognized in N. 19, according to my experiences and bibliographic research.

The name of this new species is dedicated to Frances L. PARKER of the Scripps Institution of Oceanography, who found first the peculiar morphology of the species in relation to *Sphaeroidinellopsis seminulina* (s.l.), even if her interpretation of the origin and taxonomic significance differs from mine.

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### Explanation of Plates

(In all figures, a: spiral view; b: umbilical view, c: edge view, otherwise noted)

#### Plate 1

Figs. 1–3. *Prosphaeroidinella disjuncta* (FINLAY)

- 1: Adult; Micropaleontology Collection of National Science Museum 1052; from DSDP Site 296, core 29, sect. 6 (N. 8), Philippine Sea;  $\times 100$ .
- 2: Young specimen; Micropal. Coll. N.S.M. 1070; from DSDP Site 292, core 11, sect. 5 (N. 12), Philippine Sea; a:  $\times 150$ , b, c:  $\times 100$ .
- 3: Somewhat deformed specimen; Micropal. Coll. N.S.M. 1056; from Megami, Sagaramachi, Shizuoka Prefecture, Megami Formation (N. 8); see UJIIÉ (1975 b) for the geological meaning of the species in the area; spiral view;  $\times 100$ .

#### Plate 2

Figs. 1–3. *Prosphaeroidinella disjuncta* (FINLAY)

- 1: Enlargement of the earlier part of Pl. 1, fig. 2a showing irregularly and highly relieved surface where original structure of honey-comb pattern and pore still remain;  $\times 1000$ .
- 2: Young specimen, Micropal. Coll. N.S.M. 1054; from Site 296, core 28, sect. 3 (N. 9);  $\times 150$ .
- 3: Enlargement of the earlier portion of fig. 2a showing euhedral pyramid planes of calcites still with some original framework of honey-comb structure and pore on surface;  $\times 1000$ .

#### Plate 3

Figs. 1–3. *Prosphaeroidinella disjuncta* (FINLAY)

- 1: Adult, Micropal. Coll. N.S.M. 1064; from Site 296, core 30 cc (N. 7); b: edge view;  $\times 100$ .
- 2: Enlargement of final chamber, part of fig. 1a, showing coarsely pitted honey-comb structure;  $\times 1000$ .
- 3: Enlargement of earlier portion of fig. 1b, showing remarkably thickened wall still retained original pattern of wall surface;  $\times 300$ .

Fig. 4. *Prosphaeroidinella parkerae*, n. sp.

Juvenile with bulla, already provided with very coarsely pitted honey-comb structure; Micropal. Coll. N.S.M. 1059; from 390 cm below the top of a piston core (V21–98) in the Philippine Sea (N. 19);  $\times 100$ .

**Plate 4**

Figs. 1, 2, 4. *Prosphaeroidinella parkerae*, n. sp.

- 1: Adult with four and a half chambers in last whorl; Micropal. Coll. N.S.M. 1057; from 390 cm below the top of core V21-98 (N. 19);  $\times 100$ .
- 2: Enlargement of area around the junction between final chamber and previous whorl of fig. 1a, showing deeply cleft sutures;  $\times 300$ .
- 4: Three-chambered young form, Micropal. Coll. N.S.M. 1058; from the same location as fig. 1;  $\times 100$ .

Fig. 3. *Globigerinoides quadrilobatus immaturus* LeROY

For comparison with *P. parkerae*, n. sp. from the same location as figs. 1 and 4; Micropal. Coll. N.S.M. 1081; spiral view;  $\times 150$ .

**Plate 5**

Figs. 1-4. *Prosphaeroidinella parkerae*, n. sp.

- 1: Enlargement of final chamber in Pl. 4, fig. 1a, showing details of honey-comb structure of wall and deeply cut sutures;  $\times 300$ .
- 2: Enlargement of fig. 1, showing particularly ridges of honey-comb structure susceptible to dissolution, agreeably to the results of dissolution experiment by HECHT et al. (1975);  $\times 1000$ .
- 3: Edge view of four-chambered adult, whose penultimate chamber was dissected, showing particularly nature of wall structure on the fractured face; Micropal. Coll. N.S.M. 1060; from the same location as fig. 1;  $\times 100$ .
- 4: Enlargement of fractured wall section in fig. 3, showing thick wall pierced with very coarse pits and pores;  $\times 300$ .

**Plate 6**

Figs. 1-4. *Sphaeroidinellopsis subdehiscens subdehiscens* BLOW

- 1: Earliest representative of the subspecies from N. 13 in Site 296, core 26 cc; spiral view;  $\times 150$ .
- 2: Enlargement of final chamber in fig. 1, showing particularly its "pitted distal end" which was not yet covered with Layer 3 (cortex layer) according to my opinion against JENKINS (1971);  $\times 1000$ .
- 3: Enlargement of test surface normal in the species, showing pores surrounded with pavement of flat basal planes of calcite crystals; it is noteworthy that slight elevations are observed closely around pores as shown better in fig. 2. Such phenomenon can not be expected in "buried honey-comb wall structure" of *Prosphaeroidinella parkerae*, n. sp. nor *P. disjuncta*;  $\times 1000$ .
- 4: Details of wall surface with mosaic pattern in Pl. 7, fig. 1;  $\times 1000$ .

## Plate 7

Figs. 1–4. *Sphaeroidinellopsis subdehiscens subdehiscens* BLOW

- 1: Micropal. Coll. N.S.M. 1076; from Site 296, core 26 cc (N. 13);  $\times 100$ .
- 2: Adult, its final chamber wall peeled off, exposing very coarsely pitted outer surface of Layer 2; Micropal. Coll. N.S.M. 1061; from Site 296, core 21 cc (N. 16);  $\times 150$ .
- 3: Enlargement of peeled portion of fig. 2, showing honey-comb structure of Layer 2 very similar to that of *Prosphaeroidinella parkerae*, n. sp. in shape and size and, also showing the general relationship between Layers 2 and 3;  $\times 300$ .
- 4: Showing particularly low cone-shaped structure of Layer 3; the cones disposed reverse to the outward sharpened edges of honey-comb structure of Layer 2;  $\times 1000$ .

