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TERTIARY LARGER FORAMINIFERA (FORAMINIFERIDA) FROM THE OGASAWARA ISLANDS, JAPAN

By

Kuniteru MATSUMARU

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TERTIARY LARGER FORAMINIFERA (FORAMINIFERIDA) FROM THE OGASAWARA ISLANDS, JAPAN

By

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Abstract

Sample collections from 236 stations (80 stations in Haha-Jima, 122 stations in Chichi-Jima, and 34 stations in Minami-Jima) and stratigraphic observation in three islands of the Ogasawara islands are examined in the present study of Tertiary larger foraminifers. Sixty-nine species of larger and smaller benthonic foraminifers from the middle Eocene Yusan and Okimura Formations, upper Eocene Sekimon Limestone of Haha-Jima, and lower to lower upper Oligocene Minamizaki Limestone of Chichi-Jima and Minami-Jima are described and illustrated. The new species are *Peelella boninensis*, *Boninella boninensis*, *Paleomiogypsina boninensis*, *Orbitogypsina vesicularis*, *O. globulus*, *Daviesina boninensis*, *Grzybowskia boninensis*, *Asterocyclina asterodisca*, *A. hahajimensis*, *Miogypsinella boninensis*, *Borelis boninensis*, *Bullalveolina boninensis*, *Quinqueloculina*? *boninensis*, *Cycloloculina boninensis*, and *Praerhapydionina boninensis*. The first four are type species of new genera.

Five larger foraminiferal assemblages were recognized in the respective sections of biostratigraphic sequence, based on the stratigraphic ranges of the 69 larger and smaller benthonic foraminiferal species, in association with 38 planktonic foraminifers. They are, from the oldest to youngest, (I) the *Nummulites aturicus-N. gizehensis-N. millecaput* Assemblage, (II) the *Nummulites pengaronensis-N. perforatus-Alveolina elliptica* Assemblage, (III) the *Biplanispira absurda-Pellatispira provalei* Assemblage, (IV) the *Eulepidina dilatata-E. ephippioides-Heterostegina borneensis* Assemblage, and (V) the *Miogypsinella boninensis-Spiroclypeus margaritatus-Austrotrillina howchini* Assemblage. *Asterocyclina asterodisca*, n. sp., and *A. hahajimensis*, n. sp. in Assemblages I and II, in close relation to *Asterocyclina habanensis* Cole and Bermúdez from the America-Caribbean region, and *Cyclorbiculina compressa* (d'Orbigny) in Assemblage V, suggest that foraminifers migrated to Ogasawara Islands, Japan from the America-Caribbean region. The five assemblages are also correlative with Tertiary a3, Tertiary a3, Tertiary b, Tertiary c and/or d, and Tertiary e1-4, respectively, based on the scheme of Letter Stages by Hashimoto and Matsumaru (1984). Also these assemblages are similar in those recognized in Eniwetok Atoll Drill Holes, as correlated later.

The five assemblages are also correlative with Zone P.13 or *Orbulinoides beckmanni* Zone, Zone P.13–14 or *O. beckmanni* Zone-*Truncorotaloides rohri* Zone, Zone P.15–17 or *Globigerinatheka semiinvoluta* Zone-*Turborotalia cerroazulensis* s.l. Zone, Zone P. 18?–21 or *Globigerina sellii* Zone-*Globorotalia opima opima* Zone, and Zone P.21?, respectively, based on the planktonic foraminiferal zonal scheme by Bolli (1957), Blow and Banner (1962), and Blow (1969, 1979), as modified by Toumarkine and Luterbacher (1985). Hence, these five assemblages are referable in the age to middle Eocene, late middle Eocene, late Eocene, early to late early Oligocene, and early late Oligocene, respectively. These are approximately the same as Letter Stages of the Far East in the Indo-Pacific region, and their planktonic foraminiferal equivalents.

The paleoecological environment is mainly neritic, and tropical or subtropical in character. The rate of sedimentation of the Tertiary marine sediments in Ogasawara Islands is calculated as follows: 22 m per Ma for the Yusan and Okimura Formations, 45 m per Ma for the Sekimon Limestone, and minimum 10 m per Ma for the Minamizaki Limestone (only 83 m thick exposed above sea level).

The evolution of the family Lepidocyclinidae is discussed regarding the possibility that Eocene *Orbitoclypeus* evolved into Oligocene *Eulepidina* during late Eocene (Fig. 20). The evolution of Oligocene *Nephrolepidina marginata* from either Eocene *Lepidocyclina mauretanica* or *L. pustulosa* and that of *Nephrolepidina marginata* into *Nephrolepidina tournoueri* during Oligocene-Miocene are also discussed (Fig. 22).

The early main evolutionary trend in the family Miogypsinidae is deduced from the biostratigraphic occurrence and the nepionic acceleration-retardation theory (Figs. 23 and 24): *Pararotalia mecatepecensis*→ *Paleomoiogypsina boninensis*→*Miogypsinella boninensis* during late early to early late Oligocene. Also

Boninella boninensis could evolve from *Paleomiogypsina boninensis* during early late Oligocene.

Introduction

The Ogasawara (Bonin) Islands lie in the Pacific Ocean, approximately from 1000 to 1300 km south-southeast of Tokyo (Fig. 1). The northern island of the Ogasawara Islands is Muko-Jima at 27°40′N.Lat. and 142°10′E.Long., and the southern island is Haha-Jima also called Hillsborough Island at 26°40′N.Lat. and 142°10′E.Long., (Fig. 2). Both islands are associated with other islands of various sizes extending in a north-south direction. The islands are the exposed part of the submarine Ogasawara Ridge. There are other Ogasawara Islands in the west, forming the Shichito-Iwo-Jima Ridge. They include Nishino-Shima (27°15′N.Lat. and 141°E.Long.) through Iwo-Jima (Sulphur Island) to Minami Iwo-Jima or

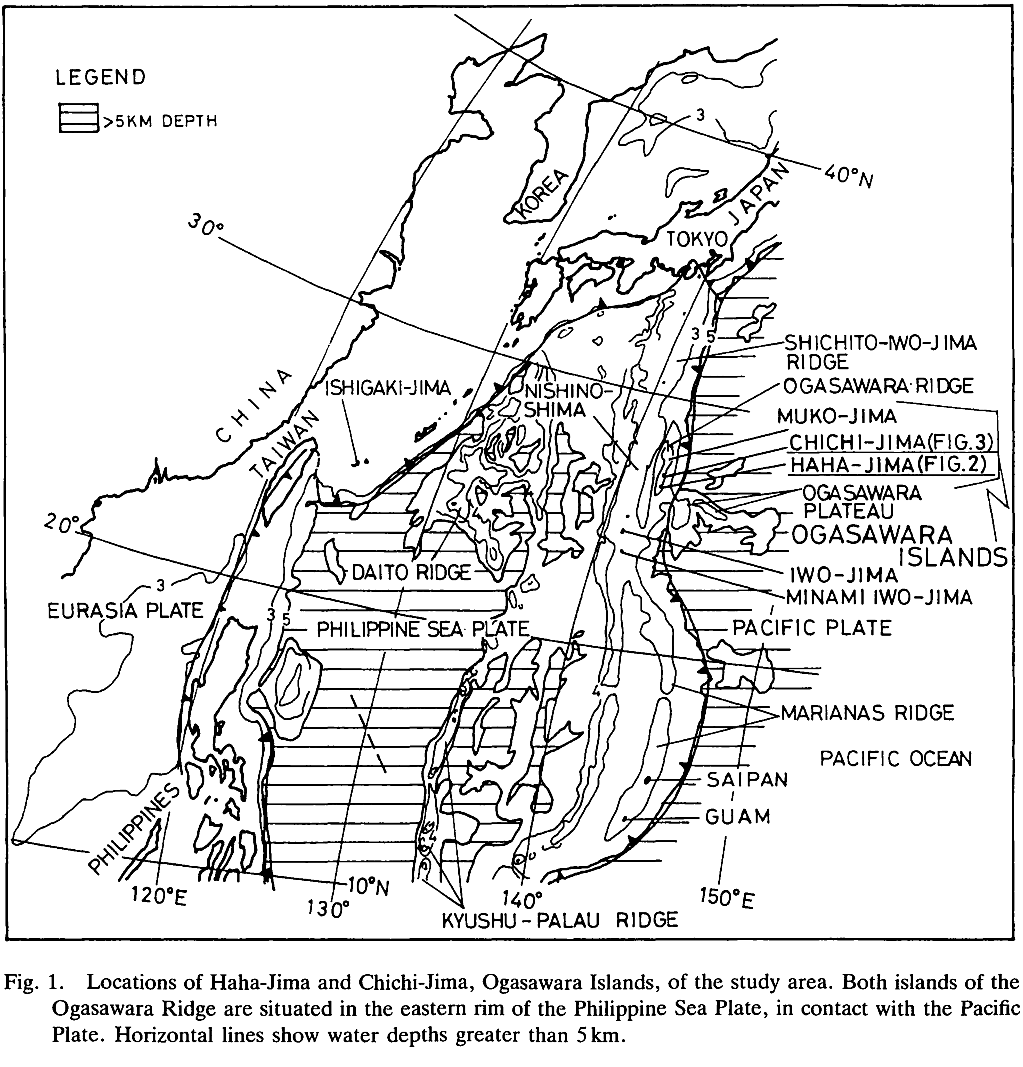

Fig. 1. Locations of Haha-Jima and Chichi-Jima, Ogasawara Islands, of the study area. Both islands of the Ogasawara Ridge are situated in the eastern rim of the Philippine Sea Plate, in contact with the Pacific Plate. Horizontal lines show water depths greater than 5 km.

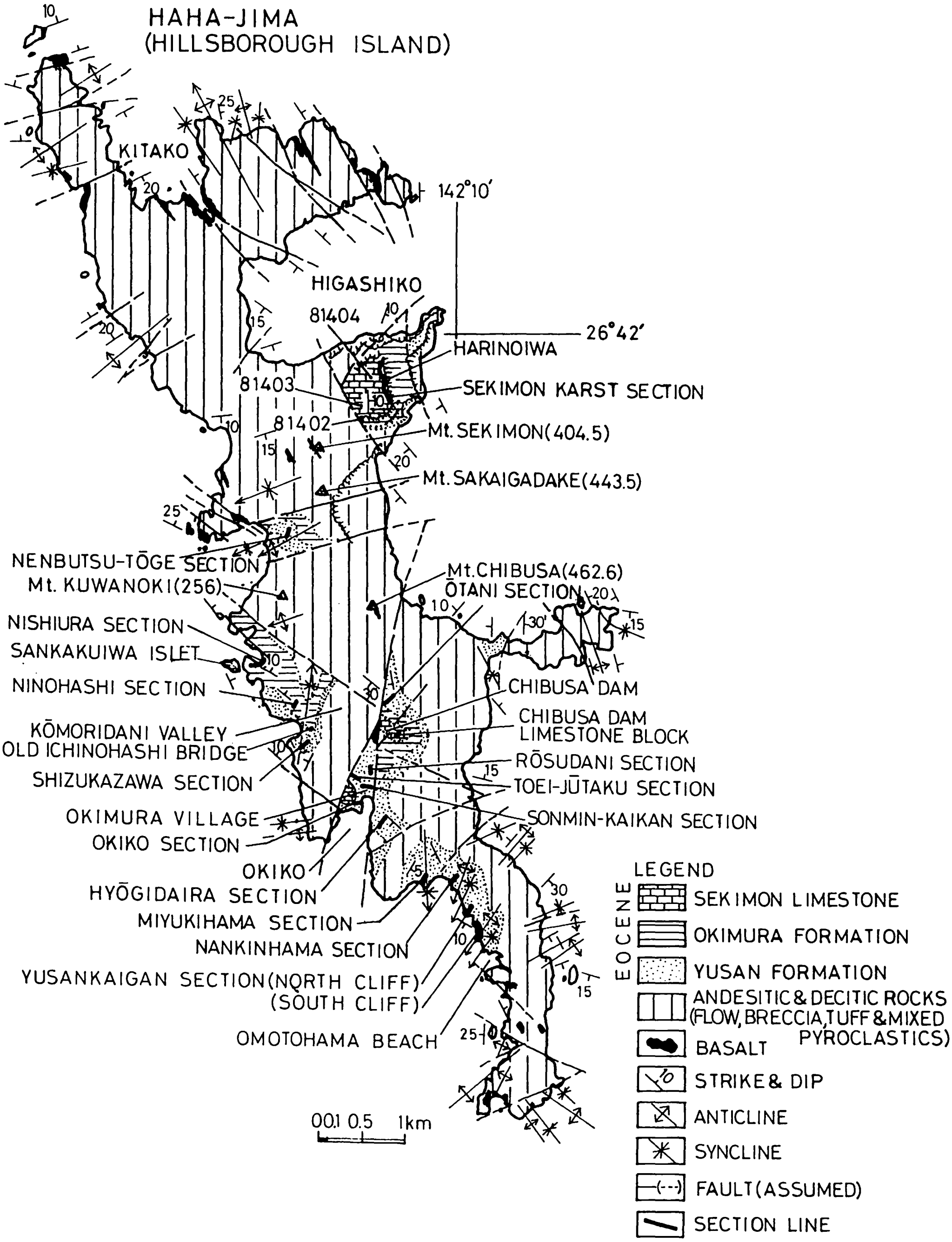

Fig. 2. Geological map of Haha-Jima, Ogasawara Islands, and locations of geological columnar sections (Figs. 5–6) of the middle Eocene Yusan and Okimura Formations, and upper Eocene Sekimon Limestone, and the locations of supplementary rock samples of the limestones.

South Sulphur Island (24°15′N.Lat and 141°30′E.Long.). The Ogasawara Plateau, which is about 200 km east-southeast of Haha-Jima, lies about 26°N.Lat. and 144°E.Long. The Izu-Mariana Trench lies almost 120 km east of the Ogasawara Ridge, and separates the Ogasawara Ridge and the Ogasawara Plateau. This Izu-Mariana Trench is regarded as a plate boundary between the Philippine Sea Plate in the west and the Pacific Plate in the east.

The largest and most populated Ogasawara Islands is Chichi-Jima (Peel Island, Fig. 3). Haha-Jima is the second in size and population. Field work in these islands is easy. The

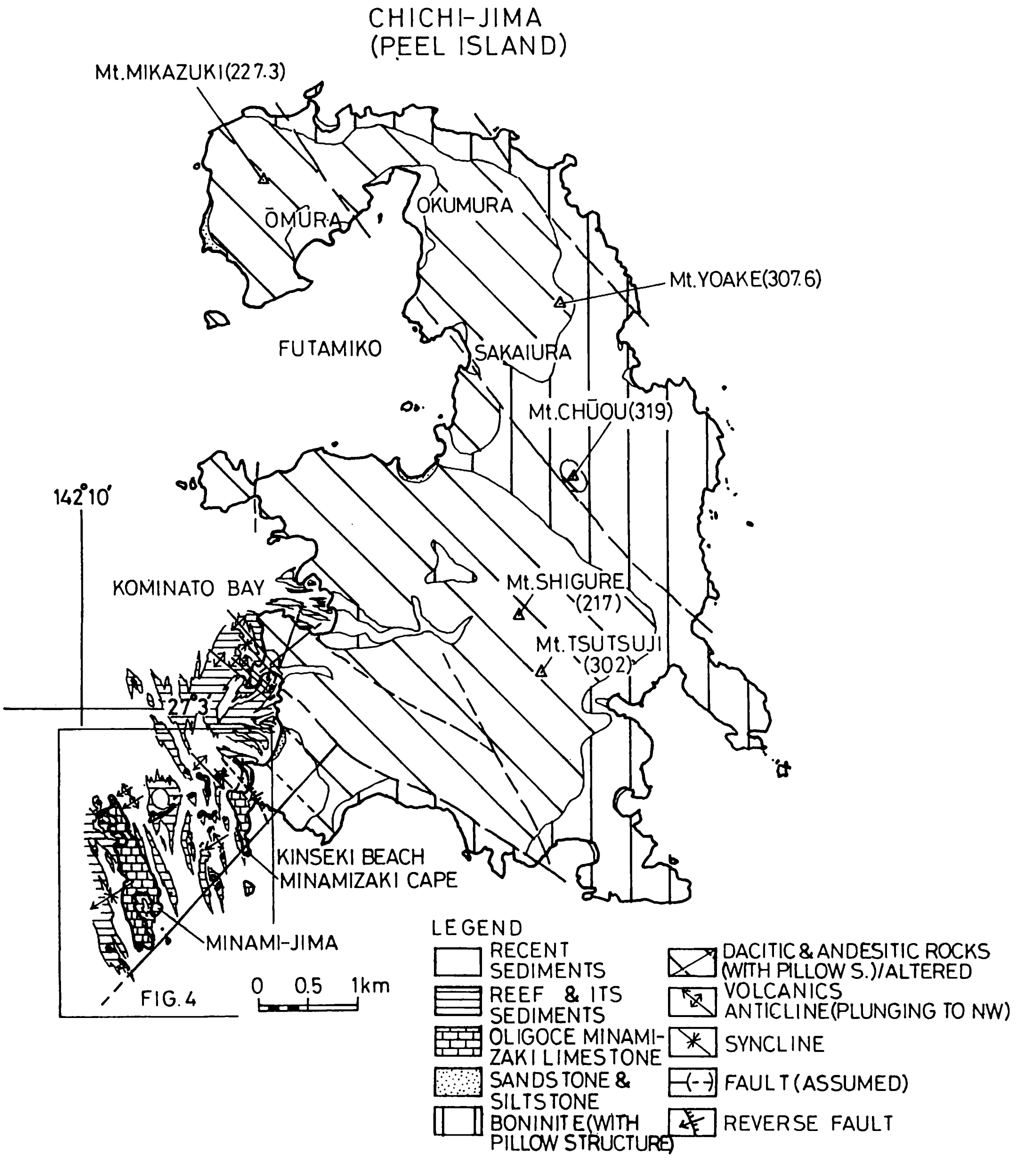

Fig. 3. Geological map of Chichi-Jima and Minami-Jima, Ogasawara Islands, showing the distribution of Holocene reefs and their sediments.

other islands, except for Iwo-Jima, are uninhabited, heavily forested or steep cliffs inland or along the seacoast. Field work in these uninhabited islands is difficult, so that little information about their geology or paleontology is available.

The present study is an introduction to the study of Tertiary larger foraminifers in sedimentary rocks of Haha-Jima, Chichi-Jima, and Minami-Jima. The paleontology deals with the systematic description of 49 genera, four of them new, and 69 species, 15 of them new. Genera are based mainly on a classification by Loeblich and Tappan (1988).

The faunal succession will be established from stratigraphic changes in lithofacies and fossil assemblages, and will be related to changes of environment and tectonic movement, and correlated with faunal successions in well known sections of the Indo-Pacific region. The evolution of certain larger foraminifers will be examined, and geologic structure will be described.

Progress of Research and Acknowledgements

The present study began with four weeks in the field in 1975, supported by the Educational Bureau of the Metropolis of Tokyo. The work continued for two weeks in 1976, supported by the National Science Museum, Tokyo. Foraminifers collected during this work were mentioned concisely in reports by Matsumaru (1976a, 1978) and Ujiié and Matsumaru (1977). Four weeks were spent in the field in 1993, supported by a Grant-In-Aid of the Ministry of Education, Japanese Government (Project No. 04640718). Samples from this work together with those collected in 1975 and 1976 form the basis for this report.

The late Dr. Haruyoshi Hujimoto and Dr. Wataru Hashimoto, both Emeritus Professors of Tokyo University of Education, kindly gave the author advice and encouragement. Prof. Hiroshi Ujiié, Ryukyu University, a former curator of the National Science Museum, Tokyo, provided founding and accompanied the author in 1976. Others who made the author's research possible include colleagues Dr. Ercüment Sirel and Dr. Evren Yazgan (M.T.A. Institution, Ankara), Prof. Izver Tansel and Prof. Engin Meriç (Istanbul University), during the scientific research in Turkey in 1992, supported by a Grant-In-Aid of the Japan Society for the Promotion of Science (JSPS); Prof. Lukas Hottinger, Universität Basel, chairman of UNESCO Project IGCP 286 and his colleagues, from 1990 to 1994; Prof. Ruggero Matteucci, and his colleagues, Università di Roma (La Sapienza), during a stay as Visiting Professor of the Università di Roma in 1993; and Dr. Dario Grignani (STIG, AGIP, Milano), for permission to study foraminifers in Dr. Alfredo Silvestri's collection. The author is also grateful to Dr. Izver Tansel, who provided much useful information on planktonic foraminiferal taxonomy and Dr. Alphonse Blondeau, Maitre de Conférences honoraire, Université Pierre et Marie Curie (Paris VI), Dr. Earl E. Brabb, Geologist Emeritus, U.S. Geological Survey, Menlo Park, California, Prof. Achille Sirotti, Università di Modena, Modena, and Prof. Tsunemasa Saito, Tohoku University, Sendai, who kindly provided comments on several scientific points in the paper.

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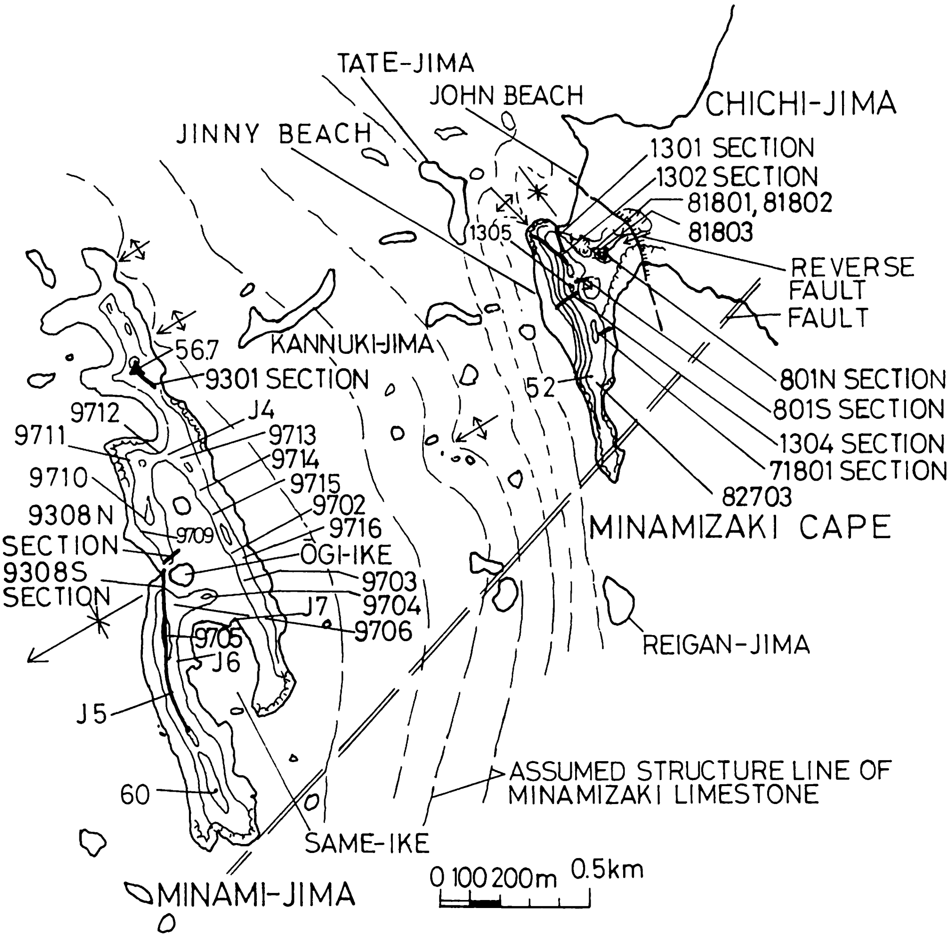


Fig. 4 Section localities and supplementary spot sample stations of foraminifera-bearing Minamizaki Limestone, Minamizaki Cape, Chichi-Jima and Minami-Jima, Ogasawara Islands.

Previous Studies

Yabe (1911) indicates that Tetsugoro Wakimizu was the first to find *Nummulites* on Haha-Jima. Yoshiwara (1902) is the first to mention and date (Eocene) *Nummulites* from this island, referring to literature sources. The rich foraminifer faunas soon attracted the attention of other workers, resulting in publications by Yabe (1911, 1920, 1921), Hanzawa (1947a, 1950), Saito (1962), Matsumaru (1976a, 1978, 1983, 1994), Konda and Okuda (1977), and Ujiié and Matsumaru (1977). Corals, echinoderms, mollusks, calcareous algae, and bryozoans were described by Yabe and Sugiyama (1935), Nishiyama (1937), Yabe and Hatai (1939), Iwasaki (1975), and others. The stratigraphy of the Ogasawara Islands has remained generally obscure (Asami, 1970), but there are some stratigraphical reports dealing with Chichi-Jima and Haha-Jima (Hanzawa, 1947; Iwasaki and Aoshima, 1970; Kuroda and Shiraki, 1975; Matsumaru, 1976a, 1978; Ujiié and Matsumaru, 1977). According to Kaneoka *et al.* (1970) and Tsunakawa (1983), K-Ar ages on boninite, andesite, dacite, and quartz dacite from Chichi-Jima vary from about 43.0 to 26.7 Ma, whereas those on andesite, basalt, and dacite from Haha-Jima are about 42.5 to 29.4 Ma. Accordingly, the main volcanic activity of Chichi-Jima and Haha-Jima is regarded as having occurred about 40 to 30 Ma ago (middle Eocene to late Oligocene), and no volcanic activity is observed at present.

Stratigraphy

The Tertiary marine sequence interfingering with or overlying the basal volcanic rocks of Haha-Jima and Chichi-Jima is described below (Figs. 2 and 3). The sequence in Haha-Jima is stratigraphically subdivided upward into the Yusan Formation (middle Eocene), the Okimura Formation (upper middle Eocene), and the Sekimon Limestone (upper Eocene), and that in Chichi-Jima and Minami-Jima is the Minamizaki Limestone (lower to lower upper Oligocene), subdivided into two members, which probably overlie conformably the Sekimon Limestone. The relationships of the Sekimon and Minamizaki Limestones are not possible to observe directly in the field, because Haha-Jima is about 50 km south from Chichi-Jima.

a) Yusan Formation

The Yusan Formation is proposed by Ujiié and Matsumaru (1977) for the series of nummulite-bearing volcanic breccia, tuff breccia, conglomerate, and medium- to coarse-grained sandstone, rhythmic alternation of coarse-grained sandstone to siltstone, and acidic tuff distributed in Yusankaigan Beach, about 2 km south-southeast of Okimura village, the only inhabited village of Haha-Jima (Figs. 2, 5 and 6).

Type locality: Seacoast cliff and beach along Yusankaigan, Haha-Jima.

Reference sections: Seacoast cliffs of Nankinhama and Miyukihama Beaches, respectively, north of Yusankaigan, Haha-Jima.

Distribution: The lower member of the Yusan Formation is narrowly distributed in the seacoast cliff and beach along Yusankaigan and Nankinhama. Yusankaigan is the southern limit of the formation. Also the member of the Yusan Formation cannot be traced north of Nankinhama.

The upper member of the Yusan Formation is widely distributed in the seacoast cliff and beach of Miyukihama, and in northern areas at Hyōgidaira, Ōtani, Shizukazawa, Ninohashi Bridge, and Nenbutsu-Tōge Pass. At Hyōgidaira, called the Yumemizaka slope by old villagers between Okimura and Miyukihama, is a nummulite-bearing medium-grained sandstone outcrop of the upper member of the Yusan Formation. This member of the Yusan Formation is distributed widely in the Ōtani area, 1 km north of Okimura village and 160 m above sea level; from Chibusa Dam to the Rōsuishi old quarry; and in the Rōsudani valley at Okimura village, 5 m above sea level. Also, this member can be traced from Shizukazawa, about 1 km northwest of Okimura village and 85 m above sea level, to Old Ichinohashi Bridge, and to Nenbutsu-Tōge Pass, 250 m above sea level. This pass is the gateway to Mt. Sekimon (404.5 m) and Sekimon Karst Plateau, and is at the northern limit of the member.

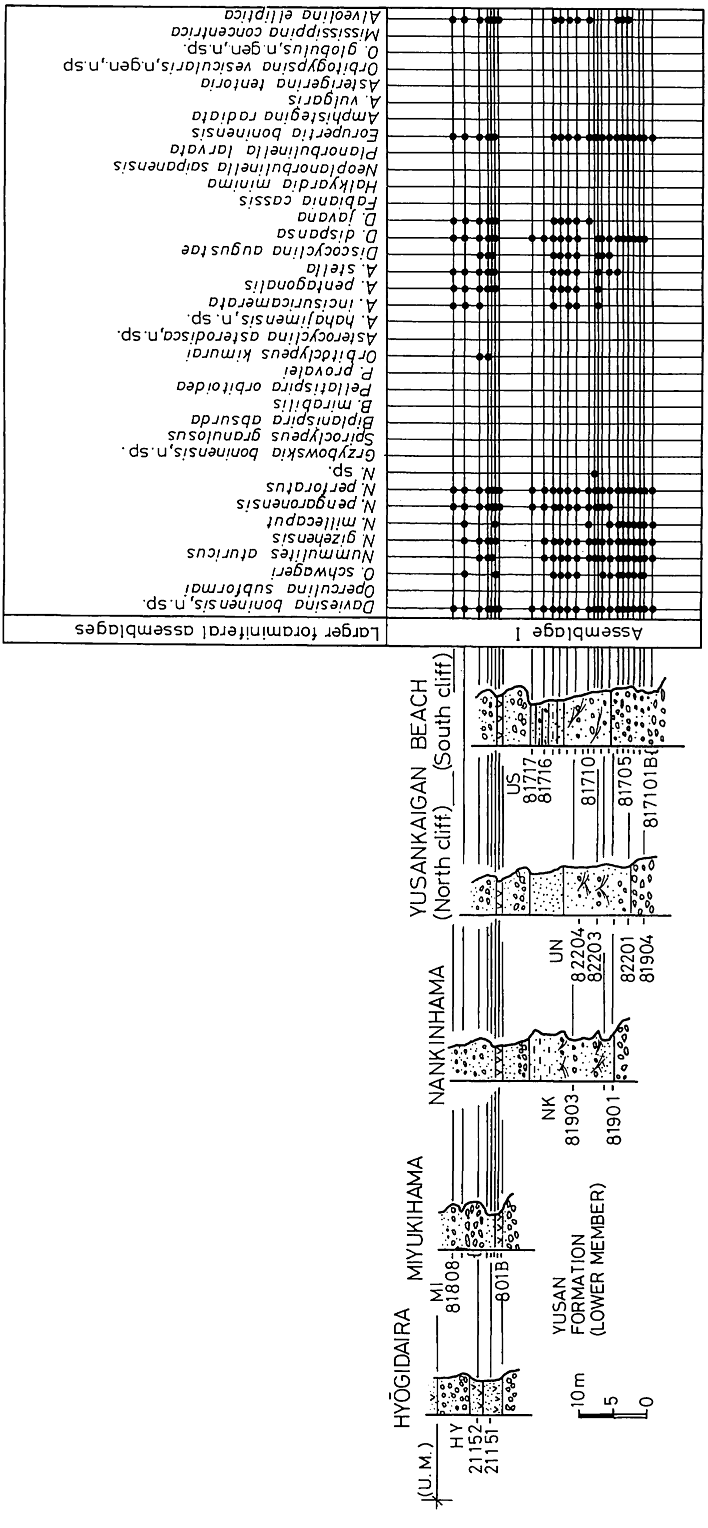


Fig. 5. Distribution of the larger and smaller foraminiferal taxa in Yusankaigan, Nankinhama, Miyukihama, and Hyōgidaira sections in Haha-Jima. The stratigraphy of columnar sections is explained in the text. Horizontal lines show the position of sampling stations from sections to the range chart, but not all the lines are numbered.

Lithology and faunal content: The lower member of the Yusan Formation along Yusankaigan Beach at the type locality is predominantly a nummulite-bearing sandstone. The lower consists of purple- to dark-colored volcanic breccia and tuff breccia, yellowish very coarse- to medium-grained sandstone with cobble-sized breccia showing cross lamination. The middle part has rhythmic alternation of sandstone and siltstone, and sandstone with breccia. The upper part has acidic tuff, sandstone with breccia, and conglomerate (Fig. 5). The white acidic tuff at the top of the cliff can be traced to Nankinhama and Miyukihama Beaches, and Hyōgidaira.

Both volcanic and tuff breccia, and sandstone of the lower member of the Yusan Formation, yield *Nummulites aturicus* Joly and Leymerie, *N. gizehensis* (Forskål), *N. millecaput* Boubée, *N. pengaronensis* Verbeek, *N. perforatus* (Montfort), *Asterocyclina incisuricamerata* Cole, *A. pentagonalis* (Deprat), *A. stella* (Gümbel), *A. asterodisca*, n. sp., *Orbitoclypeus kimurai* Matsumaru, *Discocyclina augustae* van der Weijden, *D. dispansa* (Sowerby), *D. javana* (Verbeek), *Daviesina boninensis*, n. sp., *Operculina schwageri* Silvestri, *Alveolina elliptica* (Sowerby), *Eorupertia boninensis* (Yabe and Hanzawa), mollusks, echinoids, bryozoans, scleractinian corals, and calcareous algae. In particular, *Asterocyclina asterodisca* and *Orbitoclypeus kimurai* occur in the upper beds of the lower member of the Yusan Formation. Generally, these fossils are in solid rock that needs to be quarried.

At the cliff of Miyukihama, the upper beds of the lower member of the Yusan Formation are well developed and have many larger foraminifers (Fig. 5; Table 1, MI 81805–81806), parallel to the bedding and intermixed with echinoids, mollusks, and calcareous algae. These beds are composed, in ascending order, of a grayish brown siltstone to very fine-grained sandstone 1 m thick and a white pumice tuff, tuffaceous siltstone, and tuffaceous fine-grained sandstone 1 m thick. Above these beds are 4.8 m of other pyroclastic-bearing sandstones and conglomerates with larger foraminifers. The uppermost sandstone can be traced to Hyōgidaira, where the sandstone is conformably overlain by tuffaceous sandstone of the basal bed of the upper member of the Yusan Formation (Fig. 5).

The upper member of the Yusan Formation is well developed at Ōtani, 1.1 km north of Okimura village. It is composed predominantly of a yellowish gray tuffaceous medium-grained sandstone, and tuff breccia with abundant *Nummulites* (Fig. 6, Table 1, OT72112B-72111). The top breccia is conformably overlain by yellowish gray tuffaceous sandstone of the Okimura Formation. At Shizukazawa, the upper member is composed mainly of very pale orange tuffaceous fine- to medium-grained sandstone about 7 m thick with abundant *Nummulites* (Fig. 6, Table 1, SZ72305). At Nenbutsu-Tōge Pass, the upper member of the Yusan Formation is composed of a nummulite-bearing, tuffaceous, medium-grained sandstone intercalated with a nummulite-bearing tuff breccia.

Geologic structure: The Yusan Formation has a homoclinal structure, and the general strikes and dips are N 28° to 30° W, with dips 15° to 20° SW at Yusankaigan Beach, and beds of the lower member are more than 23 m in total thickness. The strikes and dips are N 45° to 60° W with dips 10° to 15° SW at Nankinhama and Miyukihama Beaches and beds of the lower are 23 m and 7 m in thickness, respectively. The beds of the upper member at Ōtani strike N 10° to 15° W and dip 15° to 20° W, and they are 8 to 10 m in thickness.

b) Okimura Formation

The Okimura Formation was proposed by Ujiié and Matsumaru (1977) for calcarenite and/or predominantly planktonic foraminifer-bearing coarse- to medium-grained tuffaceous or calcareous sandstone near Okimura village. The rock was referred to locally as Rōsuishi (Rōsu stone).

Type locality: Rōsudani old quarry at the entrance of Rōsudani valley, northeast Okimura village, Haha-Jima (Figs. 2 and 6).

Reference sections: Seaside cliff of Okiko Port and along the stonesteps leading up to the Tsukigaoka Shrine, Okimura village.

Distribution, lithology, stratigraphy, and geologic structure: At the old quarry and Sonminkaikan, Okimura village, the Okimura Formation consists of predominantly yellowish gray tuffaceous sandstone. The sandstone is mainly massive and calcareous, but in places it is poorly stratified and in other places it grades into the mud-supported carbonate rock (wackestone, after Dunham (1962)'s classification) or marl. Both rocks contain foraminifers (Fig. 6, Table 1), mollusks, echinoids, bryozoans, and shark teeth. The Okimura Formation crops out in the cliff at Shichikenya, northwest of Okimura village, and it can be traced to Maehama Beach of Okimura village, the cliff of Okiko Port, Tsukigaoka Shrine and its surroundings.

At Toeijūtaku, west of Okimura village, the Okimura Formation comprises, in upward sequence, a yellowish gray massive, tuffaceous, *Globigerina*-bearing limestone; an alternation of medium-grained sandstone and fine-grained tuffaceous sandstone, with *Asterocyclina pentagonalis*, *A. stella*, and *Orbitoclypeus kimurai*; a white fine-grained tuff, and an alternation of lapilli-bearing coarse- to medium-grained sandstone and tuff breccia. The formation is about 20 m in total thickness.

In the area of Nishiura Beach and Sankakuiwa Islet, the Okimura Formation consists of a nummulite-bearing volcanic and tuff breccias; a white fine-grained tuff, and an alternation of tuffaceous limestone and lapilli-bearing sandstone, with abundant foraminifers (Fig. 6, Table 1). These beds are more than 16 m thick and are overlain comformably by the Sekimon Limestone.

The Okimura Formation overlies conformably the Yusan Formation in Rōsuishi quarry. The term Rōsuishi is used by old villagers for the yellowish brown massive calcarenite or sandy limestone, or weakly stratified calcareous and tuffaceous sandstone, which was used as building stone before World War II. The Okimura Formation is overlain conformably by the Sekimon Limestone at the top of the cliff in Okiko Port and Tsukigaoka Shrine. The Okimura Formation strikes N 10° to 40° W, and dips 8° to 10° SW at the seaside cliff of Okiko Port, and it is about 22 m in thickness.

c) Sekimon Limestone

The Sekimon Limestone has been proposed by Ujiié and Matsumaru (1977) for the informal name *Biplanispira*-bearing Limestone of Hanzawa (1947a) (Figs. 2 and 6).

Type locality: Sekimon Karst Plateau, Haha-Jima.

Reference sections: Precincts of Tsukigaoka Shrine, and the top part of the cliff at Okiko Port, Haha-Jima.

Distribution, lithology, stratigraphy, and geologic structure: The base of the Sekimon Limestone is distributed in the precincts and the environment of Tsukigaoka Shrine, southwest of Okiko Port, where it rests conformably on the Okimura Formation. The Sekimon Limestone consists mainly of a white or pink, compact or cavernous indurated the granular

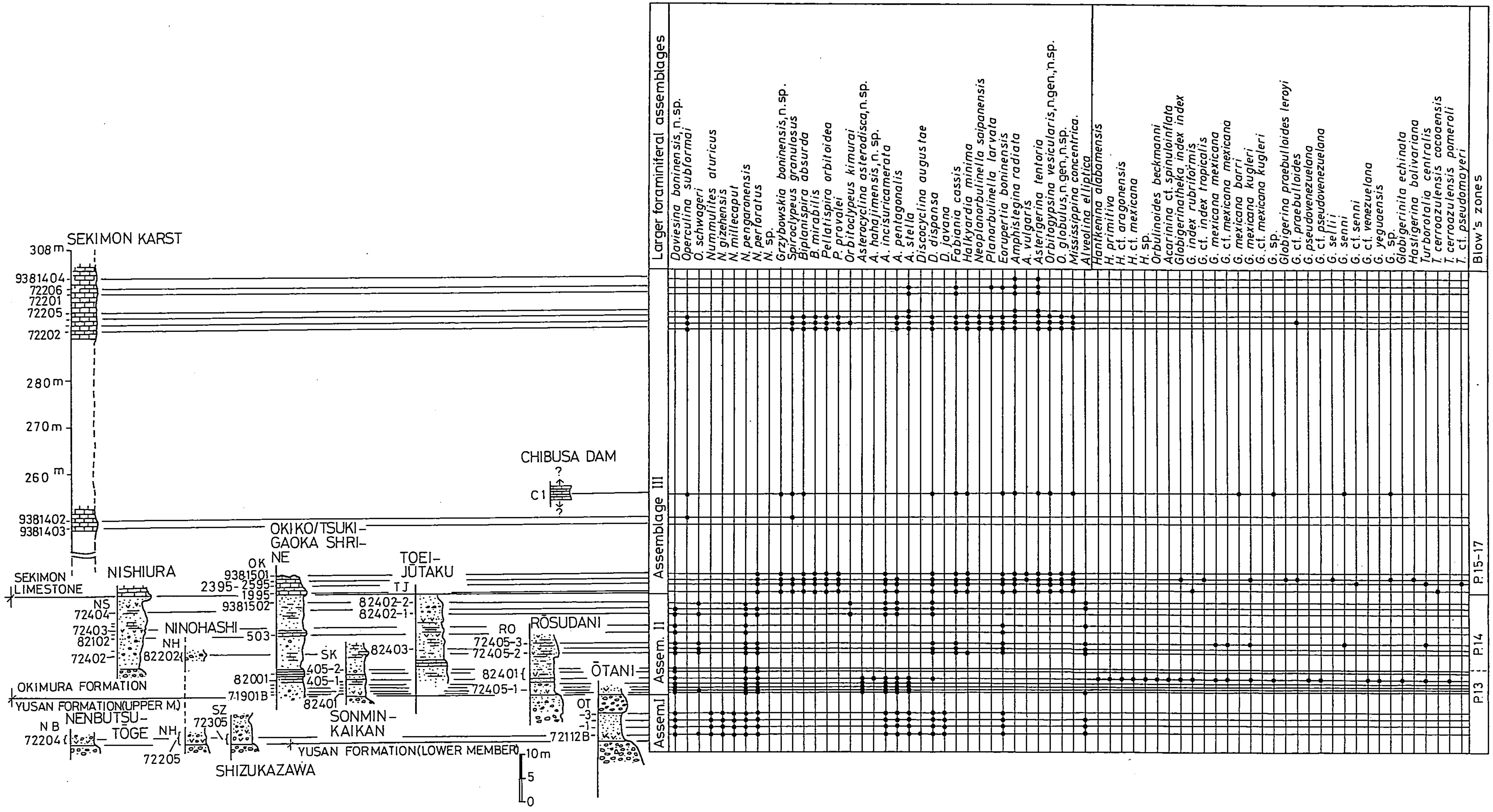


Fig. 6. Distribution of the larger and smaller, and planktonic foraminiferal taxa in Ōtani, Rōsudani, Toeijūtaku, Okiko/Tsukigaoka Shrine, Shizukazawa, Ninohashi, Nishiura, Nenbutsu-Tōge, and Sekimon Karst sections, and supplementary sample stations of Haha-Jima, Ogasawara Islands. The stratigraphy of the columnar sections is explained in the text.

material-supported carbonate rock (packstone, after Dunham's classification) and wackestone, with foraminifers (Fig. 6, Table 1), calcareous algae, and mollusks. Foraminifers are mostly intermixed with calcareous algae and mollusks in the packstone, but they are segregated in the wackestone.

