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Cenomanian Planktonic Foraminifera from Diégo-Suarez, Northern Madagascar*

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Introduction

The 1973 paleontological reconnaisance survey by the National Science Museum of Tokyo, in which Ujiié participated as sub-leader, collected numerous rock samples ranging in age from Eocene to Upper Cretaceous for foraminiferal study. Among them the oldest but extremely well-preserved foraminiferal specimens came from five localities of the so-called Cenomanian sediments along the Betahitra Valley in the Diégo-Suarez region, northernmost Madagascar.

From one of these localities, *i. e.*, Dg 2, pyritized ammonites were reported by Boule *et al.* (1906–1907), Collignon (1920–1929, 1931), and most recently by Kanie *et al.* (1977) who used the same materials obtained by the 1973 National Science Museum Mission. Kanie *et al.* (*op. cit.*) assigned the locality to the lower Cenomanian mainly because of the occurrences of *Mantelliceras*, *Sciponoceras* aff. *baculoides* (Mantell), and *Mariella* (s. s.) aff. *lewesiensis* (Spath). Planktonic foraminiferal assemblage from the same locality also indicates lower Cenomanian on the basis of its world-wide valid biostratigraphy.

Besides Locality Dg 2, planktonic Foraminifera yielded from the other four localities are also in a well-preserved condition and their geologic ages are assigned to lower to uppermost Cenomanian. As a result, a hiatus between the Cenomanian and the overlying upper Campanian has been visualized in the Diégo-Suarez region.

In addition to the significance for regional geology, these Cenomanian planktonic Foraminifera may contribute to the global biostratigraphy because no single succession representing the whole duration of Cenomanian has yet been reported in the land-based sections (Loeblich and Tappan, 1961; Pessagno, 1969 a), or even in the deep-sea drilling cores, particularly of the southern hemisphere (Sliter, 1976). It would be interesting to know whether or not the scarcity of Cenomanian records can

* Contribution to the Paleontology of Madagascar, V

** Former address: Department of Paleontology, National Science Museum, Tokyo be attributed to the so-called Mid-Cretaceous Event that is a current international scope for the Mesozoic stratigraphers.

This paper, however, gives mainly the age-determination of the collected samples accompanied by the description of a new species and some taxonomic remarks of planktonic Foraminifera obtained there.

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Geological Setting

Diégo-Suarez is located at the northern tip of Madagascar and is provided with a fairly deep bay so that it had been utilized as a French naval port until 1971. Paleontologically the region has long been noticed since BOULE *et al.* (1906, 1907) reported Cretaceous ammonites from there. According to RERAT (1962) who showed a geological map of 1: 1000,000 scale, though without explanatory text unfortunately, Diégo-Suarez Bay is surrounded by exposures of Cretaceous mollusk-bearing marl or sandstone, and the outcrops are masked with the Neogene sediments and volcanics in the north and with the Recent basaltic flow in the south.

RERAT (*op. cit.*) divided the Cretaceous into the Upper and the Middle and, so far as the legend is concerned, the Middle Cretaceous of more than 400 m in thickness is composed of Albian marl and sandstone, Cenomanian gypsum-bearing marl and Turonian sandstone, lignite- and shell-bearing mudstone and gypsum-bearing marl, while the Upper Cretaceous is 150 m thick and ranges from Coniacian to Campanian. It seems that the Cretaceous of this region includes some continuous sequences from Albian through Campanian. Actually, however, any continuous superposition from stage to stage is hardly expected according to BESAIRIE (1972), although the strata are nearly horizontal.

Among the fossil localities, those along the broadly dissected valley of Betaitra are most famous for the abundant yield of beautifully pyritized ammonites. This was the reason why our mission surveyed the valley taking time off the short-duration of the expedition. According to RERAT's (1962) geological map, the western side of the valley consists of Albian to Turonian sediments covered with Recent basalt flow which makes a plateau-topography, while the eastern side is composed of the Albian to Turonian sediments, Coniacian to Campanian sediments, infra-Lutetian dolomite and basaltic tuff, and Lutetian limestone in ascending order. The horizontally lying Lutetian limestone forms flat-topped mesa-like mountains. On the slopes of these mountains bluish grey marly mudstone to marl is rather continuously exposed up to the altitude of about

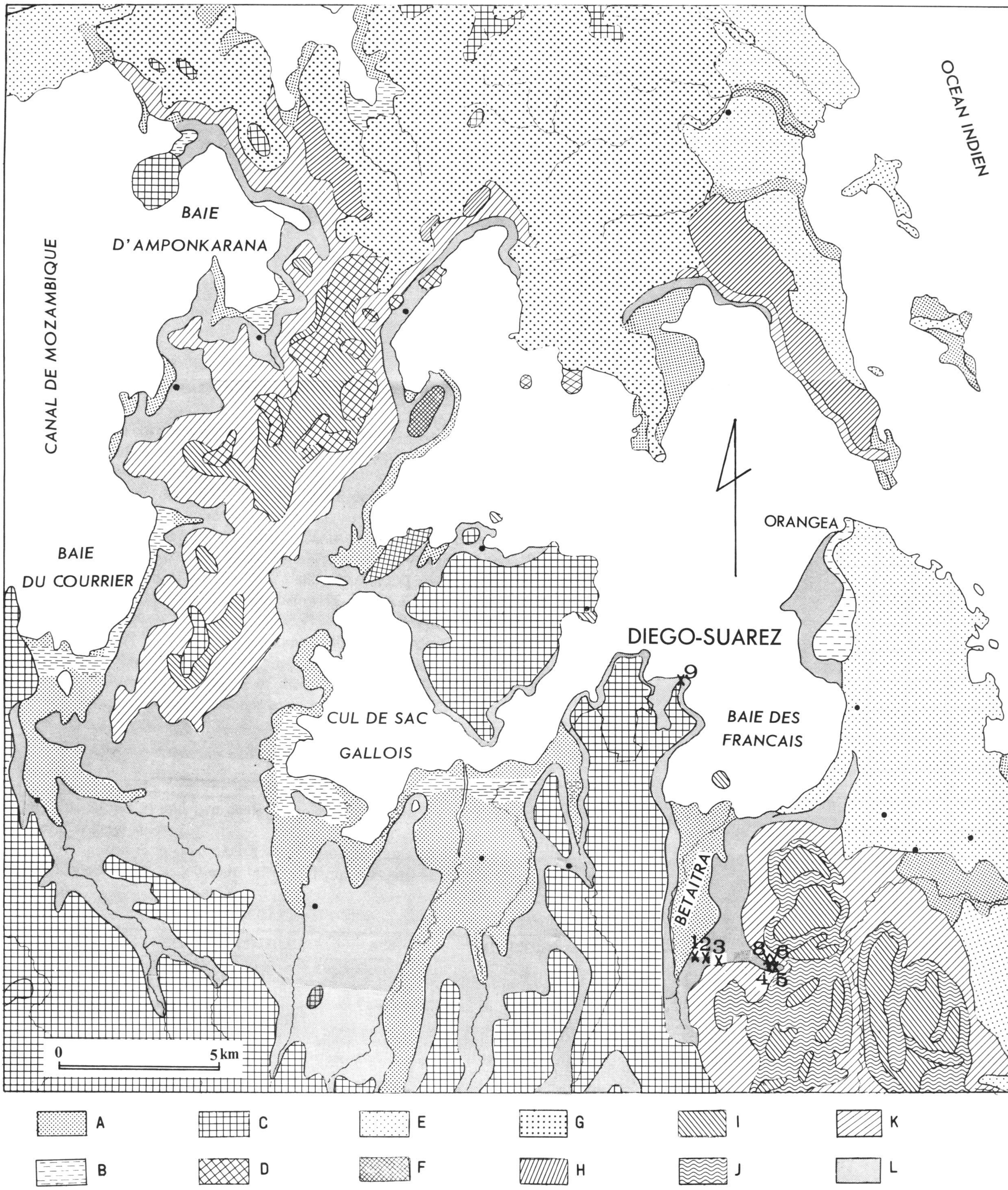

Fig. 1. Geological sketch map of the Diégo-Suarez region adopted from Rerat (1962) and showing localities of the studied samples. The geology around the localities was modified slightly by our survey.
A: Alluvial sands; B: Mangrove swamp; C: Recent basalt flow; D: Neogene basalt flow; E: Sands and coralline limestone; F: Phonolite; G: Lepidocycline-bearing basaltic tuff and ilmestone; H: Sandstone and lepidocycline-bearing limestone (both Aquitanian to Burdigalian); I: Nummulite-bearing limestone (Lutetian); J: Dolomite and basaltic tuff (infra-Lutetian); K: Upper Cretaceous, from Coniacian to Campanian (see text for further explanation); L: Middle Cretaceous, from Albian to Turonian (see text)

200 m and is thought to correspond to RERAT's "Albian to Turonian sediments". The "Coniacian to Campanian sediments" seems to be represented by chalk which overlies the marly mudstone to marl in places at such localities as Dg 8 and 6 probably with blind unconformity. At Dg 8 and 6 the chalk contains many well-sorted and rounded quartz grains suggesting aeolian origin.