## Plate 8

Figs. 1, 2. *Sphaeroidinellopsis subdehiscens subdehiscens* BLOW

- 1: Part of dissected specimen probably affected by selective dissolution; Micropal. Coll. N.S.M. 1062; from Site 296, core 21 cc (N. 16);  $\times 300$ .
- 2: Enlargement of fractured section of wall in fig. 1, showing effect of probable dissolution which seems to have been most active around the Layers 2 and 3 boundary;  $\times 1000$ .

Figs. 3, 4. *Sphaeroidinellopsis seminulina* (SCHWAGER) (s.l.)

- 3: Adult specimen peeled away partly and exposing honey-comb structure of Layer 2; umbilical view;  $\times 150$ .
- 4: Enlargement of part of Pl. 9, fig. 1a, showing mosaic pattern on surface;  $\times 1000$ .

## Plate 9

Figs. 1–4. *Sphaeroidinellopsis seminulina* (SCHWAGER) (s.l.)

- 1: Typical specimen; Micropal. Coll. N.S.M. 1077; from Site 296, core 21 cc (N. 16);  $\times 100$ .
- 2: Adult rather resembling “*S. seminulina kochi* (CAUDRI)”; Micropal. Coll. N.S.M. 1078; from Site 296, core 21 cc (N. 16);  $\times 150$ .
- 3: Enlargement of distal portion of fig. 2, showing pattern of wall surface and, particularly, slightly spinose distal end of final chamber;  $\times 450$ .
- 4: Very highly magnified micrograph of inner surface of wall; enlargement of the part in fig. 3;  $\times 4500$ .

## Plate 10

Figs. 1–3. *Sphaeroidinella dehiscens dehiscens* (PARKER & JONES)

- 1: Half cut specimen with very thick wall; Micropal. Coll. N.S.M. 1063; from 390 cm below the top of core V21–98 (N. 19);  $\times 150$ .

- 2: Enlargement of fractured section of wall, showing its three-layered structure together with flask-shaped pores; part of fig. 1;  $\times 300$ .
- 3: Enlargement of fig. 2, showing the contact area between Layers 2 and 3 which is seemingly fragile junction;  $\times 1000$ .

Fig. 4. *Prosphaeroidinella disjuncta* (FINLAY)

Micropal. Coll. N.S.M. 1065; from Site 296, core 29, sect. 6 (N. 8); spiral view;  $\times 150$ .

#### Plate 11

Figs. 1–3. *Prosphaeroidinella disjuncta* (FINLAY)

- 1: Vertical section of Pl. 10, fig. 4: a: a whole view,  $\times 200$ ; b, c: details of wall structure at final chamber and earlier chamber, respectively, both  $\times 400$ . Outer layer in seemingly three-layered structure as seen in fig. 1c has no affinity to that of *Sphaeroidinella* or *Sphaeroidinellopsis* but reminds us of a kind of incrustation.
- 2: Another vertical section of fig. 3, which shows the same pattern as fig. 1; Micropal. Coll. N.S.M. 1066; from Site 296, core 29, sect. 6 (N. 8);  $2 \times 200$ ; 3: spiral view,  $\times 150$ .

#### Plate 12

Figs. 1–3. *Prosphaeroidinella disjuncta* (FINLAY)

- 1: Rather heavily “encrusted” specimen despite of its small sized test; Micropal. Coll. N.S.M. 1067; from Site 296, core 29, sect. 2 (N. 8): a: equatorial section showing very thick wall without “cortex layer” but with very thin basal layer (Layer 1); intercameral septa are composed of Layer 1 only as pointed out by HOFKER (1972) in *Sphaeroidinella*; b: spiral view; both  $\times 200$ .
- 2: Specimen with thickened wall same as in fig. 1, but with similarity to *Sphaeroidinellopsis seminulina* in chamber arrangement; Micropal. Coll. N.S.M. 1056; from Site 292, core 11, sect. 5 (N. 12); a: equatorial section showing the same structure as seen in fig. 1, where no cortex layer exists;  $\times 200$ ; b: spiral view,  $\times 100$ .
- 3: Equatorial section of Pl. 3, fig. 1a, showing distinctly increased wall-thickness as chamber being added, although the wall structure maintains its general aspect;  $\times 200$ .

Fig. 4. *Sphaeroidinellopsis subdehiscens subdehiscens* BLOW

Young and geologically earliest specimen; Micropal. Coll. N.S.M. 1075; from Site 296, core 27 cc (N. 13); a: equatorial section showing thick evenly wall in comparison with test-size, where differentiation of wall structure is not so remarkable as observed in more advanced specimen; see also spinose distal end of final chamber;  $\times 200$ ; b: dorsal view,  $\times 100$ .

Fig. 5. *Prosphaeroidinella parkerae*, n. sp.

Micropal. Coll. N.S.M. 1071; from 390 cm below the top of core V21–98 (N. 19); spiral view;  $\times 150$ .

## Plate 13

Fig. 1. *Prosphaeroidinella parkerae*, n. sp.

Equatorial section of Pl. 12, fig. 5, showing very rough crenulate ridges throughout;  $\times 200$ .

Figs. 2, 3. *Sphaeroidinellopsis seminulina* (SCHWAGER) (s.l.)