At the vicinity of Chibusa Dam, north of Okimura village, the Sekimon Limestone can be seen as huge isolated, dislocated (?), blocks of limestone, with abundant foraminifers (Fig. 6). No outcrops of the formation occur in this area.

An extensive exposure of the Sekimon Limestone is in the Sekimon Karst Plateau, in the eastern foothills of Mt. Sekimon, where it forms needle-pointed rocks called locally Harinoiwa rocks. According to Hanzawa (1947a), the Sekimon Limestone in this area is established to be 100 m thick, and rests conformably on andesitic agglomerate and tuff, which presumably are the Okimura Formation. These rocks are the best exposed in relatively inaccessible cliffs along the Pacific Ocean where the Sekimon Limestone seems to rest conformably on the volcanic rocks, but the limestone at a distance appears to be about 135 m thick. The Sekimon Limestone in this area yields foraminifers (Fig. 6, Table 1), calcareous algae, corals, mollusks, echinoids, and bryozoans.

At the Sekimon Karst Plateau, it generally strikes NS and dips of 8° to 10°E, and in places it is composed of a weak undulation folding.

d) Minamizaki Limestone

This limestone has been proposed by Matsumaru (1976a) for a white-, buff- or pink-colored, compact or cavernous, indurated packstone, packstone to wackestone, grain-supported carbonate rock (grainstone, after Dunham's classification) or limestone conglomerate, coral biolithite, and algal biolithite, developing at and around Minamizaki Cape of Chichi-Jima, Minami-Jima, and surrounding islets (Figs. 3 and 4). The limestone is generally white and has a basal member which is pink.

Type locality: Minamizaki Cape, Chichi-Jima.

Reference section: Minami-Jima, 0.9 km west of Minamizaki Cape, Chichi-Jima.

Distribution, lithology, stratigraphy, and geologic structure: The Minamizaki Limestone is widely distributed in the Minamizaki Cape of Chichi-Jima, Minami-Jima, Tate-Jima, Kannuki-Jima, Reigan-Jima, Nihon-Iwa, and other small islets, and as a whole is regarded as a submerged karst topography from the viewpoint of the present, with summits sticking up from the sea as peninsulas, Jima (island), and islets. This largely submerged limestone is estimated to be a maximum of 244 m thick, based on correlation with the biostratigraphic units/beds of Eniwetok Atoll Drill Holes from 1978 to 2780 feet (Cole, 1957b, Tables 1 and 2).

Outcrops of the Minamizaki Limestone extend about 1.7 km in a south- to north direction; and about 1.6 km east-west. They attain a maximum height of about 60 m above sea level at Minamizaki Cape, and 60 m above sea level at Minami-Jima. The Minamizaki Limestone rests directly on unnamed altered andesite at Kinseki Beach (Fig. 3), and on boninite at John Beach (Fig. 4). Foraminifers indicate that the Minamizaki and Sekimon Limestones are represented generally in a continuous limestone section at Eniwetok Atoll, but the lithologic boundary of the units there has not been established. The units in the Ogasawara Islands may also be conformable, because foraminifers are close in age, and no zones are missing, but the volcanic rocks below the Minamizaki Limestone at Kinseki and John Beaches and their absence at Eniwetok Atoll indicates that volcanic lenses locally are

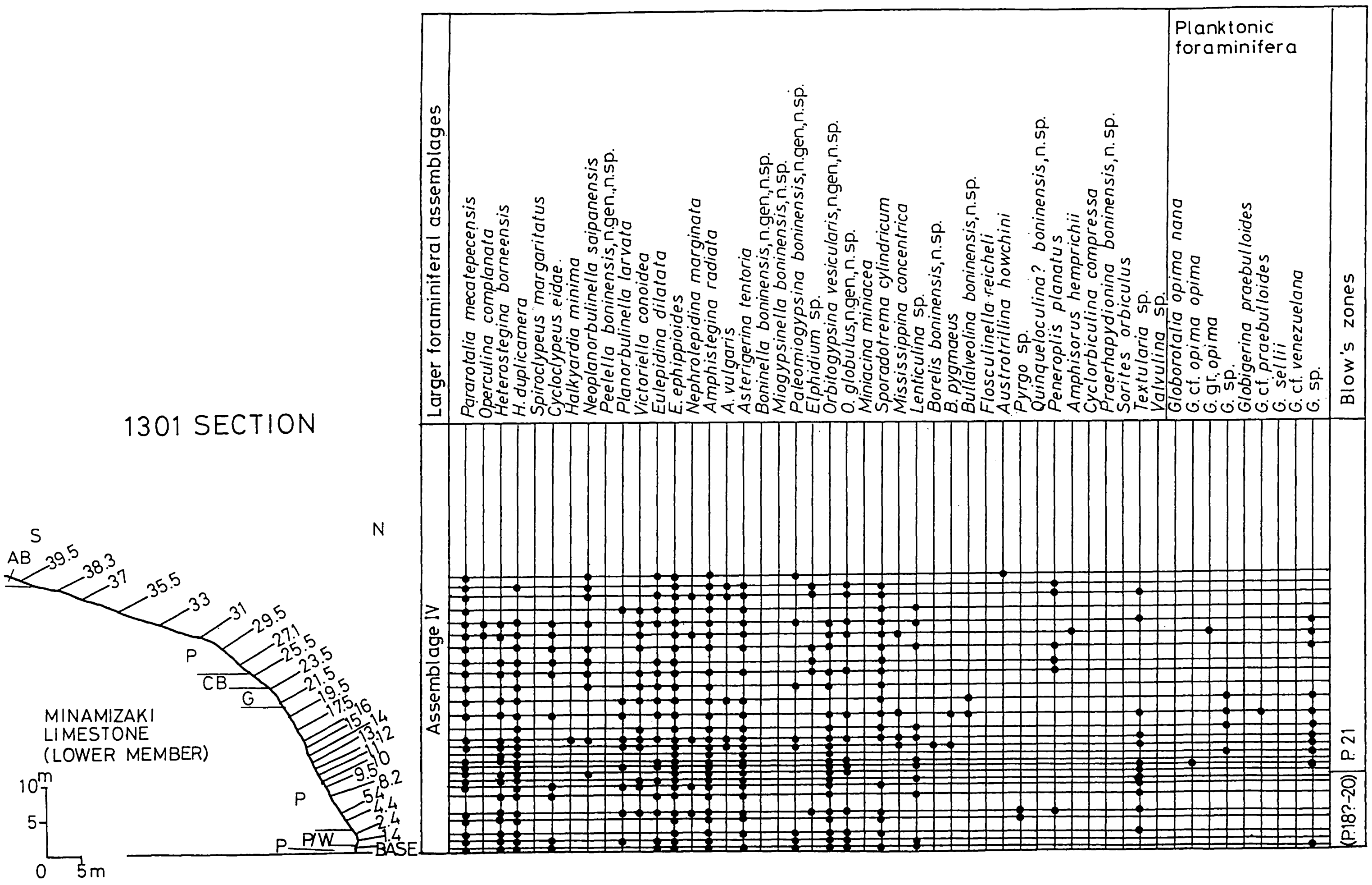


Fig. 7. Distribution of the larger, smaller, and planktonic foraminiferal taxa in 1301 section at Minamizaki Cape, Chichi-Jima, Ogasawara Islands. Symbols for lithologies are as follows: P, packstone; G, grainstone; P/W, packstone to wackestone; (P/G, packstone to grainstone); CB, coral biolithite; and AB, algal biolithite.

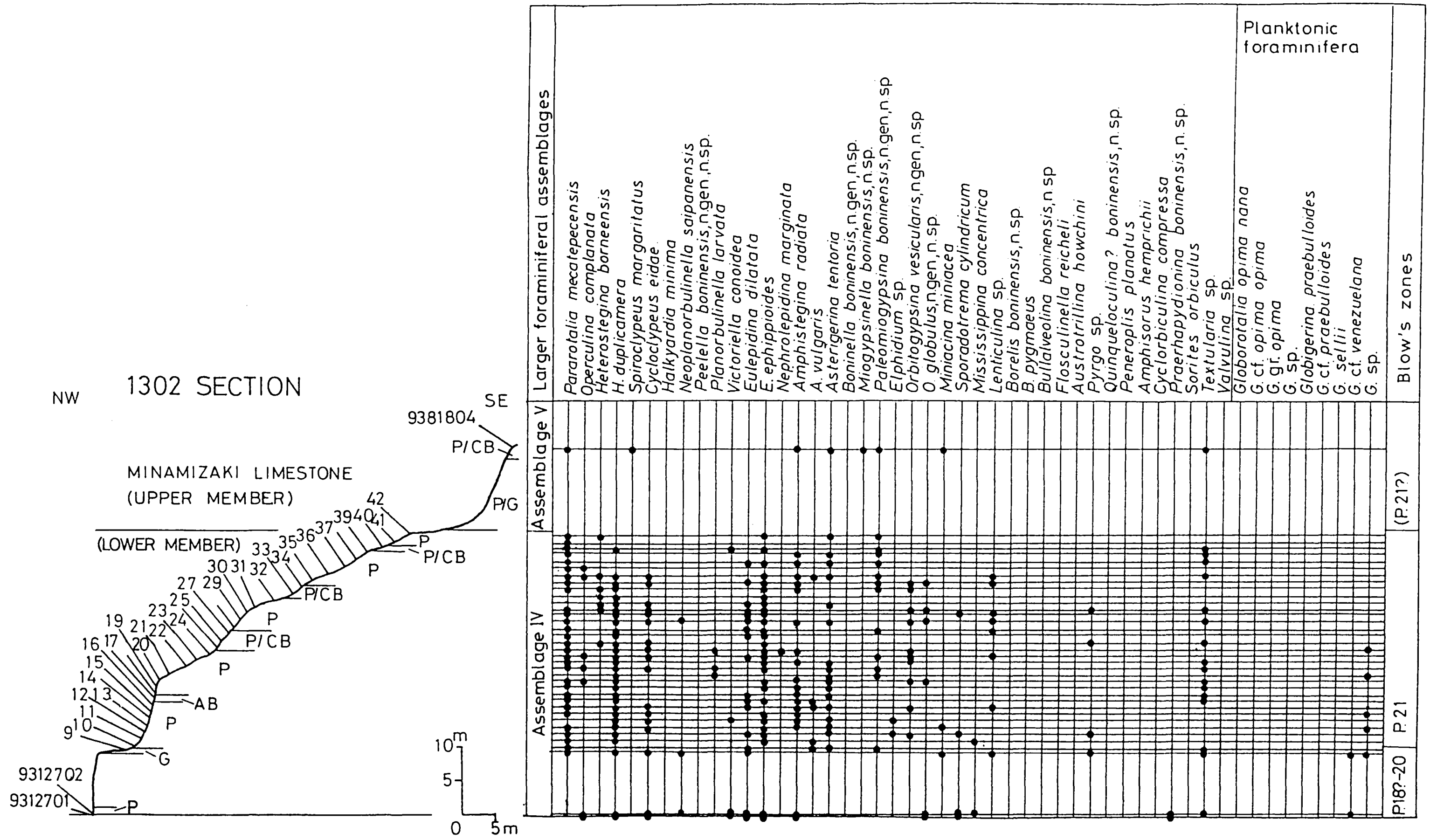


Fig. 8. Distribution of the larger, smaller, and planktonic foraminiferal taxa in 1302 section at Minamizaki Cape, Chichi-Jima, Ogasawara Islands. Symbols for lithologies are the same as those in Fig. 7.

between the two formations.

An informal lower member of the Minamizaki Limestone, in 801 South (S) and 71801 sections at Kinseki Beach, Minamizaki Cape, consists of a pink and/or white massive indurated packstone, grainstone, packstone to wackestone, and coral biolithite. The rocks contain foraminifers (Figs. 10 and 11, Table 2), calcareous algae, scleractinian corals, mollusks and bryozoans.

In 1301 section at John Beach, Minamizaki Cape, the lower member consists mainly of a buff, yellowish-white, and white, massive hard packstone, intercalated with similar-quality packstone to wackestone, grainstone, and porous coral biolithite, with a total thickness 40 meters. These beds also yields foraminifers (Fig. 7, Table 2), calcareous algae, corals, mollusks, and bryozoans.

In 1302 section (Fig. 8) between John and Jinny Beaches and 1304 section at Jinny Beach, Minamizaki Cape, the lower member consists of an alternation of a pink, buff, and white compact packstone and similar-quantity packstone to wackestone intercalated with grainstone or algal biolithite. These beds yield foraminifers (Figs. 8 and 9, Table 2), calcareous algae, corals, mollusks, bryozoans, and sponges.

The informal upper member of the Minamizaki Limestone at Minamizaki Cape overlies conformably the lower member and is recognized in sections 801 S, 801 North (N), 1302, and 1304, at stations (spot localities) 81801, 81802, 81803, 82703, and 1305 (Figs. 4, 8–10). It consists of white massive grainstone intercalated with porous coral biolithite in 801 S and 801 N sections, but consists mainly of an alternation of white cavernous compact packstone and/or porous biolithite and white massive bioclastic grainstone in 1302 and 1304 sections and other stations. The upper member, therefore, is softer, whiter, and more pure limestone than that in the lower member.

The top of the upper member of the Minamizaki Limestone forms angular, sharp peaks. These beds yield foraminifers (Figs. 8, 9 and 10, Table 2), scleractinian corals, calcareous algae, bryozoans, echinoids, and mollusks.

The Minamizaki Limestone at Minamizaki Cape generally strikes N 18° to 30° E, and dips of 20° to 45° SE at John Beach, the northern limit of the formation and N 30° to 55° W, with dips of 5° to 8° SW along 0.4 km of Jinny Beach. Thus an anticline, plunging to the southeast, is developed in the northwest corner between John and Jinny Beaches of the cape. Overall, the lower member of the Minamizaki Limestone at Minamizaki Cape is more than 43 m thick, and the upper member of the limestone is more than 17 m thick.

The Minamizaki Limestone also covers Minami-Jima (Fig. 12) where the same members as those at Minamizaki Cape are exposed. The only access to this island is at Same (shark)-Ike (pond). Topographically, the limestone there forms four doline-ponds along a main island axis of north-northwest to south-southeast. Of these, there are two inland ponds, called Inyou-Ike (Asami, 1970) or Ōgi-Ike, whereas the others are submerged dolines, and one of those is Same-Ike.

The lower member of the Minamizaki Limestone on Minami-Jima is generally pink or white massive and compact packstone, yielding foraminifers (Fig. 12, Table 3), calcareous algae, scleractinian corals, bryozoans, echinoids, and mollusks. The upper member consists of grainstone, packstone, packstone to grainstone, and contains a similar fauna (Fig. 12, Table 3).

The general strikes and dips of the Minamizaki Limestone in Minami-Jima are N 60° to

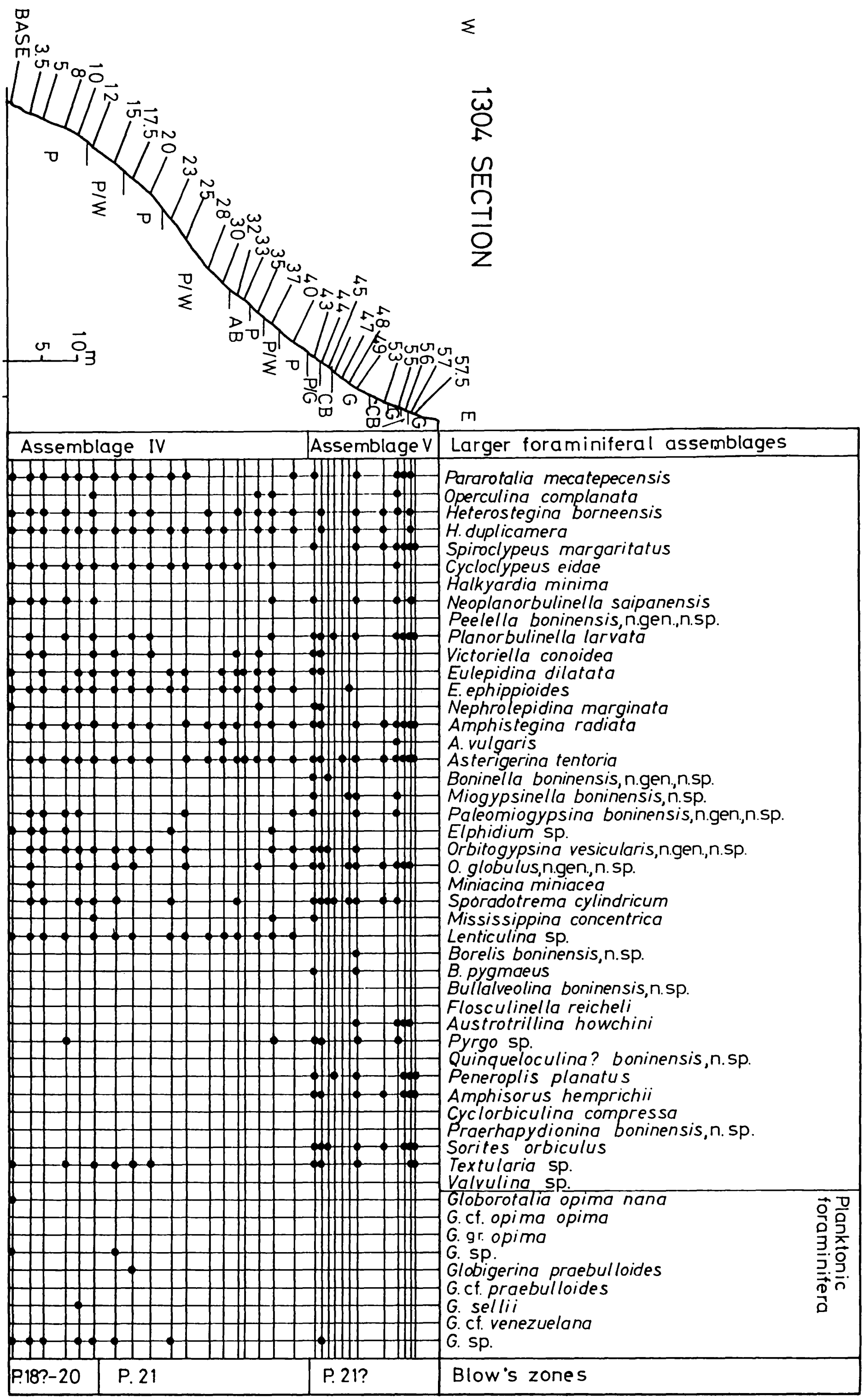


Fig. 9. Distribution of the larger, smaller, and planktonic foraminiferal taxa in 1304 section at Minamizaki Cape, Chichi-Jima, Ogasawara Islands. Symbols for lithologies are the same as those in Fig. 7.

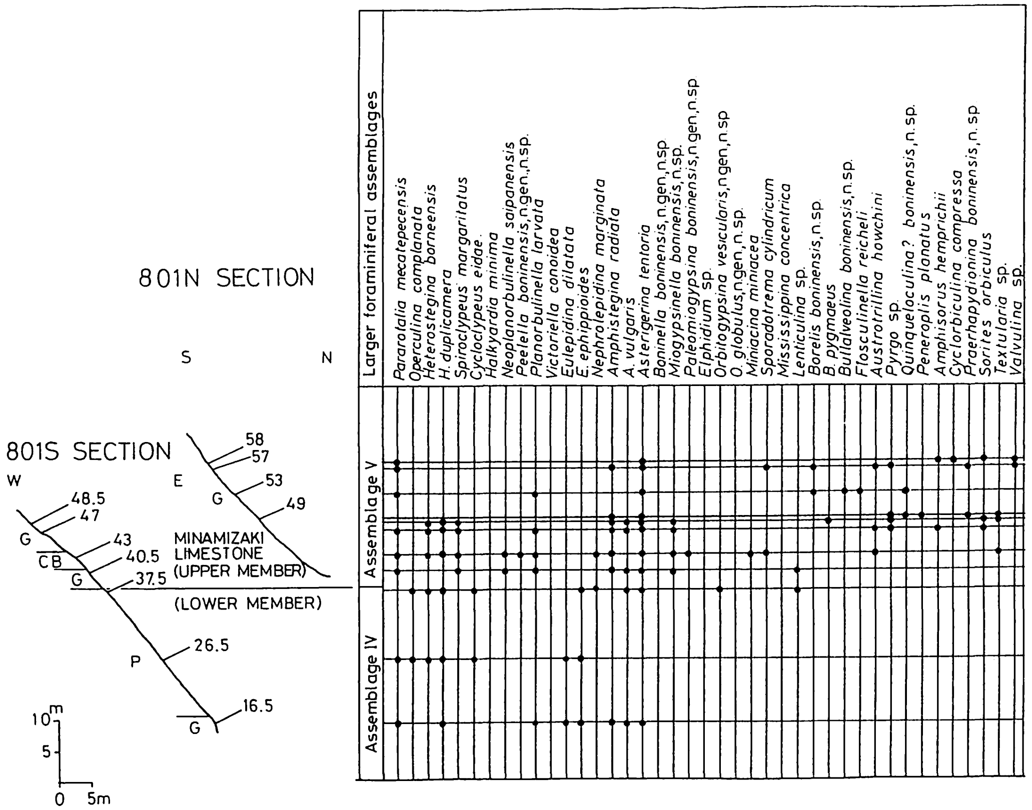


Fig. 10. Distribution of the larger and smaller foraminiferal taxa in 801S and 801N sections at Minamizaki Cape, Chichi-Jima, Ogasawara Islands. Symbols for lithologies are the same as those in Fig. 7.

65° W, with dips of 5° to 8° SW at Ōgi-Ike and the northern part of the island, whereas they are N 30° to 50° E, with dips of 5° to 8° NW at Same-Ike Bay and surroundings. A syncline extends in NE-SW direction, and has southwestward plunging axis.

The lower part of the lower member is not exposed on Minami-Jima. Only about 20 m of the member crops out above sea level. The upper member is more than 40 m thick.

Samples used in the Present Study

A total of 236 samples of sandstone and/or tuff breccia, siltstone and limestone were collected, weighing from one to three kilograms. Of these, 64 were disaggregated using sodium sulfate, washed on a 200-mesh screen and dried. Samples containing a large number of foraminiferal specimens were divided with a sample splitter, and all specimens were picked up, selected, and identified. In order to observe the inner structure of free specimens, more than 1600 thin sections were made. An additional 2120 thin sections were made to examine foraminifers in limestone.

Faunal Succession

The Yusan Formation, the Okimura Formation, the Sekimon Limestone, and the Minamizaki Limestone abundantly yield larger foraminifers, in association with smaller benthonic and planktonic foraminifers. From 236 samples, 69 species, with 15 new species, belonging to 49 genera, with 4 new genera, of larger and smaller benthonic foraminifers were identified, and described, and the stratigraphic distribution of these species in several sections is shown in Figures 5–12 and Tables 1–3. From 30 samples, 38 species and subspecies belonging to 9 genera of planktonic foraminifera were identified and shown in Figures 14–19. The stratigraphic distribution of these species in some sections is shown in Figures 6–9, 11 and Tables 1–3. The ranges of taxa of larger and smaller benthonic and planktonic foraminifers are shown on Figure 13. Planktonic foraminiferal zones are also shown on Figure 13 based on a correlation between the middle Eocene to lower upper Oligocene zones of the present areas and tropical-subtropical zones of Bolli (1957), Blow and Banner (1962), Blow (1969, 1979), Toumarkin and Luterbacher (1985), and Bolli and Saunders (1985).

The result of the present study indicates that the larger foraminifers from the Yusan Formation, the Okimura Formation, the Sekimon Limestone, and the Minamizaki Lime-

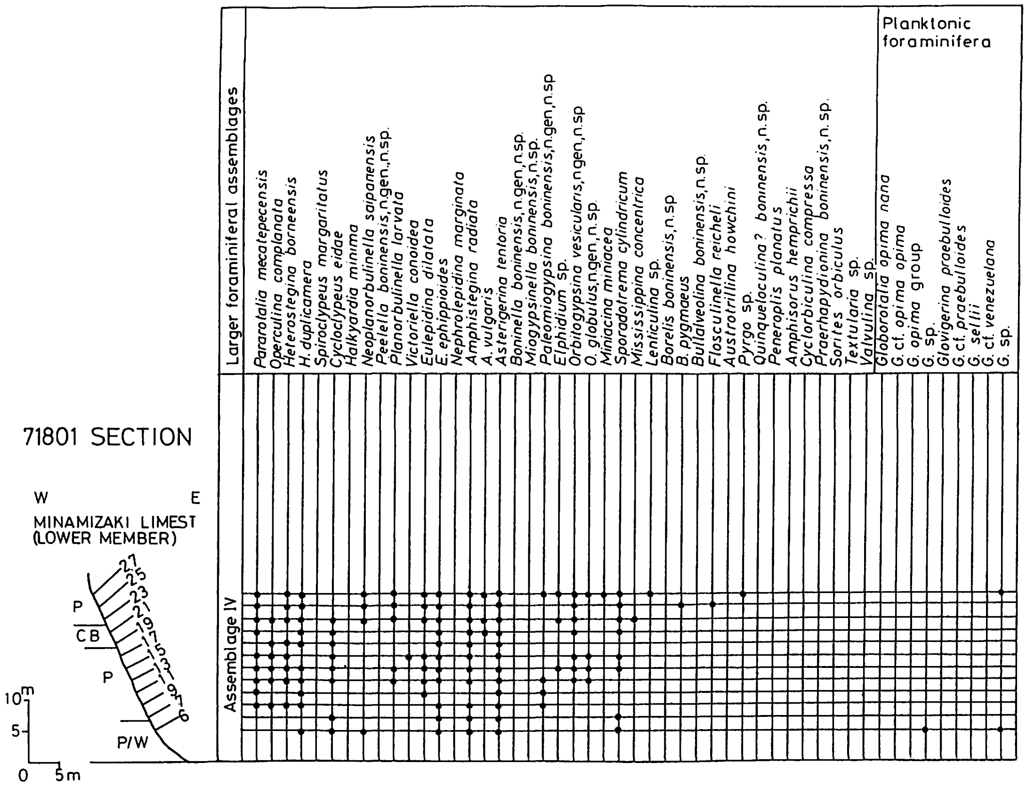


Fig. 11. Distribution of the larger, smaller, and planktonic foraminiferal taxa in 71801 section at Minamizaki Cape, Chichi-Jima, Ogasawara Islands. Symbols for lithologies are the same as those in Fig. 7.

stone can be grouped into the following five faunal assemblages, in upward sequence: *Nummulites aturicus-N. gizehensis- N. millecaput* (I), *Nummulites pengaronensis-N. perforatus- Alveolina elliptica* (II), *Biplanispira absurda-Pellatispira provalei* (III), *Eulepidina dilatata- E. ephippioides-Heterostegina borneensis* (IV), and *Miogypsinella boninensis-Spiroclypeus margaritatus-Austrotrillina howchini* (V).

1. *Nummulites aturicus-N. gizehensis-N. millecaput* Assemblage (Assemblage I)

This assemblage is dominated by *Nummulites aturicus* Joly and Leymerie, *N. gizehensis* (Forskål), *N. millecaput* Boubée, *Discocyclina augustae* van der Weijden, and *Discocyclina javana* (Verbeek). This assemblage is seen in stratigraphical sequences in Yusankaigan, Nankinhama, Miyukihama, Hyogidaira, Ōtani, Shizukazawa, Ninohashi and Nenbutsu-Tōge sections in the Yusan Formation. The assemblage is the best developed in the Yusankaigan and Miyukihama sections (Fig. 5).

Characteristic species: In addition to the five nominate species, which dominate the assemblage, the common occurrence of the following species typifies this assemblage: *Daviesina boninensis*, n. sp., *Operculina schwageri* Silvestri, *Nummulites pengaronensis* Verbeek, *N. perforatus* (Montfort), *Asterocyclina incisuricamerata* Cole, *Alveolina elliptica* (Sowerby), *Asterocyclina pentagonalis* (Deprat), *A. stella* (Gümbel), *Discocyclina dispansa* (Sowerby), *Eorupertia boninensis* (Yabe and Hanzawa), and *Orbitoclypeus kimurai* Matsumaru. *Nummultes* sp. related to a transitional form between *Nummulites acutus* (Sowerby) and *N. yawensis* Cotter, is found only within the assemblage, and *Asterocyclina asterodisca*, n. sp., closely related to *A. habanensis* Cole and Bermúdez in the America-Caribbean region, is found from the assemblage.

Correlation: This assemblage is determined to be Tertiary a3 of the Far East Letter Stages in the zonal scheme of Hashimoto and Matsumaru (1984), because of the coexistence of *Nummulites perforatus*, *N. pengaronensis*, and *Asterocyclina incisuricamerata*. According to Doornink (1932) and Oppenoorth and Gerth (1929), the *Discocyclina* Layers resting on the Djokjakartae and *Axinea* Layers of the Kalisongo Member of the Nanggulan Formation (Nanggoelan Bed), west of Yogyakarta (Djokjakarta, Jogjakarta), Central Java, are characterized by larger foraminifers of Tertiary a3, such as *Discocylina javana*, *D. dispansa*, *D. omphala* Fritch, *Nummultes semiglobula* Doornink, *N. irregularis* Deshayers, *N. pengaronensis*, *N. pustulosa* Douvillé, *N.* cf. *lucasana* Defrance, *N. orbigny* Galeotti, and *N. variolarius* Lamarck. Marks (1957) described the following species from the *Discocyclina* Beds (Layers) of the Nangulan (Nanggulan, Nangoelan) Beds (Lagen, Formation, Group): *Discocyclina javana*, *D. dispansa*, *D. fritschi* (Douvillé), *D. omphala*, *Camerina bagelensis* (Verbeek), *C. nanggulani* (Verbeek), and *Pellatispira* sp. Hartono (1969) described the following planktonic foraminifers, indicating a middle Eocene age, from the *Disocyclina* Beds: *Globorotalia centralis* Cushman and Bermúdez, *G. lehneri* Cushman and Jarvis, *G. spinulosa* Cushman, *G. bolivariana* (Petters), *Hantkenina dumblei* Weinzierl and Applin, *Hastigerina micra* (Cole), *Truncorotaloides rohri* Brönnimann and Bermúdez, *T. topilensis* (Cushman), *Globigerina yeguaensis* Weinzierl and Applin, and *Globigerinatheka barri* Brönnimann. Inasmuch as *Discocyclina javana*, indicating Tertiary a3 Stage, was found in the *Nummulites aturicus-N. gizehensis- N. millecaput* Assemblage of the Yusan Formation of Haha-Jima, in association with *Discocyclina dispansa* and *Nummulites pengaronensis*, the present assemblage (Assemblage I) of the Yusan Formation is correlated at least to Tertiary a3 Stage of the

■ Abundant (≧10%)
☒ Common (1<, <10%)
⧄ Rare (≦1%)

Table 1. Distribution of the larger, smaller, and planktonic foraminiferal species from the Yusan Formation, Okimura Formation, and Sekimon Limestone, Haha-Jima

Stations and symbols	US																	UN				
Species	817101B	817102	817103	817104	817105	817106	817107	817108	817109	817110	817111	817112	817113	817114	817115	817116	817117	81904	82201	82202	82203	82204
Nummulites aturicus Joly & Leymerie	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
N. gizehensis (Forskål)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
N. millecaput Boubée	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	☒	■	■	■	■	■
Discocyclina augustae v. d. Weijden	⧄	⧄	⧄	⧄	⧄	⧄	■	■	■	■	■	■	■	■	■	⧄	⧄	⧄	⧄	■	■	■
D. javana (Verbeek)	⧄	⧄	⧄	⧄	⧄	⧄	⧄	■	■	■	■	■	■	■	■	⧄	⧄	⧄	⧄	■	■	■
Nummulites sp.								⧄	☒	⧄	⧄											
Daviesina boninensis Matsumaru, n. sp.	☒	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Operculina schwageri Silvestri		⧄	⧄	⧄	⧄	⧄	⧄	☒	☒	■	☒	☒	■	■	■	■	☒	☒	■	■	■	
Nummulites pengaronensis Verbeek							■	■	■	■	■	■	■	■	■	■	■	⧄	⧄	■	■	■
N. perforatus (Montfort)	☒	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Asterocyclina incisuricamerata Cole	⧄	⧄	☒	☒	■	■	■	■	■	⧄	■	■	■	■	■	⧄	⧄	⧄	⧄	⧄	■	■
Alveolina elliptica (Sowerby)					⧄	⧄	⧄			⧄			⧄						⧄	⧄	⧄	⧄
Asterocyclina pentagonalis (Deprat)					☒	☒	☒	☒	☒	⧄	☒	■	■	■	■	⧄	⧄		⧄	⧄	■	■
A. stella (Gümbel)	⧄	⧄	⧄	⧄	⧄	■	■	■	☒	⧄	☒	■	■	■	■	⧄	⧄		⧄	☒	■	■
Discocyclina dispansa (Sowerby)	☒	■	■	■	■	■	■	■	■	☒	■	■	■	■	■	■	■	■	■	■	■	■
Eorupertia boninensis (Yabe & Hanzawa)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	⧄	⧄	■	■	■	■	■
Orbiloclypeus kimurai Matsumaru																						
Asterocyclina asterodisca Matsumaru, n. sp.																						
A. hahajimensis Matsumaru, n. sp.																						
Fabiania cassis (Oppenheim)																						
Halkyardia minima (Liebus)																						
Grzybowskia boninensis Matsumaru, n. sp.																						
Spiroclypeus granulosus Boussac																						
Biplanispira absurda Umbgrove																						
B. mirabilis (Umbgrove)																						
Pellatispira orbitoidea (Provale)																						
P. provalei Yabe																						
Operculina subformai Provale																						
Amphistegina radiata (Fichtel & Moll)																						
A. vulgaris d'Orbigny																						
Asterigerina tentoria Todd & Post																						
Orbitogypsina vesicularis Matsumaru, n. gen., n. sp.																						
O. globulus Matsumaru, n. gen., n. sp.																						
Mississippina concentrica (Parker & Jones)																						
Neoplanorbulinella saipanensis Matsumaru																						
Planorbulinella larvata (Parker & Jones)																						
Hastigerina bolivariana (Petters)																						
Acarinina cf. *spinuloinflata* (Bandy)																						
Globigerinatheka mexicana mexicana (Cushman)																						
G. cf. *mexicana mexicana* (Cushman)																						
G. mexicana barri Brönnimann																						
G. mexicana kugleri (Bolli,Loeblich & Tappan)																						
G. cf. *mexicana kugleri* (Bolli,Loeblich & Tappan)																						
G. index index (Finlay)																						
G. index rubriformis (Subbotina)																						
G. cf. *index tropicalis* (Blow & Banner)																						
G. sp.																						
Orbulinoides beckmanni (Saito)																						
Hantkenina alabamensis Cushman																						
H. cf. *mexicana* Cushman																						
H. primitiva Cushman & Jarvis																						
H. cf. *aragonensis* Nuttall																						
H. sp.																						
Turborotalia centralis Cushman & Bermúdez																						
T. cerroazulensis cocoaensis (Cushman)																						
T. cerroazulensis pomeroli (Toumarkine & Bolli)																						
T. cf. *pseudomayeri* (Bolli)																						
Globigerinita echinata Bolli																						
Globigerina pseudovenezuelana Blow & Banner																						
G. cf. *pseudovenezuelana* Blow & Banner																						
G. praebulloides leroyi Blow & Banner																						
G. praebulloides Blow																						
G. cf. *praebulloides* Blow																						
G. sellii (Borsetti)																						
G. senni (Beckmann)																						
G. cf. *senni* (Beckmann)																						
G. yeguaensis Weinzierl & Applin																						
G. venezuelana Hedberg																						
G. cf. *venezuelana* Hedberg																						
G. sp.																						

Stations and symbols	NK			MI								HY		OT				RO				TJ		
Species	81901	81902	81903	81801B	81802	81803	81804	81805	81806	81807	81808	21151	21152	72112B	72111	72112	72113	72405-1	82401	72405-2	72405-3	82403	82402-1	82402-2
Nummulites aturicus Joly & Leymerie	■	■	■	☒	■	■	■	■	■	⧄	⧄	☒	☒	☒	☒	☒	☒							
N. gizehensis (Forskål)	■	■	■	■	■	■	■	■	■	■	☒	■	■	■	■	■	■							
N. millecaput Boubée	■	■	■	⧄	⧄	⧄	⧄	■	⧄	■	⧄	⧄	⧄	■	■	■	■							
Discocyclina augustae v. d. Weijden	■	■	■	⧄	■	■	■	■	■	⧄	⧄	⧄	⧄	■	■	■	■							
D. javana (Verbeek)	⧄	■	■	☒	■	■	■	■	■	☒	☒	⧄	⧄	■	■	■	■	☒	■					
Nummulites sp.																								
Daviesina boninensis Matsumaru, n. sp.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	⧄	⧄
Operculina schwageri Silvestri	■	■	■		■	■	⧄	⧄	⧄	☒		⧄	⧄	■	⧄			☒	☒	■	■	☒	☒	☒
Nummulites pengaronensis Verbeek	☒	☒	☒	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	⧄	⧄	⧄	⧄	⧄
N. perforatus (Montfort)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	⧄	⧄	⧄		
Asterocyclina incisuricamerata Cole	■	■	■				⧄	⧄	■	■	☒	⧄		■	■	■	■	■	■	☒	☒	■	■	■
Alveolina elliptica (Sowerby)		⧄	⧄	⧄	⧄	☒	☒	■	■	■	☒	⧄	⧄	■	■	■	■	☒	☒	■	■	☒	☒	⧄
Asterocyclina pentagonalis (Deprat)		⧄			☒	■	■	■	■	■	■	☒	⧄	■	■	■	■			■	■	■	■	■
A. stella (Gümbel)		⧄			☒	■	■	■	■	■	■	☒	⧄	■	■	■	■			■	■			
Discocyclina dispansa (Sowerby)	■	■	■	■	■	■	■	■	■	■	■	⧄	⧄	■	■	■	■			■	■	■	■	■
Eorupertia boninensis (Yabe & Hanzawa)	■	■	■	⧄	■	■	■	■	■	■	■	☒	☒	■	■	■	■			■	■			
Orbiloclypeus kimurai Matsumaru								⧄	⧄	⧄		⧄	⧄											
Asterocyclina asterodisca Matsumaru, n. sp.							⧄	■	⧄			⧄	⧄					⧄	⧄	⧄	⧄	⧄	⧄	⧄
A. hahajimensis Matsumaru, n. sp.																								
Fabiania cassis (Oppenheim)														■	■	■	■			■	■			
Halkyardia minima (Liebus)																				■	☒			
Grzybowskia boninensis Matsumaru, n. sp.																								
Spiroclypeus granulosus Boussac																								
Biplanispira absurda Umbgrove																								
B. mirabilis (Umbgrove)																								
Pellatispira orbitoidea (Provale)																								
P. provalei Yabe																								
Operculina subformai Provale																								
Amphistegina radiata (Fichtel & Moll)																				■	■			
A. vulgaris d'Orbigny																				■	■			
Asterigerina tentoria Todd & Post																								
Orbitogypsina vesicularis Matsumaru, n. gen., n. sp.																								
O. globulus Matsumaru, n. gen., n. sp.																								
Mississippina concentrica (Parker & Jones)																								
Neoplanorbulinella saipanensis Matsumaru																								
Planorbulinella larvata (Parker & Jones)																								
Hastigerina bolivariana (Petters)																								
Acarinina cf. *spinuloinflata* (Bandy)																								
Globigerinatheka mexicana mexicana (Cushman)																					■			
G. cf. *mexicana mexicana* (Cushman)																					☒			
G. mexicana barri Brönnimann																								
G. mexicana kugleri (Bolli,Loeblich & Tappan)																					☒			
G. cf. *mexicana kugleri* (Bolli,Loeblich & Tappan)																								
G. index index (Finlay)																								
G. index rubriformis (Subbotina)																								
G. cf. *index tropicalis* (Blow & Banner)																								
G. sp.																								
Orbulinoides beckmanni (Saito)																								
Hantkenina alabamensis Cushman																								
H. cf. *mexicana* Cushman																								
H. primitiva Cushman & Jarvis																								
H. cf. *aragonensis* Nuttall																								
H. sp.																								
Turborotalia centralis Cushman & Bermúdez																					☒			
T. cerroazulensis cocoaensis (Cushman)																								
T. cerroazulensis pomeroli (Toumarkine & Bolli)																								
T. cf. *pseudomayeri* (Bolli)																								
Globigerinita echinata Bolli																								
Globigerina pseudovenezuelana Blow & Banner																								
G. cf. *pseudovenezuelana* Blow & Banner																								
G. praebulloides leroyi Blow & Banner																								
G. praebulloides Blow																								
G. cf. *praebulloides* Blow																								
G. sellii (Borsetti)																								
G. senni (Beckmann)																					■			
G. cf. *senni* (Beckmann)																								
G. yeguaensis Weinzierl & Applin																								
G. venezuelana Hedberg																								
G. cf. *venezuelana* Hedberg																								
G. sp.																								