Mollusks assigned to lower Cenomanian by KANIE *et al.* (1977) occur in the marly mudstone particularly at low altitude localities such as Dg 9, 10, and 2. From a well in the lowermost reaches of the Betahitra Valley, BESAIRIE (1972) reported ammonites ranging from upper Albian around 54 m below the sea-level to lower Cenomanian. Based upon the same materials, however, SIGAL (1956 and in BESAIRIE, 1972) indicated planktonic foraminiferal ages for the portion above 40 m below the sea-level as middle Cenomanian and the other below the depth as lower Cenomanian. Since SIGAL gave no illustration or systematic description of these Foraminifera, it remains to be ascertained by new evidences which opinion is correct.

Materials and their Treatment

Among a dozen samples from the Betahitra Valley (Table 1), five marly mudstone samples (Dg 2 to 5, and 9) and two chalk samples (Dg 6' and 8') were selected for planktonic foraminiferal study.

One hundred grams each was taken from a few kilograms of dried and crushed rock sample, heated under a 250-watt infrared lamp for approximately one hour,

Table 1. List of the studied samples

LOC.	LITHOLOGY	COLLECTED FOSSILS	AGE	ALTITUDE
Dg 1	marl	pelecypod fragments foraminifers	Cenomanian ?	ca. 80 m
Dg 2	marly mudstone	many mollusks foraminifers	Lower Cenomanian	ca. 80 m
Dg 3	marly mudstone	foraminifers	Middle Cenomanian	
Dg 4	marly mudstone	*Picnodonte fosseyi* *Trochus* sp. *Tetragonites* sp. *Scaphites* cf. *perouni* foraminifers	Upper Cenomanian	ca. 123 m
Dg 5	marly mudstone	foraminifers	Uppermost Cenomanian	
Dg 6	marly mudstone	foraminifers	Cenomanian	ca. 200 m
Dg 6′	chalk	foraminifers	Upper Campanian	ca. 200 m
Dg 8	marl		Cenomanian	ca. 142 m
Dg 8′	chalk		Upper Campanian	ca. 142 m
Dg 9	marly mudstone	*Mantelliceras suzannae* *Scaphites* sp. *Mariella* sp. foraminifers	Lower Cenomanian	ca. 5 m

soaked immediately with petroleum benzene, left at room temperature for one hour or more, added with phenol solution, boiled for twenty to thirty minutes, washed through a 200 mesh screen, and finally dried up. Residue on the screen was sieved again with a 100 mesh screen in dry condition. From residue on the 100 mesh screen, 200-odd specimens of planktonic Foraminifera were picked out under a binocular microscope and seeked scope for determination.

Planktonic Foraminiferal Ages and their Significance

Beautifully preserved planktonic Foraminifera thus obtained were classified into eight genera and 24 species and infraspecies concerning the marly mudstone as shown in Table 2. The table also indicates the occurrence of rare and minute species, for which more rock samples and finner fraction than 100 mesh screen were examined thoroughly; as a result *Schakoina cenomana* (SCHACKO) and *Clavihedbergella simplex* (MORROW) were recovered.

Judging from known ranges of the planktonic foraminiferal taxa shown in Table 2, it can be concluded that Dg 9 and 2 are of lower Cenomanian, Dg 3 of middle Cenomanian, Dg 4 of upper Cenomanian, and Dg 5 of uppermost Cenomanian. Subdivision of Cenomanian from the viewpoint of planktonic foraminiferal biostratigraphy has essentially been dependent upon the different ranges of *Rotalipora* species; for example, BOLLI (1966) proposed four zones, *i.e.*, *Rotalipora appenninica appenninica*, *R. brotzeni*, *R. reicheli*, and *R. cushmani* Zones in ascending order, defining their bases by the initial appearance datum planes of the nominated species, respectively. Although all the species were found in the Diégo-Suarez materials, we hesitate to apply BOLLI's zones here since considerably different ranges of the same species have been proposed by such authors as SIGAL (1967) or BANDY (1967).

The ages thus assigned coincide with altitudinal differences of the samples; namely, the older sample came from the lower altitude. Following this principle, the underground Cenomanian of the well near the mouth of the Betahitra Valley should be of lower Cenomanian agreeing with the ammonite age-assignment by BESAIRIE (1972) but not of middle one that was presumed by SIGAL (1956) on the basis of the planktonic Foraminifera contained.

It is noteworthy in regional geology that two chalk samples (Dg 6′ and 8′) overlying the Cenomanian marly mudstone contain also abundant but poorly preserved planktonic Foraminifera. Even though these specimens are secondarily encrusted with calcium carbonate so that there is room for exact identification, we recognized the following species:

Heterohelix globulosa (EHRENBERG) (middle Turonian to basal Danian of BANDY, 1967), *Rugoglobigerina rugosa subrugosa* (GANDOLFI) (whole Campanian), *Globotruncana rosetta* (CARSEY), (middle Campanian to top of Maestrichtian), *Globotruncana linneiana* (D'ORBIGNY) (basal Turonian to top of Maestrichtian), *Globotruncana* cf. *caliciformis* (DE LAPPARANT) (typical one from upper Campanian to top of Maestrich-

Table 2. Occurrence chart of the Cenomanian planktonic Foraminifera

	Dg-9	Dg-2	Dg-3	Dg-4	Dg-5	Stratigraphic Range
Planomalinidae BOLLI, LOEBLICH & TAPPAN, 1957						
Globigerinelloides CUSHMAN & TEN DAM, 1948						
Globigerinelloides cushmani (TAPPAN)	3	14	1	1		Upper Aptian to Cenomanian*
Globigerinelloides eaglefordensis (MOREMAN)	10	11	28	1	8	Ditto ?
Planomalina LOEBLICH & TAPPAN, 1946						
Planomalina buxtorfi (GANDOLFI)	1	5	+			Middle Albian to lower Cenomanian*
Schackoinidae POKORNY						
Schackoina THALMANN, 1932						
Schackoina cenomana (SCHACKO)	+					Middle Albian to lower Turonian*
Rotaliporidae SIGAL, 1958						
Hedbergella BRÖNNIMANN & BROWN, 1958						
Hedbergella amabilis LOEBLICH & TAPPAN	36	36	4	6	19	Upper Cenomanian? to Turonian**
Hedbergella planispira (TAPPAN)	29	40				Lower Aptian to Maastrichtian*
Hedbergella planispira, var.	3	8				
Hedbergella delrioensis (CARSEY)	13		59	25	2	Barremian to Campanian*
Hedbergella washitensis (CARSEY)		1				Middle Albian to middle Cenomanian*
Hedbergella madagascarensis, n. sp.		3?		3	53	
Hedbergella sp.	1			1		
Clavihedbergella BANNER & BLOW, 1959						
Clavihedbergella simplex (MORROW)			+	1		Cenomanian to Coniacian*
Praeglobotruncana BERMÚDEZ, 1952						
Praeglobotruncana delrioensis (PLUMMER)		28	50			Upper Albian to Cenomanian*
Praeglobotruncana delrioensis, var.		14	17			
Praeglobotruncana stephani (GANDOLFI)		2?		215	74	Middle Cenomanian to lower Turonian*
Praeglobotruncana stephani, var.				13	4	
Ticinella REICHEL, 1950						
Ticinella cf. *multiloculina* (MORROW)				1		
Rotalipora BROTZEN, 1942						
Rotalipora appenninica appenninica (O. RENZ)	66	47	29	2	10	Upper Albian to middle? Cenomanian***
Rotalipora appenninica balernaensis (GANDOLFI)	67					Upper Albian to middle Cenomanian***
Rotalipora brotzeni SIGAL	1		12			Whole Cenomanian***
Rotalipora cushmani (MORROW)			4	5	33	Upper Cenomanian†
Rotalipora evoluta SIGAL		19	10			
Rotalipora greenhornensis (MORROW)		1		9	1?	Middle to uppeı Cenomanian*
Rotalipora deeckei (FRANKE)					26	Upper Cenomanian***
Total Number of Identified Specimens	230	229	214	283	230	

* After MASTERS (1977); ** After LOEBLICH and TAPPAN (1961); *** After SIGAL (1967);
† After BANDY (1967)

tian), *Globotruncana arca* (CUSHMAN) (basal Coniacian to middle Maetrichtian), and so on. As a whole, therefore, the faunas indicate upper Campanian age and consequently a remarkable gap ranging from Turonian to lower Campanian must be supposed between the marly mudstone and the chalk in despite of unconformity which was not observed in the field work. Judging from the disposition of upper Campanian chalk at different altitudes against the horizontally bedded Cenomanian, it may be inferred that the upper Campanian sea invaded into considerably rough relief near the shore susceptible of supply of dune sands but in an open condition favoring the deposition of chalk.