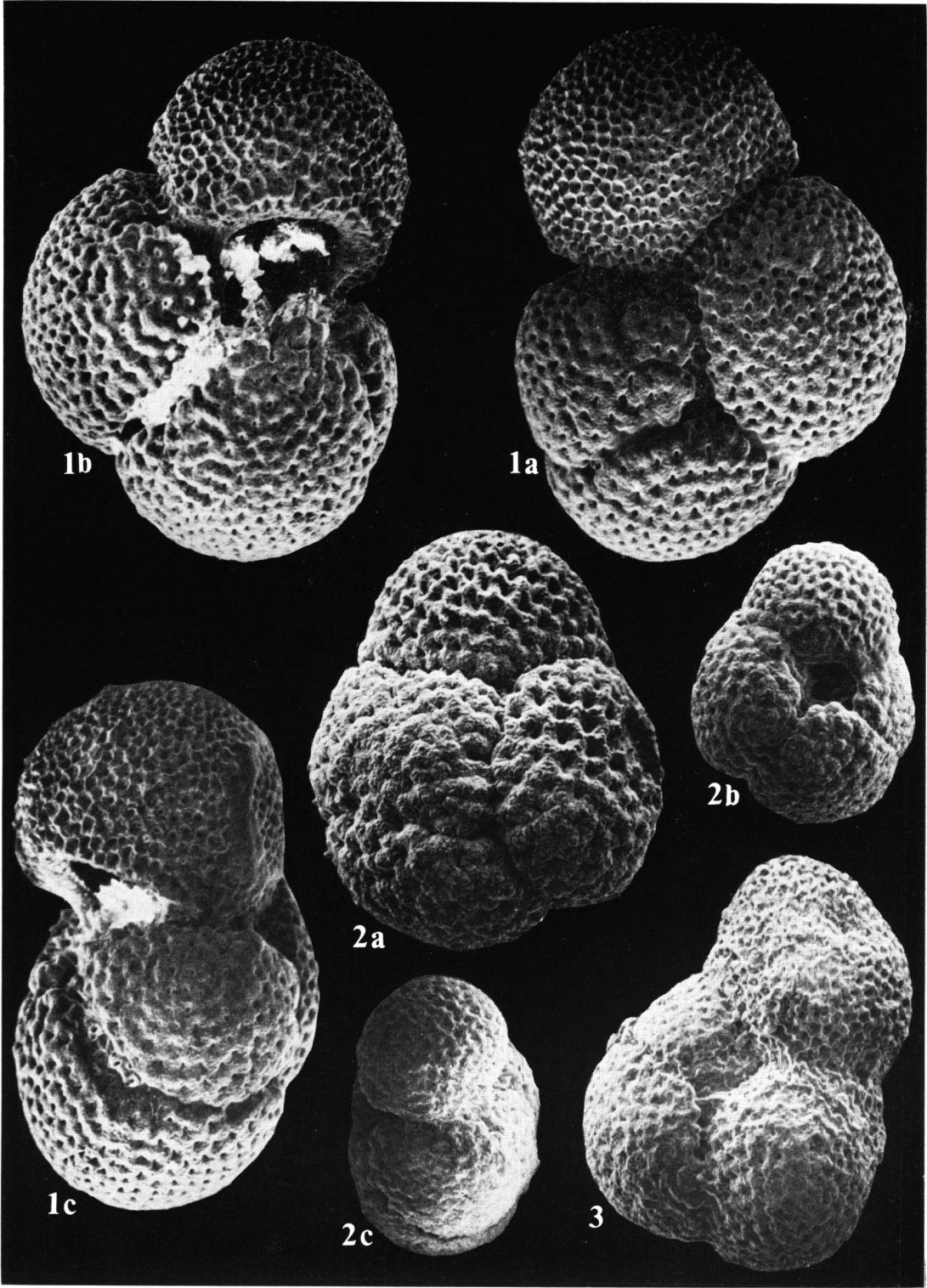
- 2: Equatorial section of Pl. 9, fig. 1, showing particularly gradational thickening of Layer 3 (cortex layer) from earlier chambers to normal final one; see also wall of a bulla-like chamber being composed of a thin homogeneous layer;  $\times 150$ .
- 3: Parts of equatorial section of Pl. 9, fig. 2;  $\times 250$ ; a: showing particularly relationship between wall-structures of normal last chamber and bulla-like chamber, external aspect of which is the same as those of normal chambers as seen in Pl. 9, fig. 3, probably because the wall of this additional chamber seems to be composed of Layer 3 which continues from normal last chamber; b: showing typical three-layered wall in earlier chambers.