Stations and symbols	SK			OK				SZ	NH		NS							NB	OK				Sekimon Karst											C1 Chibusa Dam
Species	82401	82405-1	82405-2	71901B	82001	9381503	9381502	72305	72205	82202	72402	82103	82102	72403	82101-2	82101-1	72404	72204	1995	2395	2595	9381501	9381403	9381402	72202	72203	72204	72205	72201-1	72201-2	72206-1	72206-2	9381404	
Nummulites aturicus Joly & Leymerie								☒	☒									☒																
N. gizehensis (Forskål)								■	■									■																
N. millecaput Boubée								■	■									■																
Discocyclina augustae v. d. Weijden					☒			■	■	■	☒	☒	☒					■																
D. javana (Verbeek)								■	■									■																
Nummulites sp.																																		
Daviesina boninensis Matsumaru, n. sp.	■	■	■	■	■	■	⧄	■	■	⧄	■	■	■	■	■	■	■	■																
Operculina schwageri Silvestri							⧄	■	■	☒	■	■	■				■	■																
Nummulites pengaronensis Verbeek	⧄	⧄	⧄	⧄	⧄	⧄	⧄	■	■	■	☒	☒	☒	☒	☒	☒	☒	■																
N. perforatus (Montfort)	⧄	⧄	⧄	⧄	⧄			■	■	■	☒	☒	☒	⧄	☒	☒	☒	■	⧄	⧄	⧄	⧄												
Asterocyclina incisuricamerata Cole	☒	☒	☒	☒	☒		⧄	■	■						☒	☒		■	⧄	⧄	⧄	⧄												
Alveolina elliptica (Sowerby)							☒	■	■	⧄	■	■	■					■				⧄												
Asterocyclina pentagonalis (Deprat)	☒	☒	☒	☒	☒			■	■						☒	☒		■	⧄	⧄	⧄				☒	☒	☒							
A. stella (Gümbel)	☒	☒	☒	☒				■	■									■							☒	☒	☒	⧄	☒	☒	☒	☒		
Discocyclina dispansa (Sowerby)	⧄	⧄	⧄				■	■	■	■					☒	☒		■	⧄	⧄	⧄	⧄			☒	☒	☒							☒
Eorupertia boninensis (Yabe & Hanzawa)								■	■	■	■	■	■					■	☒	☒	☒	☒												■
Orbiloclypeus kimurai Matsumaru							⧄								⧄	⧄										⧄								
Asterocyclina asterodisca Matsumaru, n. sp.	☒	☒	☒	☒	☒												⧄																	
A. hahajimensis Matsumaru, n. sp.				☒	⧄																													
Fabiania cassis (Oppenheim)				⧄	⧄			■	■	■	■	■	■					■	■	■	■	■		⧄	■	■	■		■	■				■
Halkyardia minima (Liebus)										☒	☒								☒	☒	☒	☒			☒	☒	☒							☒
Grzybowskia boninensis Matsumaru, n. sp.																			☒	☒	☒	☒												☒
Spiroclypeus granulosus Boussac																			■	■	■	■		☒	■	■	■							☒
Biplanispira absurda Umbgrove																			■	■	■	■			■	■	■							■
B. mirabilis (Umbgrove)																			☒	☒	■	■			■	■	■							
Pellatispira orbitoidea (Provale)																			■	■	■	■			■	■	■							
P. provalei Yabe																			■	■	■	■	⧄	⧄	■	■	■							
Operculina subformai Provale																							⧄	■	■	■	■							■
Amphistegina radiata (Fichtel & Moll)						☒													☒	☒	☒	☒			☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
A. vulgaris d'Orbigny																					⧄	⧄												⧄
Asterigerina tentoria Todd & Post																			■	■	■	■			■	■	■	■	■	■	■	■	■	■
Orbitogypsina vesicularis Matsumaru, n. gen., n. sp.																			☒	☒	☒	☒			☒	☒	☒							
O. globulus Matsumaru, n. gen., n. sp.																			☒	☒	☒	☒			☒	☒	☒							
Mississippina concentrica (Parker & Jones)																			☒	☒	☒	☒			☒	☒	☒							■
Neoplanorbulinella saipanensis Matsumaru																									☒	⧄	⧄							
Planorbulinella larvata (Parker & Jones)																									☒	⧄	⧄							
Hastigerina bolivariana (Petters)																					⧄													
Acarinina cf. *spinuloinflata* (Bandy)					☒																													
Globigerinatheka mexicana mexicana (Cushman)					■																													
G. cf. *mexicana mexicana* (Cushman)					☒																													
G. mexicana barri Brönnimann																																		⧄
G. mexicana kugleri (Bolli,Loeblich & Tappan)					■																⧄													
G. cf. *mexicana kugleri* (Bolli,Loeblich & Tappan)					☒																													
G. index index (Finlay)					■																⧄													
G. index rubriformis (Subbotina)					■														⧄															
G. cf. *index tropicalis* (Blow & Banner)																					⧄													
G. sp.					■																													⧄
Orbulinoides beckmanni (Saito)					■																													
Hantkenina alabamensis Cushman					■																													
H. cf. *mexicana* Cushman					☒																													
H. primitiva Cushman & Jarvis					■																													
H. cf. *aragonensis* Nuttall					☒																													
H. sp.					■																													
Turborotalia centralis Cushman & Bermúdez					⧄															⧄														
T. cerroazulensis cocoaensis (Cushman)																			⧄															
T. cerroazulensis pomeroli (Toumarkine & Bolli)					⧄																													
T. cf. *pseudomayeri* (Bolli)																				⧄														
Globigerinita echinata Bolli					■																													
Globigerina pseudovenezuelana Blow & Banner					☒																													
G. cf. *pseudovenezuelana* Blow & Banner					☒																													
G. praebulloides leroyi Blow & Banner																					⧄													
G. praebulloides Blow																																		
G. cf. *praebulloides* Blow																					⧄													
G. sellii (Borsetti)																					⧄													
G. senni (Beckmann)																																		⧄
G. cf. *senni* (Beckmann)																				⧄														
G. yeguaensis Weinzierl & Applin					■																													
G. venezuelana Hedberg					■																													
G. cf. *venezuelana* Hedberg																																		
G. sp.																					☒	☒												⧄

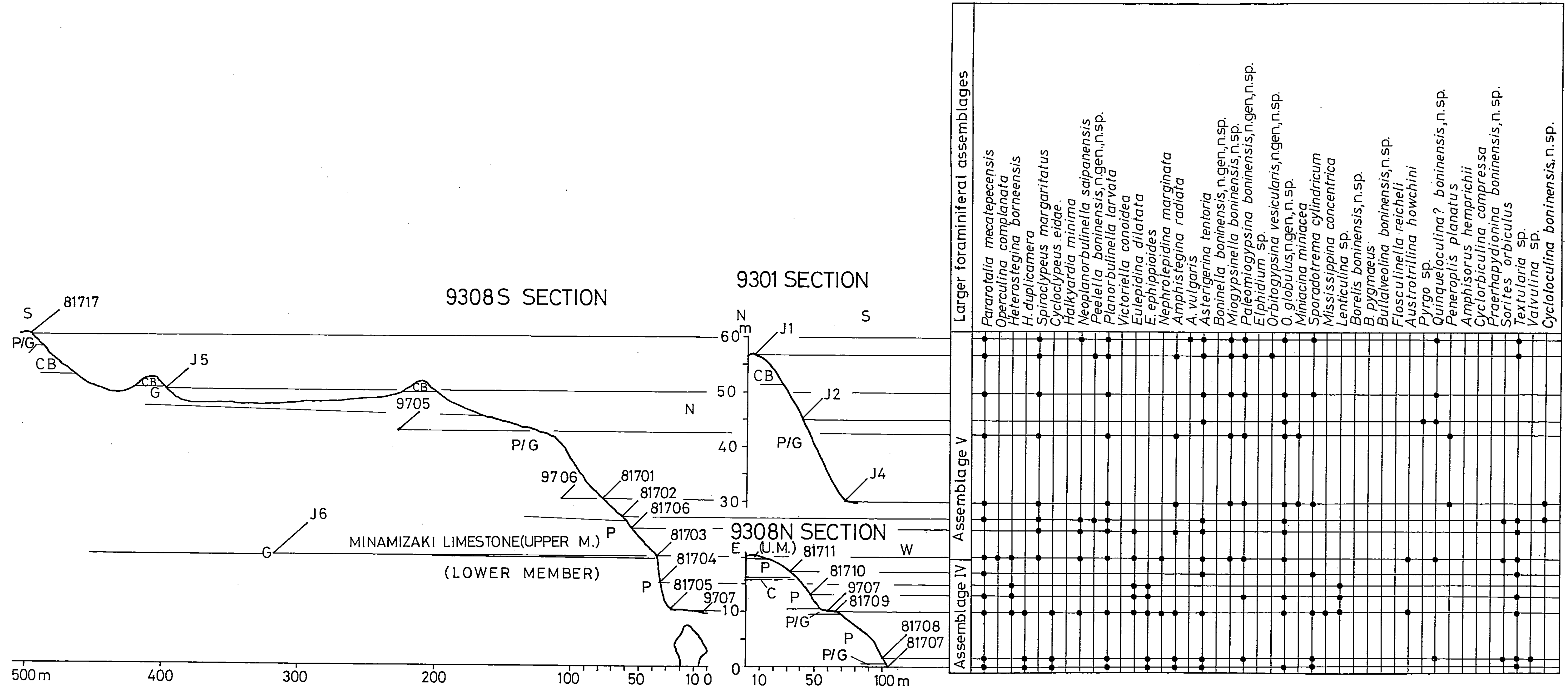


Fig. 12. Distribution of the larger and smaller foraminiferal taxa in 9308S, 9308N and 9301 sections and in supplementary sample stations on Minami-Jima, Ogasawara Islands. Symbols for lithologies are the same as those in Fig. 7.

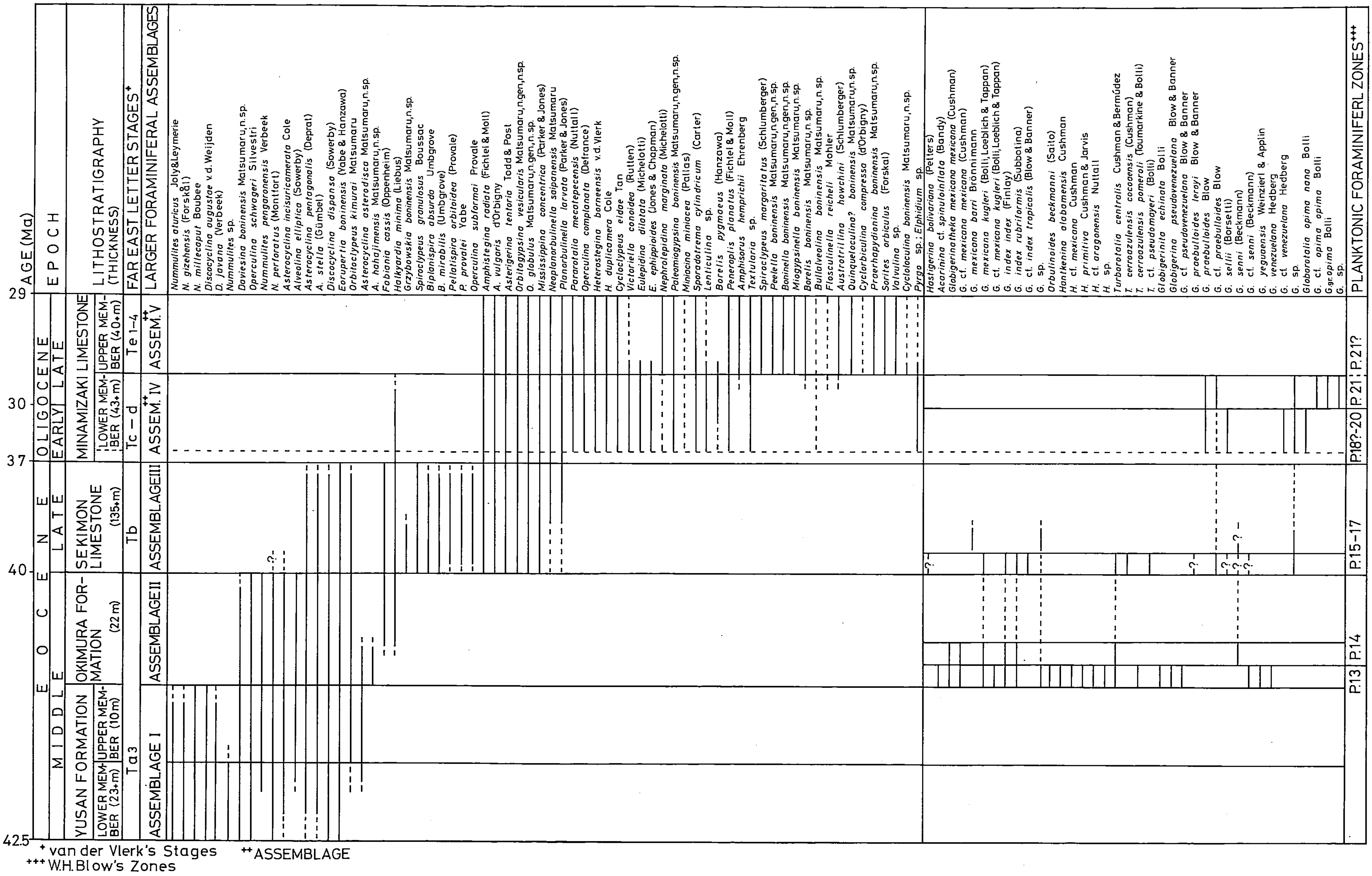


Fig. 13. Generalized relationships between the larger foraminiferal assemblages and planktonic foraminiferal zonations, established by ranges of species from the Yusan, and Okimura Formations, and Sekimon Limestone, Haha-Jima, and from the Minamizaki Limestone, Chichi-Jima and Minami-Jima, Ogasawara Islands. Age and epoch boundaries from Berggren *et al.*'s (1985), but are modified slightly from radiometric dating of volcanic rocks in Haha-Jima and Chichi-Jima by Kaneoka *et al.* (1970) and Tsunakawa (1983); from biometrical data of *Nephrolepidina marginata* (Michelotti) and the occurrence of the larger and planktonic foraminifera in the present study; and from the viewpoint of the last occurrence of *Globorotalia opima opima* by Bolli and Saunders (1985). The horizontal dashed line represents the top of the Minamizaki Limestone that is beneath sea level.

Table 2. Distribution of the larger, smaller, and planktonic foraminiferal species from the Minamizaki Limestone, Minamizaki Cape, Chichi-Jima

■ Abundant (≧10%)
☒ Common (1<, <10%)
⧅ Rare (≦1%)

Stations and symbols / Species	1301	1302	1304	801N	801S	71801	Others
	Base 1.4 2.4 4.4 5.4 8.2 9.5 10 11 12 13 14 15 16 17.5 19.5 21.5 23.5 25.5 27.1 29.5 31 33 35.5 37 38.3 39.5	9312701 9312702 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 9381804	Base 3.5 5 8 10 12 15 17.5 20 23 25 28 30 32 33 35 37 40 43 44 45 46 47 48 49 53 55 56 57 57.5	49 53 57 58	16 26 37.5/1303 40.5 43 47 48.5	6 7 9 11 13 15 17 19 21 23 25 27	81801 81802 81803 1305 82703
Halkyardia minima (Liebus)	⧅						
Amphistegina radiata (Fichtel & Moll)	■■■■■■■■■■■■■■☒☒■■☒■■■■■■ ☒☒	⧅☒■ ⧅■ ■■■☒☒ ☒☒■ ⧅⧅⧅ ■☒ ☒	☒☒■☒■ ⧅■■ ☒■■■ ☒■⧅■■ ■⧅■■☒☒	⧅ ⧅	⧅ ⧅⧅■■	⧅⧅⧅ ■■■⧅⧅ ■■■	■
A. vulgaris d'Orbigny	☒☒ ☒ ☒ ☒ ☒⧅	⧅ ☒☒ ⧅	☒		☒ ⧅⧅ ☒☒	⧅ ☒	
Asterigerina tentoria Todd & Post	■⧅■■■■☒■■■■■■■☒☒■ ☒■ ■■■■ ☒	☒⧅ ☒■ ■ ■■☒☒☒■■⧅☒☒ ■■■☒☒ ■■ ☒☒ ⧅■	☒☒ ☒■ ☒■■ ☒■■■⧅■■⧅■■ ⧅ ■⧅■■☒☒	⧅⧅⧅⧅	■ ☒⧅⧅■■	☒⧅⧅⧅■■■⧅⧅ ■■■	⧅⧅⧅ ■
Orbitogypsina vesicularis Matsumaru, n. gen., n. sp.	■☒☒■■☒☒■■■☒☒■■☒■ ☒☒☒■☒■	☒ ☒ ☒■■ ■ ☒ ■	■☒☒■■ ■■■ ■ ■■■■☒ ■⧅		☒	☒ ☒ ☒☒☒	
O. globulus Matsumaru, n. gen., n. sp.	☒■ ■ ☒■☒ ☒ ■ ☒ ☒■ ☒ ☒	☒ ☒ ■ ☒ ⧅	■ ☒■ ⧅■ ☒■ ☒ ☒■■☒ ☒■⧅☒☒☒			☒ ☒ ☒	☒
Mississippina concentrica (Parker & Jones)	☒☒ ☒ ☒	☒☒				☒ ☒	
Neoplanorbulinella saipanensis Matsumaru	☒☒ ☒ ☒☒☒☒ ☒ ☒ ⧅	☒ ☒	☒☒☒☒ ☒ ■■		☒☒	⧅ ☒☒☒	
Planorbulinella larvata (Parker & Jones)	⧅☒ ■ ☒ ☒ ■☒ ☒☒☒☒ ■	⧅⧅	■ ☒ ■ ■■ ■ ■■ ☒ ■ ☒☒■☒	☒	■ ■☒☒	☒☒ ☒☒☒	■
Pararotalia mecatepecensis (Nuttall)	■■■■■ ■■■■■ ■☒ ■■■■☒☒■■■■ ■☒	■■⧅☒⧅☒☒■■■☒☒☒■■■⧅⧅☒■■■■ ☒■■☒■■☒⧅☒■	■■■■■■ ■■■☒■ ☒■ ⧅⧅⧅	☒☒☒	■■ ■■■	☒☒■■■ ☒ ■■■	■ ■■
Operculina complanata (Defrance)	■■	☒ ⧅ ☒ ☒ ■⧅	☒ ■■		☒☒	☒ ☒☒☒⧅ ☒	
Heterostegina borneensis v.d.Vlerk	■■■☒☒☒ ■ ■☒■■☒ ☒☒ ■☒ ■■	⧅☒■■■■⧅⧅☒ ■ ⧅	■☒■■ ☒ ■☒ ■■☒ ☒■■ ⧅ ☒⧅⧅⧅⧅		■⧅ ☒☒☒	☒ ☒ ■■ ⧅ ■■■	⧅
H. duplicamera Cole	■■■■■☒■■■■☒■■☒☒☒■■☒☒■■ ⧅	■■☒ ⧅ ☒■☒☒☒☒☒☒☒■■■■⧅☒■■■■⧅⧅■■■ ⧅	■☒■■■■ ■■■■■☒☒ ■■■ ⧅ ☒⧅ ⧅		■■■ ☒☒☒	☒⧅■■☒⧅⧅ ■■■	■
Cycloclypeus eidae Tan	⧅⧅⧅☒☒	☒☒ ☒■☒☒ ☒ ■■☒☒ ⧅■■■⧅ ■☒	☒☒☒☒☒☒ ■■☒☒■☒☒☒ ☒ ⧅		☒⧅	■■ ■■■⧅⧅ ☒	
Victoriella conoidea (Rutten)	☒ ☒☒ ☒☒☒ ■☒⧅ ☒☒☒☒	☒ ⧅ ⧅	☒☒ ☒ ☒ ⧅ ☒ ⧅ ☒☒				
Eulepidina dilatata (Michelotti)	⧅☒ ☒☒ ■☒■■ ☒ ☒☒☒ ☒ ■■☒ ⧅	■■☒⧅ ⧅ ■☒ ■ ☒☒☒☒ ■ ■⧅ ⧅	■ ☒ ☒■ ■■ ■■☒☒☒⧅☒■ ⧅⧅		■■	☒■■ ☒■■	
E. ephippioides (Jones & Chapman)	■■☒■☒☒☒■■■■■■☒☒☒☒☒ ☒■■■■☒ ☒⧅	■■ ⧅⧅☒☒☒ ■ ☒⧅ ☒■■⧅☒☒☒☒ ⧅☒ ☒ ⧅ ☒	■■■■■■ ■■■■■■☒☒ ■■■ ⧅		■■	⧅⧅ ⧅■■■⧅⧅ ☒■■	
Nephrolepidina marginata (Michelotti)	☒ ⧅ ☒ ☒ ☒	☒	☒ ☒ ☒☒		☒ ☒		
Paleomiogypsina boninensis Matsumaru, n. gen., n.sp.	■■■ ■☒ ☒ ■	☒ ☒ ☒ ■ ■■☒ ☒	■■☒■☒ ☒ ■ ■		■	☒⧅■ ☒	
Miniacina miniacea (Pallas)		☒ ☒	☒		☒	⧅⧅ ☒☒ ⧅ ☒	☒
Sporadotrema cylindricum (Carter)	⧅⧅☒■☒ ☒☒☒■■☒☒■■■■■ ⧅	☒☒ ⧅ ☒	■■ ■■ ■ ■ ☒ ■■ ☒ ☒■⧅⧅	☒	☒	☒☒☒	
Lenticulina sp.	☒☒☒ ☒☒■ ☒☒ ☒☒ ☒ ■■	☒ ☒ ⧅⧅☒ ■	■☒☒ ☒☒ ☒☒⧅⧅☒ ☒☒☒		⧅⧅	☒	
Borelis pygmaeus (Hanzawa)	☒ ⧅		☒ ☒		☒☒	☒	☒☒☒
Peneroplis planatus (Fichtel & Moll)	☒ ☒☒■ ⧅⧅		■ ☒ ■ ☒☒☒	■			
Amphisorus hemprichii Ehrenberg	☒		☒☒ ⧅	☒	☒		☒
Textularia sp.	☒ ☒☒☒☒☒☒ ☒☒ ☒ ☒ ☒	☒☒☒ ■■☒☒☒ ☒ ☒ ☒ ☒ ☒ ⧅ ☒⧅⧅ ■	☒ ☒ ☒ ☒☒ ■ ☒☒	■	☒ ☒		⧅
Spiroclypeus margaritatus (Schlumberger)		■	■ ■☒■☒ ☒		■■■■		■■
Peelella boninensis Matsumaru, n. gen., n. sp.					■		
Boninella boninensis Matsumaru, n. gen., n. sp.			☒ ⧅				
Miogypsinella boninensis Matsumaru, n. sp.		■	■ ☒■ ☒		■■■■		■■
Borelis boninensis Matsumaru n. sp.	☒		☒	☒☒			☒☒☒
Bullalveolina boninensis Matsumaru n. sp.	⧅⧅			☒			
Flosculinella reicheli Mohler						☒	
Austrotrillina howchini (Schlumberger)	⧅	☒	■ ■☒☒		■■		☒
Quinqueloculina? boninensis Matsumaru n. sp.				■☒☒			
Cyclorbiculina compressa (d'Orbigny)				☒			
Praerhapydionina boninensis Matsumaru n. sp.		⧅☒		☒ ☒			■☒
Sorites orbiculus (Forskal)			☒☒☒ ☒☒ ☒☒☒	☒	☒☒		☒
Valvulina sp.				☒☒			☒
Cycloloculina boninensis Matsumaru n. sp.							☒
Pyrgo sp.	☒☒	☒ ⧅ ■	☒ ☒ ☒☒ ■ ■	■ ■	■■	☒	■■ ■☒
Elphidium sp.	☒ ☒☒☒ ⧅	⧅ ⧅ ☒ ☒	■ ☒☒ ☒ ☒			☒ ☒ ☒	
Globigerina praebulloides Blow			☒				
G. cf. *praebulloides* Blow	☒						
G. sellii (Borsetti)			☒				
G. cf. *venezuelana* Hedberg		☒ ☒					
G. sp.	⧅ ⧅ ☒☒☒☒☒☒ ☒☒☒	☒ ☒ ☒ ☒ ☒	☒☒ ☒☒ ☒ ☒			☒ ☒	
Globorotalia opima nana Bolli			⧅				
G. cf. *opima opima* Bolli	☒						
G. gr. *opima* Bolli	☒						
G. sp.	☒ ☒☒☒		☒ ☒			☒	

Table 3. Distribution of the larger, smaller, and planktonic foraminiferal species from the Minamizaki Limestone, Minami-Jima

■ Abundant (≧10%)
⊠ Common (1<, <10%)
⧅ Rare (≦1%)

Stations and symbols / Species	9301			9308N						9308S												Others												
	J2	J1-1	J1-2	81707	81708	81709	9707	81710	81711/9708	81705/9701	81704	81703	J6	81706	81702	81701	9706	9705	J5	81717-1	81717-2	J4	J7	9709	9710	9711	9712	9713	9714	9715	9702	9716	9703	9704
Halkyardia minima (Liebus)																																		
Amphistegina radiata (Fichtel & Moll)				■	■	■	⊠	■		■				■	■	■	■	■				■	■	■			⊠	⧅	⊠	■	⊠	■	■	■
A. vulgaris d'Orbigny																				⊠	⊠													
Asterigerina tentoria Todd & Post	■	■	■	■	■	■	■	■	⊠	■		■	■	■	■				■	■	■		■	■			⊠	⧅	⊠	■	⊠	■	■	■
Orbitogypsina vesicularis Matsumaru, n. gen., n. sp.		⊠	⊠																	⊠	⊠													
O. globulus Matsumaru, n. gen., n. sp.	⊠			⊠		⊠	⊠	⊠		⊠		⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	■	■	⊠	⊠	⊠					⊠	⊠	⊠	■	⊠	⊠
Mississippina concentrica (Parker & Jones)						⊠	⧅			⧅																								
Neoplanorbulinella saipanensis Matsumaru						⊠	⊠					⊠	⊠	⊠	⊠					■	■			⊠	⊠					⊠		⊠	⊠	■
Planorbulinella larvata (Parker & Jones)				⊠	⊠	⊠	⊠			⊠		⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	■	■	⊠	⊠	⊠	⊠				⊠	⊠	⊠	⊠	■	■
Pararotalia mecatepecensis (Nuttall)		■	■	■	■	■	■	■	⊠	■		■	■			■	■	■	■	■	■	■	■	■	⊠	⊠			⊠	■	⊠	■	■	■
Operculina complanata (Defrance)												■	■																					
Heterostegina borneensis v.d.Vlerk						■	■	■		■	■	■	■										⊠	■	⧅									
H. duplicamera Cole				■	■	■	■			■																								
Cycloclypeus eidae Tan				⊠	⊠	⊠	⊠			⊠													⊠	⊠										
Victoriella conoidea (Rutten)																																		
Eulepidina dilatata (Michelotti)				⊠		■	■	■		■	■	⊠	⊠	⧅										■										
E. ephippoides (Jones & Chapman)				■	■	■	■	■		■	■												■	■										
Nephrolepidiana marginata (Michelotti)				⧅		⊠	⊠			⊠		⊠	⊠											⊠										
Paleomiogypsina boninensis Matsumaru, n. gen., n. sp.		■	■		⊠			■				■	■			■	■	■	■	■	■	■		■										
Miniacina miniacea (Pallas)																⊠	⊠					⊠		■	⧅				⊠		⊠		⊠	⊠
Sporadotrema cylindricum (Carter)				⊠	⊠	⊠	■		■	■						⊠	⊠		⊠	■	■	⊠	⊠		⧅						⧅		■	■
Lenticulina sp.						⊠	⊠	⊠		⧅	⊠														⧅									
Borelis pygmaeus (Hanzawa)																																		
Peneroplis planatus (Fichtel & Moll)																■	■	■				■							⊠		⊠		■	■
Amphisorus hemprichii Ehrenberg		⊠	⊠	⊠																														
Textularia sp.		⊠	⊠	⊠	⊠	⊠	⧅	⊠	⊠	⊠		⊠	⊠	⊠	⊠					⊠	⊠		⊠											
Spiroclypeus margaritatus (Schlumberger)		■	■									■	■	■	■	■	■	■	■	■	■	■						⧅	⊠	■	⊠	■	⊠	■
Peelella boninensis Matsumaru, n. gen., n. sp.		■	■												■									■										
Boninella boninensis Matsumaru, n. gen., n. sp.																																		
Miogypsinella boninensis Matsumaru, n. sp.		■	■									■	■			■	■	■	■	■	■	■		■					⧅	⧅	⊠	■	⊠	⊠
Borelis boninensis Matsumaru, n. sp.																																		
Bullalveolna boninensis Matsumaru, n. sp.																																		
Flosculinella reicheli Mohler																																		
Austrotrillina howchini (Schlumberger)						⊠	⊠			■		■	■											■	⧅	⊠								
Quinqueloculina? boninensis Matsumaru, n. sp.	■				⊠							■	■						■	■	■													
Cyclorbiculina compressa (d'Orbigny)																																		
Praerhapydionina boninensis Matsumaru, n. sp.												⊠	⊠																					
Sorites orbiculus (Forskal)															⊠															⊠				
Valvulina sp.					⊠																													⊠
Cycloloculina boninensis Matsumaru, n. sp.					⊠										⧅	⧅	⧅					⧅												
Pyrgo sp.																		■						⊠	■	■								■
Elphidium sp.	■			⊠	⊠													■							■	■								
Globigerina praebulloides Blow																																		
G. cf. *praebulloides* Blow																																		
G. sellii (Borsetti)																																		
G. cf. *venezuelana* Hedberg																																		
G. sp.																																		
Globorotalia opima nana Bolli																																		
G. cf. *opima opima* Bolli																																		
G. gr. *opima* Bolli																																		
G. sp.																								⊠										

Discocyclina Layers of Kalisonggo Member, Nanggulan Formation, Java.

Assemblage I is also correlated with the Masungit Limestone Member of the Maybangain Formation (Reyes and Ordoñez, 1970; Hashimoto *et al.*, 1979), in Luzon, Philippines. The Masungit Limestone exposed along the Tanay-Daraitan Road, south of Pinugay Hill, yields *Nummulites* cf. *pengaronensis* Verbeek, *N. perforatus* (Montfort), *Fasciolites javana*

(Verbeek), *Assilina spira* (de Roissy), and *Asterocyclina incisuricamerata* Cole (Hashimoto *et al.*, 1979; Hashimoto and Matsumaru, 1984). The limestone also contains *Orbitolites* cf. *biplanatus* Lehmann, *Nummulites burdigalensis* (de la Harpe), *Fasciolites boscii* (Degrance), and *F.* cf. *delicatissima* (Smout) which may be reworked. Although a more detailed biostratigraphic study of the Masungit Limestone Member would be needed to solve the problem of reworking, the present status of the larger foraminiferal fauna of the Masungit (MSG Fauna) is as follows. The assemblage characterized by *Orbitolites* cf. *biplanatus* and *Nummulites burdigalensis* is designated as the MSG2 Fauna of Tertiary a2 Stage from upper Ilerdian to Cuisian, whereas the assemblage of Tertiary a3 Stage, which has no *Orbitolites* cf. *biplanatus*, is subdivided into the MSG3 Fauna without *Asterocyclina incisuricamerata*, and MSG4 Fauna with *A. incisuricamerata*. The MSG3 Fauna is considered to range from upper Cuisian to lower Lutetian, and MSG4 Fauna is assigned to Lutetian. Overall, it is possible to correlate the MSG4 Fauna, comprising *Asterocyclina incisuricamerata*, *A. stella*, *Nummulites perforatus*, *N.* cf. *pengaronensis*, *Heterostegina* sp., and *Eorupertia* sp., with Assemblage I of Haha-Jima.

2. *Nummulites pengaronensis-N. perforatus-Alveolina elliptica* Assemblage (Assemblage II)

This assemblage is dominated by *Nummulites pengaronensis* Verbeek, *N. perforatus* (Montfort), *Alveolina elliptica* (Sowerby), *Asterocyclina hahajimensis*, n. sp., *Fabiania cassis* (Oppenoorth), and *Halkyardia minima* (Liebus). This assemblage is seen in stratigraphic sequences in Rōsudani, Toeijūtaku, Sonminkaikan, Okiko/Tsukigaoka Shrine, Ninohashi, and Nishiura sections in the Okimura Formation. The assemblage is the best observed at Okiko/Tsukigaoka Shrine section (Fig. 6).

Characteristic species: In addition to the nominate species, which dominate the assemblage, the following species characterize this assemblage: *Daviesina boninensis* n. sp., *Operculina schwageri* Silvestri, *Asterocyclina incisuricamerata* Cole, *A. asterodisca* n. sp., *A. pentagonalis* (Deprat), *A. stella* (Gümbel), *Discocyclina dispansa* (Sowerby), *Eorupertia boninensis* (Yabe and Hanzawa), and *Orbitoclypeus kimurai* Matsumaru. The following planktonic foraminiferal species, in association with larger foraminifers, are found in the OK82001 bed in the Okiko/Tsukigaoka Shrine section (Figs. 14–16) *Acarinina* cf. *spinuloinflata* (Bandy), *Globigerinatheka mexicana mexicana* (Cushman), G. cf. *mexicana mexicana* (Cushman), *G. mexicana kugleri* (Bolli, Loeblich and Tappan), *G.* cf. *mexicana kugleri* (Bolli, Loeblich and Tappan), *G. index index* (Finlay), *G. index rubriformis* (Subbotina), *G.* sp., *Orbulinoides beckmanni* (Saito), *Hantkenina alabamensis* Cushman, *H.* cf. *mexicana* Cushman, *H. primitiva* Cushman and Jarvis, *H.* cf. *aragonensis* Nuttall, *H.* sp., *Turborotalia centralis* Cushman and Bermúdez, *Turborotalia cerroazulensis pomeroli* (Toumarkine and Bolli), *Globigerinita echinata* Bolli, *Globigerina pseudovenezuelana* Blow and Banner, *G.* cf. *pseudovenezuelana* Blow and Banner, *G.* cf. *senni* (Beckmann), *G. venezuelana* Hedberg, and *G. yeguaensis* Weinzierl. Of these species, *Globigerinatheka mexicana mexicana*, *G.* cf. *mexicana mexicana*, *G. mexicana kugleri*, *G. index index*, *G. index rubriformis*, and *Turborotalia centralis* are found in the RO72405-3 bed in the Rōsudani section, with a newly observed species of *Globigerina senni* (Beckmann).

Correlation: This assemblage was determined to be Tertiary a3 in the zonal scheme of Hashimoto and Matsumaru (1984), and it is correlated with the MSG4 Fauna in Luzon,

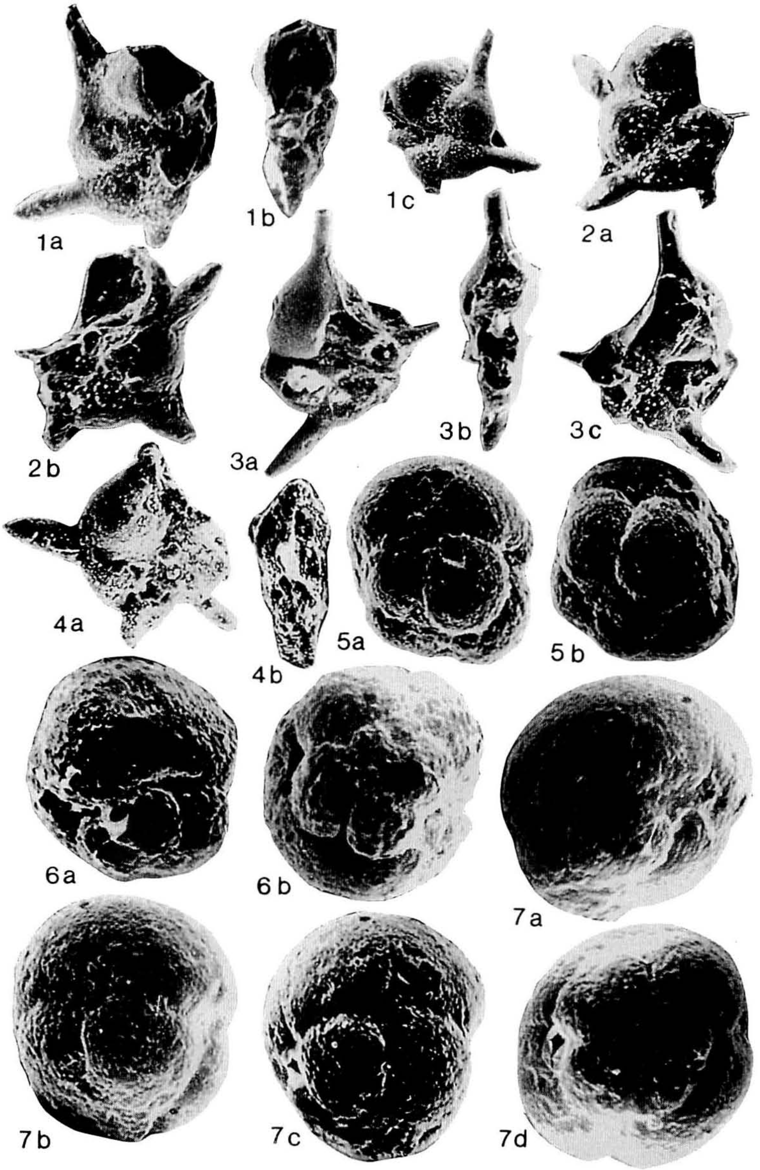


Fig. 14. Representative planktonic foraminifers from the Okimura Formation (Locality: OK82001, Okiko/Tsukigaoka Shrine Section. 1–4. ×75, 5–7. ×150)

Hantkenina alabamensis Cushman
1a, c. Side views, 1b. Apertural view.
Hantkenina primitiva Cushman and Jarvis
2a–b. Side views.
Hantkenina cf. *aragonensis* Nuttall
3a, c. Side views, 3b. Apertural view.
Hantkenina cf. *mexicana* Cushman
4a. Side view, 4b. Apertural view.
Globigerinatheca cf. *mexicana mexicana* (Cushman)
5a. Side view, 5b. Spiral view.
Globigerinatheka mexicana mexicana (Cushman)
6a. Side view, 6b. Spiral view.
Orbulinoides beckmanni (Saito)
7a–c. Side views, 7d. Spiral view.

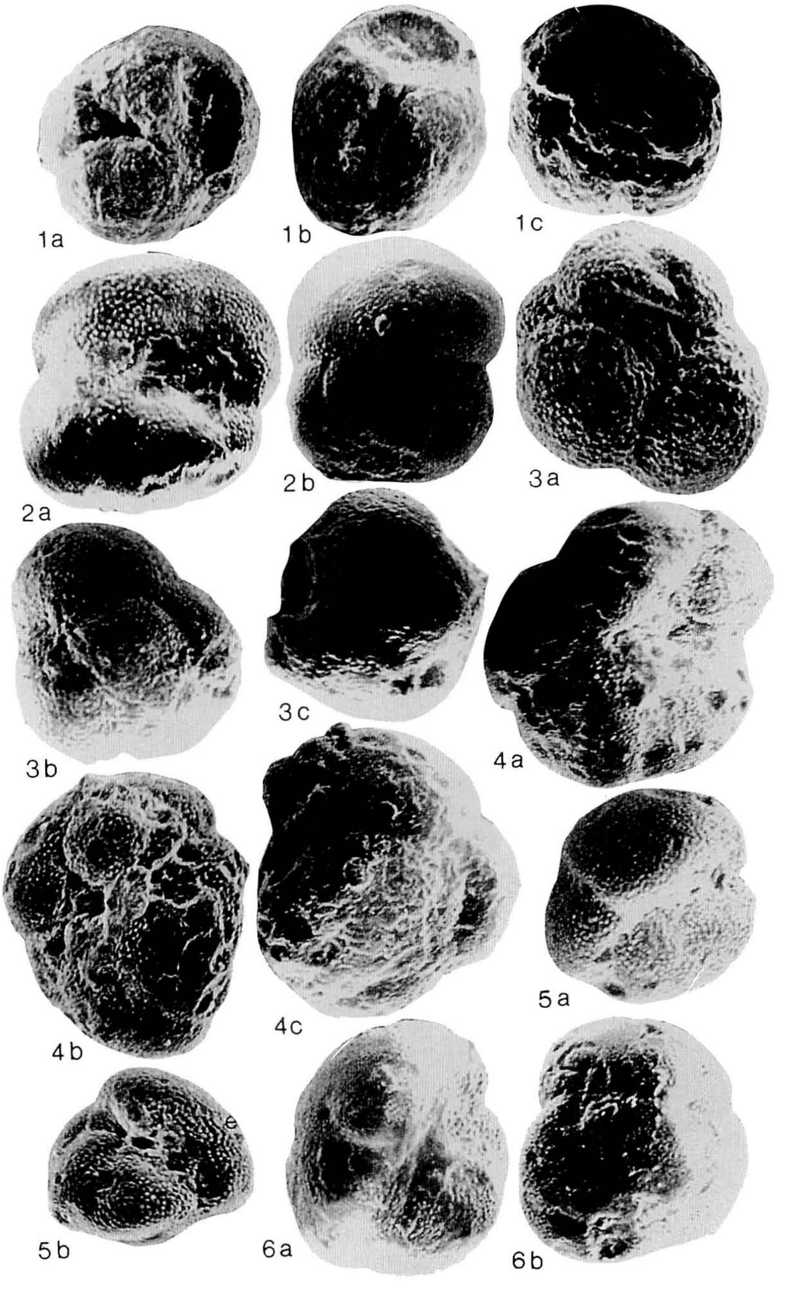


Fig. 15. Representative planktonic foraminifers from the Okimura Formation (Locality: OK82001, Okiki/Tsukigaoka Shrine Section, all figures ×150)

Globigerinatheka cf. *mexicana kugleri* (Bolli, Loeblich and Tappan)

1a. Umbilical view, 1b. Side view, 1c. Spiral view.

Globigerinatheka index index (Finlay)

2a. Umbilical view, 2b. Spiral view.

Globigerinatheka index rubriformis (Subbotina)

3a. Umbilical view, 3b. Spiral view, 3c. Side view.

Acarinina cf. *spinuloinflata* (Bandy)

4a. Umbilical view, 4b. Side view, 4c. Spiral view.

Turborotalia centralis Cushman and Bermúdez

5a, 6a. Umbilical views, 5b. Side view, 6b. Spiral view.