Most recently MATSUMOTO (1977) synthesized the mode of transgressions in the Cretaceous Period mainly on the basis of the land-based sequences. He indicates in fig. 2 that the areas which surrounded the Indian Ocean were under the Cenomanian transgression and again under the Campanian one beyond an interval from Turonian to early Santonian. Sedimentary situation in the Betahitra Valley mentioned above may reflect the present mode of transgressions in the Indian Ocean region. Contrary to the land areas, however, the Deep Sea Drilling Project has shown almost complete absence of Cenomanian in the drilling cores from the Indian Ocean (SLITER, 1976); this is true for the cores from the seas surrounding Madagascar (SIGAL, 1974). This trend suggests that the Indian Ocean of similar scale to the present-day one may have appeared after the Cenomanian, probably in the Campanian age, and afterward the sediments have developed nearly throughout the Ocean, sometimes directly upon the basaltic basement (SLITER, 1976).

Taxonomic Annotations with Description of a New Species

Globigerinelloides cushmani (TAPPAN). Pl. 1, figs. 3, 4.

Globigerinella cushmani TAPPAN, 1943, p. 513, pl. 83, fig. 5 —— For further references, see *Globigerinelloides cushmani* (TAPPAN), MASTERS, 1977, p. 408, 409, pl. 10, fig. 4; pl. 11, figs. 1, 2.

Remarks: The specimens from Diégo-Suarez are provided with fewer chambers (6 1/2) on average in the final whorl than in the typical ones (7–9). At the juvenile stage, moreover, the number is further small being five so that it resembles *Globigerinelloides escheri* (KAUFMANN) [*Nonionina escheri* KAUFMANN, 1865]. In the latter species, however, its test-periphery in transversal view is not so broadly rounded. Besides, young specimens recognized here tend to retain laterally asymmetrical edge view.

Globigerinelloides eaglefordensis (MOREMAN). Pl. 1, figs. 1, 2.

Anomalina eaglefordensis MOREMAN, 1927, p. 99, pl. 16, fig. 9; —— For further references, see *Globigerinelloides eaglefordensis* (MOREMAN), LOEBLICH and TAPPAN, 1961, p. 268, 269, pl. 2, figs. 3–7.

Remarks: Although this species was included into *G. cushmani* by MASTERS (1977), the latter differs from the former in having smaller number of chambers per a whorl, more broadly rounded test periphery, and a laterally symmetrical test at the early stage so far as the Diégo-Suarez materials are concerned.

Planomalina buxtorfi (GANDOLFI). Pl. 2, figs. 1, 2.

Planulina buxtorfi GANDOLFI, 1942, p. 103, 104, pl. 3, fig. 7; pl. 5, fig. 4; pl. 6, figs. 1, 2; pl. 9, fig. 2; pl. 12, fig. 2 (part); pl. 13, figs. 13, 15 (part); —— For further references, see *Planomalina buxtorfi* (GANDOLFI), MASTERS, 1977, p. 421–423, pl. 14, fig. 1.

Schackoina cenomana (SCHACKO). Pl. 2, fig. 3.

Siderolina cenomana SCHACKO, 1897 (*fide* ELLIS and MESSINA, 1948 *et seq.*) p. 166, pl. 4, figs. 3–5; —— For further references, see *Schackoina cenomana* (SCHACKO), MASTERS. 1977, p. 430–432, pl. 16, figs. 1, 2.

Hedbergella BRÖNNIMANN and BROWN, 1958

This Mesozoic genus has essentially the same morphology as Cenozoic *Globigerina*, except for different wall-structure as pointed out by PESSAGNO (1969 and others). The difference might be due to some environmental control as suggested by MASTERS (1977) or, more likely, due to secondary conversion through diagenesis from radial hyaline wall to microgranular one in Cretaceous Globigerinacea. For the present, however, the wall difference must be utilized for distinguishing the two genera.

Hedbergella amabilis LOEBLICH and TAPPAN. Pl. 3, figs. 3, 4.

Hedbergella amabilis LOEBLICH and TAPPAN, 1961, p. 274, pl. 3, figs. 1–10.

Remarks: Among many specimens from Diégo-Suarez someones are provided with less lobulated test-periphery and somewhat piled-up and protruded spire on spiral side as shown in Plate 3, figure 3, for an example. Although this variation is similar to *Globigerina cretacea* var. *delrioensis* CARSEY as a whole excluding the smaller number of chambers per a whorl, this is here included within a single population of *Hedbergella amabilis*.

Hedbergella planispira (TAPPAN). Pl. 3, figs. 1, 2.

Globigerina planispira TAPPAN, 1940, p. 122, pl. 19, fig. 12; —— For further references, see MASTERS, 1977, p. 470–473, pl. 24, figs. 2, 3, 5.

Hedbergella delrioensis (CARSEY). Pl. 4, figs. 1, 3.

Globigerina delrioensis CARSEY, 1926, p. 43, 44; —— For further references, see Masters, 1977, p. 454–457, pl. 20, figs. 4, 5.

Remarks: The Diégo-Suarez specimens are generally characterized by heavily pustulose ornamentation, particularly on the early volutions even for the young individuals, as typified by a junior synonym, *Globigerina gautierensis* BRÖNNIMANN.

Hedbergella madagascarensis UJIIÉ and RANDRIANASOLO, n. sp., Pl. 5, figs. 2–4.

Description: Test free, in a low trochospiral coil of about two and half volutions, early whorl flush on the spiral side, umbilical side shallowly umbilicate but distinctly concave as a whole, test periphery moderately lobulate in equatorial outline and subrounded transversely; chambers slightly flattened and trapezoidal-shaped on the spiral side, somewhat swollen and subquadangular-shaped on the umbilical side, increasing rapidly in size as added particularly after the numbers decreased from five to almost four; sutures radial, slightly depressed; wall calcareous, distinctly perforate, no indication of a keel or poreless margin; aperture a low arch on the umbilical side, interiomarginal and extraumbilical-umbilical, partially covered by a distinct lip which flares slightly at its umbilical end.

Greater diameter of holotype 0.36 mm, thickness 0.18 mm.

Remarks: This species resembles *Globotruncana havanensis* VOORWIJK–plexus, particularly *Globotruncana petaloidea* GANDOLFI (*s. l.*), in general appearance of test-construction. As essential differences, however, *G. petaloidea* has acute to subacute periphery and apertural lip which is toward development as tegillae. The species appeared in early Turonian as one of the earliest members of *Globotruncana*, while the new species exclusively occurs in the uppermost horizon of the Diégo-Suarez Cenomanian. Relationship in test-morphology and stratigraphic occurrence suggests that *H. madagascarensis*, n. sp. might be direct ancestral taxon of *G. petaloidea* or *G. havanensis*–plexus, which includes *Globotruncana* species with world-wide distribution.

Hedbergella washitensis (CARSEY). Pl. 6, fig. 4.

Globigerina washitensis CARSEY, 1926, p. 44, pl. 7, fig. 10; pl. 8, fig. 2; —— For further references, see MASTERS, 1977, p. 477–479, pl. 25, fig. 4; pl. 26, figs. 1–3.

Remarks: Only a specimen here recovered is so badly preserved that its coarse honeycomb structure on wall-surface was almost masked with secondary deposition of calcareous materials; at a glance, the specimen resembles *Globigerina hoterivica* SUBBOTINA, occurrence of which ranges from middle Bathonian to middle Aptian according to MASTERS (1977).

Clavihedbergella simplex (MORROW). Pl. 1, fig. 5.

Hastigerinella simplex MORROW, 1934, p. 198, 199, pl. 30, fig. 6; —— For further references, see *Clavihedbergella simplex* (MORROW), MASTERS, 1977, p. 443–445, pl. 19, figs. 1–3.

Praeglobotruncana delrioensis (PLUMMER). Pl. 4, fig. 2; (variety) pl. 5, fig. 1.

Globorotalia delrioensis PLUMMER, 1931, p. 199, 200, pl. 13, fig. 2; —— For further references, see *Praeglotruncana deliroensis* (PLUMMER), MASTERS, 1977, p. 486–489, pl. 27, figs. 4, 5; pl. 28, fig. 1.

Remarks: Forms designated as *P. delrioensis*, var. were distinguished qualitatively by the weaker development of keel.

Praeglobotruncana stephani (GANDOLFI). Pl. 6, figs. 1, 2, (variety) 3

Globotruncana stephani GANDOLFI, 1942, p. 130–133, pl. 3, figs. 4, 5; pl. 4, figs. 36, 37, 41–44; pl. 6, fig. 4; pl. 9, figs. 5, 8; pl. 14, fig. 2; —— For further refernces see *Praeglobotruncana stephani* (GANDOLFI), MASTERS, 1977, p. 491–494, pl. 28, figs. 2–4.

Remarks: Forms designated as *P. stephani*, var. have low-spired test with more weakly pustulose ornamentation. Because the average test-size of the variety is distinctly smaller, it may represent a kind of juvenile form.

Ticinella cf. *multiloculina* (MORROW).