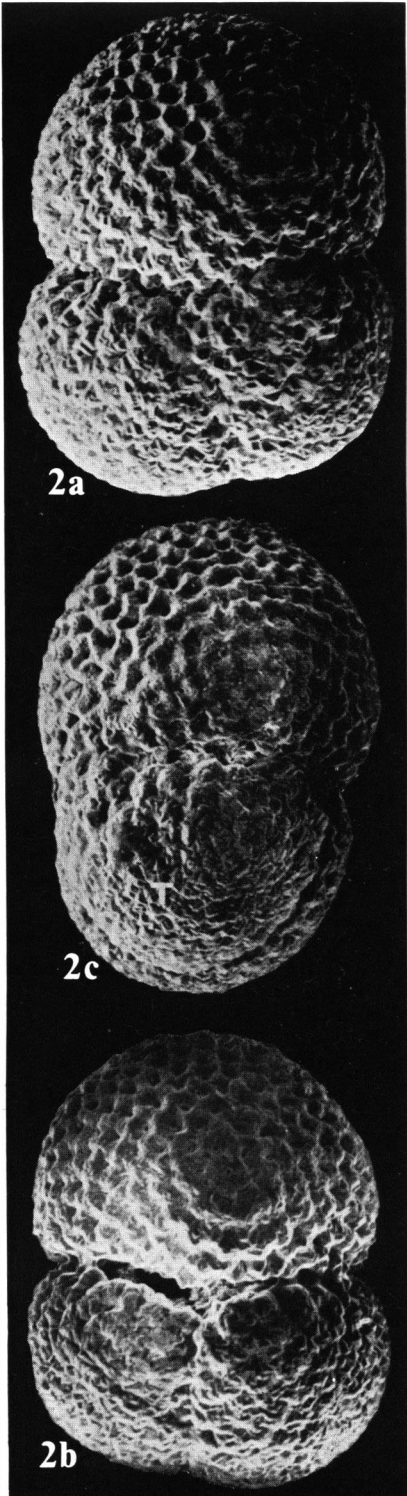
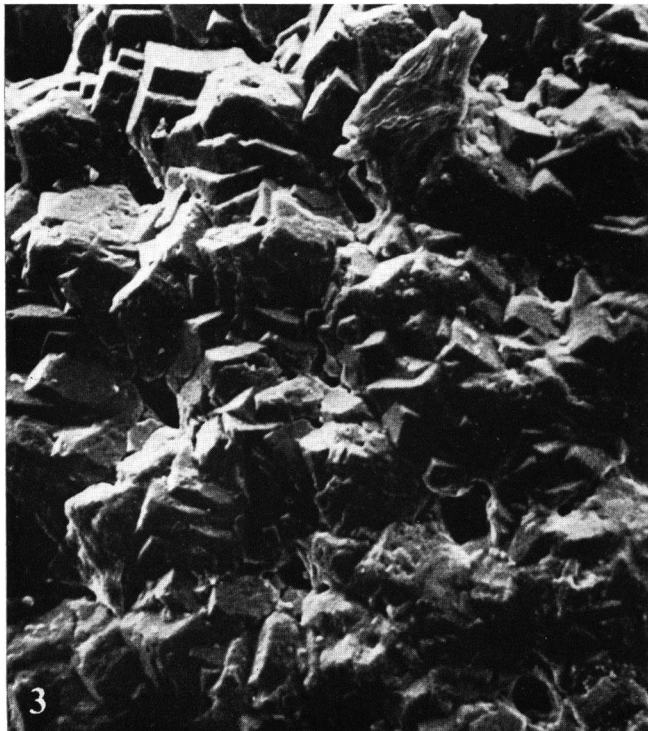
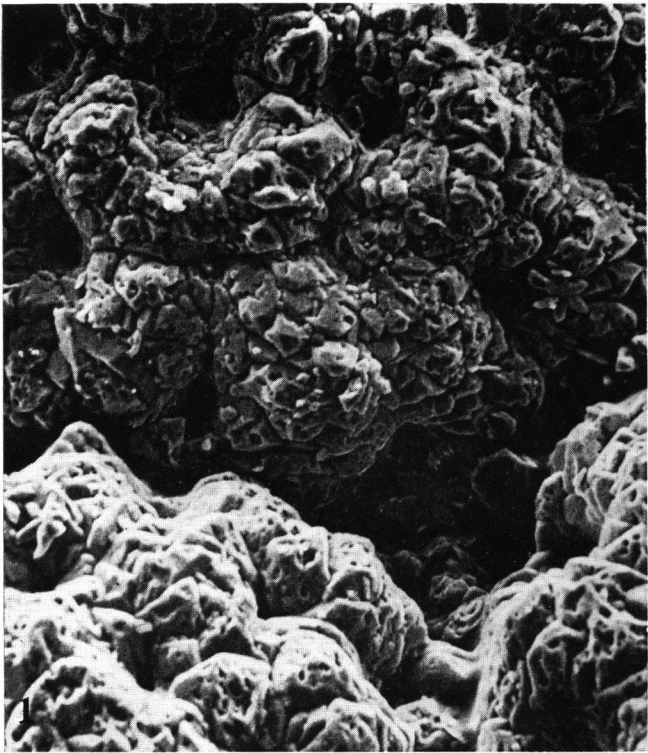
## Plate 14

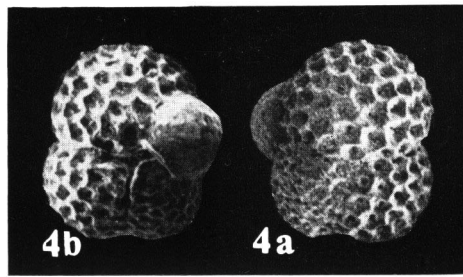
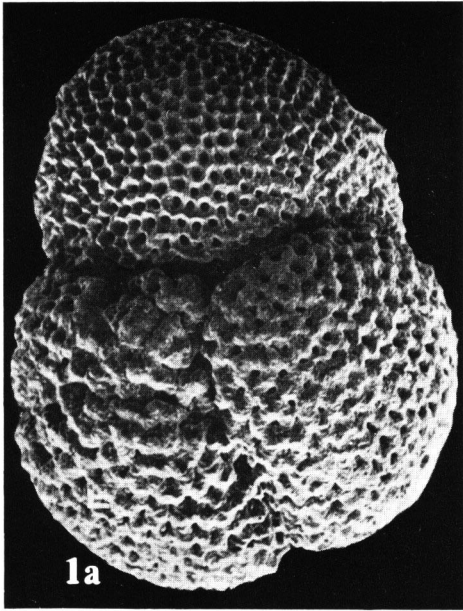
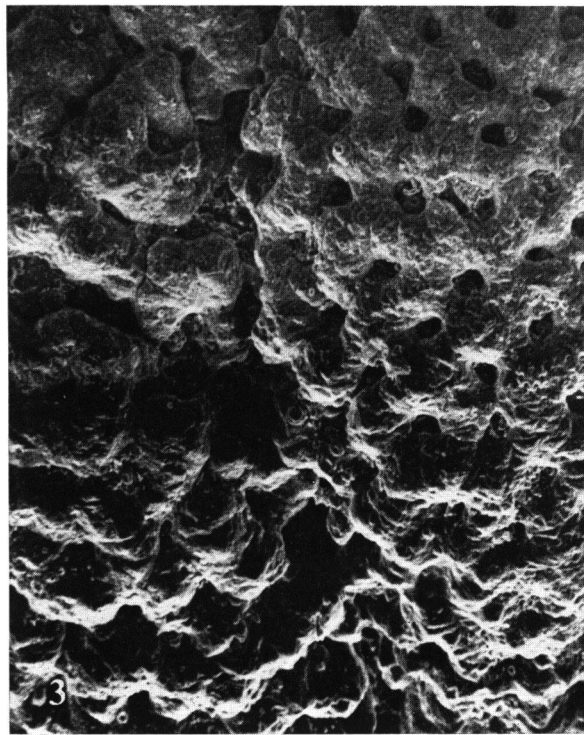
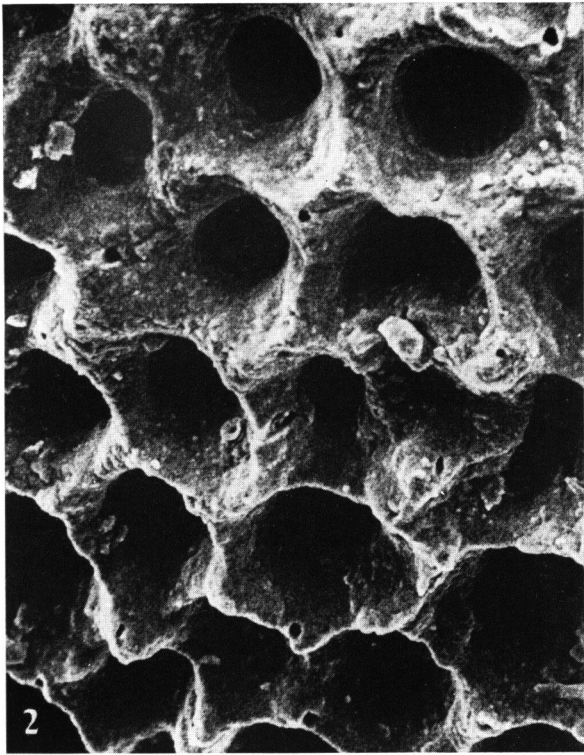
Figs. 1, 2. *Sphaeroidinella dehiscens dehiscens* (PARKER and JONES)