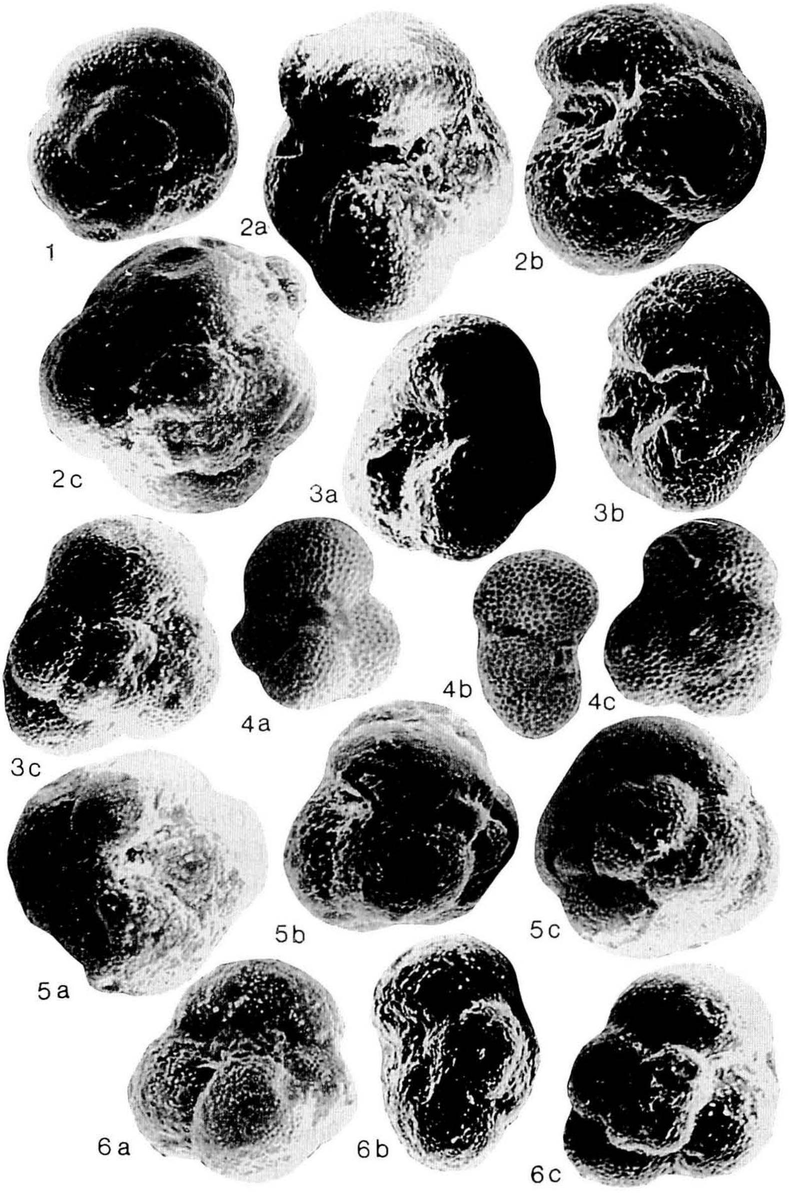


Fig. 16. Representative planktonic foraminifers from the Okimura Formation (Locality: OK82001, Okiko/Tsukigaoka Shrine Section, all figures ×150)

Turborotalia cerroazulensis pomeroli (Toumarkin and Bolli)

1. Spiral view.

Globigerina venezuelana Hedberg

2a. Umbilical view, 2b. Side view, 2c. Spiral view.

Globigerina pseudovenezuelana Blow and Banner

3a. Umbilical view, 3b. Side view, 3c. Spiral view.

Globigerina yeguaensis Weinzierl and Applin

4a. Umbilical view, 4b. Side view, 4c. Spiral view.

Globigerinita echinata Bolli

5a. Umbilical view, 5b. Side view, 5c. Spiral view.

Globigerina cf. *senni* (Beckmann)

6a. Umbilical view, 6b. Side view, 6c. Spiral view.

Philippines, because of the coexistence of *Asterocyclina incisuricamerata*, *A. stella*, *Nummulites pengaronensis*, and *N. perforatus*, and no joint occurrence of *Biplanispira* and *Pellatispira*.

Assemblage II is considered to correspond to *Orbulinoides beckmanni* total range Zone (Zone P.13) of Blow (1969, 1979) or *O. beckmanni* Zone of Toumarkine and Luterbacher (1985), because of the presence of *Orbulinoides beckmanni* (Saito) from the OK82001 bed. It is also correlated with Saito's (1962) fauna.

As such the former Assemblage I is also assigned to be Zone P.13, or possibly older. Further, Assemblage II is assigned to *Truncorotaloides rohri-Globigerinita howei* partial range Zone (Zone P.14) of Blow (op. cit.) or *Truncorotaloides rohri* Zone of Toumarkin and Luterbacher (1985), through the coexistence of *Globigerinatheka mexicana mexicana* (Cushman) and *Globigerina senni* (Beckmann) and the non-existence of *Orbulinoides beckmanni* from the RO72405 bed. Therefore, Assemblage II is correlated with two zones of the planktonic standard, P. 13 and P.14.

3. *Biplanispira absurda-Pellatispira provalei* Assemblage (Assemblage III)

This assemblage is dominated by *Biplanispira absurda* Umbgrove, *B. mirabilis* (Umbgrove), *Pellatispira orbitoidea* (Provale), *P. provalei* Yabe, *Grzybowskia boninensis*, n. sp., *Spiroclypeus granulosus* Boussac, and *Operculina subformai* Provale. This assemblage is seen in Okiko/Tsukigaoka Shrine and Sekimon Karst sections in the Sekimon Limestone, and also seen in the limestone of Chibusa Dam. The assemblage is the best developed in the Sekimon Karst area (Fig. 6).

Characteristic species: In addition to the nominate species stated above, other associated species include *Asterocyclina pentagonalis* (Deprat), *A. stella* (Gümbel), *Discocyclina dispansa* (Sowerby), *Eorupertia boninensis* (Yabe and Hanzawa), *Orbitoclypeus kimurai* Matsumaru, *Fabiania cassis* (Oppenheim), and *Halkyardia minima* (Liebus). The following species occur commonly in this assemblage: *Amphistegina radiata* (Fichtel and Moll), *A. vulgaris* d'Orbigny, *Asterigerina tentoria* Todd and Post, *Orbitogypsina vesicularis*, n. gen, n. sp., *O. globulus*, n. gen., n. sp., *Mississippina concentrica* (Parker and Jones), *Neoplanorbulinella saipanensis* Matsumaru, and *Planorbulinella larvata* (Parker and Jones). *Nummulites perforatus* (Montfort) and *Asterocyclina incisuricamerata* Cole are seen in the Okiko/Tsukigaoka Shrine section where it is poorly developed. Judging from the ill preservation and broken form of *Nummulites perforatus* and *Asterocyclina incisuricamerata*, these species are considered to be reworking from their original position. The following planktonic foraminifers are found from the Okiko/Tsukigaoka Shrine section (Fig. 17): *Globigerinatheka mexicana kugleri* (Bolli, Loeblich and Tappan), *G. index index* (Finlay), *G. index rubriformis* (Subbotina), *G.* cf. *index tropicalis* (Blow and Banner), *Turborotalia centralis* Cushman and Bermúdez, *T. cerroazulensis cocoaensis* (Cushman), *T.* cf. *pseudomayeri* (Bolli), *Globigerina praebulloides leroyi* Blow and Banner, *G.* cf. *praebulloides* Blow, *G. sellii* (Borsetti), *G. senni* (Beckmann), *G.* cf. *senni* (Beckmann), *G.* sp., and *Hastigerina bolivariana* (Petters). Of these species, the identification of *Globigerina sellii* should be questioned because this is inconsistent with the older ranges of the other foraminifers (Blow, 1969, 1979). *Hastigerina bolivariana* and *Globigerina* cf. *senni* also need additional examination. From the Sekimon Karst Plateau (sample 72203), one species belonging to *Globigerina praebulloides* Blow is present (Fig. 17). The planktonic foraminiferal species from Chibusa Dam (sample C1) are *Globigerinatheka mexicana* Brönnimann, *G.* sp., *Globigerina senni* (Beckmann), and *G.* sp. Of these,

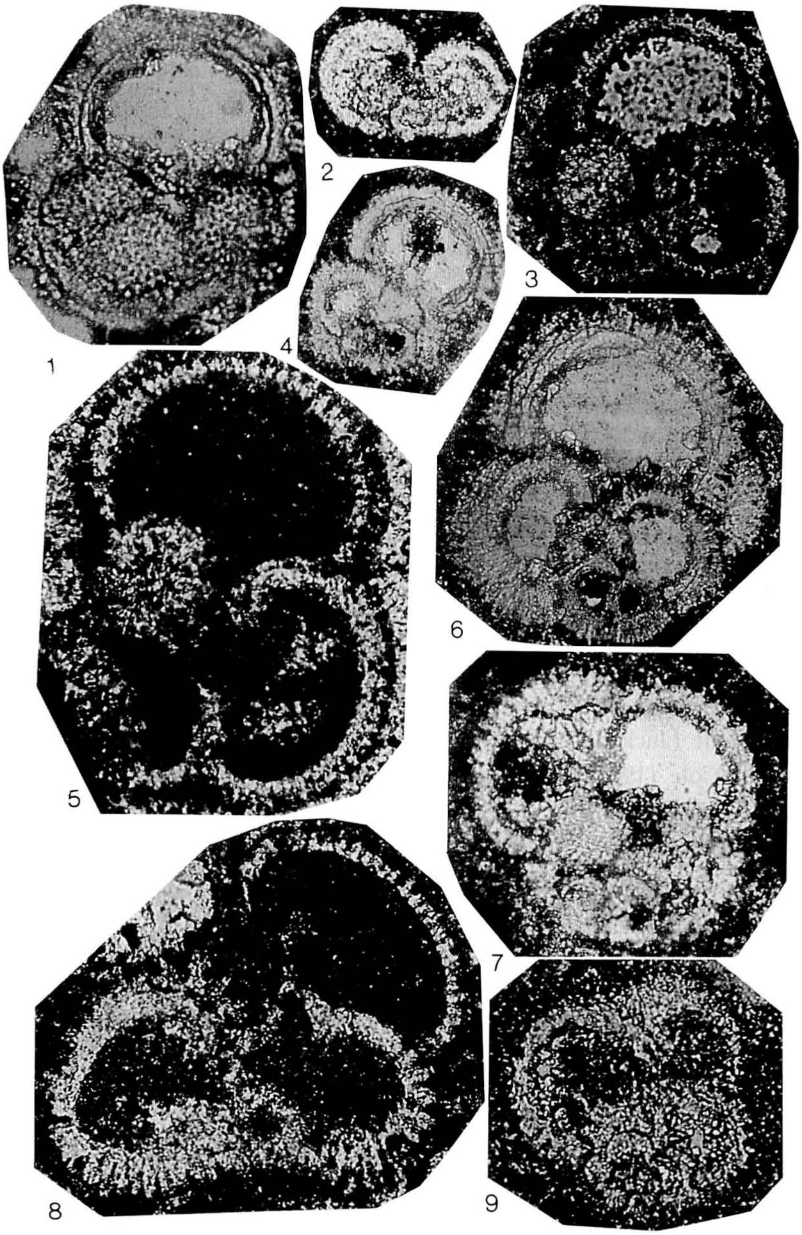


Fig. 17. Representative planktonic foraminifers from the Sekimon Limestone (Localities: 1–4, 6, 8. OK25.95, 9. OK23.95. Okiko/Tsukigaoka Shrine Section, 5. 72203, Sekimon Karst Section, 7.c1, Chibusa Dam; 1, 6. ×75, 2. ×150, 3, 5. ×158, 4. ×68, 7–9. ×165)

Globigerina praebulloides leroyi Blow and Banner
1. Oblique longitudinal section.

Hastigerina bolivariana (Petters)
2. Axial section.

Globigerina cf. *praebulloides* Blow
3, 5. Oblique longitudinal sections. 4, 6. Longitudinal sections.

Globigerina senni (Beckmann)
7. Oblique longitudinal section.

Globigerina sellii (Borsetti)
8. Axial section.

Globigerina cf. *senni* (Beckmann)
9. Oblique longitudinal section.

Globigerina senni should be reexamined (Fig. 17).

Correlation: Assemblage III was determined to be Tertiary b of upper Eocene in the zonal scheme of Hashimoto and Matsumaru (1984), because of the presence of *Biplanispira* and *Pellatispira*. Tertiary b Stage is considered to be equivalent to the Priabonian Stage of Europe by Leupold and Vlerk (1931) and Sirotti (1978).

Other correlative beds of Tertiary b Stage include the Melinau Limestone, Sarawak (Borneo), Malaysia, which contains *Nummulites javanus* Verbeek, *Discocyclina* sp., *N.* sp. (*striatus* Bruguiere), *Pellatispira orbitoidea* (Provale), *P.* sp., *Fabiania saipanensis* Cole, *Spiroclypeus vemicularis* Tan, and *Halkyardia* sp. (Adams, 1965).

The upper Eocene Hagman Formation, Densinyama Formation, and Matansa Limestone in Saipan are regarded as constituting a single faunal unit of Tertiary b Stage, because of the presence of *Pellatispira orbitoidea* (Provale), *P. provalei* Yabe, and *Asterocyclina matanzensis* Cole (Cole, 1957a). According to Hanzawa (1957), the Densinyama and Matansa Formations from Saipan, Tinian, and Rota, Micronesia, and the Aimilik Formation, Babelthuap, Palau, are characterized by *Nummulites pengaronensis* (Verbeek), *N. bagelensis* (Verbeek), *N. striatus* (Bruguiere), *Discocyclina dispansa* (Sowerby), *D. indopacifica* Hanzawa, *Asterocyclina stellaris* (Brunner), *Biplanispira, Pellatispira, Fabiania saipanensis* Cole, *Halkyardia, Acervulina linearis* Hanzawa, *Gypsina saipanensis* Hanzawa, and *Spiroclypeus vermicularis* Tan. Accordingly, the fauna is assigned definitely to Tertiary b Stage. Todd (1957) regarded the Hagman and Densinyama Formations in Saipan as late Eocene, because of the presence of *Hantkenina bermudez* Thalmann, whereas the age of the Matansa limestone is considered to be late Eocene (Jackson equivalent).

In Guam, Cole (1963a) showed that the diagnostic Tertiary b genera and species of *Asterocyclina matanzensis* Cole, *Biplanispira fulgeria* (Whipple), *B. mirabilis* (Umbgrove), *Discocyclina omphala* (Fritsch), *Fabiania saipanensis* Cole, and *Spiroclypeus vermicularis* Tan, occurred in two localities (Hjl and EK7) within the Alutom Formation. The other 11 localities in the Alutom Formation are, however, considered to represent Tertiary c (Oligocene) accumulation, into which reworked Tertiary b genera and species were carried. Blow (1969) showed that the Alutom Formation in Guam is placed at Zones P.15 to P.17 of planktonic foraminiferal zonation. As a whole, the *Biplanispira absurda-Pellatispira provalei* Assemblage (III) in Haha-Jima can be correlated with the faunal zone of Tertiary b Stage of the western Pacific Region (Saipan, Tinian, Rota, Palau, and Guam), because of the presence of the genera *Biplanispira, Pellatispira*, and *Fabiania*.

Cole (1957b) described the following species of Tertiary b Stage from the stratigraphic section of 2780 to 4553 feet in the Eniwetok Atoll Drill Holes: *Gypsina vesicularis* (Parker and Jones), *Pseudochrysalidina eniwetokensis* Cole, *Asterocyclina matanzensis* Cole, *Coskinolina rotaliformis* Cole; *Camerina djokjokartae* (Martin), *C. pengaronensis* (Verbeek), *Boreloides eniwetokensis* Cole, *Heterostegina saipanensis* Cole, *H. aequatoria* Cole, *Asterocyclina penuria* Cole, *A. incisuricamerata* Cole, *A. praecipua* Cole, *Operculina eniwetokensis* Cole, *Operculinoides saipanensis* Cole, *O. subformai* (Provale), *Pellatispira orbitoidea* (Provale), *Asterocyclina centripilaris* Cole, *Biplanispira fulgeria* (Whipple), *B. mirabilis* (Umbgrove), *Fabiania saipanensis* Cole, *Spiroclypeus vermicularis* Tan, and *S. albapustula* Cole. Accordingly, the fauna of Tertiary b Stage from the Eniwetok Atoll is correlated with Assemblage III in Haha-Jima, because of the common diagnostic species of *Biplanispira mirabilis, Pellatispira orbitoidea, Asterocyclina incisuricamerata*, and *Operculina subformai.*

Assemblage III is also correlated with both the Data (DATA) Fauna, near Bondoc, Mountain Province, northern Luzon, and the Caguray (CGR) Fauna, southern Mindoro, Philippines, which are defined by the presence of *Biplanispira mirabilis* (Umbgrove), *B.* cf, *inflata* Hanzawa, *Pellatispira madaraszi* (von Hantken), *P. orbitoidea* (Provale), *P.* cf. *rutteni* Umbgrove, *Spiroclypeus vermicularis* Tan, *Asterocyclina stellaris* (Brunner), *Nummulites acutus* Sowerby, *N. striatus* (Bruguiere), and *Fabiania cassis* (Oppenheim) (Hashimoto and Matsumaru, 1984).

The *Biplanispira absurda-Pellatispira provalei* Assemblage (III) in Haha-Jima is considered to correspond to Zones P.15 to P.17 of Blow (1969, 1979), or *Globigerinatheka semiinvoluta* Zone to *Turborotalia cerroazulensis* s. 1. Zone of Toumarkine and Luterbacher (1985), because of the presence of the following species from the Okiko Section (Fig. 18): *Globigerinatheka mexicana barri* Brönnimann, *G. mexicana kugleri* (Bolli, Loeblich and Tappan), *G. index index* (Finlay), *G. index rubriformis* (Subbotina), *G.* cf. *index tropicalis* (Blow and Banner), *Hantkenina* sp., *Turborotalia cerroazulensis cocoaensis* (Cushman). *T.* cf. *pseudomayeri* (Bolli), *Globigerina praebulloides leroyi* Blow and Banner, *G.* cf. *praebulloides* Blow, *G. sellii* (Borsetti), *G.* cf. *senni* (Beckmann), *G.* sp., and *Hastigerina bolivariana* (Petters). Of these species, the problem of *Globigerina* cf. *senni, G. sellii*, and *Hastigerina bolivariana* was discussed before.

4. *Eulepidina dilatata-E. ephippioides-Heterostegina borneensis* Assemblage (Assemblage IV)

This assemblage is dominated by *Eulepidina dilatata* (Michelotti), *E. ephippioides* (Jones and Chapman), and *Heterostegina borneensis* van der Vlerk. It is seen in stratigraphic sequences in the studied sections in the lower member of the Minamizaki Limestone in Minamizaki Cape, Chichi-Jima (Figs. 7–11), and Minami-Jima (Fig. 12). The best section for Assemblage IV is 1304 (Fig. 9).

Characteristic species: The following joint occurrence association of species characterizes this assemblage: *Halkyardia minima* (Liebus), *Pararotalia mecatepecensis* (Nuttall), *Operculina complanata* (Defrance), *Heterostegina duplicamera* Cole, *Cycloclypeus eidae* Tan, *Victoriella conoidea* (Rutten), *Nephrolepidina marginata* (Michelotti), *Paleomiogypsina boninensis*, n. gen., n. sp., *Miniacina miniacea* (Pallas), *Sporadotrema cylindricum* (Carter), *Amphistegina radiata* (Fichtel and Moll), *A. vulgaris* d'Orbigny, *Asterigerina tentoria* Todd and Post, *Orbitogypsina vesicularis*, n. gen., n. sp., *O. globulus*, n. gen., n. sp., *Mississippina concentrica* (Parker and Jones), *Neoplanorbulinella saipanensis* Matsumaru, *Planorbulinella larvata* (Parker and Jones), *Borelis pygmaeus* (Hanzawa), and *Peneroplis planatus* (Fichtel and Moll). In addition to the fauna, *Amphisorus hemprichii* Ehrenberg, *Borelis boninensis*, n. sp., *Flosculinella reicheli* Mohler, and *Austrotrillina howchini* (Schlumberger) are found in this assemblage. *Globorotalia opima nana* Bolli, *G.* cf. *opima opima* Bolli, *G.* group *opima*, *Globorotalia* sp., *Globigerina praebulloides* Blow, *G.* cf. *praebulloides* Blow, *G. sellii* (Borsetti), *G.* cf. *venezuelana* Hedberg, and *G.* sp. are also found rarely in this assemblage in 1301, 1302, and 1304 Sections, Minamizaki Cape (Figs. 7–9, Fig. 19).

Correlation: The correlation with the Tertiary Letter Stages used in the Far East is difficult because some, these stages, are based on larger foraminifers that probably lived in different environments. For example, Mohler (1950) indicated that the difference between the *Nummulites fichteli* (Michelotti)-bearing Tertiary c and d Stages is based on the absence

Fig. 18. Representative planktonic foraminifers from the Sekimon Limestone (Localities: 1, 7. OK19.95, 2, 4. OK25.95, 6, 8. OK23.95, Okiko/Tsukigaoka Shrine Section; 3, 5. c1, Chibusa Dam; 1, 3, 5, 7. ×165, 2. ×158, 4. ×163, 6, 8. ×83)

Globigerinatheka index rubriformis (Subbotina)
1. Longitudinal section.

Globigerinatheka cf. *index tropicalis* (Blow and Banner)
2. Axial section.

Globigerinatheka mexicana barri Brönnimann
3. Oblique axial section.

Globigerinatheka mexicana kugleri (Bolli, Loeblich and Tappan)
4. Oblique longitudinal section.

Globigerinatheka sp.
5. Oblique longitudinal section.

Turborotalia cf. *pseudomayeri* (Bolli)
6. Transverse section.

Turborotalia cerroazulensis cocoaensis (Cushman)
7. Axial section.

Turborotalia centralis Cushman and Bermúdez
8. Axial section.

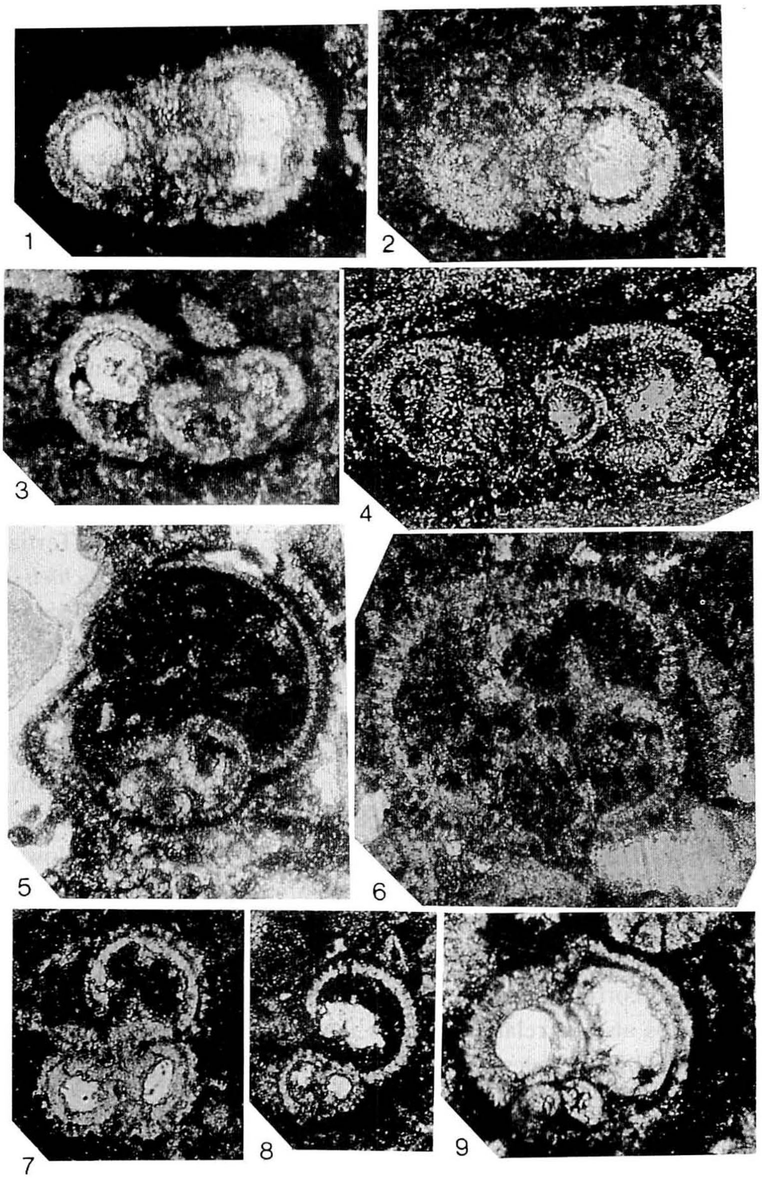


Fig. 19. Representative planktonic foraminifers from the Minamizaki Limestone (Localities: 1. 12, 2. 31, 4. 19.5, 7. 21.5, 9. 15, all belonging to 1301 Section; 3. Base, 5. 10, 8. 17.5, all belonging to 1304 Section; 6. 9312701, 1302 Section; 1–3. ×150, 4–9. ×75)

Globorotalia cf. *opima opima* Bolli
1. Axial section.

Globorotalia group *opima* Bolli
2. Axial section.

Globorotalia opima nana Bolli
3. Axial section.

Globorotalia sp.
4. Axial section.

Globigerina sellii (Borsetti)
5. Axial section.

Globigerina cf. *venezuelana* Hedberg
6. Oblique section.

Globigerina cf. *praebulloides* Blow
7. Longitudinal section.

Globigerina praebulloides Blow
8. Axial section.

Globigerina sp.
9. Oblique section.

and presence of *Eulepidina*, respectively. From the viewpoint of a paleoenvironmental interpretation of larger foraminifers, it is easy to say, by their occurrence, associated genera and species, living occurrence, and lithology, that *Nummulites* may have lived in deep euphotic shelf of bottoms, at 30 to 55 m by Deecke (1914), or 50 to 130 m by Hottinger (1983), whereas *Eulepidina* could have lived in reefs, open platforms, and foreslopes (Frost and Langenhaim, 1974; Chaproniere, 1975; Matsumaru, 1978). This shows that there were different ecological conditions for each of *Nummulites* and *Eulepidina*, and that the Tertiary c Formation may be stratigraphically equivalent to the Tertiary d Formation.

Assemblage IV in Chichi-Jima and Minami-Jima was determined to be Tertiary c and/or d in the zonal scheme of Hashimoto and Matsumaru (1984), based on the coexistence of *Eulepidina dilatata* (Michelotti), *E. ephippioides* (Jones and Chapman), *Heterostegina borneensis* van der Vlerk, *Nephrolepidina marginata* (Michelotti), *Halkyardia minima* (Liebus), and *Borelis pygmaeus* (Hanzawa). Judging from the existence of a reworking problem, Tertiary c and d Stages from the Bugton Limestone at Bugton Point, Mindoro, Philippines, are not easy distinguished (Corby *et al.*, 1951; Hashimoto *et al.*, 1977). Therefore, Hashimoto *et al.* (op. cit.) could discriminate only the following fact: Tertiary c Bugton Fauna (BGT Fauna) is marked by the occurrence of *Nummulites fichteli* (Michelotti), *Halkyardia minima* (Liebus), and *Amphistegina radiata* (Fichtel and Moll). Tertiary d Bugton Fauna is characterized by the joint occurrence of *Nummulites fichteli* (Michelotti), *Nephrolepidina praetournoueri* H. Douvillé, *N. morgani* (Lemoine and R. Douvillé), *Eulepidina planata* (Oppenoorth), *E. dilatata* (Michelotti), *E. favosa* (Cushman), *E. formosa* (Schlumberger), *E. papuaensis* (Chapman), *Borelis pygmaeus* (Hanzawa), *Heterostegina borneensis* van der Vlerk, *Cycloclypeus* sp., *Operculina bartschi* Cushman, *O. venosa* (Fichtel and Moll), *Amphistegina radiata* (Fichtel and Moll), and *Planorbulinella larvata* (Parker and Jones). The latter has further been subdivided into the lower and upper biozones, according to the absence or presence of *Spiroclypeus*. In any case, *Nummulites fichteli* of Tertiary c Bugton Fauna might have existed in a deeper ecological condition than *Eulepidina dilatata* of Tertiary d Bugton Fauna. With the present status of knowledge, Assemblage IV could correlate Tertiary c and/or d of Bugton Fauna.

Assemblage IV is also correlated with the fauna of the Tertiary beds of 1629 to 2687 feet, in Eniwetok Atoll Drill Holes (Cole, 1957b), and 1723.5 to 2359.5 feet, in Bikini Atoll Drill Holes (Cole, 1954), respectively, because of the coexistence and range of *Eulepidina ephippioides (= E. formosa, E. abdopustula), Heterostegina borneensis (= H. nigripustula), H. duplicamera*, and *Halkyardia minima (= H. bikiniensis)*. Moreover, Assemblage IV is correlative with the fauna from the Calagasan Formation and Butong Limestone, south Cebu, Philippines, where *Eulepidina ephippioides* (Jones and Chapman), *E. formosa* (Schlumberger), *Heterostegina borneensis* van der Vlerk, and *Borelis pygmaeus* (Hanzawa) were reported by Alcantala (1980). Hashimoto *et al.* (1977) regarded the Calagasan Formation of the marine deposits to be equivalent to the nonmarine Cebu Coal Measure, and the Butong Limestone to be correlated with the Cebu Orbitoid Limestone in the Cebu coalfield, central Cebu, because of the presence of *Eulepidina ephippioides* and *Heterostegina borneensis*.

Sparse specimens of planktonic foraminifers in the lower part of Assemblage IV (see Fig. 13, Fig. 19) are *Globigerina sellii* (Borsetti), *G.* cf. *venezuelana* Hedberg, and *Globorotalia opima nana* Bolli, which correlate with *Globigerina sellii* Zone of lower Oligocene, or Zone P. 18?–20 of Blow (1969, 1979). Sparse specimens of planktonic foraminifers in the upper part of Assemblage IV include *Globorotalia* cf. *opima opima* Bolli, and *G.* group *opima* Bolli, which correlate with *Globorotalia opima opima* Zone of Bolli (1957), of upper Oligocene, or Zone P. 21 of Blow (op. cit.).

5. *Miogypsinella boninensis-Spiroclypeus margaritatus-Austrotrillina howchini* Assemblage (Assemblage V)

This assemblage is dominated by *Miogypsinella boninensis*, n. sp., *Spiroclypeus margaritatus* (Schlumberger), and *Austrotrillina howchini* (Schlumberger). This assemblage is generally seen in stratigraphic sequences in 1302, 1304, 801 S, and 801 N sections, and 9308 S and 9301 sections in the upper member of the Minamizaki limestone, in Chichi-Jima and Minami-Jima, respectively. Section 1304 probably is the most characteristic (Fig. 9).

Characteristic species: In addition to three nominated species, *Eulepidina dilatata* (Michelotti), *E. ephippioides* (Jones and Chapman), and *Borelis pygmaeus* (Hanzawa) are found in this assemblage. The common occurrence of the following species typifies this assemblage: *Amphistegina radiata* (Fichtel and Moll), *A. vulgaris* d'Orbigny, *Asterigerina tentoria* Todd and Post, *Orbitogypsina vesicularis*, n. gen., n. sp., *O. globulus*, n. gen., n. sp., *Mississippina concentrica* (Parker and Jones), *Neoplanorbulinella saipanensis* Matsumaru, *Planorbulinella larvata* (Parker and Jones), *Pararotalia mecatepecensis* (Nuttall), *Operculina complanata* (Defrance), *Heterostegina borneensis* van der Vlerk, *H. duplicamera* Cole, *Cycloclypeus eidae* Tan, *Victoriella conoidea* (Rutten), *Nephrolepidina marginata* (Michelotti), *Paleomiogypsina boninensis*, n. gen., n. sp., *Peelella boninensis*, n. gen., n. sp., *Boninella boninensis*, n. gen., n. sp., *Miniacina miniacea* (Pallas), *Sporadotrema cylindricum* (Carter), *Peneroplis planatus* (Fichtel and Moll), *Quinqueloculina ? boninensis*, n. sp., *Cyclorbiculina compressa* (d'Orbigny), *Cycloloculina boninensis*, n. sp., *Amphisorus hemprichii* Ehrenberg, *Borelis boninensis*, n. sp., *Bullalveolina boninensis*, n. sp., *Flosculinella reicheli* Mohler, *Praerhapydionina boninensis*, n. sp., *Austrotrillina howchini* (Schlumberger), and *Sorites orbiculus* (Forskål).

Correlation: The correlation depends on subjective opinions about the evolution of the Miogypsinidae. If the arrangement of the nepionic chambers and following the reverse principle of nepionic retardation is considered, *Miogypsinella boninensis*, n. sp., is the most primitive species. Moreover, *Miogypsinella grandipustulus* (Cole) is more advanced (younger) and this in turn evolved into either *Miogypsinella complanata* (Schlumberger) or *M. ubaghsi* (Tan) (Fig. 24). Using this evolutionary framework, Assemblage V was correlated with the earliest part of the Tertiary e1-4 by Hashimoto and Matsumaru (1984). Similarly, Assemblage V also may correlate with Tertiary e Stage limestones in boreholes at Eniwetok Atoll Drill Holes at depth from 1210 to 1599 feet, and at Bikini Atoll Drill Holes at depth from 1597.5 to 1671 feet, respectively, where *Miogypsinella grandipustula* (Cole) and *M. ubaghsi* (Tan) were reported by Cole (1957b, 1954).

Assemblage V is also correlative with the fauna of the Bugton Limestone, Mindoro, Philippines, which has *Spiroclypeus leupoldi* van der Vlerk, and *S. tidoenganensis* van der Vlerk, and both index fossils are junior synonyms of *Spiroclypeus margaritatus* (Schlumberger). Moreover, Assemblage V is regarded as probably Zone P.21 of the planktonic foraminiferal zonation of Blow (1969, 1979).

Summary of Geological Age

The five assemblages based on the larger foraminifers in the Ogasawara Islands are assigned to the Tertiary a3, Tertiary a3, Tertiary b, Tertiary c and/or d, and Tertiary e1–4 of the Far East Letter Stages, respectively. In addition, they are associated with planktonic foraminifers, and are considered to be correlative with planktonic foraminiferal Zone P.13, Zones P.13–14, Zones P.15–17, Zones P. 18?–21, and probable Zone P.21, respectively. Therefore, they are regarded as middle Eocene, late middle Eocene, late Eocene, early to late early Oligocene, and early late Oligocene, respectively.

Paleoecological Environment

The biota is dominated by shallow water forms, chiefly calcareous algae of red algae (Rhodophyta) and green algae (Chlorophyta), scleractinian corals as rock builders, bryozoans, echinoids, mollusks, and encrusting larger and smaller benthonic foraminifers. Larger foraminifers are especially known to be characteristic organisms of neritic environments in tropical to subtropical provinces, and of the photic zone, in order to acquire algal symbionts in their cytoplasm.

The biota was probably influenced by volcanic activity in the Ogasawara-Mariana Islands from middle Eocene to late Oligocene time, but this influence was probably subtle, because the organisms seem similar throughout the sections (Figs. 5–12), and *Nummulites perforatus* (Montfort) has a trimorphism reproduction under a productive ecological environment (Fig. 25; Matsumaru, 1994).

The sedimentary cycle in middle Eocene time began with a marine transgression represented by the basal deposits of the Yusan Formation (containing Assemblage I). A shallow shelf environment is indicated by larger foraminifers such as *Nummulites, Operculina, Discocyclina, Asterocyclina*, and *Daviesina*. Succeeding rocks contain *Alveolina*, indicating an inner shelf and/or lagoon environment. This environment in the Ogasawara Islands, except Haha-Jima, was interrupted, perhaps by tectonic forces or a drop in sea level as indicated by conglomerates and sandstones in the Yusankaigan and Miyukihama sequences (Fig. 5).

The sedimentation in an open marine basin with a slope environment resumed in late middle Eocene time when the Okimura Formation (containing Assemblage II) was deposited. This formation contains pelagic foraminifer-bearing sandstone and marl with several interbeds of thin limestone. The overlying Sekimon Limestone (containing Assemblage III) with abundant calcareous (coralline) algae (Rhodophyta); larger foraminifers, such as *Biplanispira, Pellatispira, Fabiania, Amphistegina*, and *Asterigerina*; echinoids; and thin coral biostromes, suggest coral reefs and/or a shelf environment.

The major regression of sea-level accompanied by cooling temperature of ocean deep water in the latest Eocene and/or earliest Oligocene (Douglas and Woodruff, 1981) has not yet been found either the Ogasawara Islands or at Eniwetok Atoll. This regressing/cooling interval, between Assemblages III and IV in the Ogasawara Islands may be present in the part of the Minamizaki Limestone (containing Assemblage IV) below sea level, or in the part of the Sekimon Limestone removed by erosion. The interval is presumably present at

Eniwetok Atoll where carbonate deposition seems continuous from late Eocene to Oligocene, but has not yet been recognized. The interval could also be present but unrecognized in the sections represented by Assemblages III and IV.

The Oligocene environment represented by the lower member of the Minamizaki Limestone was probably open ocean at the shelf edge, as indicated by *Eulepidina* and *Heterostegina* faunas (Assemblage IV). The environment was shallower and more protected during deposition of the upper member, as indicated by abundant *Miogypsinella, Spiroclypeus*, and *Austrotrillina* (Assemblage V). Perhaps the member represents a barrier reef adjacent to a lagoon.

Rate of Sedimentation

The rate of sedimentation can generally be determined from the total thickness of sediments deposited during an interval of geologic time, provided that the rate was constant. The following ages provide calibration points for the sections in the Ogasawara Islands. The radiometric age of the basal andesite of Hah-Jima (basal Assemblage I) is assumed to be about 42.5 Ma, by Kaneoka *et al.* (1970), and that of the boundary between the late middle Eocene Okimura Formation (Assemblage II) and late Eocene Sekimon Limestone (Assemblage III) is estimated at 40 Ma, by Berggren *et al.* (1985). The radiometric age between the Eocene/Oligocene boundary (between Assemblages III and IV) is generally assumed to be about 37 Ma, and that of the top of the Minamizaki Limestone (top of Assemblage V) is assumed to be about 29 Ma, based on relations of planktonic foraminiferal zonation of *Globorotalia opima opima* Zone at 1301, 1302, and 1304 sections and radiometric dating (Berggren *et al.*, 1985; Bolli and Saunders, 1985) (Fig. 13). Accordingly, the rates of sedimentation in the Tertiary sedimentary rocks in the Ogasawara Islands are as follows:

1. Middle Eocene Yusan and Okimura Formations (total 55 m thick)................ 22 m/Ma
2. Late Eocene Sekimon Limestone (135 m thick).. 45 m/Ma
3. Oligocene Minamizaki Limestone (only 83 m thick exposed above sea level)... minimum 10 m/Ma

Some examples will be given to investigate the calculation done so far. In Java, Indonesia, clastic sediments of the middle Eocene Kalisonggo Member of the Nanngulan Formation, from Tertiary a2 *Axinea* Layers to Tertiary a3 *Discocyclina* Layers, are 300 m thick (Marks, 1957), which is a duration from 8 Ma, based on the planktonic foraminiferal zonation (probably from Zone P. 11? to P. 14? of Blow, 1969, 1979) by Hartono (1969). Then the rate of sedimentation of the member is calculated to be 38 m per Ma. In Luzon, Philippines, the total thickness of the Masungit Limestone, from the middle Eocene MSG3 to MSG4 Faunas, is assumed to be 144 m (Hashimoto *et al.*, 1979, Fig. 3) during 9 Ma from 51 to 42 Ma. As the result, the rate of sedimentation of this limestone is estimated to be 16 m per Ma. As such, it may be difficult to accurately compare the rate of sedimentation of shallow water sediments in three areas of Java, Luzon and Haha-Jima.

Concerning the rate of sedimentation during the upper Eocene, there are three formations in Saipan: the Hagman Formation (335 m thick), Densinyama Formation (244 m thick), and Matansa Limestone (152 m thick), as described by Cloud *et al.* (1956). The rate of sedimentation of these three formations is calculated to be 112 m, 81 m, and 51 m per Ma, respectively.

In Guam, the total thickness of the upper Eocene and lower Oligocene Alutom Formation, with carbonate rocks, is more than 610 m (Schlanger, 1964). Then the rate of sedimentation of the formation is calculated to be 61 m per Ma, because the radiometric age of the upper part of the Alutom Formation is about 30 Ma. In Eniwetok Atoll, the thickness of upper Eocene beds is 1773 feet (540 m) from 2780 to 4553 feet (Cole, 1957b), and the rate of sedimentation of the beds is calculated to be 180 m per Ma. Moreover, in Ishigaki-Jima, 1862 km west-southwest of Haha-Jima, as shown in Fig. 1, the upper Eocene Miyara Formation, with carbonate rocks is estimated to be about 141 m thick (Foster, 1965). Then the rate of sedimentation of the formation is calculated to be 47 m per Ma. Therefore, the rate of sedimentation of the Matansa Limestone, Alutom Formation, and Miyara Formation seems to be in harmony with that of the Sekimon Limestone, whereas the rate of sedimentation of other beds is maximum four times than that of the Sekimon Limestone.

Concerning the rate of sedimentation during Oligocene beds, the thickness of the Oligocene-Miocene Tagpochau Limestone in Saipan is 1000 feet (305 m) (Cloud *et al.*, 1956). Then the rate of sedimentation of the limestone is calculated to be 16 m per Ma, if the radiometric age of the upper part of the limestone is about 11 Ma. According to Schlanger (1964), the thickness of the Oligocene-Miocene Umatac Formation in Guam is 2200 feet (671 m), and the rate of sedimentation of the formation is calculated to be 35 m per Ma. In Eniwetok and Bikini Atolls, both of the lower to lower upper Oligocene beds, which may be a duration from 8 Ma from 37 to 29 Ma, are estimated to be 1570 feet (479 m) thick from 1210 to 2780 feet, and 958.5 feet (292 m) thick from 1597.5 to 2556 feet, respectively, (Cole, 1957b, 1954). Then, the rate of sedimentation of each beds is 60 m per Ma and 37 m per Ma. In Kita-Daito-Jima (North Borodino Island) of Daito Ridge, as shown in Fig. 1, Sr isotope age of the upper Oligocene *Miogypsinella-* to middle Miocene *Miogypsina*-bearing beds, from 428.8 to 143.1 m in depth is 24.3 to 15.4 Ma by Ohde and Elderfield (1992) (Fig. 24). Then the rate of sedimentation from the beds is calculated to be 32 m per Ma. According to Ozima *et al.* (1977), the average sedimentation rate for the time interval from 47.5 to 20.5 Ma in the Deep Sea Drilling Project (DSDP) Leg. 31) (Site 296) at Kyushu-Palau Ridge, as shown in Fig. 1, is calculated to be 27.2 m per Ma.

Note on Evolutionary Trends

The author (1991) has indicated that Eocene *Orbitoclypeus* Silvestri, 1907 in the America-Europe and Indo-Pacific regions evolves into Oligocene *Eulepidina* H. Douvillé, 1911 in the same regions, based on the morphogenetic pattern in the microspheric form and many occurrences of adauxiliary chambers in the periembryonic stage in the megalospheric form, as one of evolutionary trends (lineage 3) in the family Lepidocyclinidae. The evolution of these forms in Ogasawara Islands is not clear, because specimens of *Orbitoclypeus kimurai* Matsumaru, 1989 from the Yusan and Okimura Formations and Sekimon Limestone in Haha-Jima are limited in occurrence, poorly preserved, and not in continuous sequence with *Eulepidina* species in Chichi-Jima and Minami-Jima. However, the evolution of *Orbitoclypeus* to *Eulepidina* is suggested by specimens in the same bed of the Kurusuno Formation (upper Eocene) in Shikoku, Japan (Matsumaru and Kimura, 1989; Matsumaru *et al.*, 1993), where *Orbitoclypeus kimurai* is associated with a species of *Orbitoclypeus* sp. (see Fig.