Cf. *Globorotalia ? multiloculata* MORROW, 1934, p. 200, pl. 31, figs. 3. 5; —— *Ticinella multiloculata* (MORROW), LOEBLICH and TAPPAN, 1961, p. 292, 294, pl. 6, fig. 13.

Remarks: Because of scarce occurrence and bad preservation, exact identification was impossible for this case.

Rotalipora appenninica appenninica (O. RENZ). Pl. 7, fig. 1, (an intermediate form toward *R. greenhornensis*) 3.

Globotruncana appenninica O. RENZ, 1936 (*fide* ELLIS and MESSINA, 1948 *et seq.*), p. 20, 135, text-figs. 2, 7a; pl. 6, figs. 1–11; pl. 7, fig. 1; pl. 8, fig. 4; —— For further references, see *Rotalipora appenninica* (O. RENZ), LOEBLICH and TAPPAN, 1961, p. 296, 297, pl. 7, figs. 11, 12.

Rotalipora appenninica balernaensis (GANDOLFI). Pl. 7, fig. 2.

Globotruncana (*Rotalipora*) *appenninica balernaensis* GANDOLFI, 1957, p. 60, pl. 8, fig. 3; —— For further references, see *Rotalipora balernaensis* GANDOLFI, LOEBLICH and TAPPAN, 1961, p. 297, pl. 8, fig. 11.

Rotalipora evoluta SIGAL. Pl. 8, figs. 3, 4.

Rotalipora cushmani MORROW var. *evoluta* SIGAL, 1948 (*fide* ELLIS and MESSINA, 1948 *et seq.*), p. 100, pl. 1, fig. 3; pl. 2, fig. 2; —— For further references, see *Rotalipora evoluta* SIGAL, LOEBLICH and TAPPAN, 1961, p. 298, 299, pl. 7, figs. 1–4.

Remarks: The above-mentioned three taxa were rather artificially divided following with LOEBLICH and TAPPAN's (1961) opinions as much as possible. For the present, however, we are inclined to MASTERS' (1977) treatment which united altogether under the name of *R. appenninica*.

Rotalipora greenhornensis (MORROW). Pl. 8, fig. 2; (intermediate form toward *R. appenninica*) pl. 7, fig. 4.

Globorotalia greenhornensis MORROW, 1934, p. 199, 200, pl. 31, figs. 5, 6; —— For further references, see *Rotalipora greenhornensis* (MORROW), LOEBLICH and TAPPAN, 1961, p. 299–301, pl. 7, figs. 5–10.

Rotalipora brotzeni (SIGAL). Pl. 8, fig. 1.

Thalmanninella brotzeni SIGAL, 1948 (*fide* ELLIS and MESSINA, 1948 *et seq.*), p. 102, pl. 1, fig. 5; pl. 2, figs. 6a, 7: —— SIGAL, 1956, p. 212, text-fig. 2.

Remarks: As reported by SIGAL (1956) from a well in Diégo-Suarez we recognized specimens identical with *Rotalipora brotzeni* at Localities Dg 9 and 3. On the other hand, *R. greenhornensis* occurs at Dg 2, 4 and 5. From morphological viewpoint, however, the two species may be conspecific as stated by MASTERS (1977) who united together them under the name of *R. greenhornensis*.

Rotalipora cushmani (MORROW). Pl. 9, figs. 4–6; pl. 8, fig. 5 (?).

Globorotalia cushmani MORROW, 1934, p. 199, pl. 31, figs. 2, 4; —— For further references, see *Rotalipora cushmani* (MORROW), MASTERS, 1977, p. 501–506, pl. 30, fig. 4; pl. 31, figs. 1–4.

Rotalipora deeckei (FRANKE). Pl. 9, figs. 1–3.

Rotalia deeckei FRANKE, 1925 (*fide* ELLIS and MESSINA, 1948 *et seq.*), p. 90, 91, pl. 8, fig. 7; —— For further references, see *Rotalipora deeckei* (FRANKE), MASTERS, 1977, p. 506–508, pl. 32, figs. 1–3.

Remarks: This species has long been known as *Rotalipora reicheli* (MORNOD) [*Globotrunacana* (*Rotalipora*) *reicheli* MORNOD].

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Explanation of Plates

(a: spiral view; b: apertural and edge view; c: umbilical view in all scanning electron micrographs)

Plate 1

Fig. 1b, c. *Globigerinelloides eaglefordensis* (MOREMAN). Micropaleontology Collection, National Science Museum, Tokyo (Micropal. Coll. NSM) 1803, from Loc. Dg 2, ×150.

Fig. 2b, c. *Globigerinelloides eaglefordensis* (MOREMAN). Young form, Micropal. Coll. NSM 1804, from Dg 2, ×150.

Fig. 3a-c. *Globigerinelloides cushmani* (TAPPAN). Young form, Micropal. Coll. NSM, 1802 from Dg 3, ×300.

Fig. 4a-c. *Globigerinelloides cushmani* (TAPPAN). Micropal. Coll. NSM 1801, from Dg 3, ×150.

Fig. 5a-c. *Clavihedbergella simplex* (MORROW). Micropal. Coll. NSM 1818, from Dg 3, ×150.

Plate 2

Fig. 1a-c. *Planomalina buxtorfi* (GANDOLFI). Micropal. Coll. NSM 1805, from Dg 2, ×150.

Fig. 2a, b. *Planomalina buxtorfi* (GANDOLFI). Young form, Micropal. Coll. NSM 1806, from Dg 2, ×150.

Fig. 3a-c. *Schackoina cenomana* (SCHACKO). Micropal. Coll. NSM 1807, from Dg 9, ×300.

Plate 3

Fig. 1a-c. *Hedbergella planispira* (TAPPAN). Micropal. Coll. NSM 1810, from Dg 2, ×150.

Fig. 2a-c. *Hedbergella planispira* (TAPPAN). Planispiral form, Micropal. Coll. NSM 1811, from Dg 9, ×150.

Fig. 3a-c. *Hedbergella amabilis* LOEBLICH and TAPPAN. Form with protruded spire; Micropal. Coll. NSM 1809, from Dg 5, ×300.

Fig. 4a-c. *Hedbergella amabilis* LOEBLICH and TAPPAN. Micropal. Coll. NSM 1808, from Dg 9, ×150.

Plate 4

Fig. 1a-c. *Hedbergella delrioensis* (CARSEY). Micropal. Coll. NSM 1812, from Dg 3, ×150.

Fig. 2a, b. *Praeglobotruncana delrioensis* (PLUMMER). Micropal. Coll. NSM 1819, from Dg 3, ×150.

Fig. 3a-c. *Hedbergella delrioensis* (CARSEY). Young form, Micropal. Coll. NSM 1813, from Dg 3, ×150.

Plate 5

Fig. 1a-c. *Praeglobotruncana delrioensis* (PLUMMER), var. Micropal. Coll. NSM 1820, from Dg 3, ×150.
Fig. 2a-c. *Hedbergella madagascarensis*, n. sp. Holotype, Micropal. Coll. NSM 1815, from Dg 3, ×150.
Fig. 3a-c. *Hedbergella madagascarensis*, n. sp. Paratype with somewhat protruded spire, Micropal. Coll. NSM 1816, from Dg 3, ×150.
Fig. 4a-c. *Hedbergella madagascarensis*, n. sp. Paratype, young form, Micropal. Coll. NSM 1817, from Dg 3, ×150.

Plate 6

Fig. 1a-c. *Praeglobotruncana stephani* (GANDOLFI). Low-spired form, Micropal. Coll. NSM 1821, from Dg 5, ×100.
Fig. 2a-c. *Praeglobotruncana stephani* (GANDOLFI). High-spired form, Micropal. Coll. NSM 1822, from Dg 4, ×100.
Fig. 3a-c. *Praeglobotruncana stephani* (GANDOLFI) var. Micropal. Coll. NSM 1823, from Dg 5, ×100.
Fig. 4a-c. *Hedbergella washitensis* (CARSEY). Micropal. Coll. NSM 1814, from Dg 2, ×100.