- 1: Parts of equatorial section; Micropal. Coll. N.S.M. 1079; from 390 cm below the top of core V21-98;  $\times 250$ ; a: showing particularly final chamber with very thick cortex layer (Layer 3); b: showing two-layered structures in spirothecal wall of earlier chambers enclosed inside the test, where Layer 3 is absent probably due to secondary and biological absorption; c: showing typically three-layered wall in earlier chambers of last whorl and also apertural flange composed of Layer 3 alone as seen well in fig. 1b.
- 2: Parts of an equatorial section; Micropal. Coll. N.S.M. 1080; from the same location as fig. 1; a: showing relationship in wall structure from the penultimate chamber with thick Layer 3 to the final one with thin Layer 3, and relationship between the two and a portion of penultimate chamber wall enclosed inside the test where Layer 3 was secondarily dissolved;  $\times 250$ ; b: enlargement of the upper corner of fig. 2a, showing a horizontal section through the honey-comb structure of Layer 2 of an inside chamber, where some selective dissolution appears to have worked at ridges as etched spots are left there besides tracks of spine bases; similar phenomenon can be recognized in Pl. 5, figs. 1 and 2 for *Prosphaeroidinella parkerae*, n. sp.;  $\times 400$ .

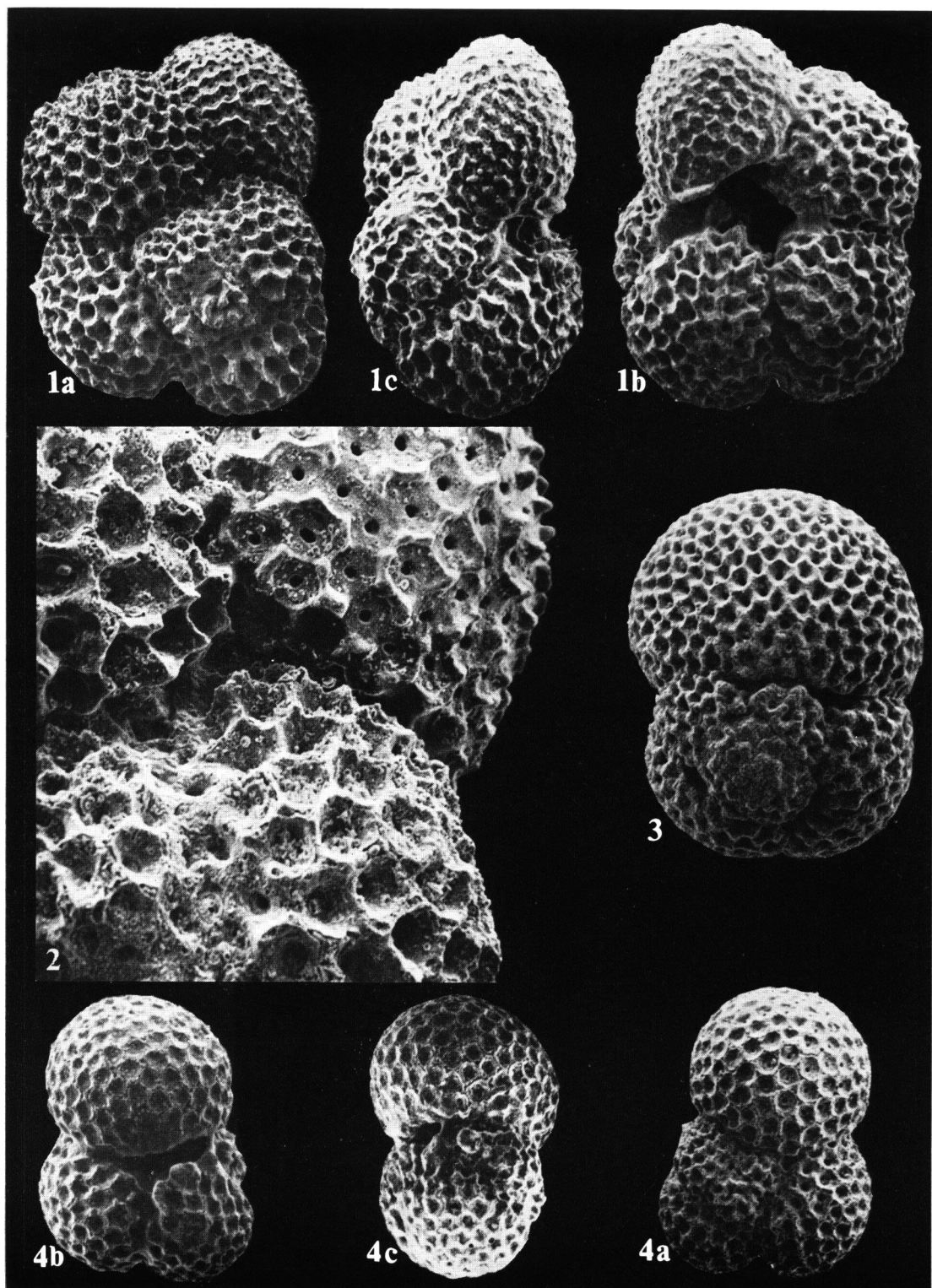


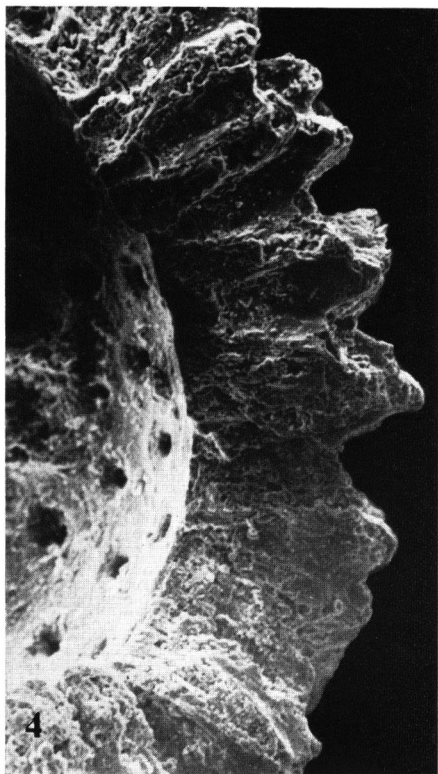
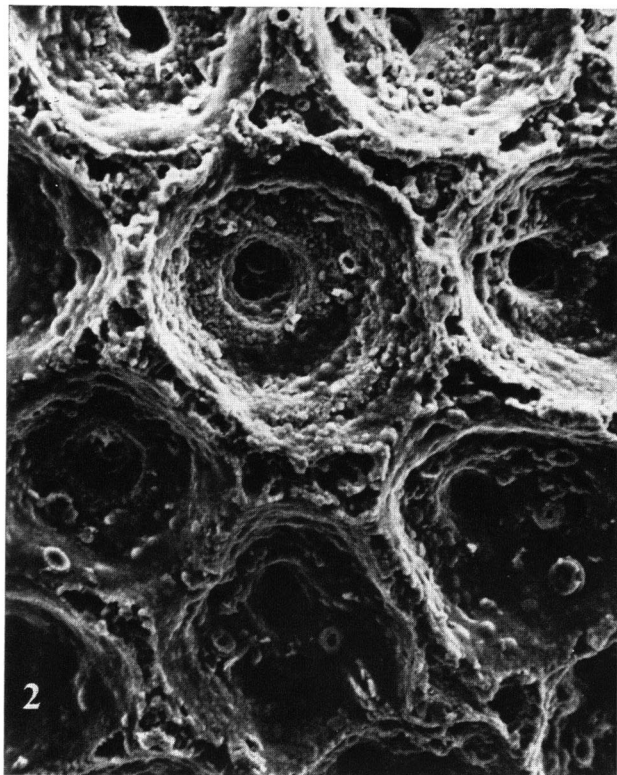
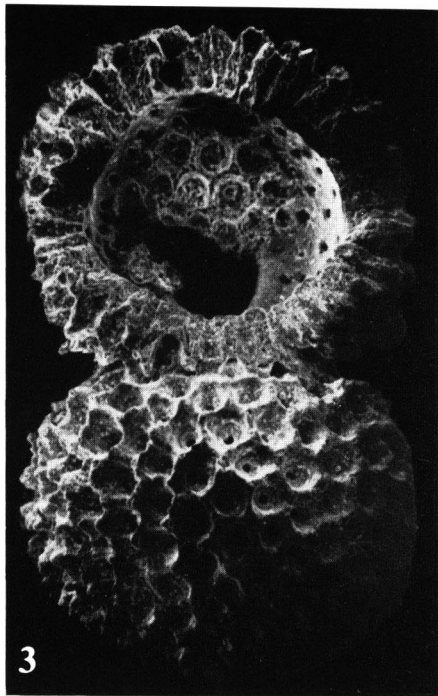
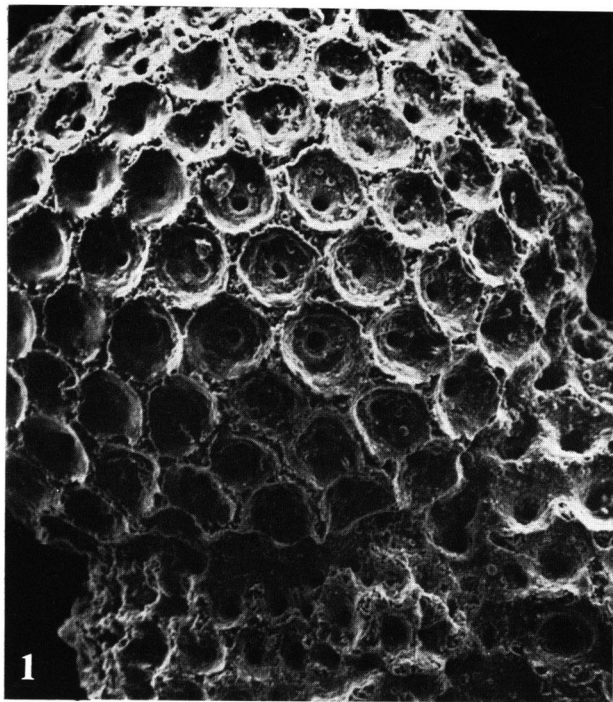