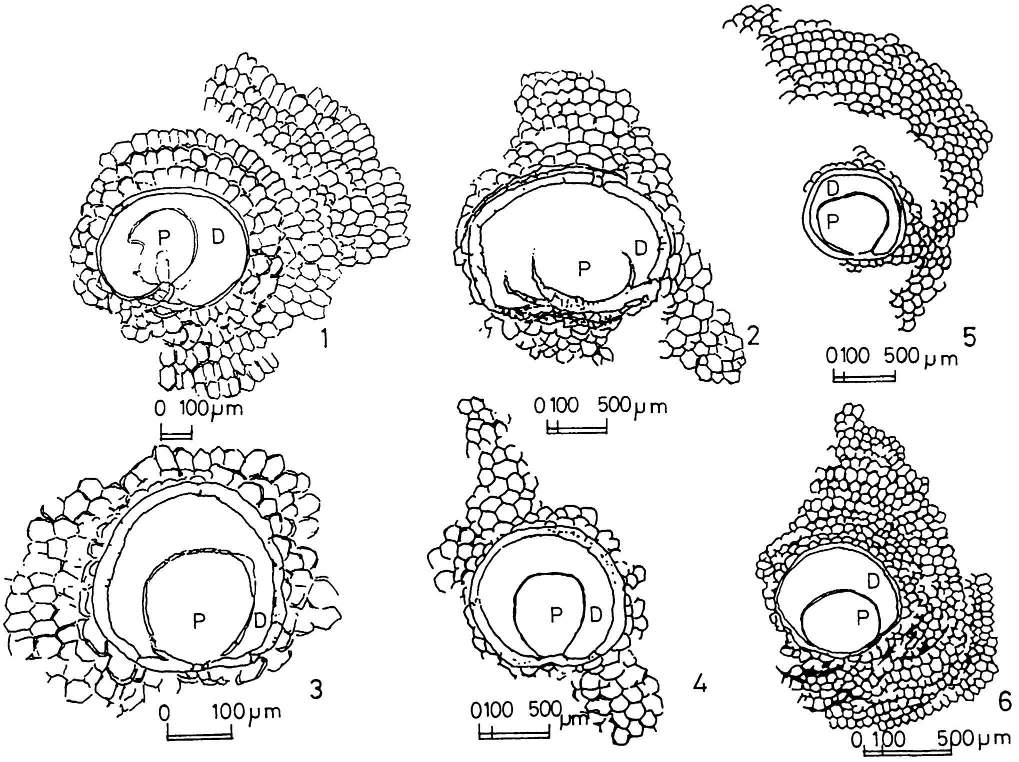


Fig. 20. Drawings of the embryonic, nepionic, and neanic stage in equatorial sections of species of: 1. *Orbitoclypeus himerensis* A. Silvestri, Lectotype, A. Silvestri's collection no. 500 (see Laghi and Sirotti, 1982, text-fig. 1); 2, 4. *Eulepidina dilatata* (Michelotti). 2, 1304–35–19 specimen (Plate 61, fig. 6), 4. 1304–17.5–3 specimen (Plate 61, fig. 2); 3. *Orbitoclypeus* sp., AZ141–1 specimen, Kurusuno Formation, Shikoku, Japan (Matsumaru and Kimura, 1989, fig. 5–3); 5. *Eulepidina ephippioides* (Jones and Chapman). 1301–12.2 specimen (Plate 65, fig. 3); 6. *Eulepidina papuaensis* (Chapman). Geological Survey, Bandoeng specimen, Tertiary d Tempilan Beds, east Borneo (van der Vlerk, 1928, fig. 7a). P: protoconch, D: deuteroconch of the embryonic chambers.

20–3), which has a full, large nucleoconch and enough thick outer walls of nucleoconch very close in concept to the genus *Eulepidina*. Moreover, the lectotype of *Orbitoclypeus himerensis* Silvestri, 1907 (see Fig. 20–1) has the same trochoid spiral from the embryonic to nepionic stages as *Eulepidina dilatata* (Michelotti, 1861) (see Fig. 20–2, Plate 61, fig. 6) from 35 station in 1304 section, Minamizaki Cape, Chichi-Jima, suggesting a close affinity.

The evolution of *Nephrolepidina marginata* (Michelotti, 1841) (Fig. 22–15) from the Minamizaki Limestone, Chichi-Jima and Minami-Jima, Ogasawara Islands, in evolutionary trends (lineage 2) in the family Lepidocyclinidae (Matsumaru, 1991) can be determined, in part, from the global geographic and stratigraphic distribution of some related middle to upper Eocene and Oligocene Lepidocyclinids (Fig. 22), and the morphological characters of Lepidocyclinids. In the America-Caribbean region, the lower Oligocene *Lepidocyclina yurnagunensis* Cushman, 1919 with equatorial chambers arranged in curves that intersect (Fig. 22–4), and *Lepidocyclina mantelli* (Morton, 1833), with equatorial chambers arranged in concentric rings (Fig. 22–5), have evolved from the upper Eocene *Lepidocyclina pustulosa*

H. Douvillé, 1917 (Fig. 22–3) and *Lepidocyclina macdonaldi* Cushman, 1918 (Fig. 22–2), respectively (Frost and Langenheim, 1974; Butterlin, 1987). During Oligocene, *Lepidocyclina yurnagunensis* evolved into *Lepidocyclina canellei* Lemoine and R. Douvillé, 1904 with equatorial chambers arranged in both intersecting curves (Fig. 22–6b) and concentric rings (Fig. 22–6a) (Cushman, 1919; Cole, 1961b).

In the Europe-Africa region, Oligocene *Nephrolepidina marginata* (Michelotti) (= *Nephrolepidina praemarginata* (R. Douvillé, 1908) (Fig. 22–8), *N. praetournoueri* (H. Douvillé, 1925) (Fig. 22–9)), with isolepidine to typical nephrolepidine embryos and equatorial chambers arranged in curves that intersect, is considered to evolve from the upper Eocene *Lepidocyclina mauretanica* (Bourcart and David, 1933) (Fig. 22–7), which is similar to *Lepidocyclina pustulosa* H. Douvillé in the America-Caribbean region (Brönnimann, 1940; Butterlin, 1991). Also, Oligocene *Nephrolepidina morgani* (Lemoine and R. Douvillé, 1904), with a nephrolepidine embryo and equatorial chambers arranged in intersecting curves (Fig. 22–10), evolves into Oligocene to Miocene *Nephrolepidina tournoueri* (Lemoine and R. Douvillé, 1904), with nephrolepidine to trybliolepidine embryos and equatorial chambers arranged in intersecting curves (Vervloet, 1966; Lange, 1968; Mulder, 1975; Matteucci and Schiavinotto, 1977). The author (Matsumaru, 1992) has indicated that *Nephrolepidina marginata* is a diploid, multinucleate agamont (microspheric form), whereas *Nephrolepidina morgani* is a haploid, uninucleate gamont (megalospheric form), and *Nephrolepidina marginata* is a senior synonym of *Nephrolepidina morgani*. Then, *Nephrolepidina marginata* evolved from *Lepidocyclina mauretanica* and, in turn, evolved into *Nephrolepidina tournoueri* in the Europe-Africa region.

In the Indo-Pacific Region, *Nephrolepidina parva* (Oppenoorth, 1918) and *Lepidocyclina formosensis* Hanzawa, 1939, both with equatorial chambers arranged in intersecting curves, are recognized as *Lepidocyclina yurnagunensis* in the America-Caribbean region (Grimsdale, 1959; Hashimoto and Matsumaru, 1973, 1975a). Also, both *Lepidocyclina isolepidinoides* van der Vlerk, 1929 (Fig. 22–14) and *Nephrolepidina sumatrensis* (Brady, 1875), with isolepidine to nephrolepidine embryos and equatorial chambers arranged in intersecting curves (Fig. 22–16), may be junior synonym of *Nephrolepidina marginata*, because they have similar embryos and equatorial chamber arrangement. *Nephrolepidina plicomargo* (Hanzawa, 1940) from the limestone of Oligocene and Miocene age in Kita-Daito-Jima (Hanzawa, 1940) has similar characters of a primitive nephrolepidine embryo and equatorial chambers arranged in intersecting curves to those of *Nephrolepidina marginata*. Moreover, *Nephrolepidina plicomargo* evolved into *Nephrolepidina tournoueri* from the lower Miocene part of the limestone in Kita-Daito-Jima (Fig. 24). If *Nephrolepidina plicomargo* is a junior synonym of *Nephrolepidina marginata*, this lineage of *Nephrolepidina plicomargo* to *N. tournoueri* is the same in the Indo-Pacific region as it is in the Europe-Africa region.

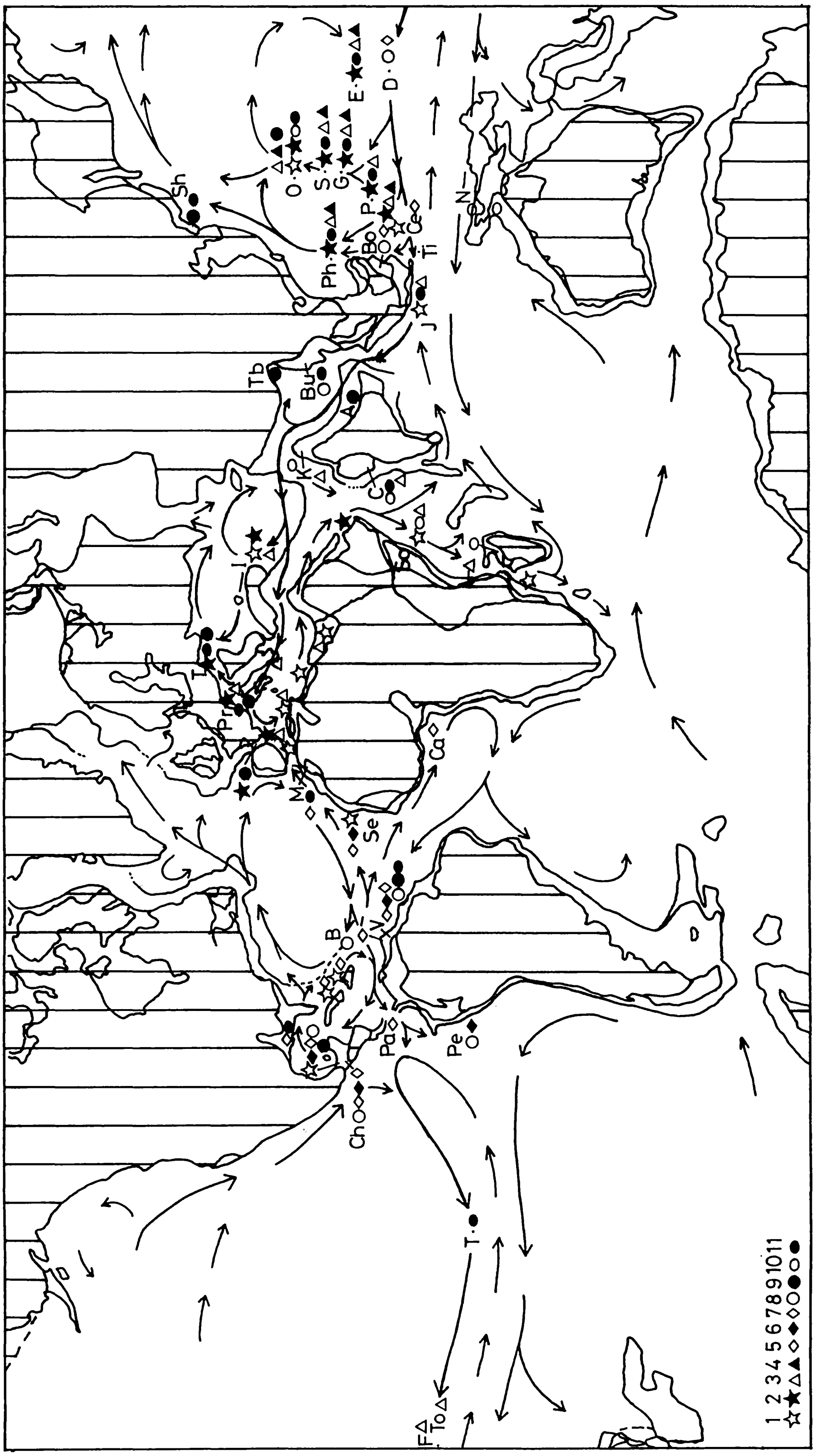
Nephrolepidina marginata (Michelotti) from the Minamizaki Limestone, Ogasawara Islands may evolve either from Eocene *Lepidocyclina mauretanica* (Bourcart and David) in the Europe-Africa region or from Eocene *Lepidocyclina pustulosa* H. Douvillé in the America-Caribbean region, because both have intersecting equatorial chambers. However, neither *Lepidocyclina mauretanica* or *L. pustulosa* have found yet from the Sekimon Limestone, Haha-Jima, Ogasawara Islands. *Nephrolepidina marginata* probably evolved into *Nephrolepidina tournoueri* in Kita-Daito-Jima of the Indo-Pacific region during Oligocene-Miocene (Fig. 24), similar to it's evolution in the Europe-Africa region.

Lepidocyclinids in the Ogasawara Islands, therefore, evidently evolved from species that migrated both from the America-Caribbean region and from the Europe-Africa region. In addition to the *Nephrolepidina marginata* lineages with intersecting equatorial chambers, lineages with concentric equatorial chambers are important in both regions of the Indo-Pacific and America-Caribbean. For example, *Lepidocyclina boetonensis* van der Vlerk, 1928 with isolepidine embryo and equatorial chambers arranged in concentric rings (Fig. 22–13), is regarded as more primitive species than Oligocene Tertiary d species in the Indo-Pacific region (Tan, 1936a, p. 9–10; Bemmelen, 1949, p. 131), whereas *Lepidocyclina mantelli* (Morton) has the same characters and the same age in the America-Caribbean region.

Similarly, *Polylepidina zeijlmansi* Tan, 1936a (Fig. 22–11) and *P. birmanica* Rao, 1940 (Fig. 22–12) from the Eocene beds in Borneo and Burma, respectively (Tan, 1936a; Rao, 1940; Matsumaru, 1991), in evolutionary trends (lineage 1) in the family Lepidocyclinidae (Matsumaru, 1991) have the same characteristics as *Polylepidina antillea* (Cushman, 1919) (Fig. 22–1) in the America-Caribbean region, but are missing in Europe and Africa, showing the close association of the Indo-Pacific and America-Caribbean faunas during the Eocene time. Moreover, Premoli Silva and Brusa (1981) found *Polylepidina antillea* and other larger foraminifers in the upper Oligocene bed (Leg. 61, Site 462, core 22–1, 69–71 cm), and *Polylepidina* sp. in the upper Eocene bed (Leg. 61, Site 462, core 34), both from the Deep Sea Drilling Project Hole 462 in the Nauru Basin, Marshall Islands, Pacific Ocean (Fig. 21–D). The most of them were reworked into the pelagic foraminifers composing clastic sediments by a turbidity current. Both *Polylepidina* species would have migrated by a paleocurrent from the America-Caribbean region to the Indo-Pacific region during the Eocene time (Fig. 21). However, the evolution of *Polylepidina* is obscure in the Indo-Pacific region.

The evolution of the family Miogypsinidae is discussed below. *Paleomiogypsina boninensis*, n. gen., n. sp., occurs in the lower and upper members of the Minamizaki Limestone as foraminifers having intermediate morphogenetical features between *Pararotalia mecatepecensis* (Nuttall, 1932) and *Miogypsinella boninensis*, n. sp. (Figs. 7–13, 23 and 24). Accordingly, *Paleomiogypsina boninensis* is regarded as a bridge species in the evolutionary trends from *Pararotalia mecatepecensis* to *Miogypsinella boninensis*. Tan (1936b, p. 47) thought that *Miogypsinoides* evolved from a *Rotalia* ancestor. Drooger (1952, p. 59–60) and Hanzawa (1964, p. 309) thought that *Rotalia* aff. *mexicana* Nuttall and *Neorotalia* Bermúdez, both of *Pararotalia* Le Calvez, 1949 were an ancestor of the Family Miogypsinidae and *Miogypsinoides*, respectively. The discovery of *Paleomiogypsina boninensis* provides a more reasonable explanation for this evolution.

Paleomiogypsina boninensis evolved from *Pararotalia mecatepecensis* by having a few advanced subsidiary equatorial chambers on the frontal side of the last whorl of the low trochspirally-coiled test during the early Oligocene (Tertiary c and/or d). At that time, *Paleomiogypsina boninensis* could have evolved into *Miogypsinella boninensis*, which is found in the upper member of the Minamizaki Limestone, and which has larger embryonic chambers and many equatorial chambers in the frontal side of the test. *Miogypsinella boninensis* is a more primitive species than *Miogypsinella grandipustula* (Cole, 1954), because it has more nepionic chambers or whorls, from the viewpoint of the reverse principle (nepionic retardation) of nepionic acceleration by Tan (1936b, p. 47–50), Drooger (1952,


Sh
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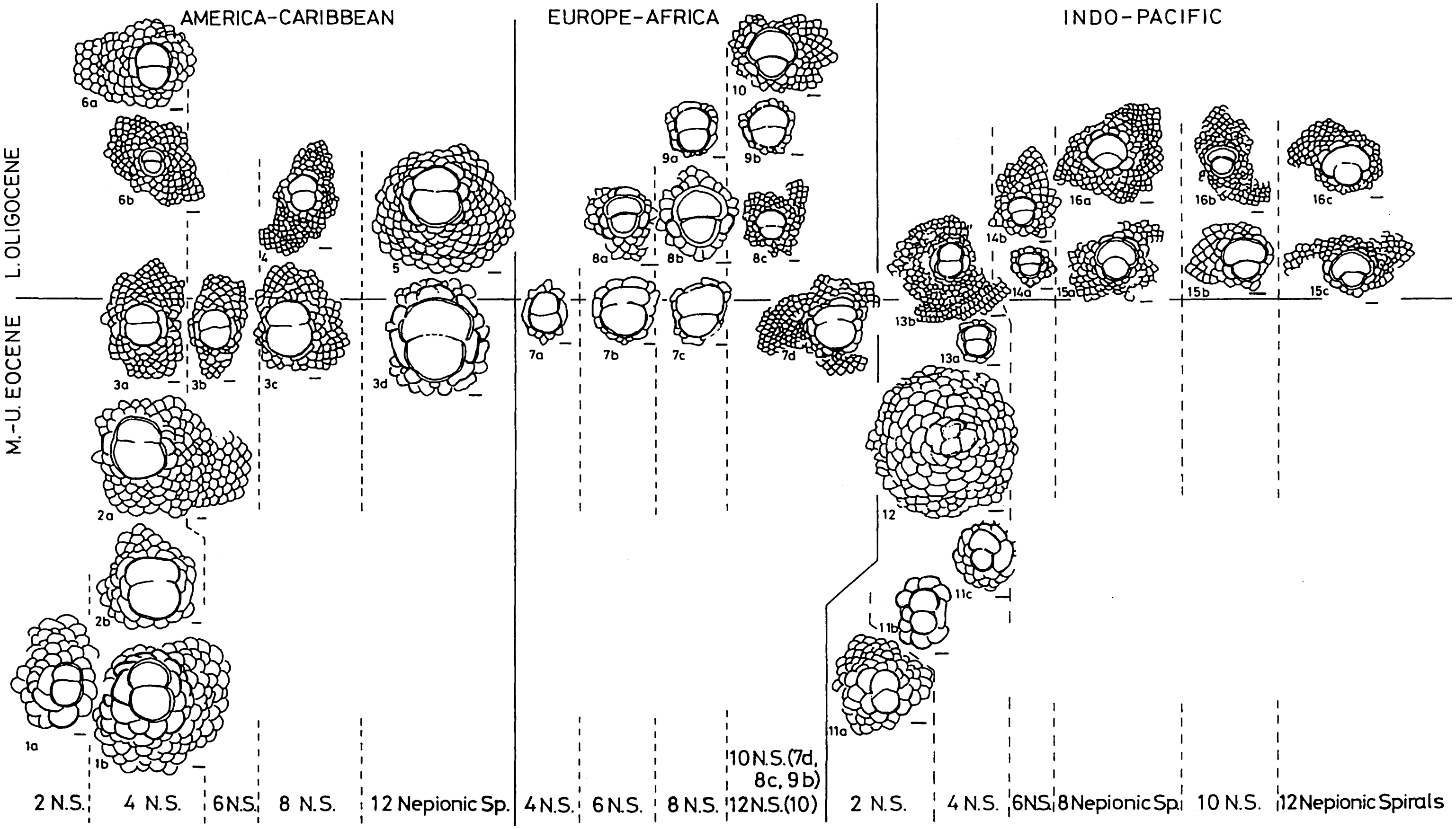
p. 64), and Hanzawa (1957, 1964, 1965). Therefore, the following evolutionary trends of the Miogypsinidae are deduced from the biostratigraphic occurrence and the nepionic acceleration-retardation theory: *Pararotalia mecatepecensis* (Nuttall) → *Paleomiogypsina boninensis* Matsumaru → *Miogypsinella boninensis* Matsumaru → (*Miogypsinella grandipustula* (Cole)). After that *Miogypsinella grandipustula* could evolve into *Miogypsinella ubaghsi* (Tan, 1936b) or *M. complanata* (Schlumberger, 1900). *Miogypsinella ubaghsi* (Tan) could evolve into *Miogypsinella borodinensis* Hanzawa, 1940 which, in turn, could evolve into *Miogypsinoides dehaartii* (van der Vlerk, 1924), as shown by stratigraphical occurrences from the Eniwetok and Bikini Atolls Drilling Holes and Kita-Daito-Jima Drill Hole (Cole, 1954, 1957b; Hanzawa, 1940) (Fig. 24).

Boninella boninensis Matsumaru occurs in the upper member of the Minamizaki Limestone and is regarded as a new form belonging to a filiation of the main lineage *Paleomiogypsina* → *Miogypsinella* (Figs. 9, 13, 23 and 24). *Boninella boninensis* is characterized by having two low trochoid spirals of subquadrate chambers, formed by repeated doubling, originating from bilocular chambers; a few advanced equatorial chambers in the final whorl on the distal margin; and a compact lateral wall without rudimentary lateral chambers. Accordingly, *Boninella boninensis* is considered to have evolved from *Paleomiogypsina boninensis* during the early late Oligocene (Tertiary e1–4). This new lineage of *Boninella boninensis* has been discovered in the Ogasawara Islands for the first time.

Fig. 21. Global geographic distribution of some upper middle to upper Eocene larger foraminifera, with paleocurrent directions (arrow) inferred from present currents. Vertical lines show continents. Map mainly based on data from Barron *et al.* (1981, Plate 7). *Nummulites* group *gizehensis* (Forskål) records mainly followed Blondeau (1972) and Fleury *et al.* (1985). 1. *Nummulites* group *gizehensis* (Forskål); 2. *Spiroclypeus* group *granulosua* Boussac; 3. *Pellatispira*; 4. *Biplanispira*; 5. *Lepidocyclina* s. s.; 6. *Helicolepidina*; 7. *Helicostegina*; 8. *Polylepidina*; 9. *Orbitoclypeus*; 10. *Alveolina* group *elliptica* (Sowerby); 11. *Asterocyclina*. Sh: Shikoku (Matsumaru and Kimura, 1989), O: Ogasawara Is. (this paper), S: Saipan Is. (Cole, 1957a; Hanzawa, 1957), G: Guam Is. (Cole, 1963a), E: Eniwetok Atoll (Cole, 1957b), D: DSDP462 (Premoli Silva and Brusa, 1981), P: Palau Is. (Hanzawa, 1957), Ce: Celebes (Tan, 1936a), N: New Guinea (Rutten, 1914a), Ph: Philippines (Hashimoto and Matsumaru, 1984), Bo: Borneo (Tan, 1936a; Bemmelen, 1949), Ti: Timor (Henrici, 1934; Bakx, 1932), J: Java (Doornink, 1932; Bakx, 1932), Tb: Tibet (Ho Yen *et al.*, 1976), Bu: Burma/Myanmar (Rao, 1940; Nagappa, 1959), A: Assam (Samanta, 1965), K: Kohat (Davies, 1925), C: Cutch/Kutch (Sowerby, 1840), I: Iran (Ghose, 1972), So: Somalia (Silvestri, 1937), Lindi (Eames *et al.*, 1962), T: Tatra (Bieda, 1963), Pr: Priabona (Sirotti, 1978), Aquitaine (Neumann, 1958), M: Marocco (Brönnimann, 1940), Se: Senegal (Freudenthal, 1972; Neumann *et al.*, 1986), Ca: Cameroon (Brun *et al.*, 1982), B: St. Barthelemy Is. (Cushman, 1919; Vaughan, 1924), V: Venezuela (Cizancourt, 1951; Raadshooven, 1951), Cuba (Cushman and Bermúdez, 1936), Veracruz (Barker and Grimsdale, 1936), Ch: Chiapas (Vaughan, 1924; Frost and Langenheim, 1974), Pa: Panama (Vaughan and Cole, 1941), Pe: Peru (Rutten, 1928), T.: Tuamotu (Cole, 1959b), To: Tonga (Umbgrove, 1928), F: Fiji (Whipple, 1934; Cole, 1960)


AMERICA-CARIBBEAN
EUROPE-AFRICA
INDO-PACIFIC
L. OLIGOCENE
M.-U. EOCENE
6a
6b
4
5
3a
3b
3c
3d
2a
2b
1a
1b
10
9a
9b
8a
8b
8c
7a
7b
7c
7d
14b
14a
16a
16b
16c
15a
15b
15c
13b
13a
12
11c
11b
11a
2 N.S.
4 N.S.
6N.S.
8 N.S.
12 Nepionic Sp.
4 N.S.
6 N.S.
8 N.S.
10 N.S. (7d, 8c, 9b)
12 N.S. (10)
2 N.S.
4 N.S.
6N.S.
8 Nepionic Sp.
10 N.S.
12 Nepionic Spirals

Systematic Paleontology

Phylum Protozoa Goldfuss, 1817
Subphylum Sarcodina Schmarda, 1871
Class Rhizopoda von Siebold, 1845
Order Foraminiferida Eichwald, 1830
Suborder Rotaliina Delage and Hérouard, 1896
Superfamily Rotaliacea Ehrenberg, 1839
Family Rotaliidae Ehrenberg, 1939
Subfamily Cuvillierininae Loeblich and Tappan, 1964
Genus *Daviesina* Smout, 1954
Daviesina boninensis Matsumaru, n. sp.

Plate 1, figures 1–5; Plate 2, figures 1–8.

Type material: Holotype, horizontal section of megalospheric form, Saitama University coll. no. 8816 (Plate 1, fig. 3); Paratype, axial section of microspheric form, Saitama University coll. no. 8817 (Plate 2, fig. 5).

Description: Test lenticular, with moderately wide, thin flange on distal part; 1.52 to 2.50 mm in diameter, 0.6 to 1.0 mm in thickness; form ratio of diameter to thickness, 1.6 to 3.5; surface covered with big pustules (120 to 270 µm across) in central part of dorsal side, covered by a kind of rugged big plug (110 to 300 µm across) in central part of ventral side; low trochospiral to planispiral coil. Megalospheric apparatus, biloculine; protoconch, spherical, 637 × 637 µm in diameter; deuteroconch, reniform, 588 × 120 µm in diameter; microspheric proloculus, spherical to subspherical, 20 × 18, 20 × 20, and 16 × 14 µm in diameter; 1 and 3/4 whorls discernible in megalospheric form; a radius of 735 µm in a half whorl with 4

Fig. 22. Global geographic and stratigraphic distribution of some related middle to upper Eocene and lower Oligocene Lepidocyclinids. Scale bars = 100 microns. 1. *Polylepidina antillea* (Cushman) (= *Polylepidina chiapasensis* Vaughan). 1a–b. Cole, 1963b, pl. 1, fig. 3, pl. 6, fig. 1; 2. *Lepidocyclina macdonaldi* Cushman. 2a. Vaughan and Cole, 1941, pl. 31, fig. 2, 2b. Butterlin, 1987, pl. 1, fig. 3; 3. *Lepidocyclina pustulosa* H. Douvillé. 3a–c. Cole, 1963b, pl. 2, figs. 3, 2, 6, 3d. Cole, 1963a, pl. 3, fig. 2; 4. *Lepidocyclina yurnagunensis* Cushman. Vaughan and Cole, 1941, pl. 38, fig. 3; 5. *Lepidocyclina mantelli* (Morton). Cole, 1963b, pl. 1, fig. 2; 6. *Lepidocyclina canellei* Lemoine and R. Douvillé. 6a–b. Cole, 1961b, pl. 33, figs. 3, 1; 7. *Lepidocyclina mauretanica* (Bourcart and David). 7a–d Brönnimann, 1940, text-fig. 7a–c, pl. 4, fig. 2; 8. *Nephrolepidina praemarginata* (R. Douvillé). 8a-b. Schiavinotto, 1978, pl. 75, figs. 3–4; 8c. Vervloet, 1966, pl. 12, fig. 3; 9. *Nephrolepidina praetournoueri* H. Douvillé. 9a–b. Brönnimann, 1940, text-fig. 14a, c; 10. *Nephrolepidina morgani* (Lemoine and R. Douvillé). Lemoine and R. Douvillé, 1904, pl. 3, fig. 2; 11. *Polylepidina zeijlmansi* (Tan). 11a–c. Tan, 1936a, pl. 1, figs. 3b–c, 5; 12. *Polylepidina birmanica* Rao. Rao, 1940, fig. 1; 13. *Lepidocyclina boetonensis* van der Vlerk, 13a. Tan, 1935, fig. 12, 13b. van der Vlerk, 1928, fig. 58a; 14. *Lepidocyclina isolepidinoides* van der Vlerk. 14a. Tan, 1935, fig. 13, 14b. van der Vlerk, 1928, fig. 48c; 15. *Nephrolepidina marginata* (Michelotti). 15a, c. 9707–3 specimen, Minami-Jima (Plate 71, fig. 1), 9707–9 specimen, Minami-Jima (Plate 71, fig. 2), 15b. 9703–3′ specimen, Minami-Jima, which isn't illustrated on Plate; 16. *Nephrolepidina sumatrensis* (Brady). 16a–c. Cole, 1957b, pl. 242, figs. 15, 10, 12.

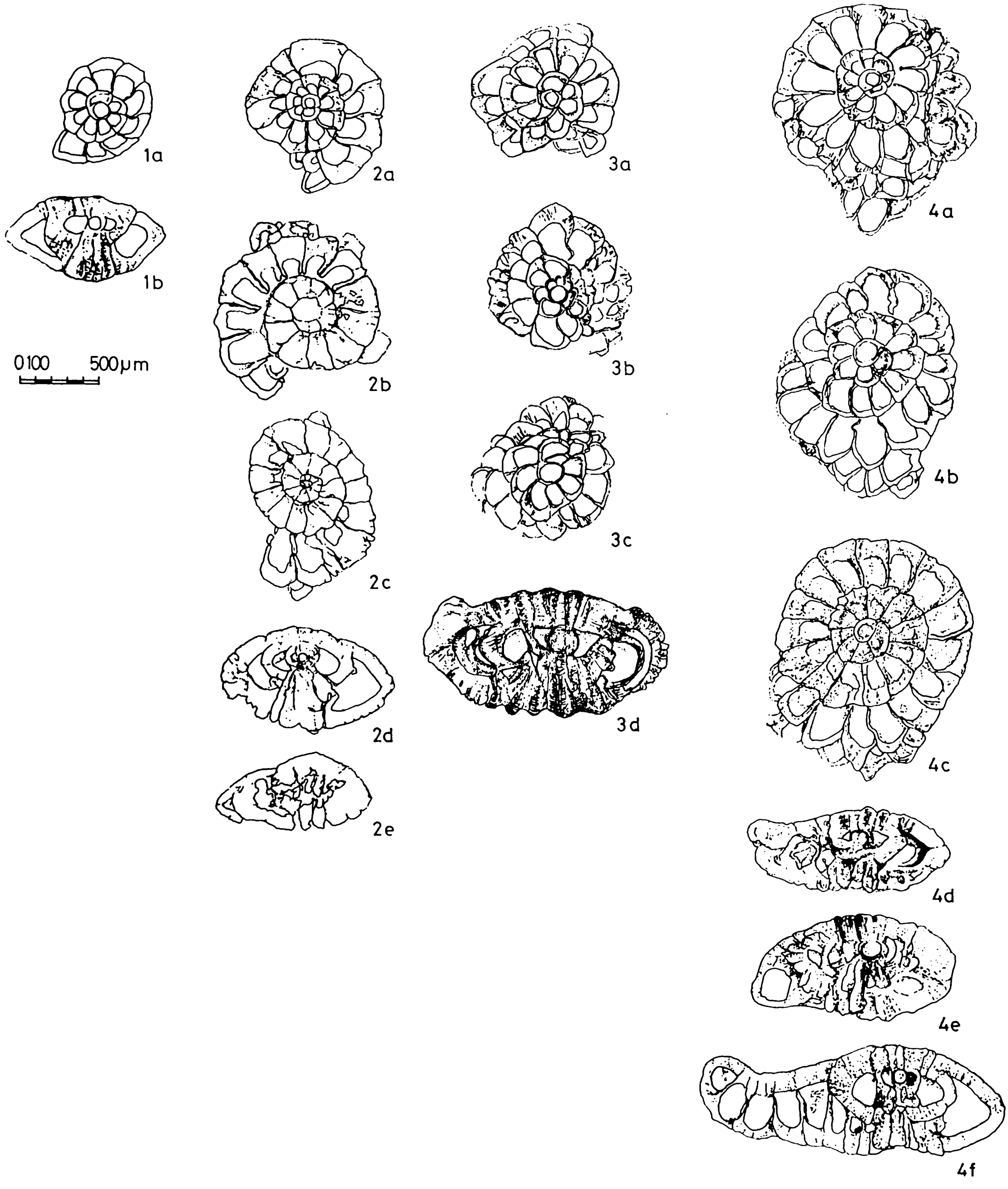


Fig. 23. Drawings of the embryonic, nepionic, and neanic stages in the equatorial and vertical sections of species of: 1. *Pararotalia mecatepecensis* (Nuttall). 1a. 1304–17.5–10 specimen (Plate 3, fig. 1), 1b. 1304–5–10 specimen (Plate 3, fig. 5); 2. *Paleomiogypsina boninensis*, n. gen., n. sp. 2a. Holotype, 1304–8–7 specimen (Plate 8, fig. 1), 2b. 71801–11–10 specimen (Plate 8, fig. 2), 2c. Paratype, 1301–15–13 specimen (Plate 9, fig. 1), 2d. 1304–25–7 specimen (Plate 9, fig. 7), 2e. 1301–15–2 specimen (Plate 9, fig. 11); 3. *Boninella boninensis*, n. gen., n. sp. 3a. Holotype, 1304–45–7 specimen (Plate 4, fig. 1), 3b. 1305–4 specimen (Plate 4, fig. 2), 3c. Paratype, 1304–45–19 specimen (Plate 4, fig. 4), 3d. 1304–43–7 specimen (Plate 4, fig. 3); 4. *Miogypsinella boninensis*, n. sp. 4a. 1304–43–20a specimen (X = 25, AP = 500°; Plate 6, fig. 4), 4b. Holotype, 1304–43–20b specimen (X = 30, AP = 590°; Plate 6, fig. 7), 4c, 9716–3 specimen (X = 31, AP = 610°; Plate 6, fig. 8), 4d. 1304–43–15 specimen (Plate 7, fig. 10), 4e. 82703–6 specimen (Plate 7, fig. 7), 4f. Paratype, 801S–4.5–3 specimen (Plate 7, fig. 12). Scale is applicable to 1 to 4.

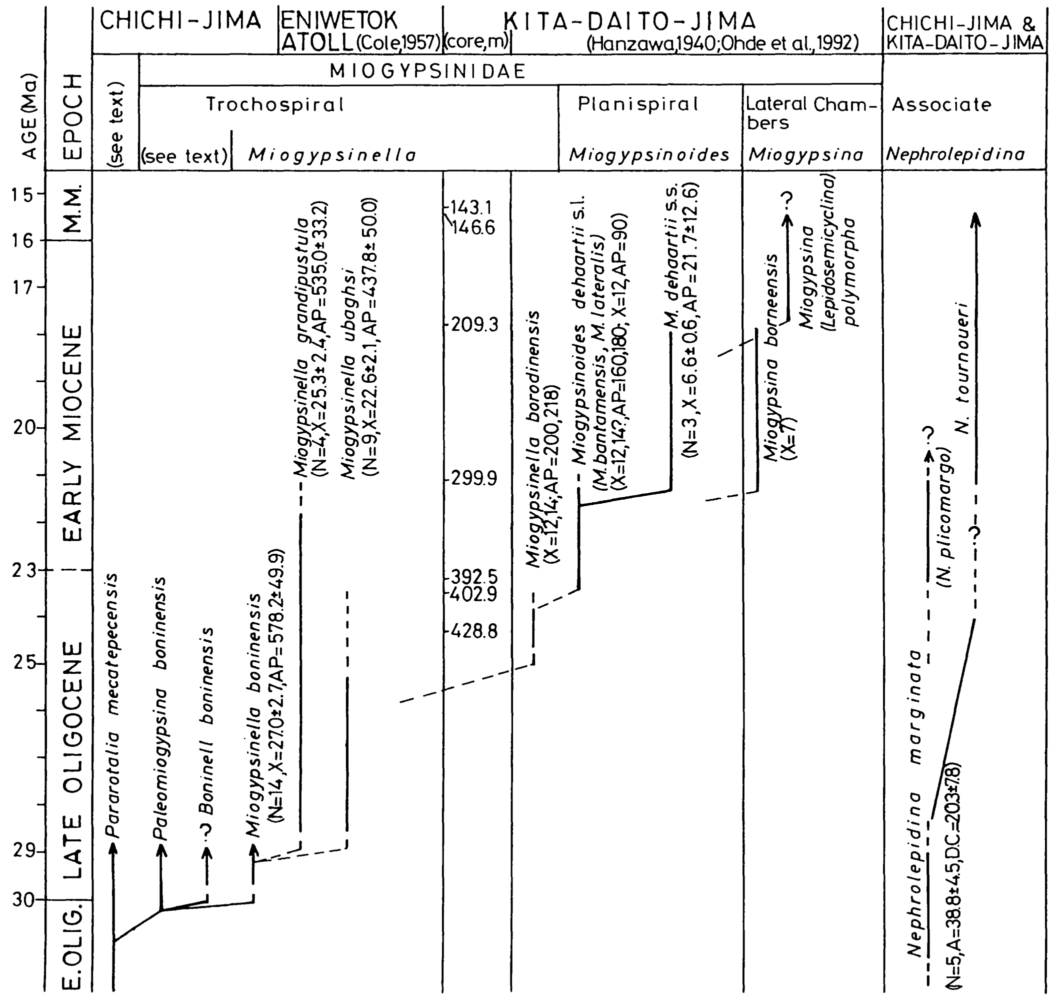


Fig. 24. Evolution of western Pacific Miogypsinids from Chichi-Jima, Eniwetok Atoll, and Kita-Daito-Jima, and the stratigraphic position of associated *Nephrolepidina* species from Chichi-Jima and Kita-Daito-Jima. The stratigraphic position of *Miogypsinella grandipustula* (Cole), and of *Miogypsinella ubaghsi* (Tan) from Eniwetok Atoll (Cole, 1957b), is tentatively inferred by the X and Ap values of both species, and by associated *Miogypsinella boninensis* Hanzawa, and *Miogypsinoides dehaartii* (van der Vlerk).

chambers, 980 μm in the first whorl with 9 chambers, and 1299 μm in the first and a half whorl with 9 chambers; 4 whorls in microspheric form; a radius of 84 to 100 μm in the first whorl with 7 to 8 chambers, 240 to 280 μm in the second whorl with 11 chambers, 468 to 582 μm in the third whorl with 16 to 17 chambers, and 1020 to 1030 μm in the 4th whorl with 25 to 26 chambers. Equatorial chambers in megalospheric form, irregularly elongate and curved near periphery; those in microspheric form, narrow, high, and operculine in appearance; septa, doubled, forming intraseptal canal system; wall very thick, calcareous, lamellar, and radially fibrous; with vertical canals on both side of test; no marginal cord present; median ridges and nodes, present in outer wall of chambers; aperture interiomarginal.

Stratigraphic horizon: Yusan and Okimura Formations.

Remarks: The present form is similar to *Daviesina khatiyahi* Smout, 1954, the type species of *Daviesina* Smout, 1954, from the Paleocene beds of Qatar, in general appearance of a rotaloid to operculine test without marginal cord, but is different from the latter by the presence of smaller pustules, fewer chambers, and a large embryonic apparatus. The present form differs from all other species of *Daviesina ruida* (Schwager, 1883), *D. langhami* Smout, 1954; *D. danieli* Smout, 1954; *D. tenuis* (Tambareau, 1967); *D. garumnensis* Tambareau, 1972; *D. chattoni* Caus, Hottinger, and Tambareau, 1980; *D. persica* Rahaghi, 1983; *D. shirazensis* Rahaghi, 1983; and *D. iranica* Rahaghi, 1983, by the characteristics of operculine chambers and large megalospheric apparatus. Thus the present form is assigned to *Daviesina boninensis*, n. sp. Also the present new species, without a median equatorial layer of spatulate, and without hexagonal chambers and differentiated lateral chambers, is regarded as the genus *Daviesina* in the Subfamily Cuvillierininae Loeblich and Tappan, 1964, Family Rotaliidae Ehrenberg, 1839, but not in the Subfamily Lepidorbitoidinae Vaughan, 1933, Family Lepidorbitoididae Vaughan, 1933.

Subfamily Pararotaliinae Reiss, 1963

Genus *Pararotalia* Y. Le Calvez, 1949

Pararotalia mecatepecensis (Nuttall, 1932)

Plate 3, figures 1–7; Plate 52, figure 1 (left); Fig. 23–1.

Rotalia mexicana Nuttall var. *mecatepecensis* Nuttall, 1932, p. 26, pl. 4, figs. 11–12; Barker and Grimsdale, 1937, p. 167, pl. 6, fig. 7; pl. 7, figs. 7–9.