Plate 7

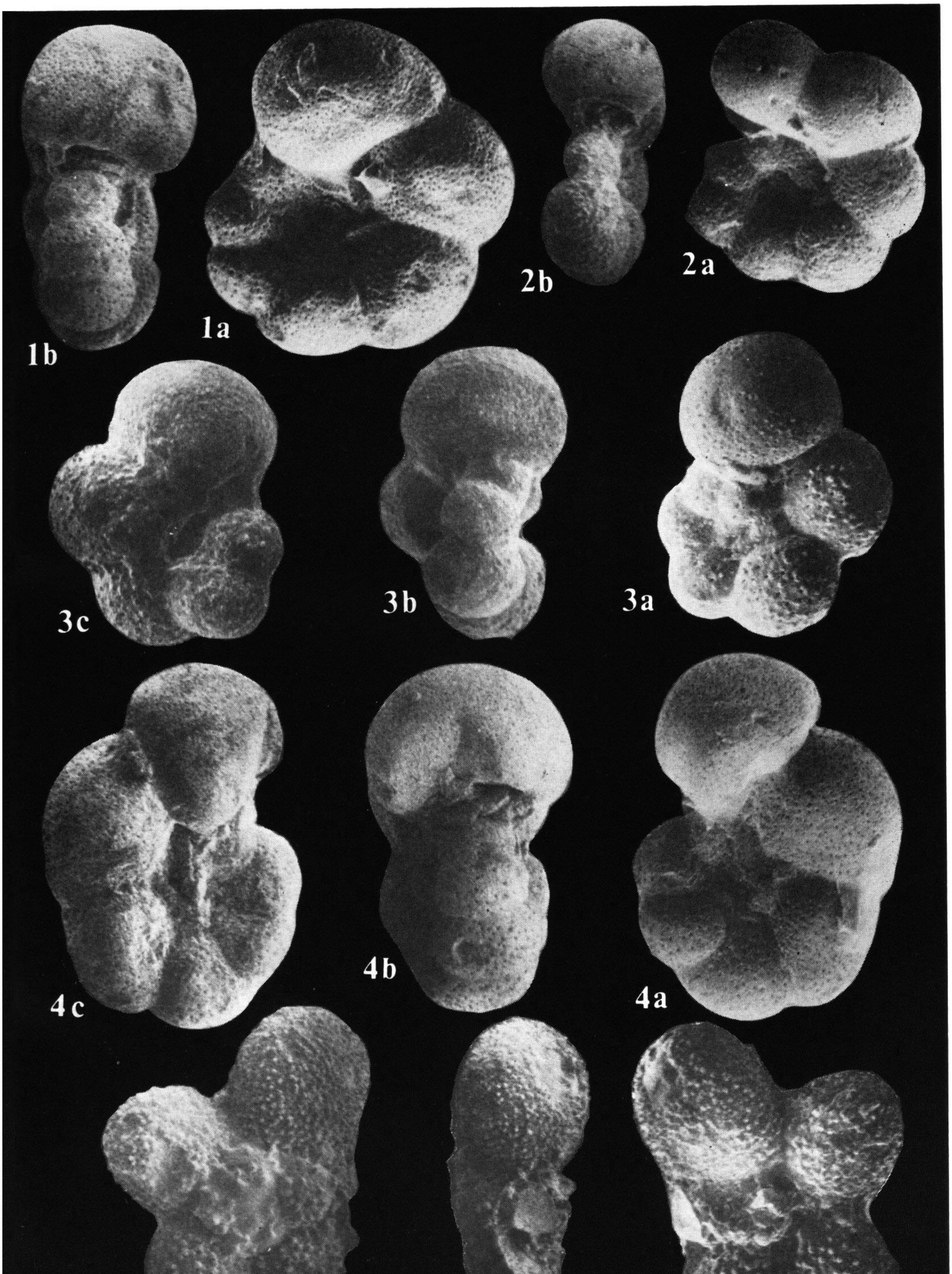
Fig. 1a-c. *Rotalipora appenninica appenninica* (O. RENZ). Micropal. Coll. NSM 1824, from Dg 9, a: ×67, b: ×73, c: ×78.
Fig. 2a-c. *Rotalipora appenninica balernaensis* (GANDOLFI). Micropal. Coll. NSM 1826, from Dg 9, ×100.
Fig. 3a-c. *Rotalipora appenninica/R. greenhornensis* intermediate form. Micropal. Coll. NSM 1825, from Dg 3, a: ×100, b, c: ×80.
Fig. 4a-c. *Rotalipora greenhornensis* (MORROW)/*R. appenninica* intermediate form. Micropal. Coll. NSM 1827, from Dg. 5, ×67.

Plate 8

Fig. 1a-c. *Rotalipora brotzeni* SIGAL. Micropal. Coll. NSM 1829, from Dg 3, ×67.
Fig. 2a-c. *Rotalipora greenhornensis* (MORROW). Micropal. Coll. NSM 1828, from Dg 4, ×67.
Fig. 3a-c. *Rotalipora evoluta* SIGAL. Young form, Micropal. Coll. NSM 1838, from Dg 2, ×100.
Fig. 4a-c. *Rotalipora evoluta* SIGAL. Micropal. Coll. NSM 1837, from Dg 2, ×100.
Fig. 5a-c. *Rotalipora cushmani* (MORROW)? Micropal. Coll. NSM 1833, from Dg 5, ×100.