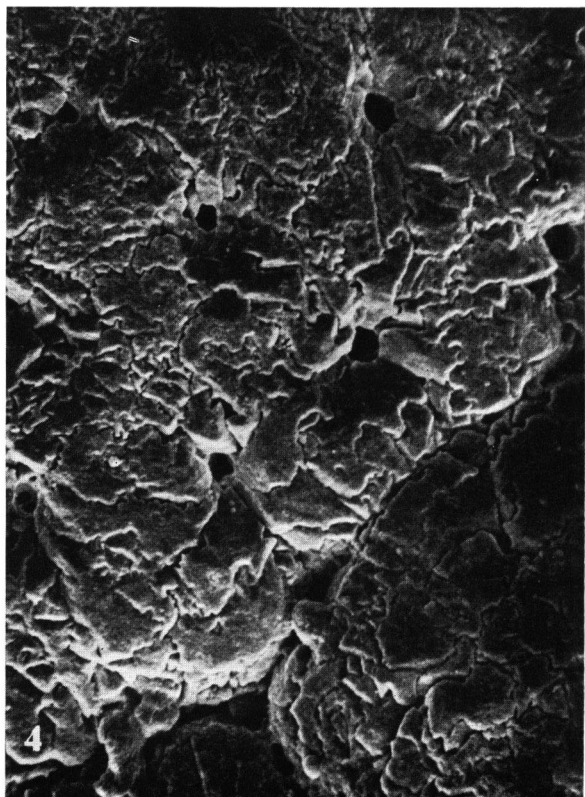
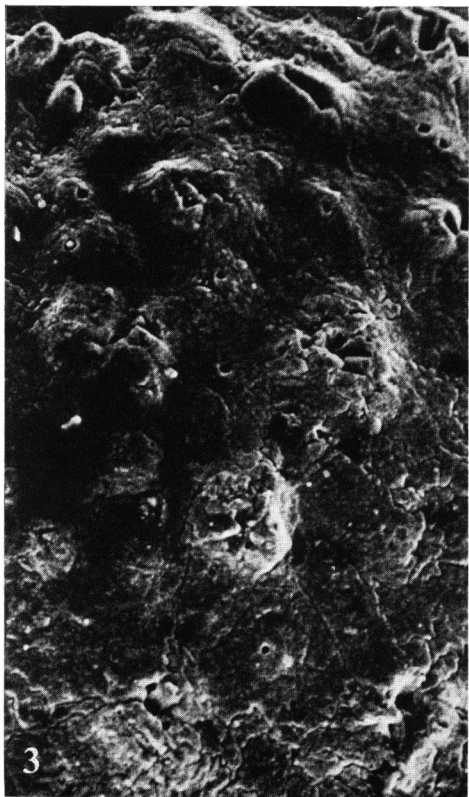
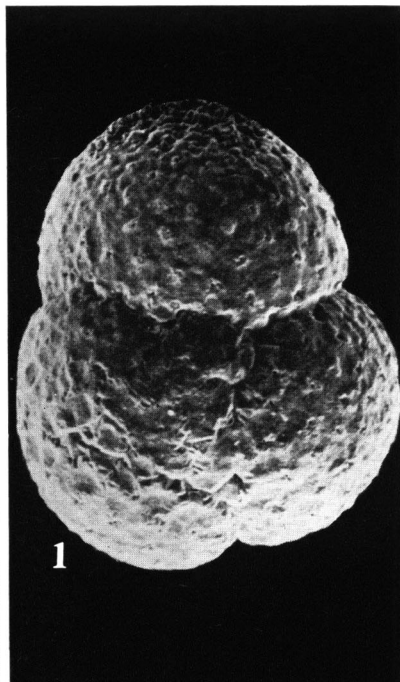