Rotalia mecatepecensis Nuttall. Hanzawa, 1957, p. 59–60, pl. 2, figs. 1–11.

Pararotalia sp. Matsumaru, Myint Thein, and Ogawa, 1993, p. 12, figs. 2–5–6.

Description: Test small, roughly circular and trochoid, planoconvex to subglobular,

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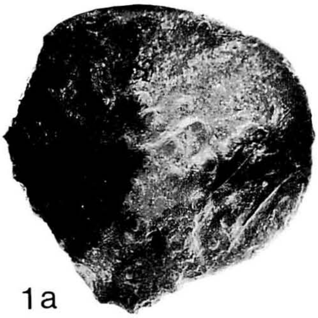
Explanation of Plate 1

Daviesina boninensis Matsumaru, n. sp.

1a, 4a. Dorsal views. ×17. 1b, 5a. Oblique ventral views. 1b. ×17, 5a. ×8.2. 2. Vertical section of microspheric form. ×20. 3a–b. Horizontal sections of megalospheric form. Holotype, Saitama University coll. no. 8816. 3a. ×20, 3b, Partially enlarged of Figure 3a. ×40. 4b, 5b. Ventral views. 4b. ×17, 5b. × 8. Okimura Formation; Locality: NS72402.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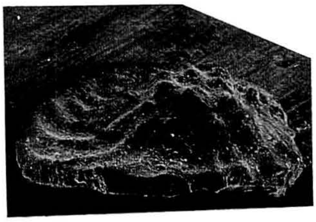
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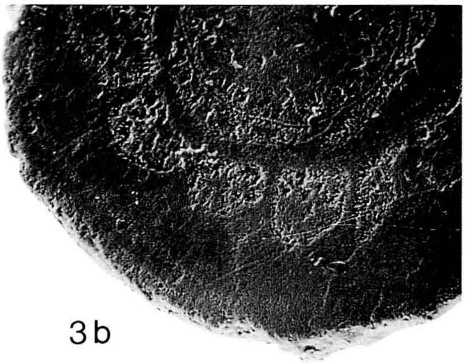
3a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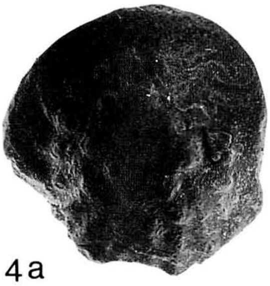
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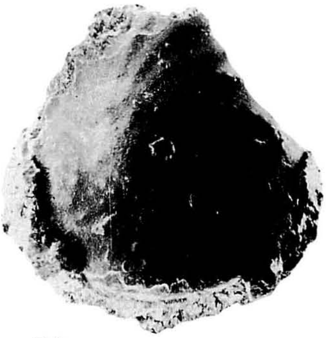
5a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with dorsal side slightly more vaulted than ventral side; surface ornamented with numerous tubercles on dorsal side, and with large umbilical plug and solid massive pillars filling ventral side; 0.82 to 1.35 mm in diameter, and 0.55 to 0.68 mm in thickness. Megalospheric test, composed of 1 and 1/2 to 2 and 1/4 whorls, with 8 to 10 subquadrate chambers in the first whorl, and 11 to 12 chambers in the second whorl. Protoconch, spherical to subspherical; internal diameter, 75 × 75, 85 × 87, and 88 × 88 μm, and deuteroconch, reniform; inner diameter, 65 × 38 and 75 × 70 μm; succeeding subquadrate chambers, of dimmension 75 × 150, 80 × 95, 100 × 100, 110 × 138, 125 × 163, 125 × 188, 133 × 133, 150 × 163, 163 × 163, and 158 × 250 μm in inner radial and tangential diameters; rudimentary subsidiary chambers, on frontal side of test between subquadrate chambers in last whorl; of dimension 25 × 58 and 33 × 83 μm, in inner radial and tangential diameters. Lateral layers on dorsal side of test, not thick; 100 to 150 μm, and those on ventral side, thickly developed with solid plugs and shell materials; 300 to 450 μm. Vertical canals, 3 to 14 μm in diameter, and lateral canals, 6 to 8 μm in diameter.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form closely resembles *Rotalia mecatepecensis* Nuttall from Saipan, as described by Hanzawa (1957), in external and internal structures and overall size, although no mention of peripheral subsidiary chambers was made by Hanzawa. The present form belongs to the genus *Pararotalia*, according to Le Calvez (1949), based on the description and illustration. Then, the present form is assigned to *Pararotalia mecatepecensis* (Nuttall). This species is slightly different from *Pararotalia mexicana* (Nuttall) from the upper Eocene of Mexico, in having fewer chambers. *Pararotalia mecatepecensis* from the Minamizaki Limestone, Chichi-Jima, resembles *Pararotalia floscula* (Todd and Post, 1954) from the Oligocene beds of Bikini Drill Holes, but is different from the latter in having an asymmetric biconvex test and many chambers in the mature form. *Pararotalia mecatepecensis* resembles *Pararotalia viernoti* (Creig) from the Maastrichtian to Oligocene beds in the middle East and western Asia, but it differs from the latter in having rudimentary subsidiary chambers.

Family Miogypsinidae Vaughan, 1928

Genus *Boninella* Matsumaru, n. gen.

Type species: *Boninella boninensis* Matsumaru, n. sp.

Diagnosis: Test flabelliform in outline, in low trochospiral, with spiral side evoluted and finally involute; biconvex, with two spires of subquadrate to arcuate chambers, formed by

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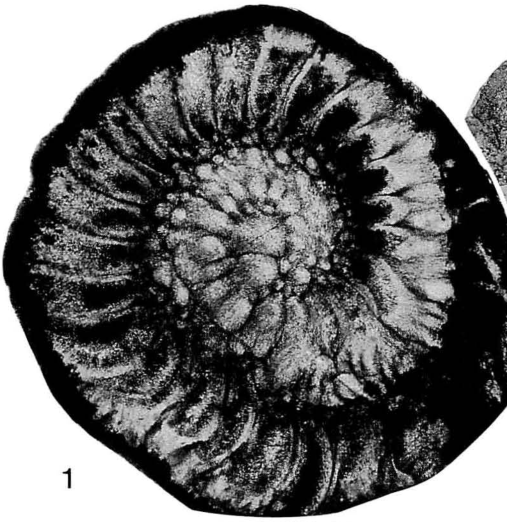
Explanation of Plate 2

(All figures ×42)

Daviesina boninensis Matsumaru, n. sp.

1, 3–4. Transverse sections. 1,4. Megalospheric forms, 3. Microspheric form. 2, 6–8. Equatorial sections of microspheric form. 5. Axial section of Microspheric form. Paratype, Saitama University coll. no. 8817. Yusan Formation; Localities: 1, 3. US82202, 2. US81704, 4. MI81806. Okimura Formation; Localities: 5–7. NS72402, 8. RO72405.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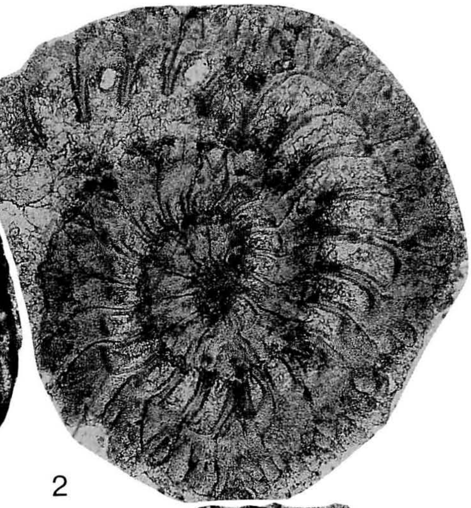
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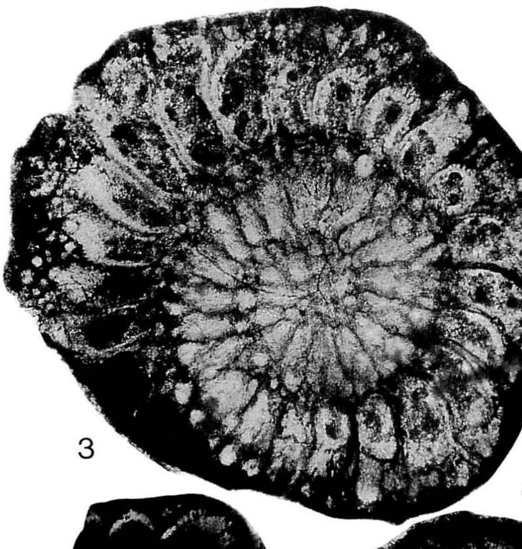
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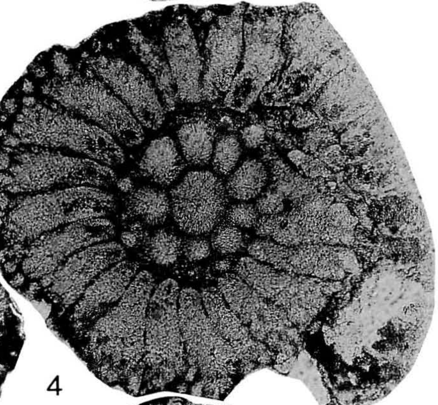
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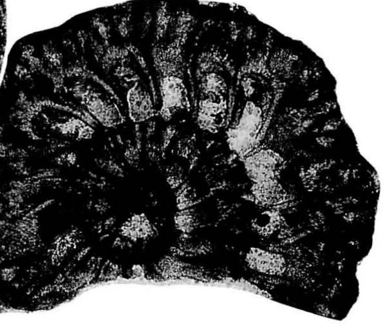
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repeated doubling, originating from bilocular embryonic chambers of protoconch and deuteroconch, similar to *Dictyokathina* Smout, 1954; a few advanced ogival equatorial chambers, present in front of final whorl on distal margin; septal flap present, and intraseptal canal system present around each embryonic, nepionic, and equatorial chamber; vertical canals extend to both ventral and dorsal sides from intersections of intraseptal canals, and to ventral side from spiral canal lying between umbilical plugs and umbilical flaps; several umbilical plugs present on ventral side below protoconch; lateral canal system present on ventral side; dorsal side, massive; wall calcareous; lateral walls thick, compact; rudimentary lateral chambers absent; surface smooth to pustulose.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Comparison: The present genus resembles *Dictyokathina* Smout, 1954, but is distinguished from the latter in having only two chamber spires and a few advanced ogival equatorial chambers. The present genus resembles *Paleomiogypsina*, n. gen., as described later, and *Miogypsinella* Hanzawa, 1940, but is distinguished from the latter two in having two chamber spires.

Boninella boninensis Matsumaru, n. sp.

Plate 4, figures 1–4; Plate 5, figure 8; Fig. 23–3.

Type material: Holotype, equatorial section of megalospheric specimen, Saitama University coll. no. 8806 (Plate 4, fig. 1). Paratype, horizontal section parallel to equatorial section of microspheric specimen, Saitama University coll. no. 8807 (Plate 5, fig. 8).

Description: Megalospheric specimens, small flabelliform tests; of diameter 1.0 to 1.58 mm, and thickness 0.85 mm, from 5 specimens; paratype specimen of microspheric generation, small flabelliform test with very inflated spiral chambers from central plug below small proloculus. Test, biconvex, ventral side more strongly convex than dorsal side; several conical umbilical plugs, 150 to 225 μm, extending to the protoconch; dorsal side, rather smooth, compact, and lamellae; but rudimentary lateral chamber absent; with several pustules of diameter 138 to 160 μm. Megalospheric embryonic chambers, biloculine; spherical to subspherical protoconch; inner diameter 90 × 90, 105 × 107, 105 × 116, and 116 × 116 μm; reniform deuteroconch; inner diameter 95 × 70, 116 × 70, 116 × 70, and 163 × 116 μm; diameter of whole embryonic chambers, 186, 186, 200, and 250 μm across both protoconch and deuteroconch. Embryonic chambers, followed by repeated doubling of two spires of subquadrate chambers, evoluted dorsally and finally involuted; protoconchal spires number 1 to 2, and deuteroconchal one numbers 1 to 2 and 1/4; subquadrate chambers intercommunicate by foramen, intraseptal and subsutural canals, and vertical canals between

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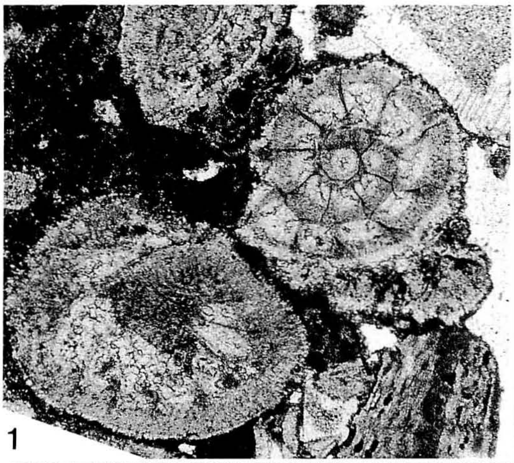
Explanation of Plate 3

(All figures ×40)

Pararotalia mecatepecensis (Nuttall)

1 (right), 4. Equatorial sections. 1 (left), 2–3, 7 (left). Oblique sections, 5 (left), 6. Vertical sections. Minamizaki Limestone; Localities: 1, 6–7. 17.5 (1304 Section), 2. 20 (1304 Section), 3.8 (1304 Section), 4. 15 (1304 Section), 5. 5 (1304 Section).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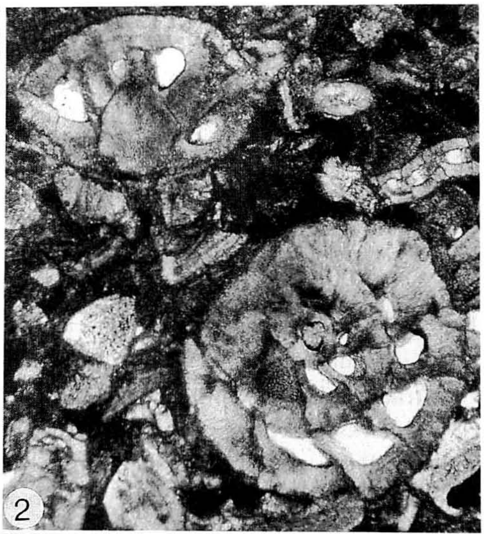
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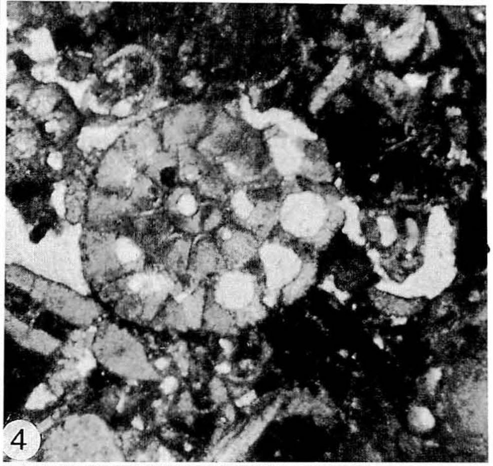
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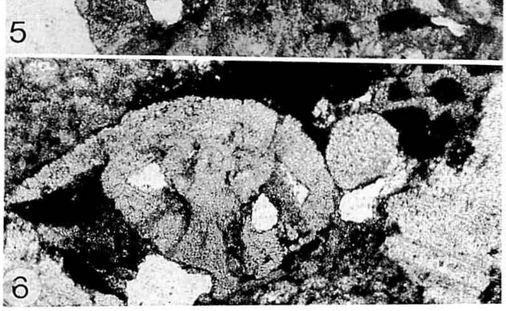
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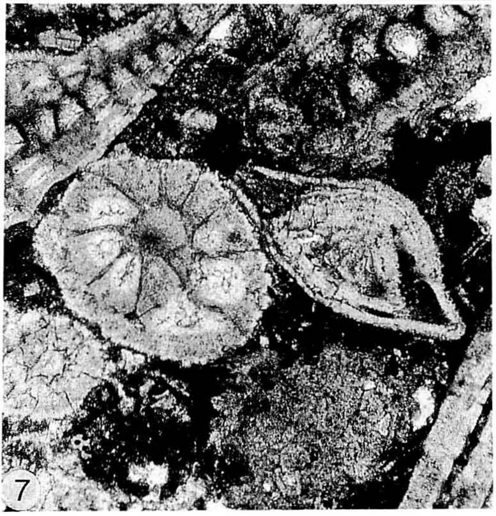
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umbilical plugs; those from protoconch number 9 to 16, from 4 specimens; of dimension 146 × 112, 155 × 108, 210 × 140, and 162 × 116 μm; and 120 × 86, 155 × 105, 163 × 108, 190 × 103, and 165 × 140 μm, in inner radial and tangential diameters, from two specimens, respectively. Subquadrate chambers from deuteroconch number 10 to 22, from 4 specimens; of dimension 95 × 78, 130 × 95, 103 × 130, and 115 × 120 μm; and 103 × 103, 112 × 137, 120 × 130, 125 × 130, and 130 × 130 μm, in inner radial and tangential diameters, from two specimens, respectively. Advanced ogival equatorial chambers, present on frontal side of final whorl; of dimension 56 × 102, 58 × 93, and 128 × 128 μm, in inner radial and tangential diameter. Lateral layers on dorsal side of test, thick, 300 μm, while those on ventral side, thickly developed with conical plugs and shell materials, 425 μm thick. Vertical canals, 10 to 15 μm in diameter, present between several umbilical plugs.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: *Boninella boninensis*, n. sp. resembles *Dictyokathina simplex* Smout, 1954, from the Paleocene beds of Qatar, Arabian shore of the Persian Gulf, but is distinguished from the latter in having only two spires of subquadrate chambers and ogival equatorial chambers present on the frontal side of the final whorl. The present new species differs from *Paleomiogypsina boninensis* Matsumaru, n. gen., n. sp., and *Miogypsinella boninensis*, n. sp., in having two spires of subquadrate chambers. The author considers that *Boninella boninensis* could have evolved from *Paleomiogypsina boninensis*, by developing repeated doubling subquadrate chambers, originating from the bilocular embryonic chambers.

Genus *Miogypsinella* Hanzawa, 1940

Miogypsinella boninensis Matsumaru, n. sp.

Plate 5, figures 1–7; Plate 6, figures 1–12; Plate 7, figures 1–16; Fig. 23–4.

Type material: Holotype, equatorial section of megalospheric form, Saitama University coll. no. 8823 (Plate 6, fig. 7); Paratype, equatorial section of megalospheric form, Saitama University coll. no. 8824 (Plate 6, fig. 12); Paratype section, Saitama University coll. no. 8825 (Plate 7, fig. 12).

Diagnosis: A species of *Miogypsinella* Hanzawa, 1940, with flabelliform test; biconvex; several umbilical plugs present on ventral side of test; embryonic chambers near apex, followed by nepionic chambers, disposed in trochoid spires; and later ogival to rhombic

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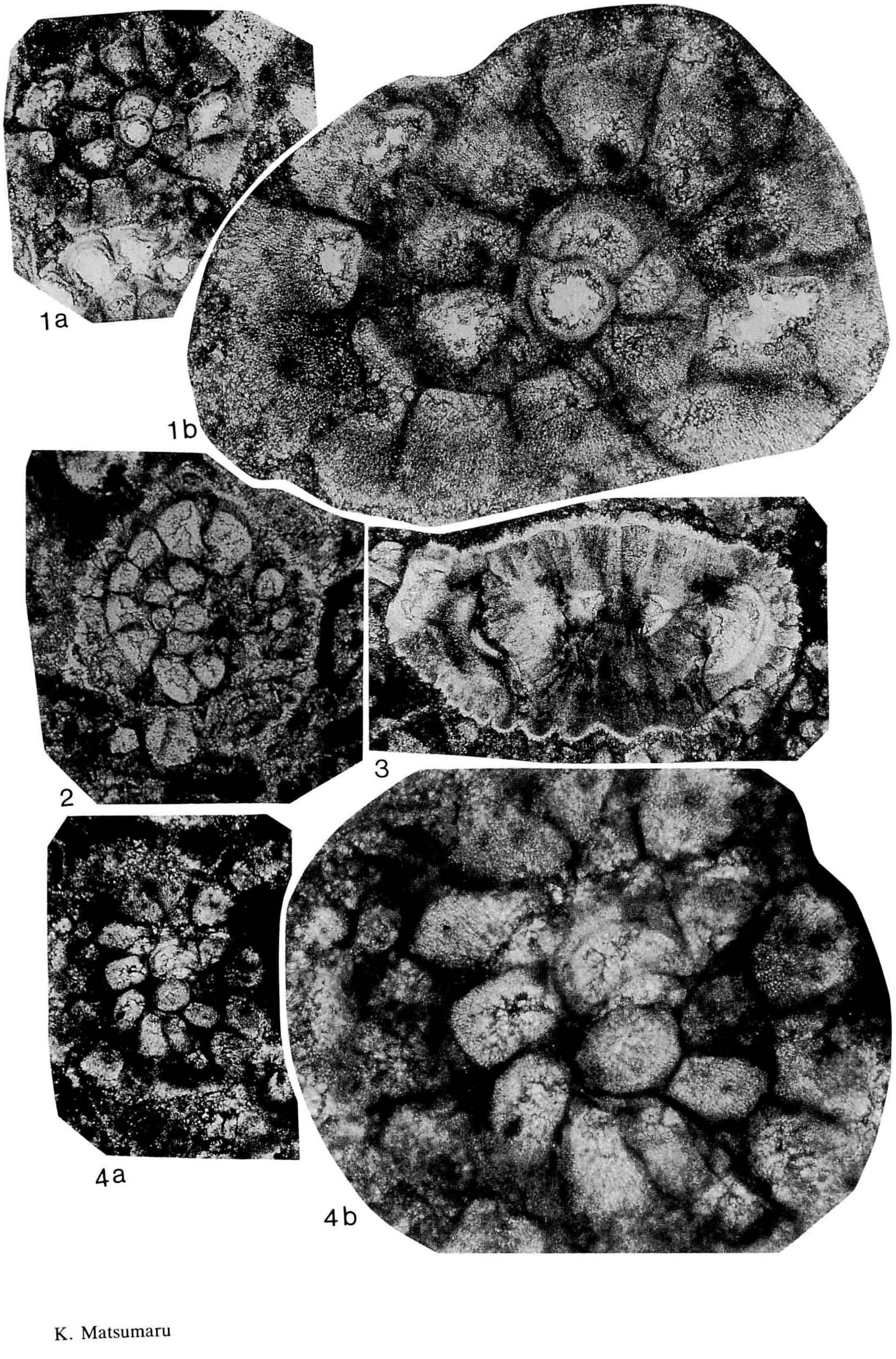
Explanation of Plate 4

Boninella boninensis Matsumaru, n. gen., n. sp.

1–2, 4. Equatorial sections of megalospheric form. 1a. Showing the whole test of megalospheric form. Holotype, Saitama University coll. no. 8806. ×40, 1b. Enlarged form of Figure 1a showing two spire of subquadrate to arcuate chambers originated from bilocular embryonic chambers. ×100, 2. Whole test of megalospheric form showing two low trochospiral spire of subquadrate to arcuate chambers. ×40, 4a. Showing central part of megalospheric test. ×40, 4b. Enlarged form of Figure 4a showing two spire of subquadrate to arcuate chambers from bilocular embryonic chambers. ×100, 3. Axial section of megalospheric form showing double low trochoid spire. ×40. Minamizaki Limestone; Localities: 1. 45, 3, 4. 43 (Both of 1304 Section), 2. 1305 (Minamisaki Cape).

Plate 4



equatorial chambers arranged trochoidal or planispiral, and partial on distal margin of test. Rudimentary lateral chambers absent between spiral lamellae of whorls, similar to *Miogypsina abunensis* Tobler, 1927, type species of *Miogypsinoides (Conomiogypsinoides)* Tan, 1936b.

Description: Test large, flabelliform in outline, biconvex, rimmed by thick equatorial layer on one side; 1.5 to 2.1 mm in diameter, and 0.7 to 0.8 mm in thickness, from 6 specimens; larger raised pustules, on dorsal side, distributed over embryonic chambers; pustules large, 88 to 160 μm in diameter; stout conical umbilical plugs present on ventral side under embryonic chambers; plugs, 140 to 210 μm in diameter. Bilocular embryonic chambers in megalospheric generation, spherical to subspherical protoconch; of diameter 95 × 85 to 150 × 140 μm; reniform deuteroconch; of diameter 95 × 82 to 163 × 110 μm, respectively, from 15 specimens. Spherical proloculus in microspheric generation; of diameter about 15 μm. Both bilocular embryonic chambers and proloculus, followed by subquadrate nepionic chambers disposed in low trochoid spire. Number of coils of nepionic chambers, 2 and 1/4 to 2 and 3/4 in megalospheric generation; chambers in the first whorl, 8 to 9, and in the second whorl, 20 to 24. Total number of nepionic chambers (= X), from 23 to 28 in 2 and 1/4 coils, and 31 in 2 and 3/4 coils; mean value and standard deviation of X parameter in 14 specimens, 27.0 ± 2.7. In microspheric generation, number of coils, 4 and 1/4 coils of about 55 nepionic chambers in one specimen of diameter 1.7 mm. Largest nepionic chambers of 5 megalospheric and 2 microspheric specimens; of dimension 300 × 200, 302 × 280, 310 × 200, 313 × 230, and 374 × 225; and 325 × 210 and 372 × 280 μm, in inner radial and tangential diameter, respectively. Equatorial chambers in partial row on distal margin in equatorial sections, ranging in shape from ogival to rhombic, with 4 stolons passing through septa; and of dimension 95 × 95, 138 × 113, 150 × 150, 175 × 125, 175 × 150, 175 × 175, 188 × 175, 188 × 188, 200 × 162, 200 × 188, 230 × 210, 250 × 200, 275 × 175, 280 × 250, 300 × 256, and 312 × 250 μm, in inner radial and tangential diameter. AP angle (Hanzawa, 1957, 1962, 1965), indicating angle between apico-distal axis and line joining center of protoconch and deuteroconch, from 540° to 665°, from 14 specimens; mean value and standard deviation of AP angle in 14 specimens, 578.2° ± 49.9°. In vertical section, equatorial chambers, trochoidally or planispirally arranged, increasing gradually toward frontal margin of test; chambers, of dimension 88 × 75, 100 × 80, 150 × 150, 250 × 163, and 375 × 300 μm, in inner height and radial diameter, in one specimen; vertical canals, 10 to 30 μm in diameter, present between several umbilical plugs.

Stratigraphy: Upper member of Minamizaki Limestone.

Remarks: *Miogypsinella boninensis*, n. sp., has more nepionic chambers and a large AP

Explanation of Plate 5

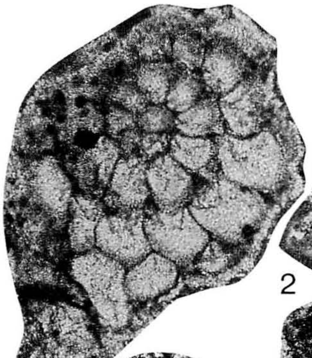
(All figures ×40)

Miogypsinella boninensis Matsumaru, n. sp.

1–2, 4. Oblique sections. 1–2. Megalospheric forms. 4. Microspheric form, 3, 5–7. Equatorial sections. 3. Megalospheric form, 5–7. Microspheric forms. Minamizaki Limestone; Localities: 1. 48, 4–5. 49 (Both of 1304 Section), 2–3, 6–7. 82703 (Minamizaki Cape).

Boninenella boninensis Matsumaru, n. gen., n. sp.

8. Equatorial section of microspheric form. Paratype, Saitama University coll. no. 8807. Minamizaki Limestone; Locality: 9704 (Minami-Jima).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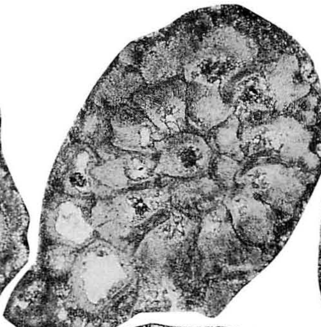
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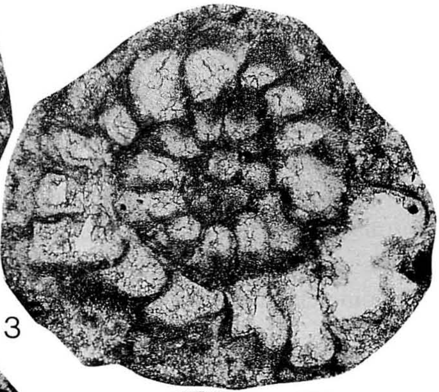
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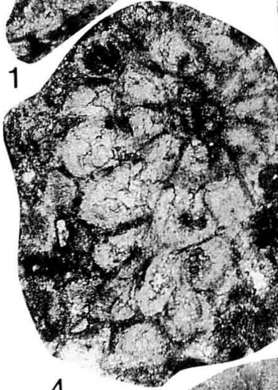
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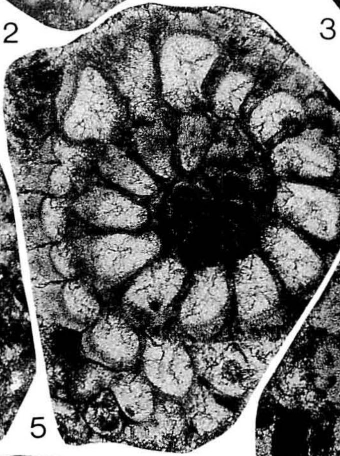
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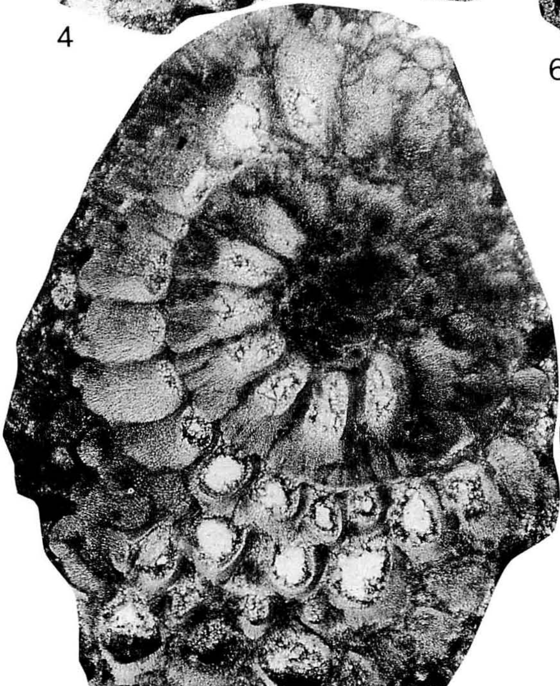
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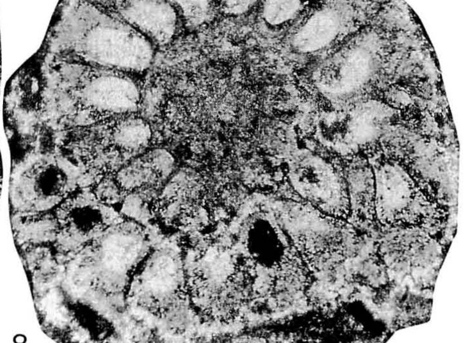
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angle than each of *Miogypsinella grandipustula* (Cole) (i.e. in 4 specimens; X = 25.3 ± 2.4, AP = 535.0° ± 33.2°; Fig. 24) and *M. ubaghsi* (Tan) (i.e. in 9 specimens; X = 22.6 ± 2.1, AP = 437.8° ± 50.0°; Fig. 24) from Eniwetok Atoll. The present new species differs from *Paleomiogypsina boninensis* Matsumaru, n. gen., n. sp., from the Lower Minamizaki Limestone, in having many equatorial chambers, large embryonic chambers, and a large AP angle. As such, the author considers that *Miogypsinella boninensis* could have evolved from *Paleomiogypsina boninensis* during early late Oligocene, and evolved into *Miogypsinella grandipustula*. Moreover, *Miogypsinella ubaghsi* (Tan), belonging to *Miogypsinella* Hanzawa, 1940, could have evolved from *Miogypsinella grandipustula*, remarkably by decreasing nepionic chambers and the AP angle.

Genus *Paleomiogypsina* Matsumaru, n. gen.

Type species; *Paleomiogypsina boninensis* Matsumaru, n. sp.

Diagnosis: Test moderately small, subcircular to flabelliform in outline, planoconvex, ventral side more strongly convex than dorsal side; chambers in low trochospiral coil, with a few equatorial chamber enlarged in last whorl along margin of dorsal side, showing almost lobate periphery. Megalospheric embryonic apparatus of protoconch and deuteroconch, followed, first, by 8 to 11 subquadrate chambers, or 10 to 11? ones in microspheric generation, and later by ogival to rhombic ones in whorl. These peri-embryonic chambers, centrally elevated on spiral side, and inflated around umbilicus, with pseudoumbilical shoulder surrounding several solid umbilical plugs of shell material; in adults a few advanced ogival to rhombic equatorial chambers, present on frontal side of spiral chambers; septal flap present, and intraseptal canal systems developed around each embryonic, nepionic, and equatorial chambers; vertical canals extend to both ventral and dorsal sides from intersections of intraseptal canals, and to ventral side from spiral canal lying between umbilical plugs and umbilical flaps; lateral canal system, present on ventral side; dorsal side massive; stolon system of equatorial chambers, simple; wall calcareous, coarsely perforate; lateral walls thick, compact, lamellar; rudimentary lateral chambers absent; surface, smooth to pustulose.

Comparison: The present genus resembles *Pararotalia* Y. Le Calvez, 1949, but is distinguished from the latter in having a few advanced subsidiary ogival to rhombic equatorial chambers on the frontal side of the last whorl, low-trochospirally coiled. *Paleomiogypsina* Matsumaru, n. gen. also resembles *Miogypsinoides* Yabe and Hanzawa, 1928, and *Miogypsinella* Hanzawa, 1940, but is distinguished from the latter two in having only a few

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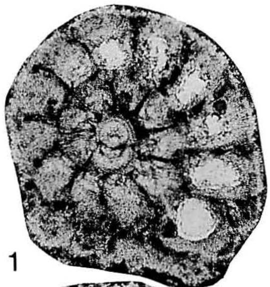
Explanation of Plate 6

(All figures ×40)

Miogypsinella boninensis Matsumaru, n. sp.

1–12. Equatorial sections of megalospheric form. 1. Number of nepionic chambers (= X) being 23. AP angle (= AP) being 540°, 2.X = 27, AP = 540°, 3. X = 23, AP = 540°, 4. X = 25, AP = 500°, 5. X = 25, AP = 575°, 6. X = 24, AP = 630°, 7. Holotype, Saitama University coll. no. 8823. X = 30, AP = 590°, 8. X = 31, AP = 610°, 9. X = 27, AP = 580°, 10. X = 30, AP = 630°, 11. X = 28+, AP = 665°. 12. Paratype, Saitama University coll. no. 8824. X = 30, AP = 665°. Minamizaki Limestone; Localities: 1, 3–5, 7, 9–10, 12. 43 (All belonging to 1304 Section), 2, 6. 43, 11. 47 (801S Section), 8. 9716 (Minami-Jima).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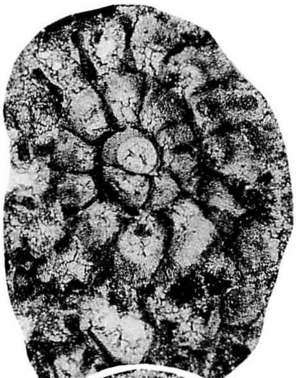
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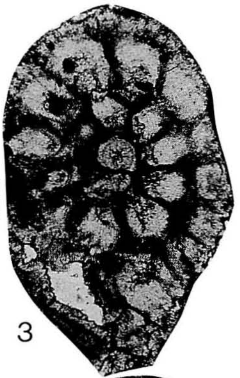
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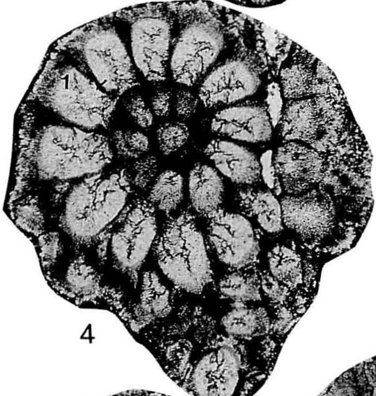
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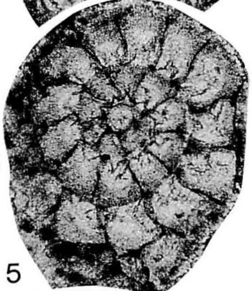
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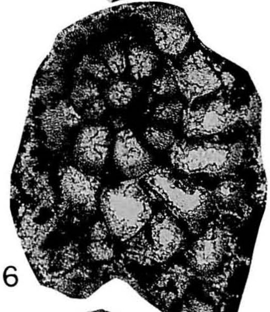
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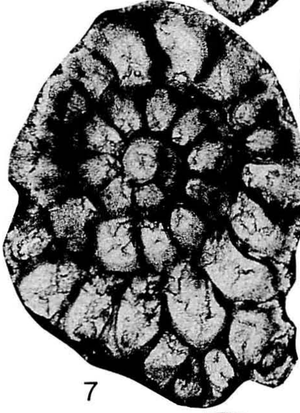
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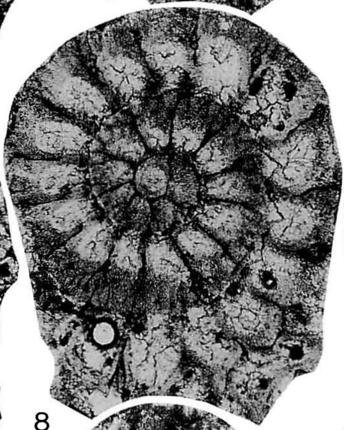
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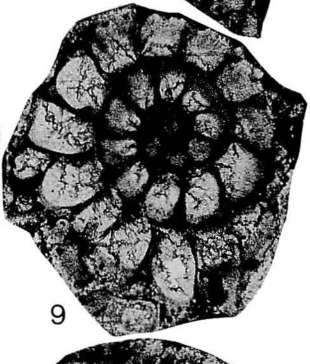
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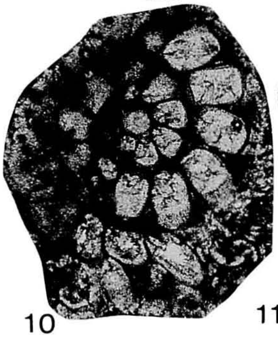
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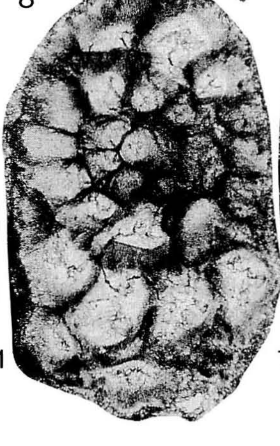
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undeveloped equatorial chambers on the distal margin and well-developed umbilical plugs on the ventral side of the test, and in lacking rudimentary lateral chambers between spiral lamellae of whorls. As such, the author considers that *Paleomiogypsina* Matsumaru could have arisen from *Pararotalia* Le Calvez, while *Miogypsinella* Hanzawa, which has a more primitive form, with a trochoid spire, could have evolved from *Paleomiogypsina* Matsumaru.

Paleomiogypsina boninensis Matsumaru, n. sp.

Plate 8, figures 1–2; Plate 9, figures 1–14; Plate 32, figure 7; Fig. 23–2.

Type material: Holotype, equatorial section of megalospheric specimen, Saitama University coll. no. 8808 (Plate 8, fig. 1). Paratype, equatorial section of microspheric specimen, Saitama University coll. no. 8809 (Plate 9, fig. 1).

Description: Megalospheric specimens, small subcircular to flabelliform tests; of diameter 1.13 to 1.50 mm and thickness 0.62 to 0.75 mm, from 26 specimens; microspheric specimens, slightly large subcircular tests; of diameter 1.30 to 1.60 mm and thickness 0.75 to 0.95 mm, from 4 specimens. Test biconvex in vertical section; raised pustules measuring from 70 to 75 μm, sometimes distributed at thickest portion over periembryonic chambers; most inflated part of ventral side, studded with several conical umbilical plugs; of diameter 100 to 280 μm, extending to protoconch. Megalospheric test, composed of 2 to 2 and 3/4 whorls, with 8 to 11 subquadrate chambers in the first whorl, and 10 to 13 chambers in the second whorl; inner diameter of spherical to subspherical protoconch, 70 × 70 to 128 × 116 μm, and that of reniform deuteroconch, 84 × 58 to 116 × 70 μm, respectively, from 4 specimens; diameter of whole embryonic apparatus, 125 to 155 μm, across both protoconch and deuteroconch chambers. Microspheric test of paratype specimen, composed of 3 whorls, with 10 to 11? subquadrate chambers in the first whorl, 11 chambers in the second whorl, and 12 chambers in the third whorl; inner diameter of protoconch, about 20 × 20 μm. Succeeding subquadrate to rhombic chambers in mature forms; of dimension 70 × 60, 130 × 120, 140 × 110, 146 × 140, 162 × 188, 180 × 175, and 190 × 210 μm, in inner radial and tangential diameters. Subsidiary equatorial chambers present on frontal side between subquadrate chambers in the last whorl; of dimension 50 × 86, 75 × 88, 100 × 100, 180 × 140, 210 × 190, and 220 × 160 μm, in inner radial and tangential diameters. Lateral layers on dorsal side of test above equatorial layer of embryonic, nepionic, and equatorial chambers, not very thick, 130 to 170 μm, while those on ventral side, thickly developed with conical solid plugs and shell materials, 300 to 450 μm thick. Vertical canals, 10 to 30 μm in diameter, and lateral canals, 10 to 15 μm in diameter; several umbilical plugs present.

Stratigraphic horizon: Minamizaki Limestone.

Explanation of Plate 7

(All figures ×40)

Miogypsinella boninensis Matsumaru, n. sp.

1–16. Axial sections, 12. Paratype, Saitama University coll. no. 8825. Minamizaki Limestone; Localities: 1. 9716, 13. 9703 (Both of Minami-Jima), 2, 6, 9–11. 43 (All belonging to 1304 Section), 3, 7, 16. 82703 (Minamizaki Cape), 4–5, 8, 12, 14. 43, 15. 40.5 (Both of 801S Section).