Plate 9

Fig. 1a-c. *Rotalipora deeckei* (FRANKE). Micropal. Coll. NSM 1835, from Dg 5, ×100.
Fig. 2. *Rotalipora deeckei* (FRANKE). Apertural and edge view of young form, Micropal. Coll. NSM 1836, from Dg 5, ×100.
Fig. 3a, c. *Rotalipora deeckei* (FRANKE). Full grown form, Micropal. Coll. NSM 1834, from Dg 5, ×67.
Fig. 4a-c. *Rotalipora cushmani* (MORROW). Young form, Micropal. Coll. NSM 1832, from Dg 5, ×100.
Fig. 5a-c. *Rotalipora cushmani* (MORROW). Micropal. Coll. NSM 1831, from Dg 5, ×67.
Fig. 6a-c. *Rotalipora cushmani* (MORROW). Gerontic form, Micropal. Coll. NSM 1830, from Dg 4, ×67.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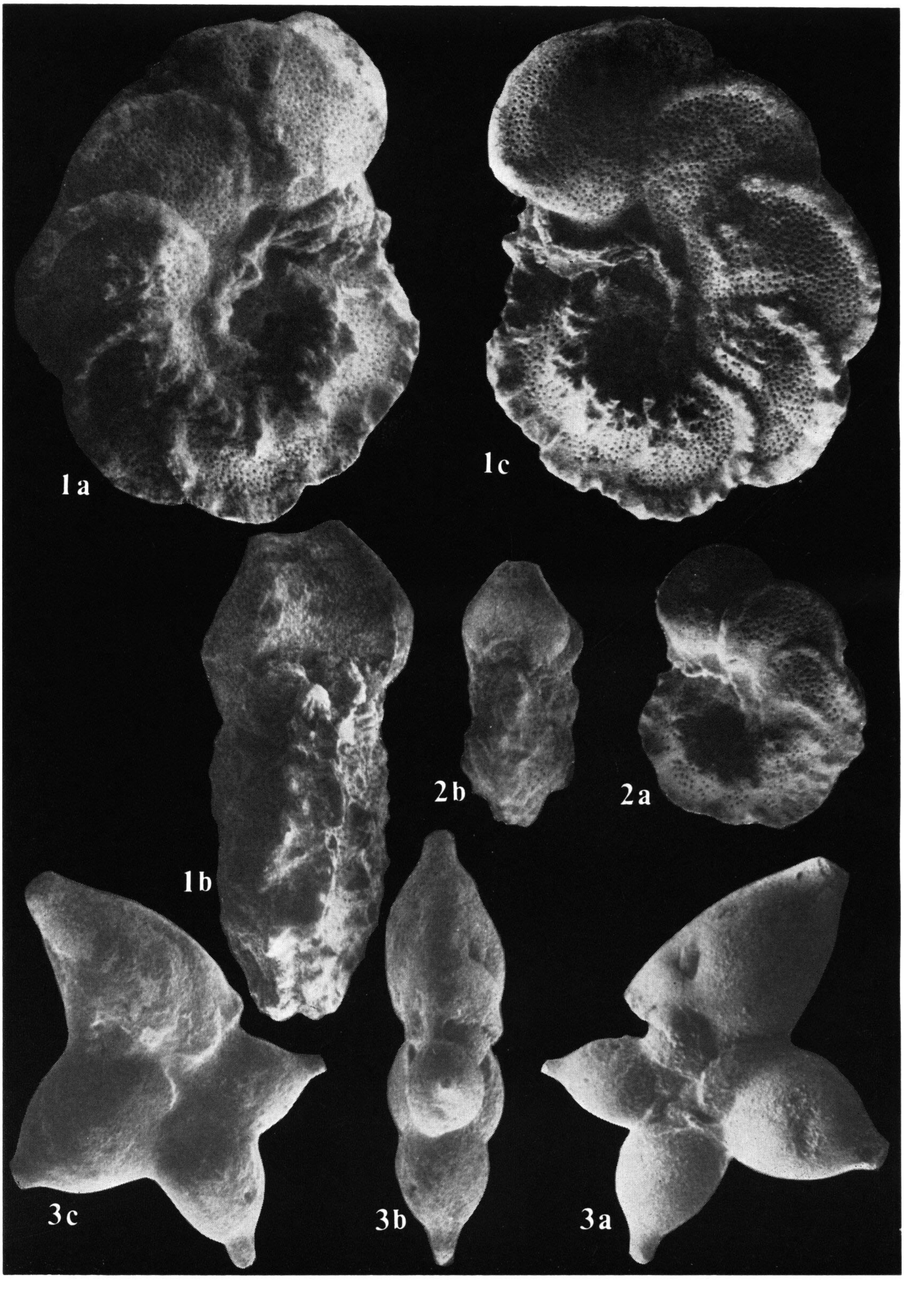
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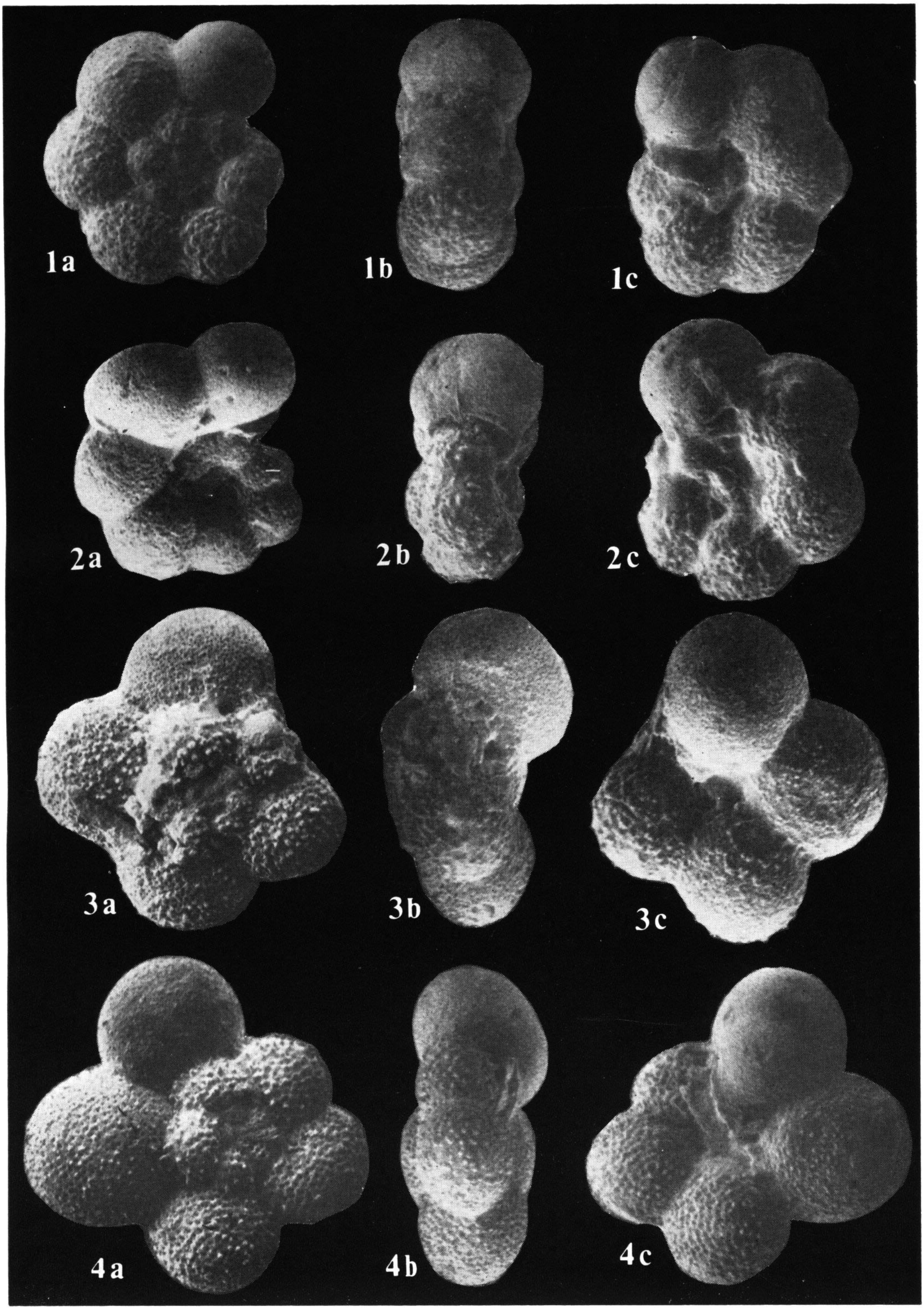
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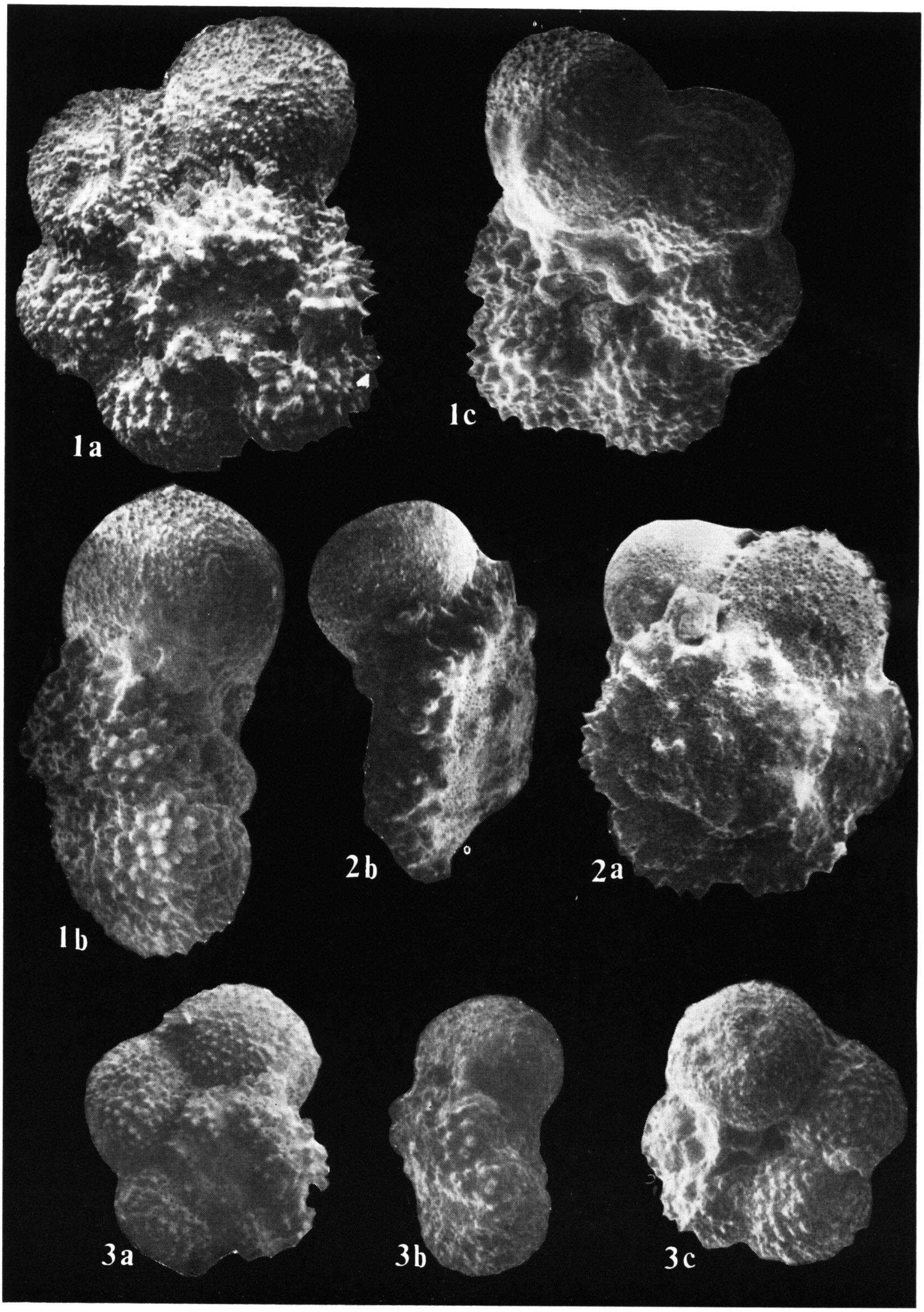
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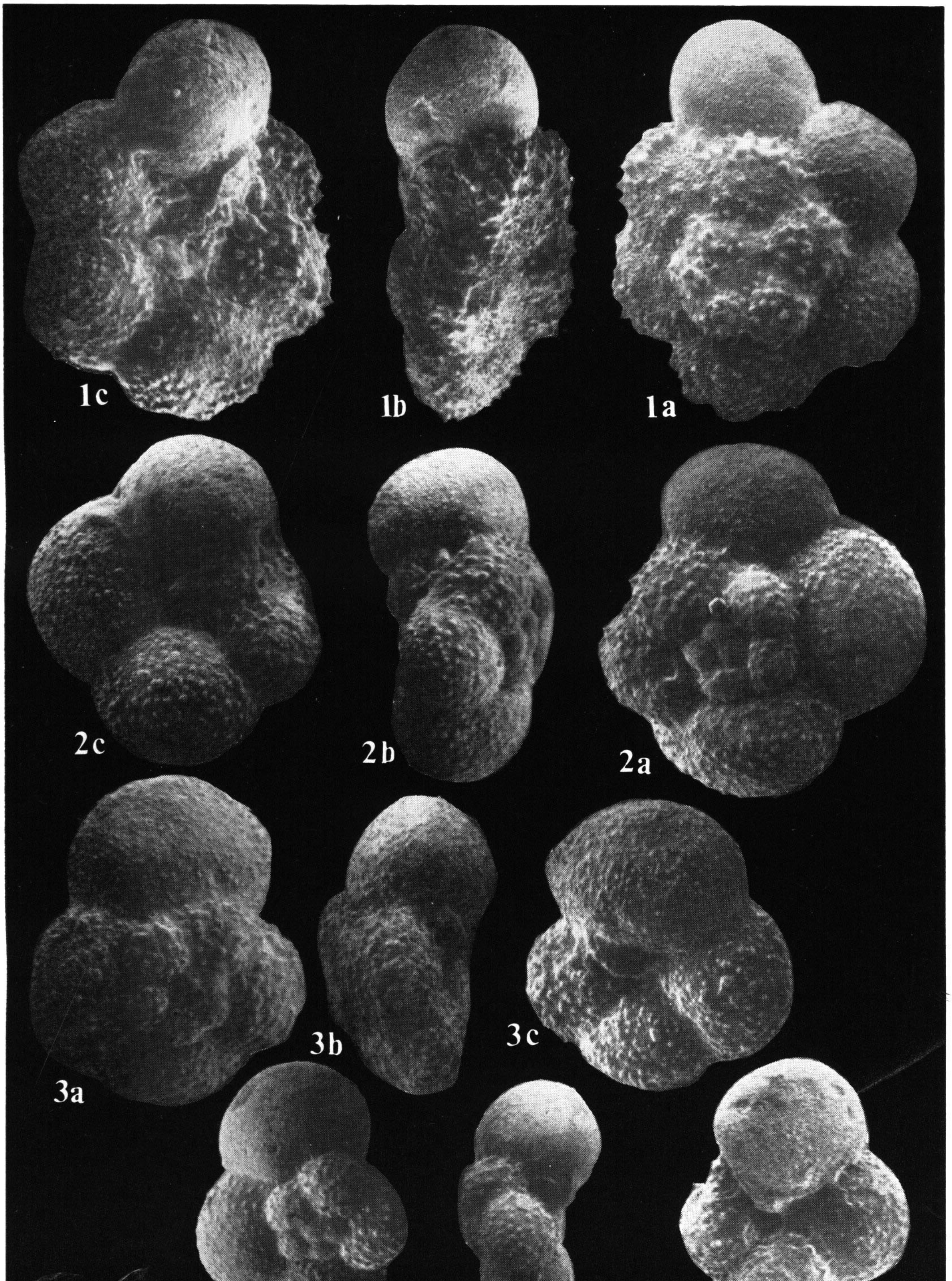