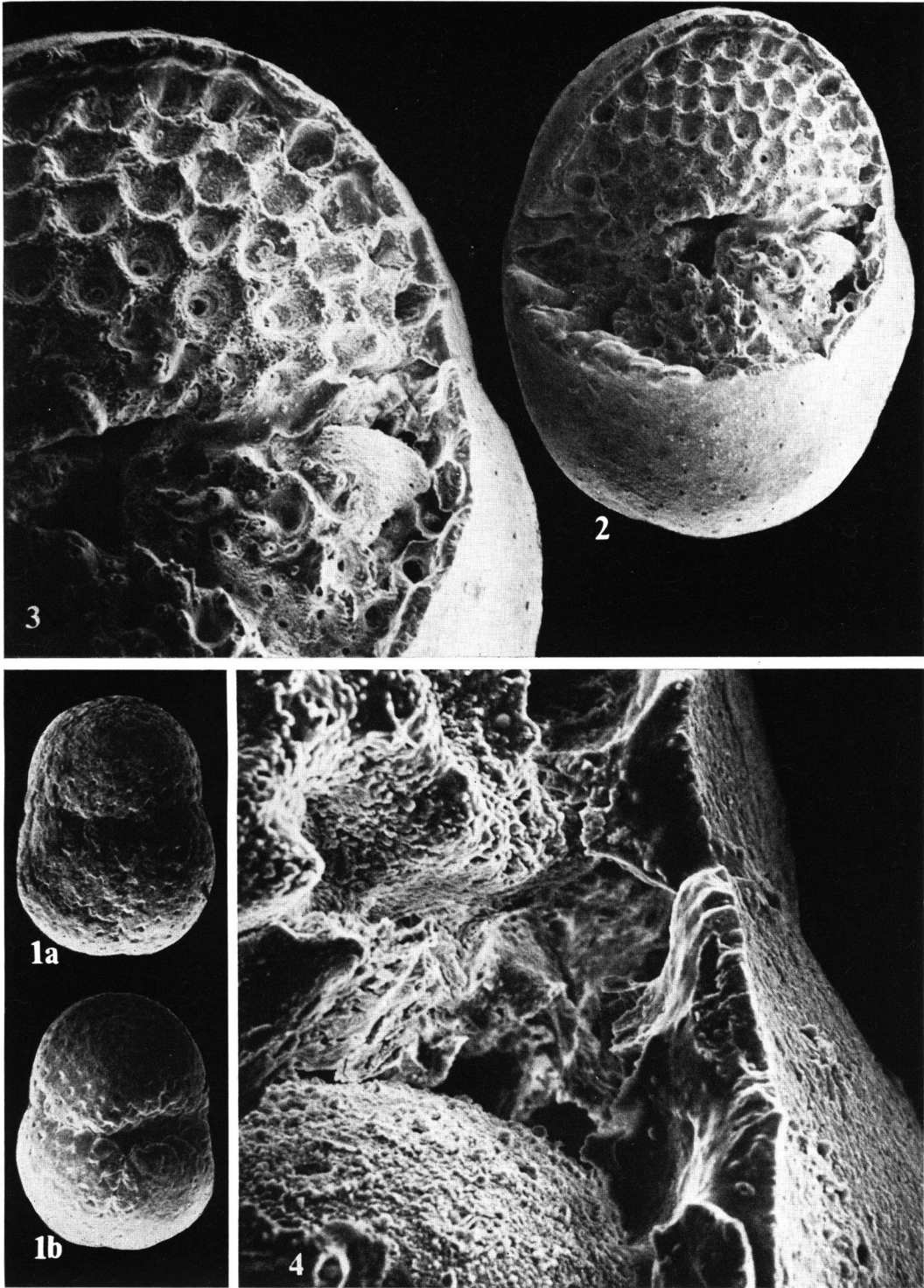




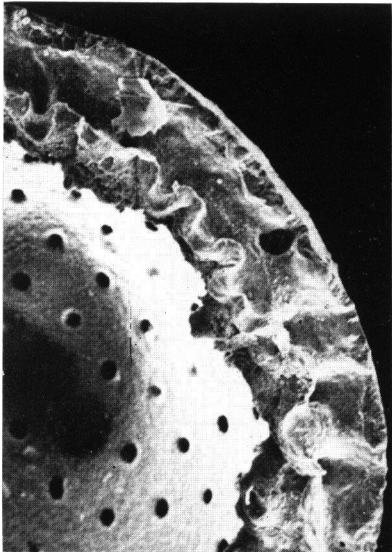




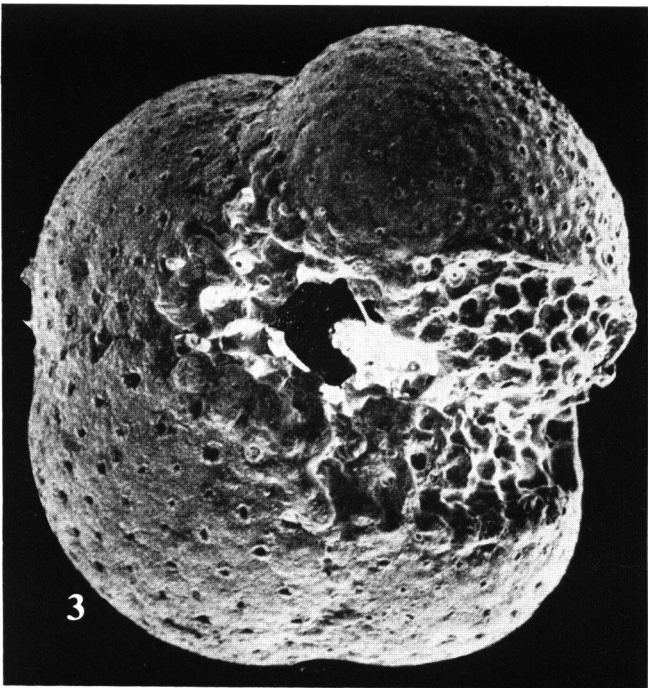




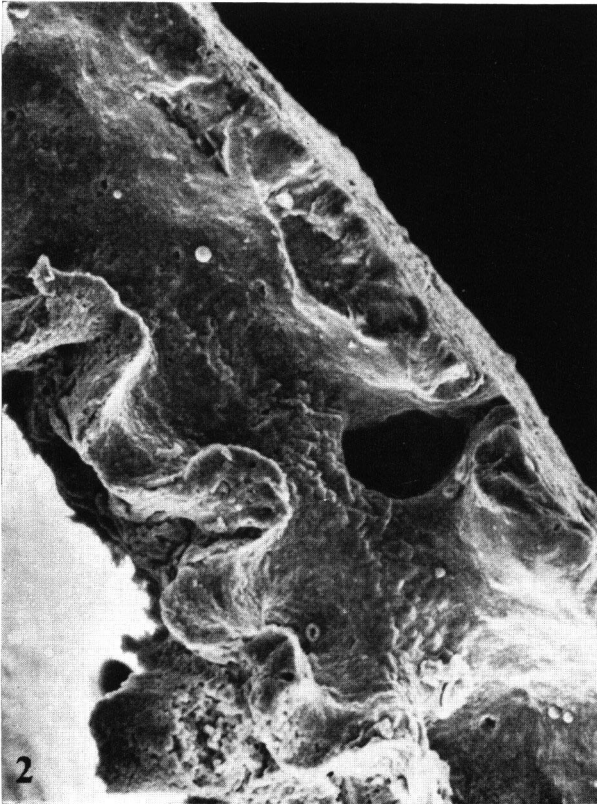




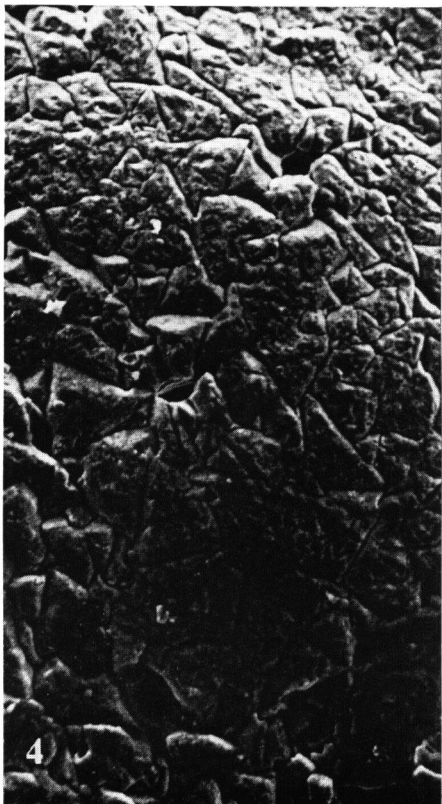
1



3



2



4