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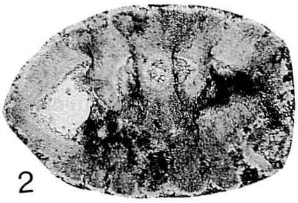
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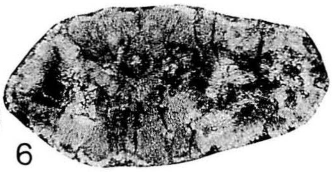
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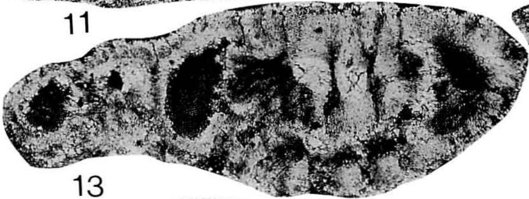
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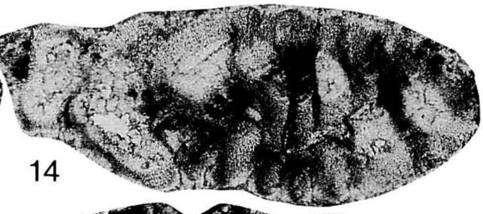
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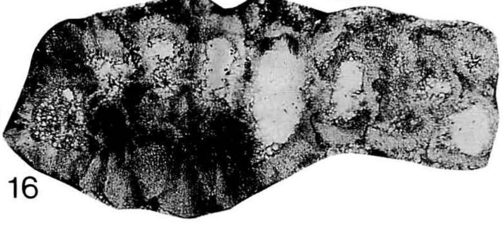
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Remarks: *Paleomiogypsina boninensis*, n. sp., resembles *Pararotalia mecatepecensis* (Nuttall, 1932), but is different from the latter in having a test with much more vaulted ventral side than its dorsal side, rhombic chambers, and well-developed subsidiary chambers. Also, the former presents more primitive arrangement of spiral subquadrate to ogival chambers and fewer ogival to rhombic equatorial chambers than each of *Miogypsinella borodinensis* Hanzawa, 1940, from Kita-Daito-Jima (North Borodino Island), and *Miogypsinella grandipustula* (Cole), 1954, from Bikini Atoll (Cole, 1954) and Eniwetok Atoll (Cole, 1957b).

Family Elphidiidae Galloway, 1933

Subfamily Elphidiinae Galloway, 1933

Genus *Elphidium* de Montfort, 1808

Elphidium sp.

Plate 10, figures 8–9.

Description: Test lenticular, planispiral involution; 1.0 to 1.5 mm in diameter, and 1.0 to 1.4 mm wide; chambers numerous, with numerous retral processes extending from chamber lumen along sutures; septa secondarily doubled near center and outer edges, where it enclosing canal system, 15 to 16 mm thick at midpoint, intraseptal canal, 5 μm across; wall calcareous, bilamellar, optically radial in structure; consisting of outer lamella, coarsely perforate, pectinate, 50 to 60 μm thick, and inner lamella, finely perforate, 10 μm thick near midpoint of septum; aperture and foramina, single interiomarginal pore, at base of apertural face.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: Some specimens of *Elphidium* de Montfort, 1808 occur in random thin sections from the Minamizaki Limestone. The present form does not, however, show distinct characteristics that enable identifying species.

Superfamily Nummulitacea de Blainville, 1827

Family Nummulitidae de Blainville, 1827

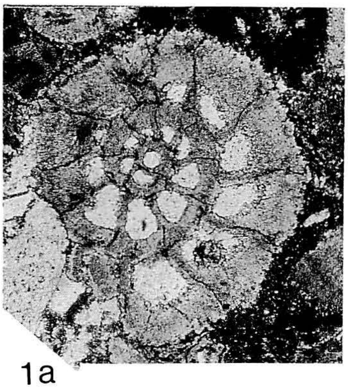
Genus *Operculina* d'Orbigny, 1826

Operculina complanata (Defrance, 1822)

Explanation of Plate 8

Paleomiogypsina boninensis Matsumaru, n. gen., n. sp.

1–2. Equatorial sections of megalospheric form. 1a. Holotype, Saitama University coll. no. 8808. ×40, 1b. Enlarged form of Figure 1a showing embryonic chambers, spiral chambers, and a few advanced ogival to rhombic equatorial chambers on frontal side of spiral chambers. ×100, 2a–b. Equatorial sections of megalospheric form showing a few advanced equatorial chambers on frontal side of low trochoid spiral chambers. 2a. ×40, 2b. ×100. Minamizaki Limestone; Localities: 1.8 (1304 Section), 2. 11 (71801 Section).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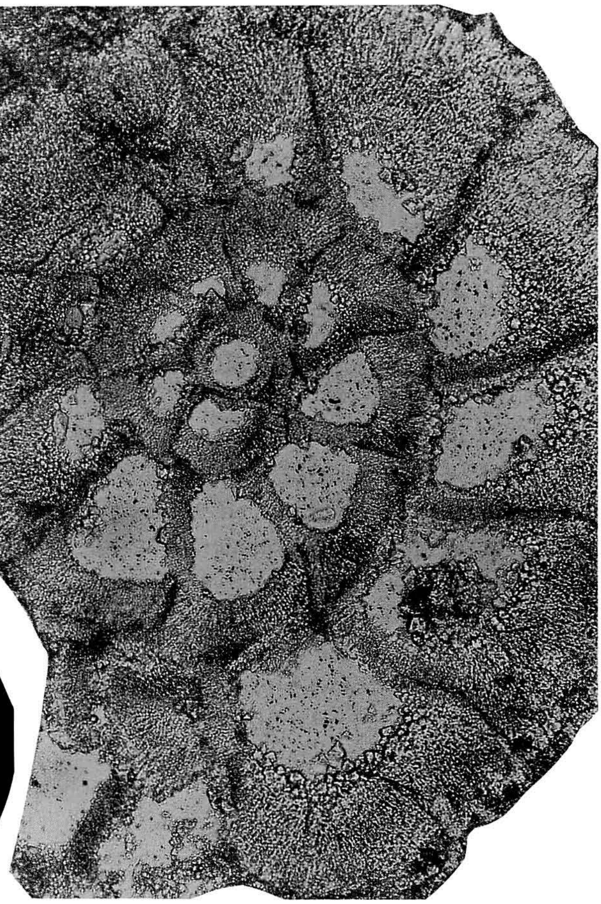
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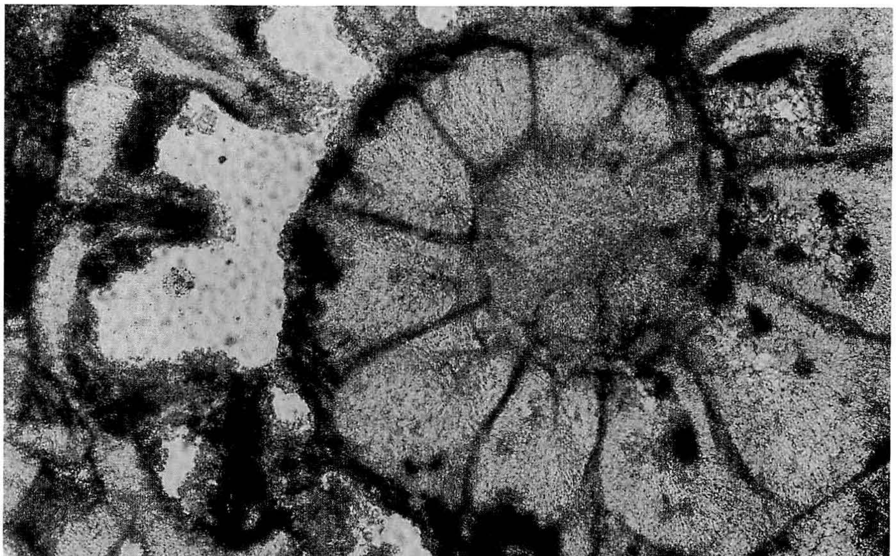
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Plate 11, figures 1–5.

Lenticulites complanata Defrance, 1822, p. 453.

Operculina complanata (Defrance). Brady, 1884, p. 743, pl. 112, figs. 3–5, 8; Newton and Holland, 1902, p. 13–14, pl. 1, figs. 3, 5, pl. 2, fig. 3; Yabe, 1918, p. 120–121, pl. 17, figs. 1–6 (non fig. 7); Cole, 1959a, p. 361, pl. 29, fig. 16, pl. 31, figs. 2–4.

Operculina complanata (Defrance) var. *granulosa* Leymerie. Brady, 1884, p. 743, pl. 112, figs. 6–10.

Operculina complanata (Defrance) *japonica* Hanzawa, 1935, p. 19–22, pl. 1, figs. 4–28; Cole, 1945, p. 278, pl. 12, figs. D-G, pl. 13, figs. F-I.

Operculina bartschi Cushman. Cole, 1945, p. 277–278, pl. 12, figs. H-K, pl. 14, fig. I; Cole, 1959a, p. 360–361, pl. 28, fig. 16.

Operculina complanata complanata (Defrance). Papp and Küpper, 1954, p. 156, text -pl. 2, figs. 1–3, 5–8.

Camerina complanata (Defrance). Cole, 1961a, p. 120–122, pl. 15, fig. 1, pl. 16, figs. 1–9.

Planoperculina complanata (Defrance). Hottinger, 1977, p. 101–105, pl. 39, figs. 1–6, pl. 40, figs. 1–6, text-figs. 39–41C-E.

Description: Test complanate, compressed, or with eccentric small umbo near thin, compressed, wide rim; surface smooth, apparently devoid of ornamentation, to surface ornamentation, with small beaded sutures and several pillars; of diameters 47 to 52 μm in umbonal areas of both sides; moderate in size, 3 to 4.6 mm in diameter, and 0.4 to 0.5 mm in thickness. Megalospheric embryonic chambers, biloculine; proloculus, spherical to subspherical; inner diameter, 52 × 50, 62 × 48, 62 × 62, 64 × 70, 65 × 70, 73 × 50, 83 × 73, 83 × 80, 89 × 83, 110 × 83, 114 × 104, and 120 × 104 μm, in 12 specimens; and deuteroconch, reniform; of inner diameter 62 × 35, 62 × 42, 62 × 44, 73 × 46, 73 × 48, 83 × 62, 90 × 54, 94 × 42, 104 × 42, 104 × 46, 104 × 48, 110 × 62, and 116 × 75 μm, in 13 specimens; inner height of embryonic apparatus, 84 to 104 μm in vertical section; microspheric proloculus small, 20 × 20 μm in inner diameter. Megalospheric form, with a radius of 230–330 μm in the first whorl, with 7–9 chambers; 530–940 μm in the second whorl, with 11–16 chambers; and 1100–2000 μm in the 3rd whorl, with 15–17 chambers; microspheric form, of a radius 88 μm in the first whorl, with 8 chambers; 182 μm in the second whorl, with 12 chambers; 456 μm in the 3rd whorl, with 15 chambers; and 1540 μm in the 4th whorl, with 19 chambers. Chamber walls, straight and radial until near distal ends, where sharp recurvature occurring; marginal revolving wall, 50 to 100 μm in thickness.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: *Operculina* specimens from the Minamizaki Limestone are of complanate shape, with evoluted and coiled whorls, and there are no alar prolongations from the compressed test which has a wide rim. Oblique sections of specimens demonstrate the gradation from unornamented to ornamented surfaces of small beaded sutures and several pillars. Some specimens have no pillars on one side of the test, but pillars are present on the

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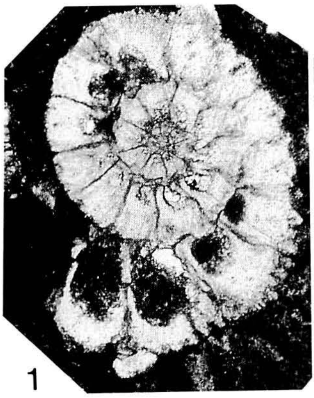
Explanation of Plate 9

(All figures ×40)

Paleomiogypsina boninensis Matsumaru, n. gen., n. sp.

1–2. Equatorial sections. 1. Microspheric form. Paratype, Saitama University coll. no. 8809, 2. Megalospheric form. 3, 6. Oblique sections. 4–5, 7–14. Axial sections showing trochospiral coil with few equatorial chamber in the last whorl along margin of dorsal and ventral sides. Minamizaki Limestone; Localities: 1–2, 11–12. 15, 3, 8. 1.4, 6. 33, 9, 14. 16 (All belonging to 1301 Section), 4–5. 15 (71801 Section), 7.25, 10.8 (Both of 1304 Section), 13. 9702 (Minami-Jima).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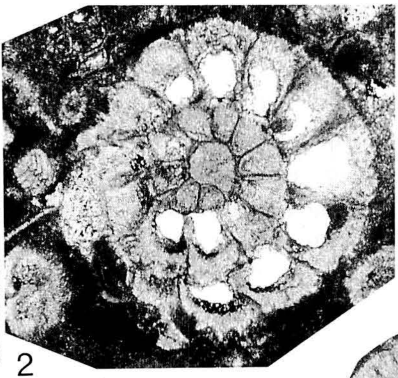
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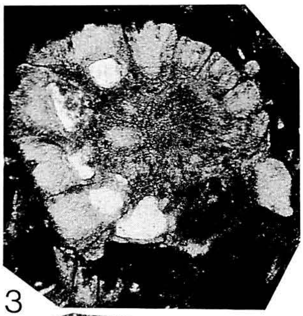
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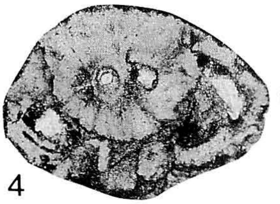
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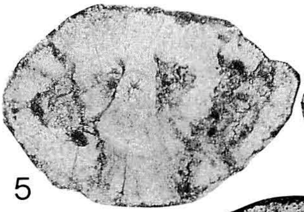
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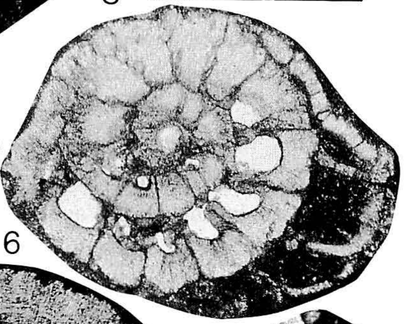
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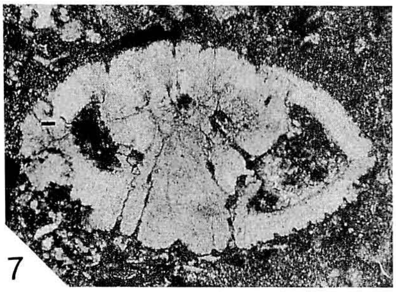
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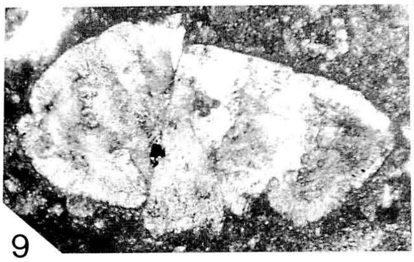
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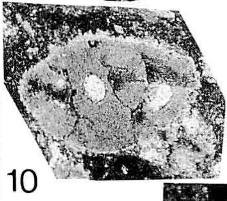
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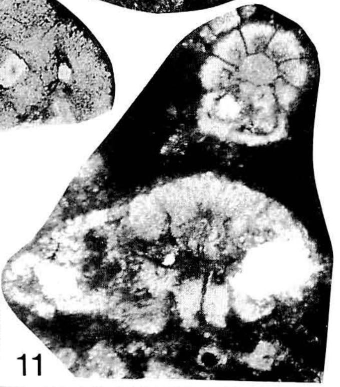
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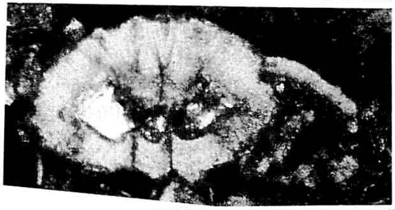
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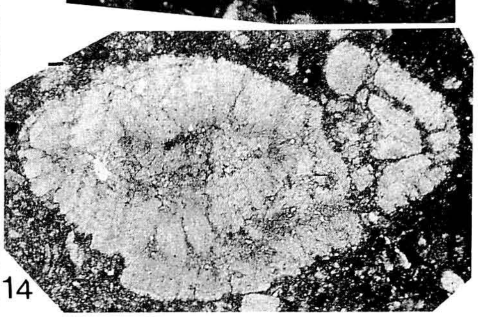
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other side. Judging from the detailed study of many descriptions and illustrations of *Operculina* species, specimens from the Minamizaki Limestone closely resemble *Operculina complanata* (Defrance), referred to by Brady (1884, pl. 112, figs. 3–5, 8) and *O. complanata* var. *granulosa* Leymerie, described by Brady (1884, pl. 112, figs. 6–7, 9–10). Newton and Holland (1902, p. 14) indicate that there is a very considerable and constant difference between specimens of *Operculina complanata*, as figured in Brady (op. cit.), and the topotype specimens of *Operculina complanata* from the Burdigalian Stage of Bordeau (d'Orbigny, 1826). Two forms of *Operculina complanata*, described by Newton and Holland (1902, pl. 1, figs. 3, 5), may, however, be referred to *O. bartschi* Cushman, 1921, whereas two forms of *O. complanata* var. *granulosa*, described by Newton and Holland (1902, pl. 3, figs. 4–5), may be assigned to *O. ammonoides* (Gronovius, 1781), although Hanzawa (1935, p. 2) assigned Newton and Holland's *O. complanata* var. *granulosa* to *O. (= Operculinella) venosa* (Fichtel and Moll, 1798). Barker (1960) has pointed out that one form (pl. 112, fig. 10) of *Operculina complanata* var. *granulosa*, described by Brady (1884), may be assigned to *O. gaimardi* d'Orbigny. Cole (1959a, 1961a) interpreted that there are only three species in the Indo-Pacific Operculinids (= Camerinids): *Operculina (= Camerina) ammonoides, O. (= C.) complanata*, and *O. (= C.) venosa*. Cole's inference seems to be desirable. *Operculina complanata*, with a complanate test, is apparently distinguished from *O. venosa*, with a completely involuted test. There is, however, confusion between *Operculina venosa* and *O. ammonoides* (Yabe and Hanzawa, 1925, p. 49; Chapman and Parr, 1938, p. 290). Cole (1959a, p. 363) indicates that *Operculina venosa* differs from *O. ammonoides* in having bifurcation of the sutures. As far as the author observed the present *Operculina* specimens from the Minamizaki Limestone, it seems desirable that all the present forms is referred to *Operculina complanata* (Defrance).

Operculina subformai (Provale, 1908)

Plate 12, figures 1–6; Plate 13, figures 1–6.

Nummulites (Gumbelia) subformai Provale, 1908, p. 64–66, pl. 4, figs. 16–20.
Operculina subformai (Provale). Cole, 1957b, p. 755–756, pl. 232, figs. 1–6; Cole, 1963a, p. 16, pl. 2, figs. 1–4.

Description: Test inflated, with central boss and evenly lenticular, surrounded by broad, thin, flat rim; 1.34 to 2.58 mm in diameter; 1.02 to 1.92 mm in diameter of central

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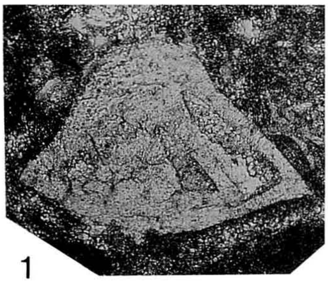
Explanation of Plate 10

Asterigerina tentoria Todd and Post
1, 4. Axial sections. 1. ×43, 4. ×110, 2, 5–6. Oblique sections. 2, 6. Ventral secondary chamberlets showing rosette shaped around umbilical plug. 5. Showing dorsal chambers are visible in spiral. 2. ×43, 5–6. ×110. 3, 7. Equatorial sections. 3. ×43, 7. ×110. Minamizaki Limestone; Localities: 1, 6. 9704 (Minami-Jima), 2, 5, 7. 37, and 4. 49 (Both of 1304 Section). Sekimon Limestone; Locality: 3. 72203 (Sekimon Karst Section).

Elphidium sp.
8. Equatorial section, 9. oblique section. ×40. Minamizaki Limestone; Localities: 8. Base, 9. 8 (Both of 1304 Section).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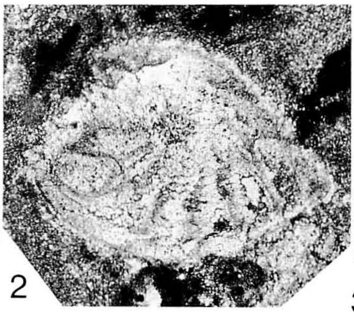
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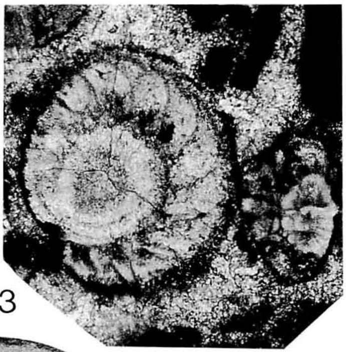
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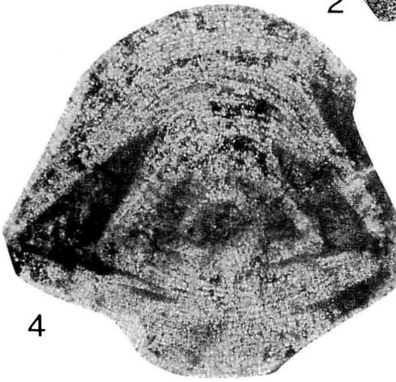
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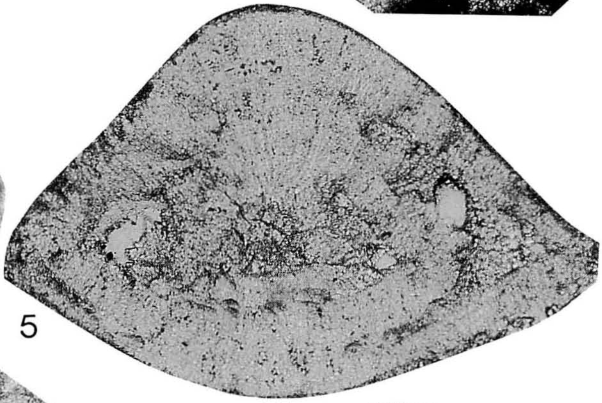
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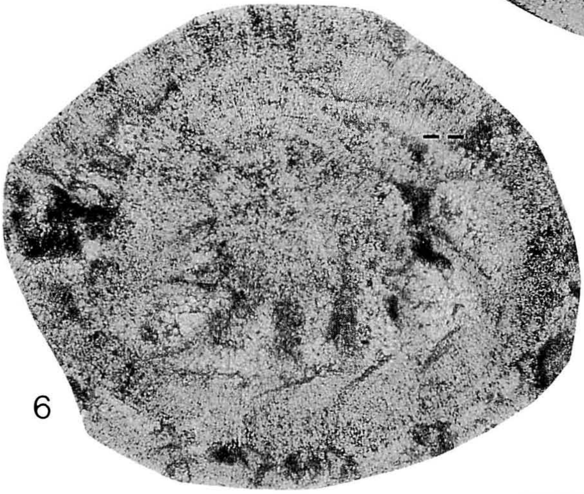
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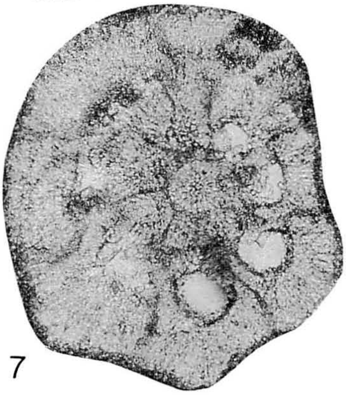
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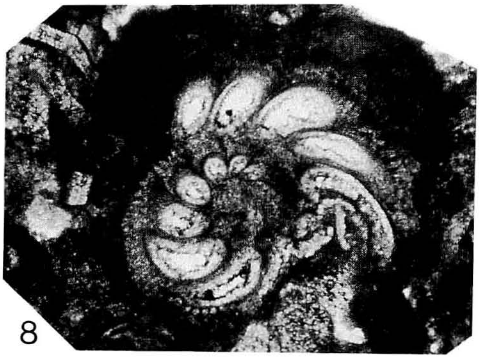
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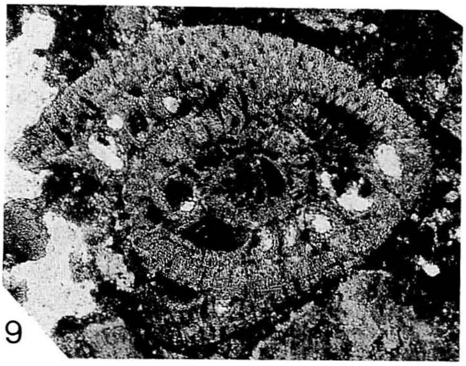
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boss; 0.56 to 1.01 mm in thickness; form ratio of diameter to thickness, 1.70 to 1.98; surface pustulose, with umbonal plugs, of diameter 167 to 267 μm, with numerous septal and cameral pustules of diameter 105 to 195 μm; planispirally enrolled involutes, 3 to 4 whorls in number, after that evolving two and a half to three whorls. Megalospheric apparatus, biloculine; protoconch, spherical to subspherical; 55 × 44, 60 × 53, 65 × 47, 65 × 50, 66 × 66, 70 × 55, 76 × 65, and 100 × 80 μm in diameter, in 8 specimens; deuteroconch, reniform; 66 × 44, 86 × 48, 65 × 44, 75 × 43, 95 × 51, 110 × 95, 109 × 50, and 120 × 72 μm in diameter, in 8 specimens; microspheric apparatus, proloculus spherical to subspherical, 44 × 44 and 44 × 40 μm in diameter, deuteroconch reniform, 55 × 29 and 54 × 43 μm in diameter. Mature form, with a radius of 206 to 305 μm in the first whorl, with 7 to 9 chambers; 423 to 619 μm in the second whorl, with 13 to 21 chambers; 624 to 1009 μm in the third whorl, with 18 to 22 chambers; and 905 to 1338 μm in the third and a half whorl, with 10 to 11 chambers; septa curved back at periphery; wall lamellar, finely perforate, intraseptal, marginal and vertical canals present; intraseptal foramen at base of septal face.

Stratigraphic horizon: Sekimon Limestone.

Remarks: The present form is assigned to *Operculinoides subformai* (Provale, 1908), from the Tertiary b beds in Eniwetok Atoll (Cole, 1957b), and from the upper Eocene Altom Formation, Guam (Cole, 1963a), based on comparison with the measurement of sections of *Operculinoides subformai* from these sites. In the present status, the author considers that *Operculinoides* Hanzawa, 1935, is a junior synonym of *Operculina* d'Orbigny, 1826, based on the numerous remarkable characteristics of the coiled whorls, canal system, and wall structure.

Operculina schwageri Silvestri, 1928

Plate 14, figures 1–6.

Operculina schwageri Silvestri, 1928, p. 112; Hottinger, 1977, p. 82–84, pl. 38, figs. 1–3, text-figs. 4A, 31A, 32A–G.

Operculina alpina Douvillé, Llucca, F. G., 1929, p. 246, pl. 18, figs. 24–27, pl. 19, figs. 1–2; Nemkov, 1967, pl. 269, pl. 45, figs. 5, 7–19 (non fig. 6).

Description: Test evoluted, thin lenticular, with slightly inflated subumbonal area over embryonic chambers, surrounded by wide rim; 1.73 to 4.0 mm in diameter, and 0.42 to 0.71 mm in thickness; form ratio of diameter to thickness, 4.1 to 6.0; surface, slightly raised pustules (135–168 μm across) covering subumbonal area and lines of beads on sutures, planispirally enrolled, 2 and 3/4 to 3 and 1/2 whorls in number. Megalospheric embryonic chambers, biloculine; protoconch, spherical to subspherical; 78 × 67, 130 × 130, and 130 ×

Explanation of Plate 11

(All figures ×40)

Operculina complanata (Defrance)

1–2, 4–5. Equatorial sections. 1–2, 5. Megalospheric forms, 4. Microspheric form. 3. Vertical section. Minamizaki Limestone; Localities: 1–3, 5. 35 (1304 Section), 4. 31 (1301 Section).


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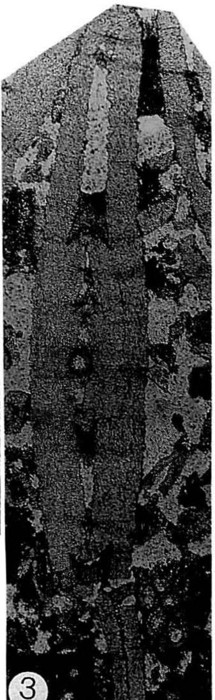
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140 in diameter, deuteroconch, reniform; 78 × 38, 245 × 120, and 222 × 106 μm in diameter, respectively; a radius of 270 × 630 μm in the first whorl, with 7 to 8 chambers; 742 to 2057 μm in the second whorl, with 13 to 16 chambers; 1267 μm in the second and a half whorl, with 11 chambers; and 21 chambers in the third whorl. Septa, straight and radial for about one-third of their length, and then bended backwards near margin of periphery; wall lamellar, finely perforate; intraseptal and vertical canals present; interseptal foramen at base of septal face.

Stratigraphic horizon: Sekimon Limestone.

Remarks: The present form is characterized by having a compressed evoluted test with better-developed surface ornamentation and the remarkable characteristic of the coiled whorls and number of chambers per whorls. Thus the present form is assigned to *Operculina schwageri* Silvestri from the upper Lutetian in Europe. Based on their occurrence and morphological features, Eocene *Operculina schwageri* Silvestri may have evolved into Oligocene *Operculina complanata* (Defrance).

Genus *Nummulites* Lamarck, 1801

The genus *Nummulites* Lamarck, 1801 from the Middle Eocene in Haha-Jima, Ogasawara Islands was once identified as being *Nummulites javanus* (Verbeek) by Yoshiwara (1902), and as being *Nummulites boninensis* Hanzawa by Hanzawa (1947a). Recently, the author (1984) described that all *Nummulites* specimens from Haha-Jima, which were described under *Nummulites boninensis* Hanzawa, were better classified among *Nummulites aturicus* Joly and Leymerie, *N. aturicus-perforatus*, and *N. perforatus* (Montfort). In the present critical research of the genus *Nummulites* from Haha-Jima, the author identified 6 species, including one incomplete, for positive identification as follows: *Nummulites aturicus* Joly and Leymerie, *N. gizehensis* (Forskål), *N. millecaput* Boubée, *N. pengaronensis* Verbeek, *N. perforatus* (Montfort), and *N.* sp. that is similar to *Nummulites yawensis* Cotter or *N. acutus* (Sowerby), as stated later.

According to Blondeau (1972), all of the descendant *Nummulites* originated phylogenetically from three ancestral species from the upper Paleocene: *Nummulites fraasi de la Harpe, N. deserti* de la Harpe, and *N. solitarius* de la Harpe. From the viewpoint of Blondeau's phylogenetic series, *Nummulites millecaput* derived from *Nummulites fraasi* descendant series, while *Nummulites gizehensis*, *N. pengaronensis*, and *N.* sp (such as *N. yawensis* or *N.acutus*) are descendants of *Nummulites partschi* and *N. praecursor*. The latter evolved from *Nummulites deserti*. Both *Nummulites aturicus* and *N. perforatus* are descendants of *Nummulites solitarius*. Therefore, it is evident that there exist three phylogenetic series of *Nummulites fraasi*, *N. deserti*, and *N. solitarius* in six *Nummulites* species from the

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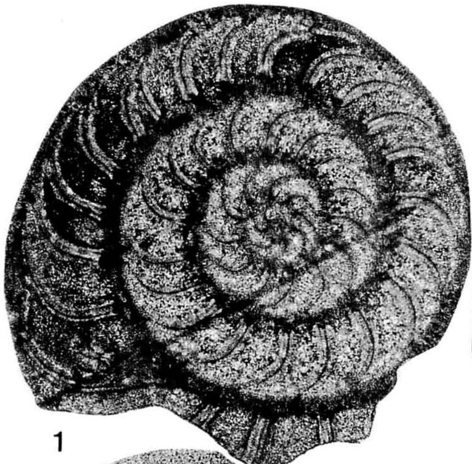
Explanation of Plate 12

(All figures ×45)

Operculina subformai Provale

1–6. Equatorial sections. 1–4, 6. Microspheric forms, 5. Megalospheric form. Sekimon Limestone; Locality: cl (Chibusa Dam).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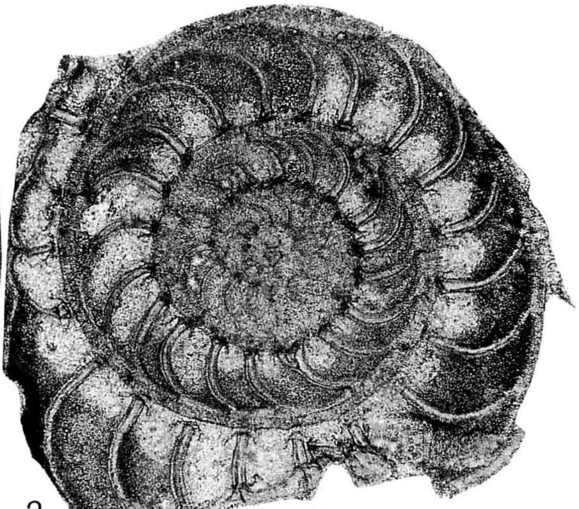
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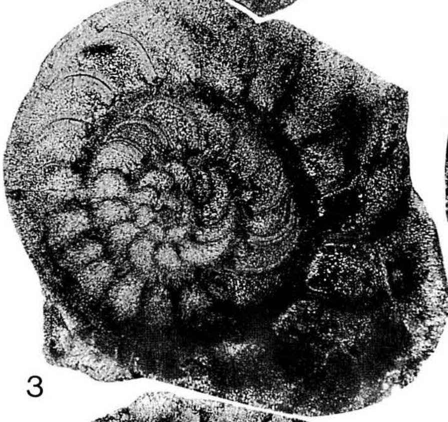
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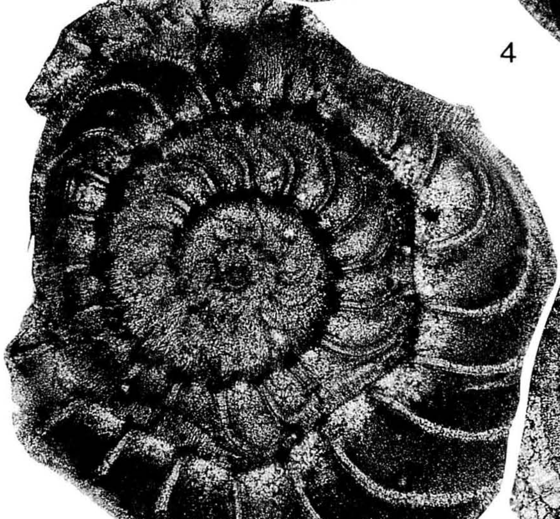
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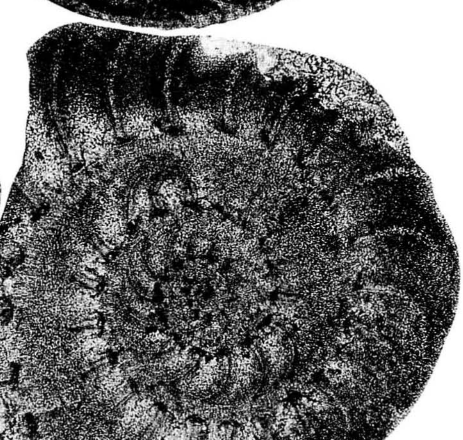
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K. Matsumaru

middle Eocene in Haha-Jima, Ogasawara Islands. In addition, spira-diagram of *Nummulites aturicus* and *N. perforatus* from Haha-Jima show close similarity regarding their ontogeny, which supports the phylogenetic trends from *Nummulites aturicus* to *Nummulites perforatus*, as Blondeau (1972) has indicated.

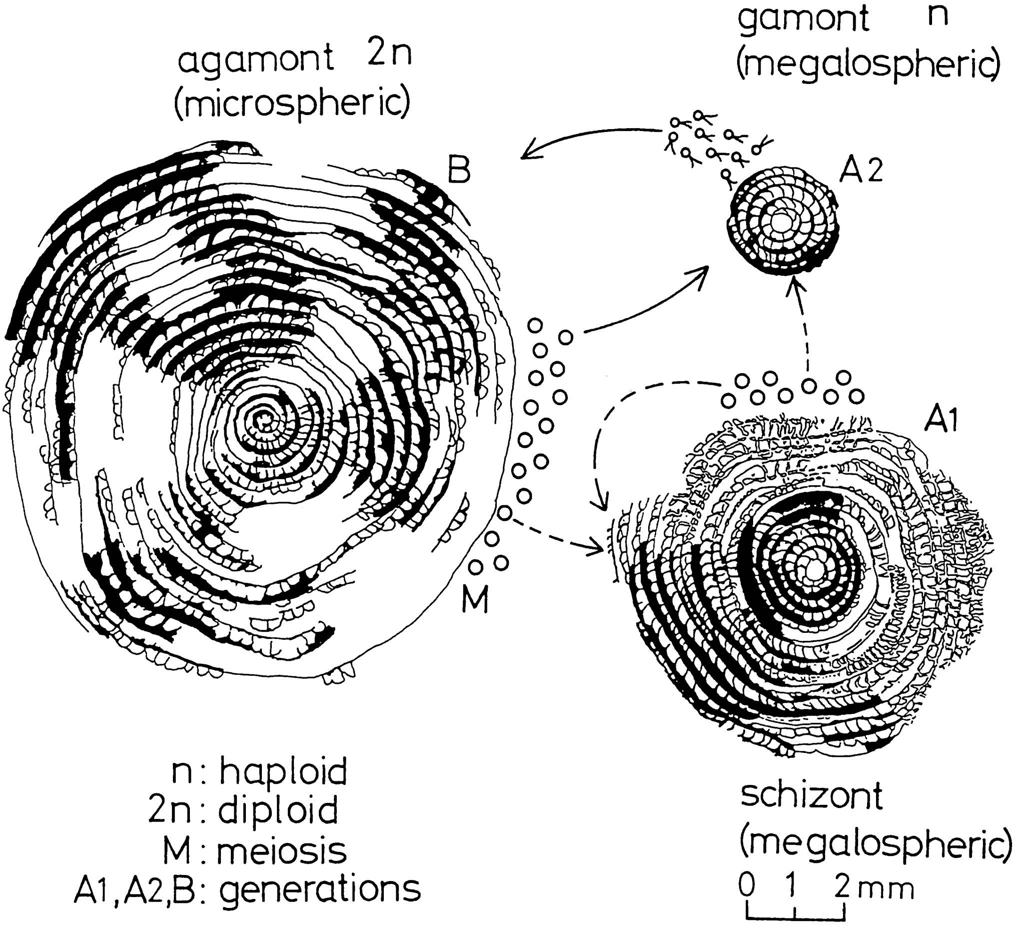


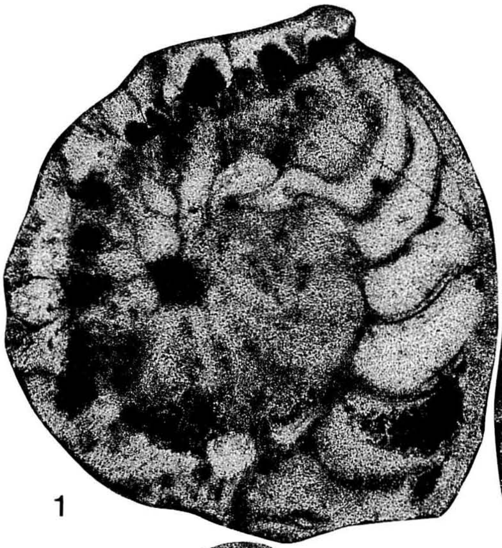
Fig. 25. Hypothetical trimorphic life cycle of *Nummulites perforatus* (Montfort). The asexually reproducing microspheric agamont, and the sexually reproducing megalospheric gamont, have been well documented, and are sketched from specimens of Figure 8 in Plate 15 and Figure 4 in Plate 26, respectively. The megalospheric schizont form is sketched from a Haha-Jima specimen (Matsumaru, 1994, pl. 1, fig. 2). The scale is applicable to all three forms.