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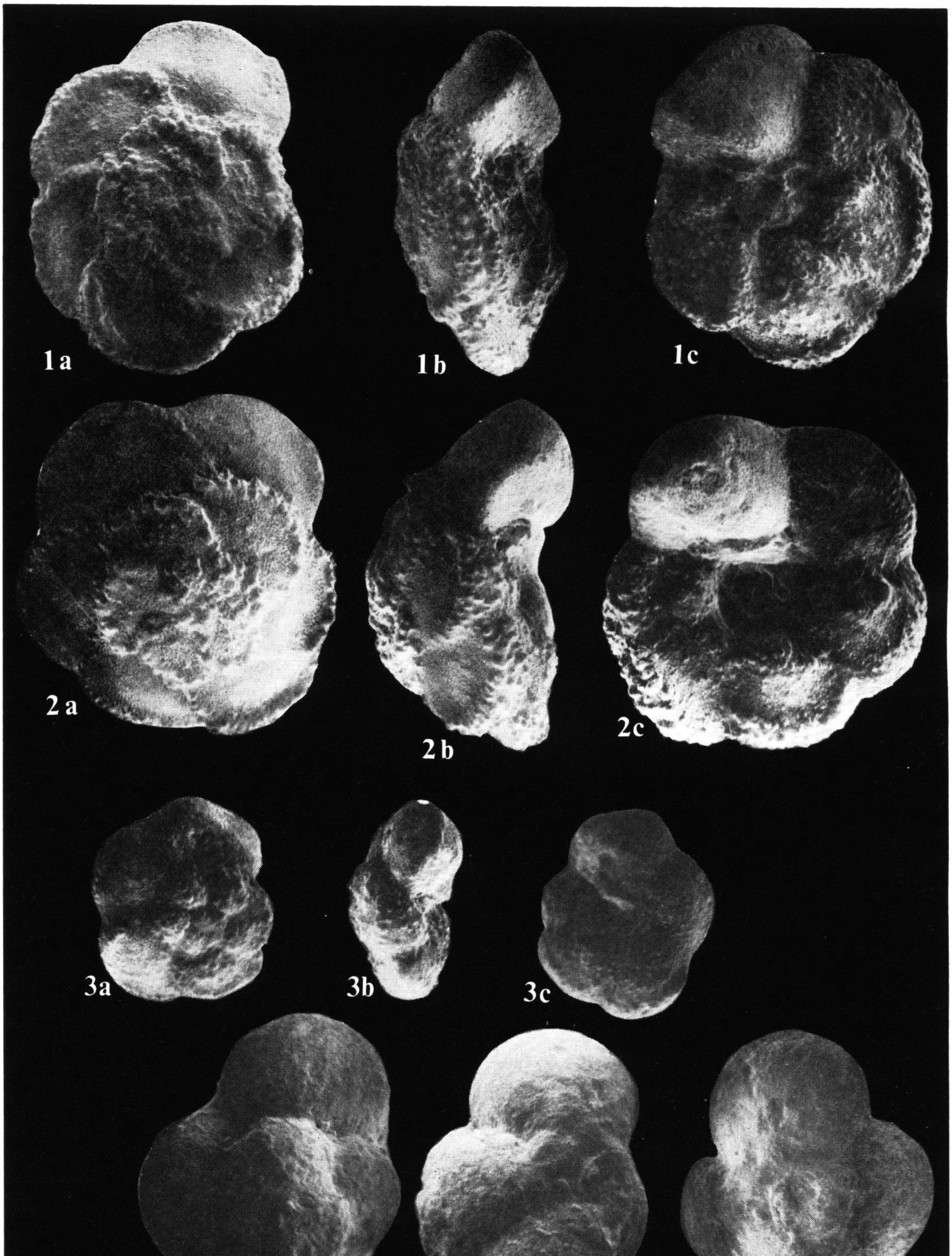
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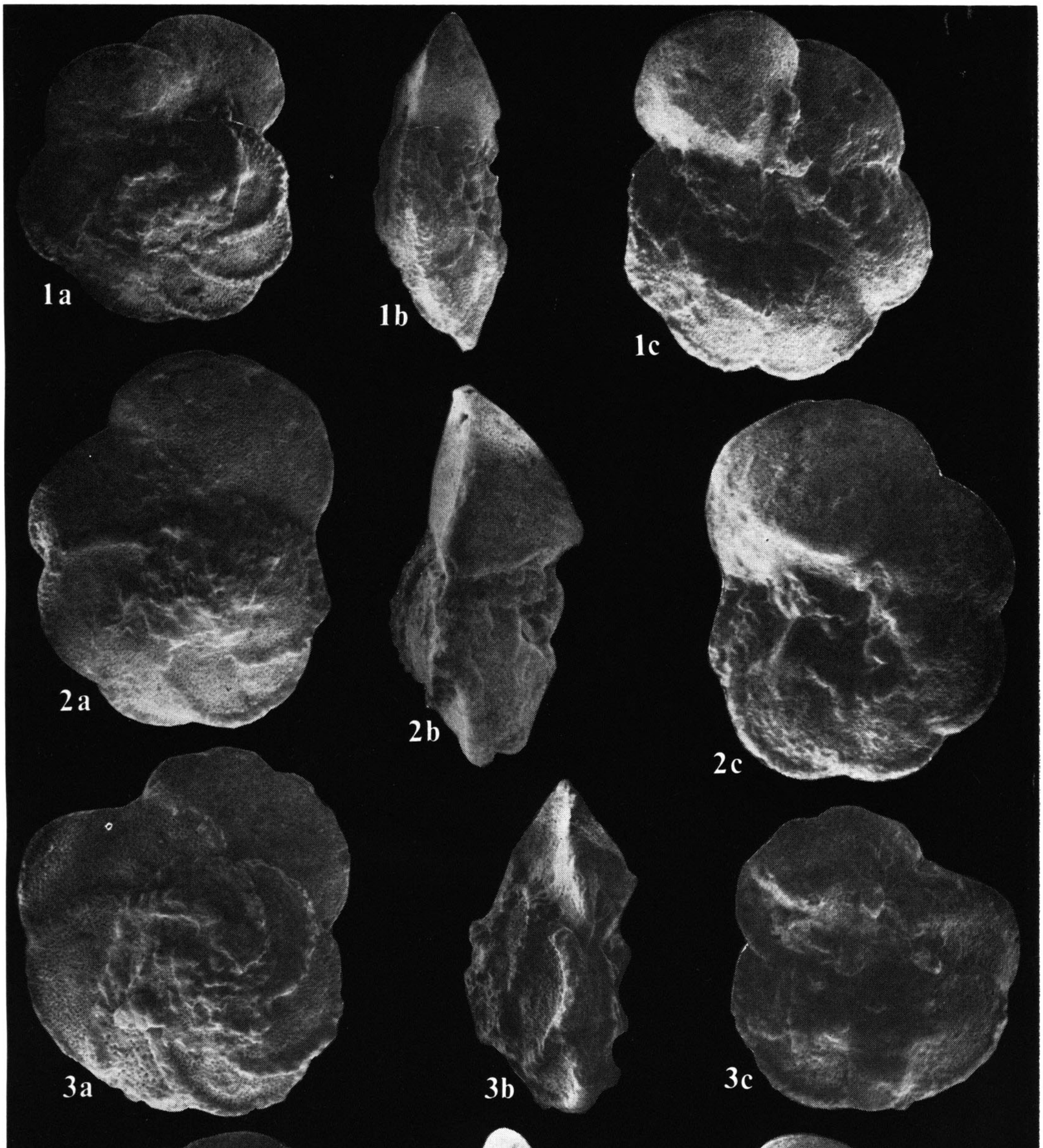
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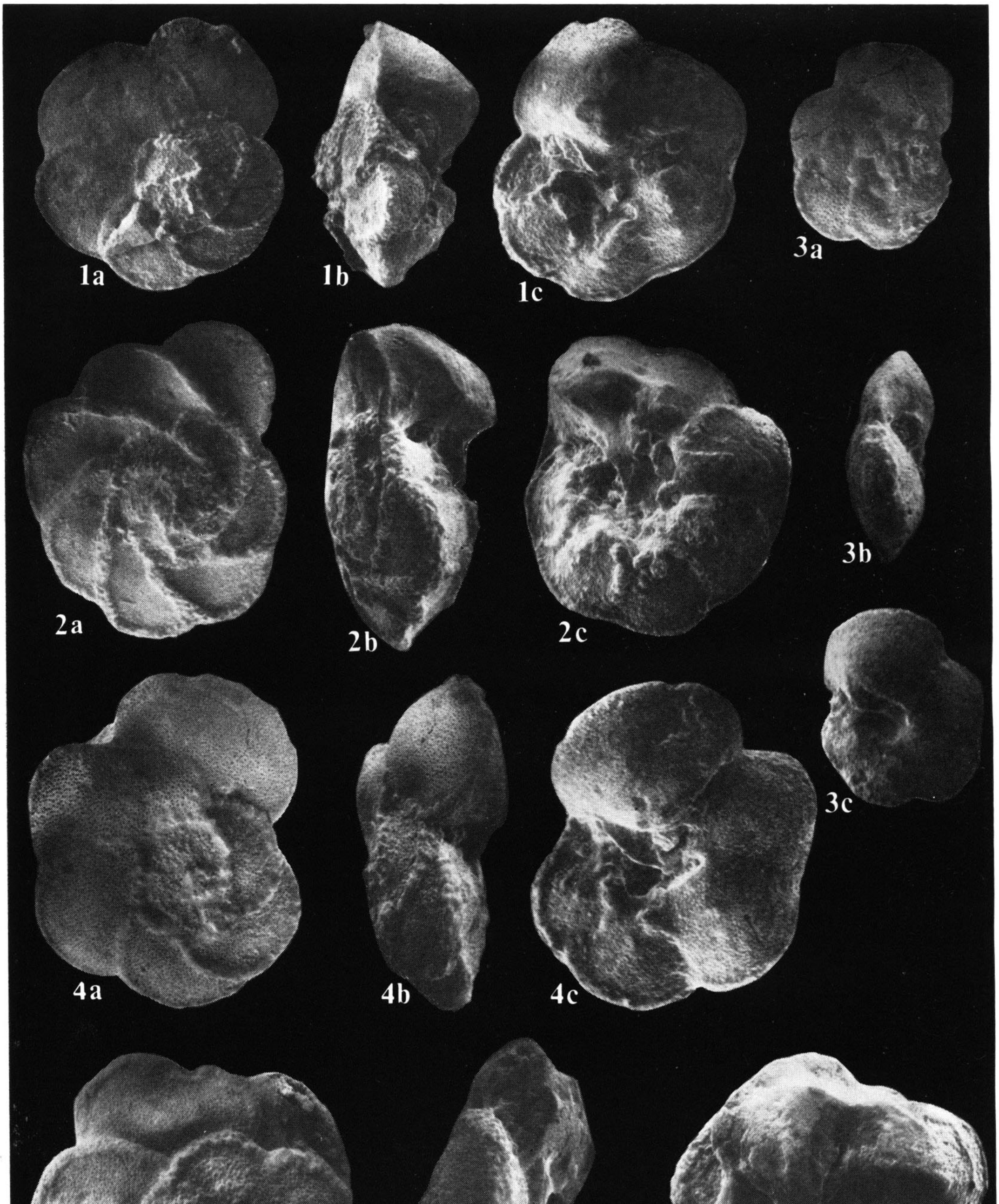
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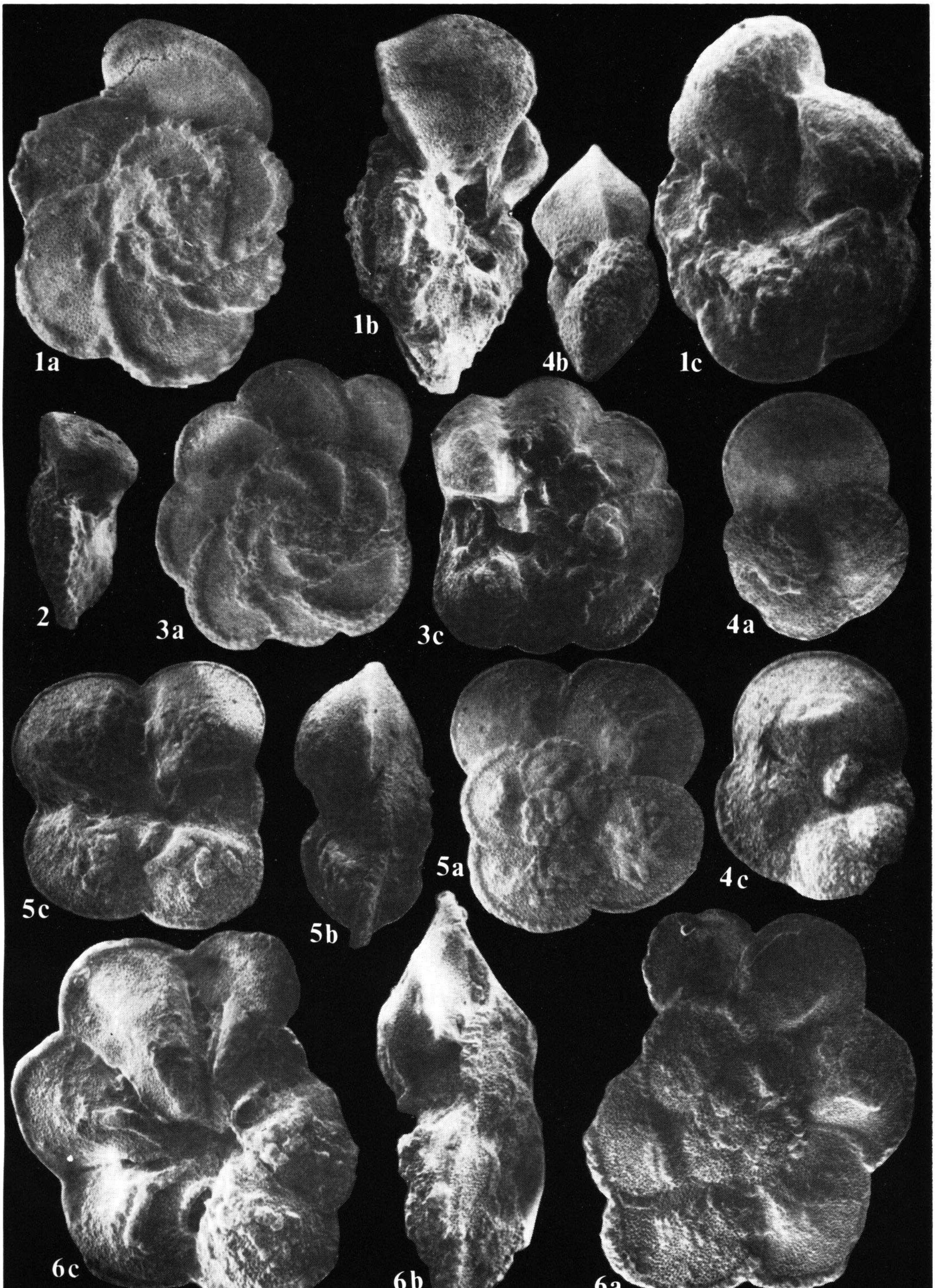
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