Explanation of Plate 13

(All figures ×45)

Operculina subformai Provale

1, 3. Oblique sections showing surface pustulose and umbonal plugs. 2. Centered oblique section of megalospheric form. 4–6. Axial sections. Sekimon Limestone; Locality: 72203 (Sekimon Karst Section).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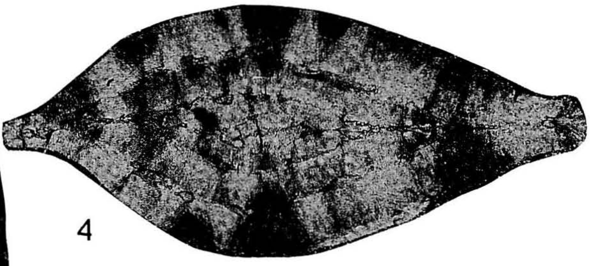
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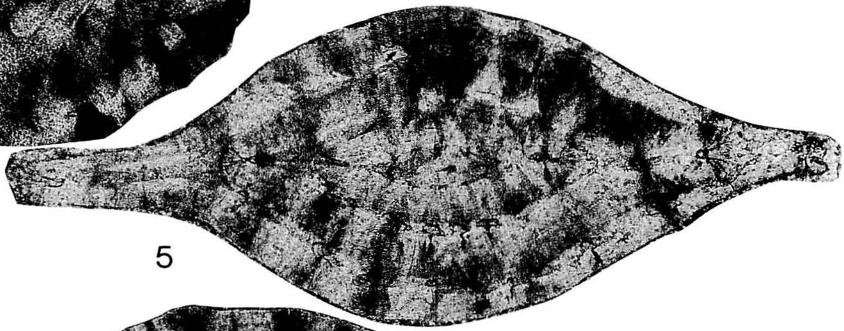
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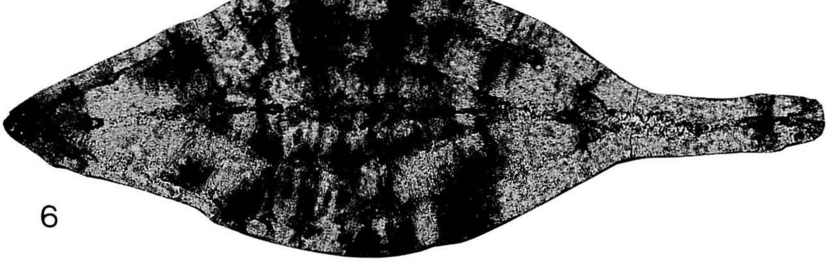
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Recently, Boukhary *et al.* (1982) put forth that *Nummulites gizehensis* (Forskål) derived from *Nummulites irregularis* Deshayes, 1838, from the lower Eocene (upper Cuisian) Minia Formation, Nile Valley, Egypt. The latter is a descendant of *Nummulites fraasi.* Schaub (1981) described more detailed and complicated phylogenetic series of the genus *Nummulites.* According to Schaub, *Nummulites millecaput* is a descendant of *Nummulites* group *distans* Deshayes, whose ancestor is questionable. Also, *Nummulites gizehensis* is a descendant of *Nummulites praecursor* de la Harpe, which evolved from *Nummulites* aff. *praecursor* de la Harpe from the upper Paleocene-lower Eocene (Ilerdian), while *Nummulites aturicus* and

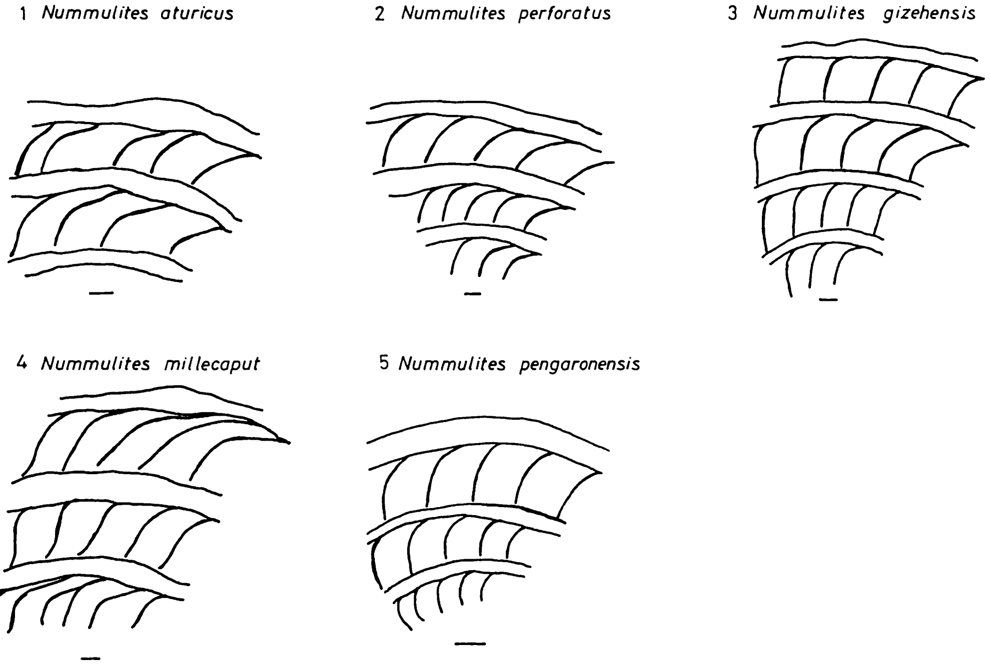
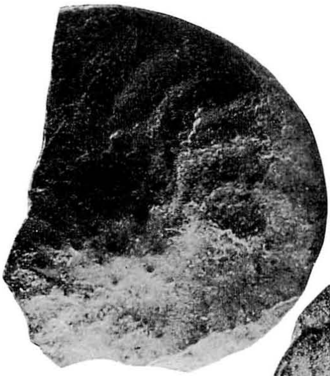


Fig. 26. Mature chamber form in the whorl of *Nummulites* in equatorial section. Scale bars = 100 microns. 1. *Nummulites aturicus* Joly and Leymerie. Chambers are variable from lower than broad to higher than broad, and chamber walls (septa) are rather irregular and radial, with an undulate curvature. 2. *Nummulites perforatus* (Montfort). Chambers are slightly higher than broad, and septa are even and regular, with blunt curvatures at rather distal ends. 3. *Nummulites gizehensis* (Forskål). Chambers are higher than broad, and septa are even regular, and radial, with sharp curvatures at distal ends. 4. *Nummulites millecaput* Boubée. Chambers are higher than broad, and septa are even to irregular, and radial, with an undulate curvature. 5. *Nummulites pengaronensis* Verbeek. Chambers are higher than broad, and septa are even regular, and radial, with a blunt curvature.

Explanation of Plate 14

Operculina schwageri Silvestri

1, 2a–b. Side views. 1. Megalospheric form. ×14, 2a–b. Microspheric forms. 2a. ×30, 2b. ×37. 3–4, 6. Equatorial sections. 3. Microspheric form. ×18, 4, 6. Megalospheric forms. ×18.5. Axial section of megalospheric form. ×18. Yusan Formation; Locality: UN82204 (Yusankaigan Section).



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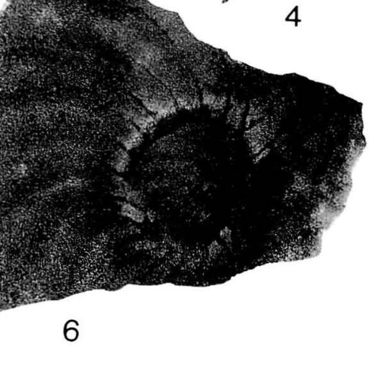

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N. perforatus are descendants of *Nummulites solitarius*, which came from *Nummulites gamardensis* Kapellos and Schaub, 1973, from the basal Ilerdian.

Therefore these differing opinions have caused considerable chaos regarding the evolution of *Nummulites* Lamarck, 1801. Moreover the author (1994) verifies a part of the biologic trimorphism of *Nummulites* foraminifers (Fig. 25). As such, further research of this foraminifers should be pursued.

Nummulites aturicus Joly and Leymerie, 1848

Plate 15, figures 4, 7; Plate 16, figures 1a–c; Plate 17, figures 1–2, 6–8; Plate 22, figure 1; Plate 23, figure 2; Fig. 26–1; Fig. 27.

Nummulites aturicus Joly and Leymerie, 1848, p. 70, pl. 2, figs. 9–10.
Nummulites perforatus d'Orbigny var. *aturicus* d'Archiac and Haime, 1853, p. 117, pl. 6, figs. 5a–b.
Nummulites rouaulti d'Archiac and Haime, 1853, p. 121, pl. 4, figs. 14a–d.
Camerina gizehensis Forskål. Doornink, 1932, p. 275–277, 309, pl. 2, figs. 1–2 (non pl. 1, fig. 6).
Nummulites boninensis Hanzawa, 1947a, p. 256–259, pl. 39, fig. 2 (non pl. 39, figs. 1, 3–13, pl. 40, figs. 1–9).
Nummulites aturicus Joly and Leymerie. Schaub, 1962, p. 537, figs. 7–8; Schaub, 1963, p. 286–294, figs. 1–2; Blondeau, 1972, p. 161, pl. 34, figs. 1–4; Schaub, 1981, p. 95–97, pl. 15, figs. 20–26, pl. 16, figs. 1–30, text-figs. 79–80, tab. 2p; Serra-Kiel, 1984, p. 111–116, pl. 17, fig. 4, pl. 18, figs. 1–6, pl. 19, figs. 1–3, text-figs. 4–126–132; Matsumaru, 1984, p. 418–419, text-figs. 5–6.

Description: Megalospheric test, lenticular with rather sharp margin; 3.5 to 5.0 mm in diameter, 1.9 to 2.4 mm in thickness; form ratio of diameter to thickness, 1.73 to 2.60; surface smooth, septal filaments radial, thin, gentle curved flush from central boss to periphery; round granules embedded in spiral lamellae, distributed among septal filaments and on septal filaments, rather large at center and small towards margin. Embryonic apparatus biloculine; subspherical protoconch; 800 × 760, 880 × 996, 940 × 760, 1000 × 780, and 1050 × 910 μm in diameter, in 5 specimens, and reniform deuteroconch; 680 × 120, 720 × 80, 820 × 148, 660 × 88, and 840 × 140 μm in diameter, in 5 specimens. Spire tight coil, 3 to 4 whorls; the first whorl divided by radial and curved septa, into 6 to 7 chambers; the second, 13 to 15 chambers; and the third, 20 to 23 chambers. Microspheric test, discoidal, with sharp periphery, to thin lenticular; 12.5 to 35 mm in diameter, and 3 to 6 mm in thickness; form ratio of diameter to thickness, 4.2 to 5.8; surface smooth, septal filaments

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Explanation of Plate 15

(All figures ×3)

Nummulites perforatus (Montfort)

1, 5–6, 8–9. Equatorial sections of microspheric form. Yusan Formation; Localities: 1. US81707, 6. US81709, 8. US81703, 9. US81701B (Yusankaigan Section), 5. MI81806 (Miyukihama Section).

Nummulites gizehensis (Forskål)

2. Equatorial section of microspheric form. Yusan Formation; Locality: UN82202 (Yusankaigan Section).

Nummulites millecaput Boubée

3. Equatorial section of microspheric form. Yusan Formation; Locality: MI81805 (Miyukihama Section).

Nummulites aturicus Joly and Leymerie

4, 7. Equatorial sections of microspheric form. Yusan Formation; Localities: 4. MI81801B, 7. MI81806 (Miyukihama Section).

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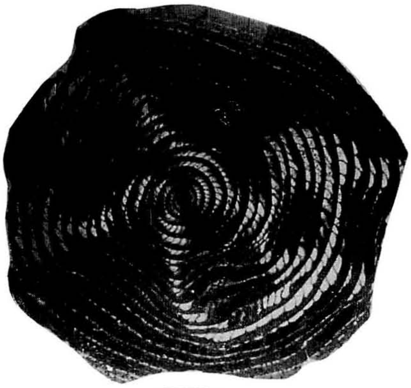

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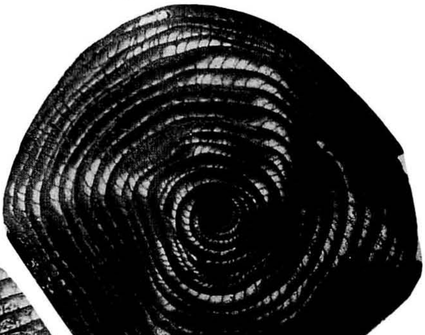

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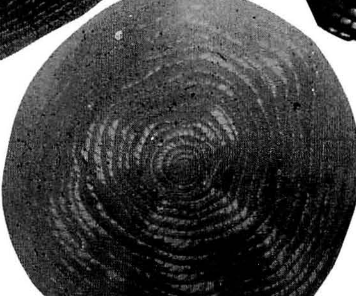

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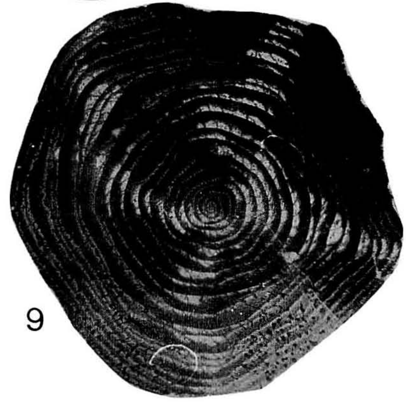

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usually found on peripheral margin of test; numerous round granules, embedded in spiral lamellae and found on whole surface of test. Minute proloculus, 29 to 31 μm in diameter; with closely coiled whorls, 16 to 21 in number; mature form of a radius 60 to 68 μm in the first whorl, 160 to 180 μm in the second whorl, 300 to 370 μm in the third whorl, 500 to 620 μm in the 4th whorl, 770 to 1000 μm in the 5th whorl, 1050 to 1400 μm in the 6th whorl, 1380 to 2000 μm in the 7th whorl, 1750 to 2540 μm in the 8th whorl, 2200 to 3270 μm in the 9th whorl, 2980 to 3850 μm in the 10th whorl, 3520 to 4450 μm in the 11th whorl, 3950 to 5150 μm in the 12th whorl, 4570 to 5750 μm in the 13th whorl, 5070 to 6330 μm in the 14th whorl, 5580 to 6940 μm in the 15th whorl, 6250 to 7550 μm in the 16th whorl, 6950 to 7050 μm in the 17th whorl, 6980 to 7700 μm in the 18th whorl, 7400 to 8200 μm in the 19th whorl, 7780 to 8650 μm in the 20th whorl, and 8170 to 9100 μm in the 21th whorl. Spiral wall, rather thick, lamellar, finely peforate; septa, regular, curved, and oblique. Chambers, isometric in width and height in first whorl, then larger in width than in height in later whorls.

Stratigraphic horizon: Yusan Formation.

Remarks: *Nummulites* from Haha-Jima is similar to *Nummulites gizehensis* (Forskål), but Hanzawa (1947) has assigned it to *Nummulites boninensis*. The septal filaments of microspheric specimens of Haha-Jima vary, however, from gently curved to meandering. Modes of spirals and septa of both megalospheric and microspheric specimens indicate that the Haha-Jima nummulite is five species, *Nummulites aturicus* Joly and Leymerie, *N. gizehensis* (Forskål), *N. millecaput* Boubée, *N. pengaronensis* Verbeck and *N. perforatus* (Montfort) (Fig. 26).

Both megalospheric and microspheric specimens from Haha-Jima as described above are characterized by granulation on the test and radiating and gently curved septal filaments. The megalospheric form from Haha-Jima is very similar to *Camerina gizehensis* (Forskål), described by Doornink (1932, p. 275–277, pl. 2, figs. 1–2), from Padasan, Java, but is different from *Nummulites gizehensis*, described by Schaub (1981, pls. 36–37), in having fewer chambers. The Haha-Jima megalospheric form and Doornink's *Camerina gizehensis* A form (megalospheric form) are not assigned to *Nummulites gizehensis*, but are assigned to *Nummulites aturicus* Joly and Leymerie, described by many authors from many localities in the Tethys region. Both these species have granular tests, similar external form, gently curved filaments, the same number of whorls, the same chamber shape, and a similar number of chambers. Although the size of megalospheric embryonic chambers in the present form from Haha-Jima and Doornink's Java form is larger than that of *Nummulites aturicus*, the difference of the embryo size between them can be considered as a species variation of *Nummulites aturicus*.

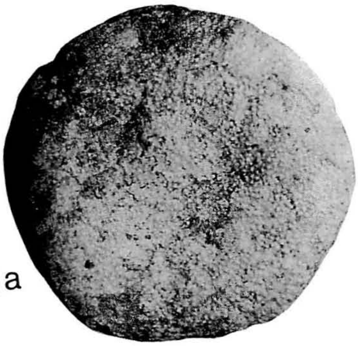
Explanation of Plate 16

Nummulites aturicus Joly and Leymerie

1a. Side view of microspheric form, 1b. Axial view, 1c. Equatorial section. ×3. Yusan Formation; Locality: MI81805 (Miyukihama Section).

Nummulites perforatus (Montfort)

2a, 3a–b. Side views of microspheric form. 2a.×3, 3a–b. ×2. 2b, 3c. Axial views. 2b. ×3, 3c. ×2. 2c, 3d. Equatorial sections. 2c. ×4, 3d. ×3. Yusan Formation; Locality: MI81805 (Miyukihama Section).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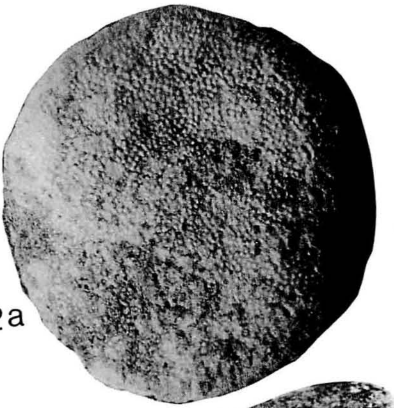
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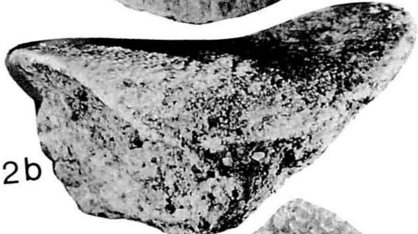
1b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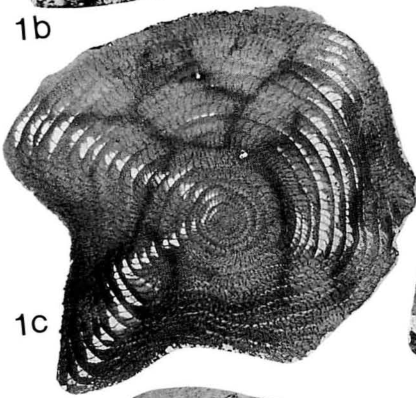
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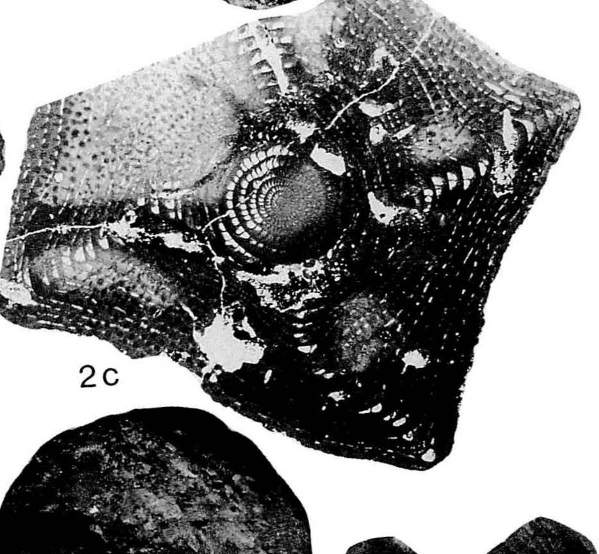
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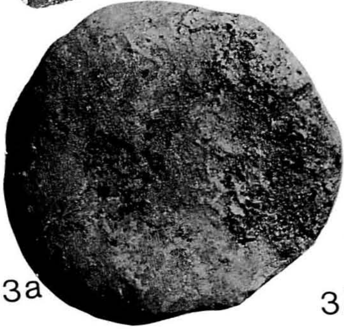
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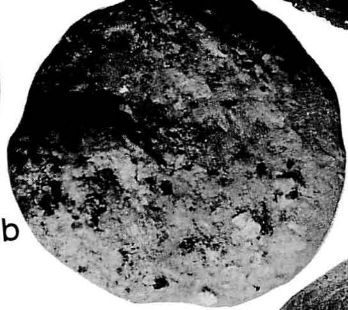
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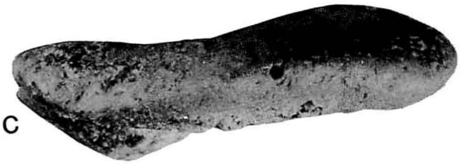
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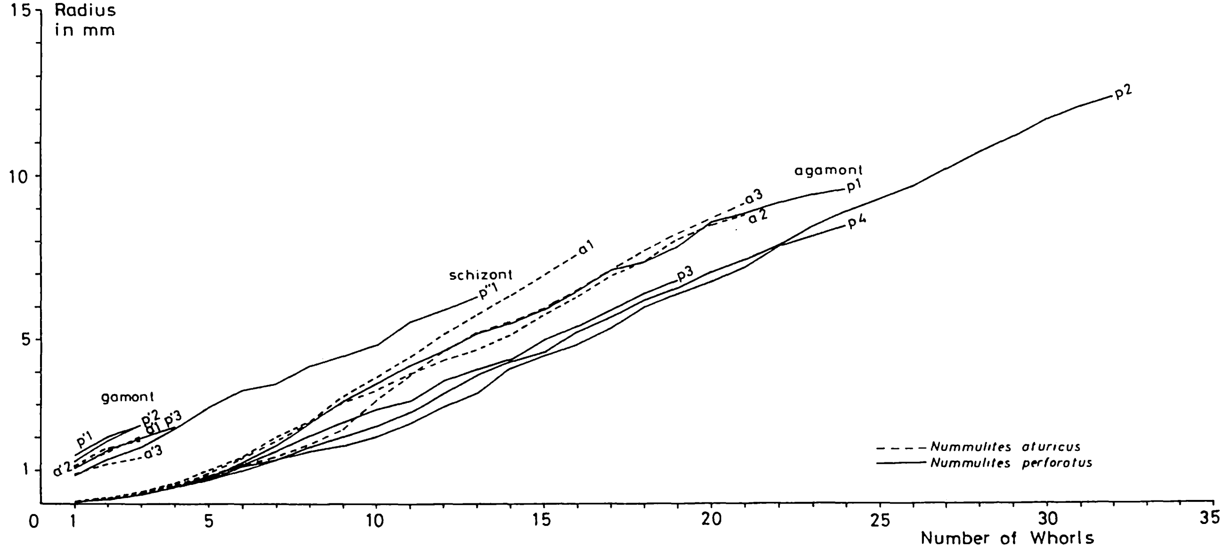


Fig. 27. Spira-diagram of gamont megalospheric, schizont megalospheric, and agamont microspheric forms of *Nummulites aturicus* Joly and Leymerie, and *Nummulites perforatus* (Montfort) from the Yusan Formation, Haha-Jima, Ogasawara Islands. p'1. MI81802 a.7 specimen (Plate 26, fig. 6); p'2. MI81801 Base a.4 specimen (Plate 26, fig. 3); p'3. US81701 Base a.6 specimen (Plate 26, fig. 1); p"1. US81707 specimen (Matsumaru, 1994, pl. 1, fig. 2); a'1. NK c17 specimen (Plate 17, fig. 2); a'2. NK c6 specimen (Plate 17, fig. 1); a'3. NK c22 specimen (Plate 17, fig. 7); a1. MI81805 specimen; a2. MI81804 specimen (Plate 23, fig. 2); a3, US81704–17 specimen) p1. US81707–2 specimen (Plate 15, fig. 1); p2. MI81806–2 (Plate 15, fig. 5); p3. UN82203-1 specimen; p4. US81703–24 specimen (Plate 15, fig. 8).

Explanation of Plate 17

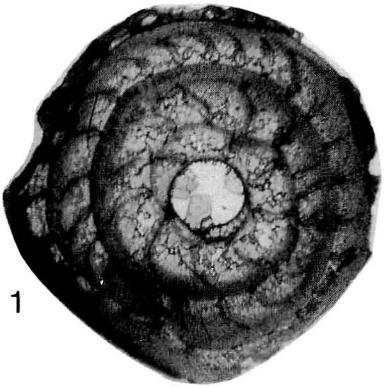
(All figures ×12)

Nummulites aturicus Joly and Leymerie

1–2, 6–8. Equatorial sections of megalospheric form. Yusan Formation; Locality: NK81902 (Nankinhama Section).

Nummulites gizehensis (Forskål)

3–5. Equatorial sections of megalospheric form. Yusan Formation; Localities: 3, 5. US81716 (Yusankaigan Section), 4. NK81902 (Nankinhama Section).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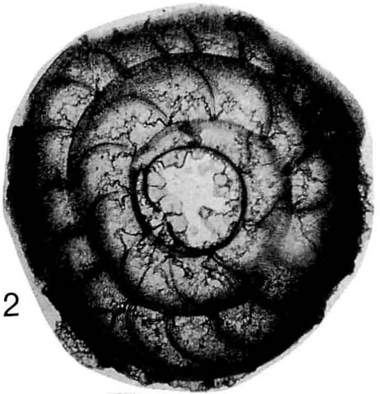
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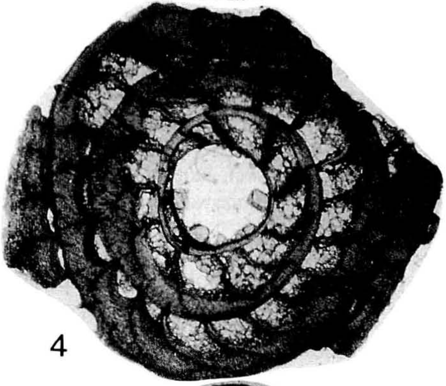
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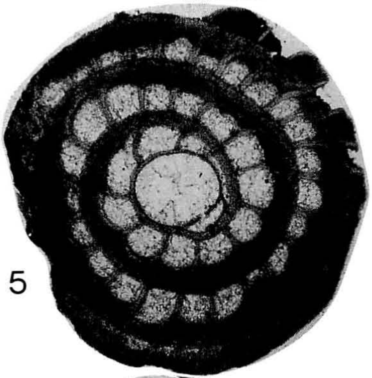
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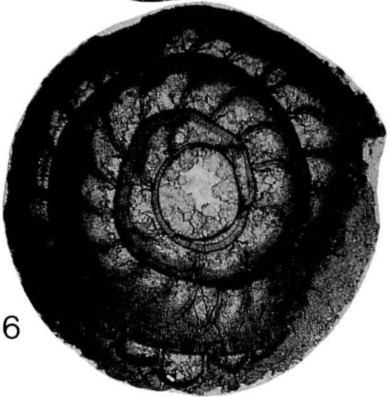
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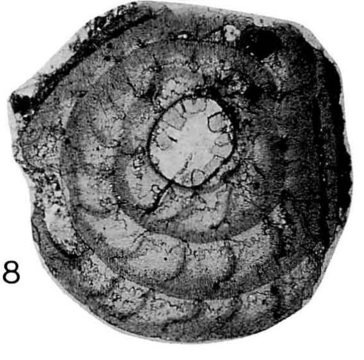
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The microspheric form of Haha-Jima specimens is also assigned to the microspheric form of *Nummulites aturicus*, because the spira-diagram of the present form (Fig. 27) is the same as that of *Nummulites aturicus* from the upper Lutetian beds of la Fontaine de la Medaille, Gamarde, Landes, France (Schaub, 1981, fig. 79) and chamber shape of the former coincides to that of *Nummulites aturicus.*

Nummulites gizehensis (Forskål, 1775)

Plate 15, figure 2; Plate 17, figures 3–5; Plate 18, figures 1–4; Plate 19, figures 1–8; Plate 21, figures 1–2, 8–11; Plate 22, figures 3–4; Plate 24, figure 3; Plate 26, figures 5, 7–8; Fig. 26–3; Fig. 28.

Nautilus gizehensis Forskål, 1775, p. 140.
Nummulites gyzehensis Ehrenberg, 1839, p. 93.
Nummulites gizehensis Ehrenberg. d'Archiac and Haime, 1853, p. 94, pl. 2, figs. 6a–f, 7a, 8; de la Harpe, 1883, p. 190, pl. 3, figs. 16–25, pl. 4, figs. 1–2.
Nummulites gizehensis (Forskål). Cuvillier, 1930, p. 141, pl. 14, figs. 1–2, pl. 16, figs. 1–2, 7; Said, 1951, p. 120, figs. 2–8; Blondeau, 1972, p. 151, pl. 26, figs. 1–7, pl. 27, figs. 1–5; Schaub, 1981, p. 115–116, pl. 36, figs. 26–52, pl. 37, figs. 1–13, tab. 6d; Boukhary *et al.*, 1982, p. 72–73, pl. 1, figs. 13–14.
Camerina gizehensis Forskål. Doornink, 1932, p. 275–277, 309, pl. 1, fig. 6 (non pl. 2, figs. 1–2).
Nummulites boninensis Hanzawa, 1947a, p. 256–259, pl. 39, figs. 1, 3–11, pl. 40, figs. 3, 6–9 (non pl. 39, figs. 2, 12–13, pl. 40, figs. 1–2, 4–5).

Description: Megalospheric test, lenticular to inflated lenticular, with sharp margin; 3.3 to 6.5 mm in diameter, 1.9 to 2.5 mm in thickness; form ratio of diameter to thickness, 1.91 to 2.48; surface smooth, septal filaments, radial and thin, gently curved, flushed from central boss to margin; round granules distributed among septal filaments and on septal filaments, large at the center and small toward the margin. Embryonic chambers, biloculine; subspherical protoconch; 540 × 504, 560 × 480, 586 × 572, 590 × 544, 616 × 460, 620 × 500, 656 × 544, 710 × 640, 712 × 580, 744 × 496, 756 × 648, 900 × 824, 932 × 862, 980 × 784, and 1140 × 960 μm in diameter, in 15 specimens, and reniform deuteroconch; 400 × 102, 492 × 96, 600 × 120, 516 × 48, 408 × 116, 560 × 140, 584 × 96, 400 × 92, 384 × 56, 816 × 148, and 1080 × 124 μm in diameter, in 11 specimens. Spires tight coiled, regularly, 4 and 1/2 to 6 whorls; the first whorl divided by radial and curved septa into 7 to 12 chambers; the second, into 15 to 20 chambers; the third, into 25 to 35 chambers; the fourth, into 27 to 43 chambers; and the fifth, into 34 to 45 chambers. Microspheric test, discoidal, with sharp margin; 20 to 44 mm in diameter, and 5 to 10 mm in thickness; form ratio of diameter to thickness, 4.0 to 6.0; surface smooth, with meandriform, septal filaments and round granules distributed over whole surface of test. Mature forms, of minute proloculus, nearly 30 μm in diameter, and closely and regularly coiled whorls, 19 to more than 21 in number; a radius of

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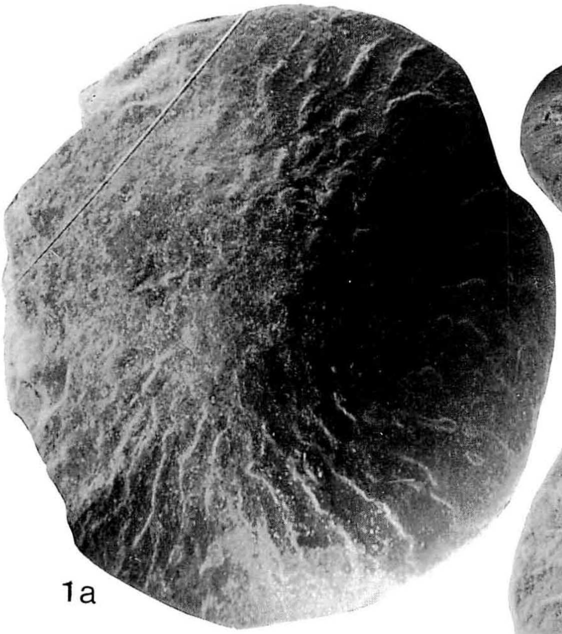
Explanation of Plate 18

(All figures ×15)

Nummulites gizehensis (Forskål)

1a, 2a, 3a. Side views of megalospheric form. 1b, 2b. Oblique views showing thin lenticular megalospheric test with low central boss. 3b, 4. Axial views showing thick lenticular megalospheric test with prominent central boss. Yusan Formation; Locality: MI80806 (Miyukihama Section).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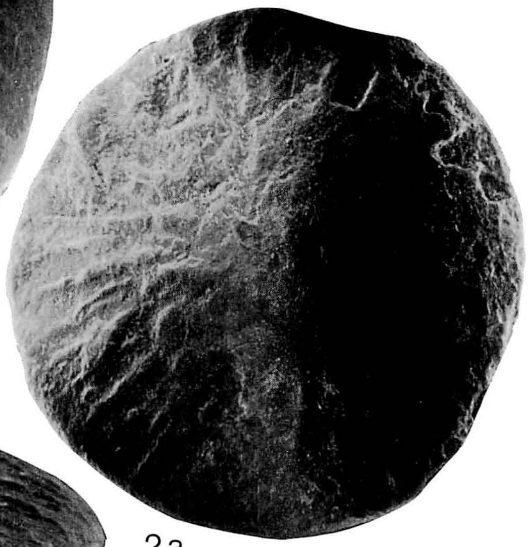
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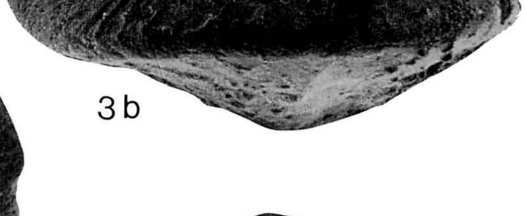
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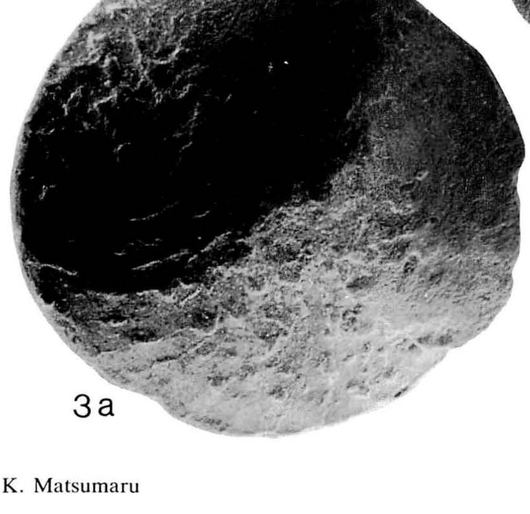
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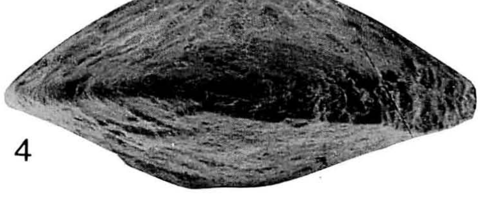
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68 μm in the first whorl, 170 μm in the second whorl, 360 μm in the third whorl, 590 μm in the fourth whorl, 930 μm in the 5th whorl, 1360 μm in the 6th whorl, 1870 μm in the 7th whorl, 2200 μm in the 8th whorl, 2830 μm in the 9th whorl, 3330 to 3340 μm in the 10th whorl, 3780 to 4000 μm in the 11th whorl, 4200 to 4720 μm in the 12th whorl, 4600 to 5450 μm in the 13th whorl, 5240 to 5870 μm in the 14th whorl, 5820 to 6200 μm in the 15th whorl, 6300 to 6900 μm in the 16th whorl, 6870 to 7750 μm in the 17th whorl, 7470 to 8400 μm in the 18th whorl, 8350 μm in the 19th whorl, and 8870 to 8900 μm in the 20th whorl. Spiral wall, regular thickening, lamellar, finely perforate; septa, regular, slightly oblique, curved, and rectilinear. Chambers, isometric in width and height, then smaller in width than in height in later whorls.

Stratigraphic horizon: Yusan Formation.

Remarks: The present form is characterized by a lenticular and discoidal test with a sharp edge, closely and regularly coiled whorls, regular and slightly oblique and curved septa, and rather rhombic-shaped chambers. Thus the present form is assigned to *Nummulites gizehensis* (Forskål), described by various authors from many localities in the Tethys region. The spira-diagram of microspheric specimens of the present form is very similar to that of *Nummulites gizehensis* from the middle Lutetian Samalut Member of the lower Mokattam Formation, Nile Valley, Egypt, described by Boukhary *et al.* (1982, fig. 5). This evidence proves that the present form from Haha-Jima can be identified as *Nummulites gizehensis* (Forskål).

Nummulites millecaput Boubée, 1832

Plate 15, figure 3; Plate 20, figures 1a–d; Plate 21, figure 6; Plate 23, figure 1; Plate 24, figures 4, 7; Plate 26, figure 2; Plate 27, figure 3; Fig. 26–4; Fig. 28.

Nummulites millecaput Boubée, 1832, p. 444, pl. 15, figs. 1–4; Boussac, 1911, p. 93, text-fig. 6, pl. 1, figs. 7, 15; Blondeau, 1972, p. 131, pl. 13, figs. 1–9; Schaub, 1981, p. 186–187, pl. 37, figs. 14–16, pl. 68, figs. 24–30, pl. 69, figs. 1–7, text-fig. 109, tab. 13b.

Nummulites boninensis Hanzawa, 1947a, p. 256–259, pl. 40, figs. 1, 4–5 (non pl. 39, figs. 1–13, pl. 40, figs. 2–3, 6–9).

Description: Megalospheric test, lenticular, with sharp margin; 4.0 to 6.0 mm in diameter, and 1.5 to 2.5 mm in thickness; form ratio of diameter to thickness, 1.5 to 2.4; surface smooth, septal filaments, rather radial, curved to meandered, flush from central boss to periphery; tiny granules distributed sporadically among septal filaments. Embryonic apparatus, biloculine, spherical to subspherical protoconch; 856 × 692, 920 × 880, 1024 × 864, 1056 × 840, 1080 × 1052, 1152 × 1076, 1200 × 936, and 1200 × 1200 μm in diameter, in 8 specimens, and

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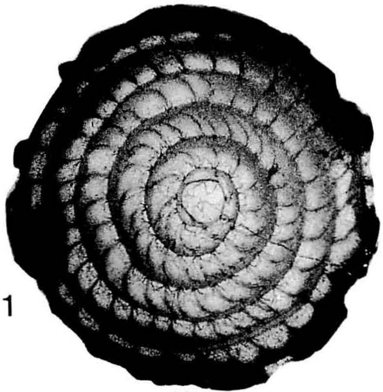
Explanation of Plate 19

(All figures ×12)

Nummulites gizehensis (Forskål)

1–8. Equatorial sections of megalospheric form. Yusan Formation; Localities: 1. US81713, 2. US81701B, 3. US81716, 8. US81709 (Yusankaigan Section), 4, 7. MI81805 (Miyukihama Section), 5–6. NH72205 (Ninohashi Section).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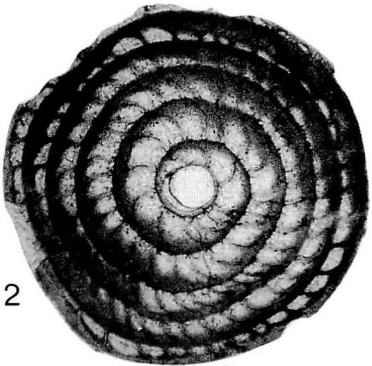
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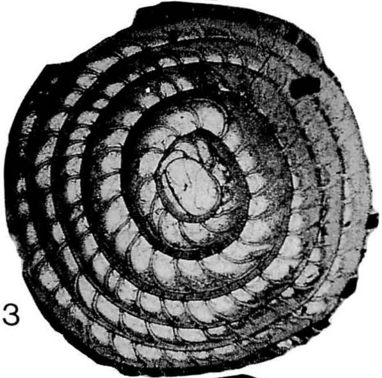
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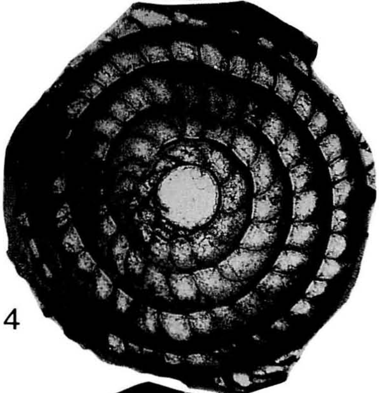
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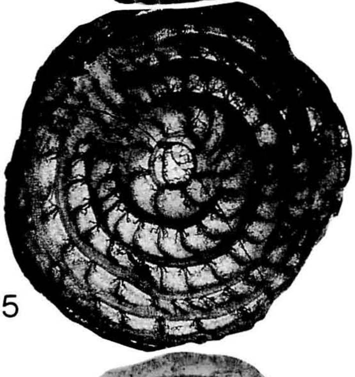
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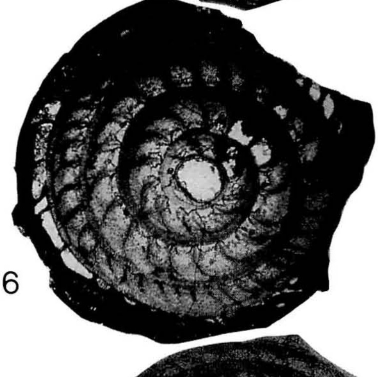
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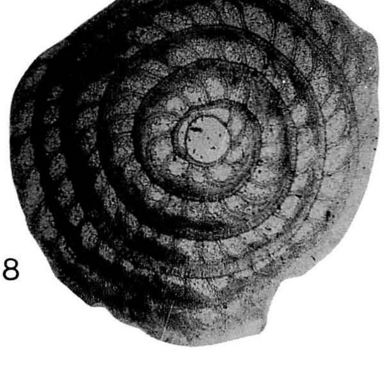
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reniform deuteroconch; 756 × 140, 360 × 80, 620 × 40, 624 × 160, 732 × 160, 780 × 120, 600 × 80, and 800 × 100 μm in diameter, in 8 specimens. Spires tight coiled, 3 and 1/2 to 5 and 1/2 whorls; the first whorl divided by radial, curved, and, in places, sinuous septa into 7 to 10 chambers; the second, into 14 to 18 chambers; the third, into 22 to 30 chambers; and the fourth, into more than 24 chambers. Microspheric test, subdiscoidal to discoidal, with sharp periphery; 18 to 60 mm in diameter, rarely 100 mm in diameter, and 6.5 to 7.1 mm in thickness; form ratio of diameter to thickness, 8.6 to 10.0, rarely 15.4; surface smooth, septal filaments, meandered; tiny granules, distributed over the whole surface of the test. Mature forms, with minute proloculus; and closely whorls, 20 to more than 38 in number; a radius of 603 μm in the third whorl, 759 μm in the 4th whorl, 1180 μm in the 5th whorl, 1700 μm in the 6th whorl, 2240 μm in the 7th whorl, 2800 μm in the 8th whorl, 3400 μm in the 9th whorl, 3800 μm in the 10th whorl, 4280 μm in the 11th whorl, 4840 μm in the 12th whorl, 5320 μm in the 13th whorl, 6080 μm in the 14th whorl, 6600 μm in the 15th whorl, 7050 μm in the 16th whorl, 7296 μm in the 17th whorl, 8220 μm in the 18th whorl, 8640 μm in the 19th whorl, and 8940 μm in the 20th whorl. In vertical section, thickness of test involutions, 280 μm in the third volution, 560 μm in the 4th volution, 960 μm in the 5th volution, 1120 μm in the 6th volution, 2200 μm in the 7th volution, 2480 μm in the 8th volution, 3312 in the 9th volution, 3400 μm in the 10th volution, 4000 μm in the 11th volution, 4560 μm in the 12th volution, 4800 μm in the 13th volution, 5680 μm in the 14th volution, 5756 μm in the 15th volution, 6840 μm in the 16th volution, 7760 μm in the 17th volution, 8000 μm in the 18th volution, 8280 μm in the 19th volution, and 8560 μm in the 20th volution. Spiral wall thin, lamellar, finely perforate; septa, curved and strongly oblique; chambers, usually smaller in width than in height.

Stratigraphic horizon: Yusan Formation.

Remarks: The present form of megalospheric test is characterized by lenticular, with a sharp edge; large protoconch; more or less irregular in spires; higher than broad in chambers; and oblique septa. Further, the present form of microspheric test is characterized by large discoidal, with a sharp edge; very closely coiled whorls; thin spiral lamellar wall; higher than broad in chambers; and oblique septa. Thus the present form is assigned to *Nummulites millecaput* Boubée, described by many authors from many localities in the Tethys region.

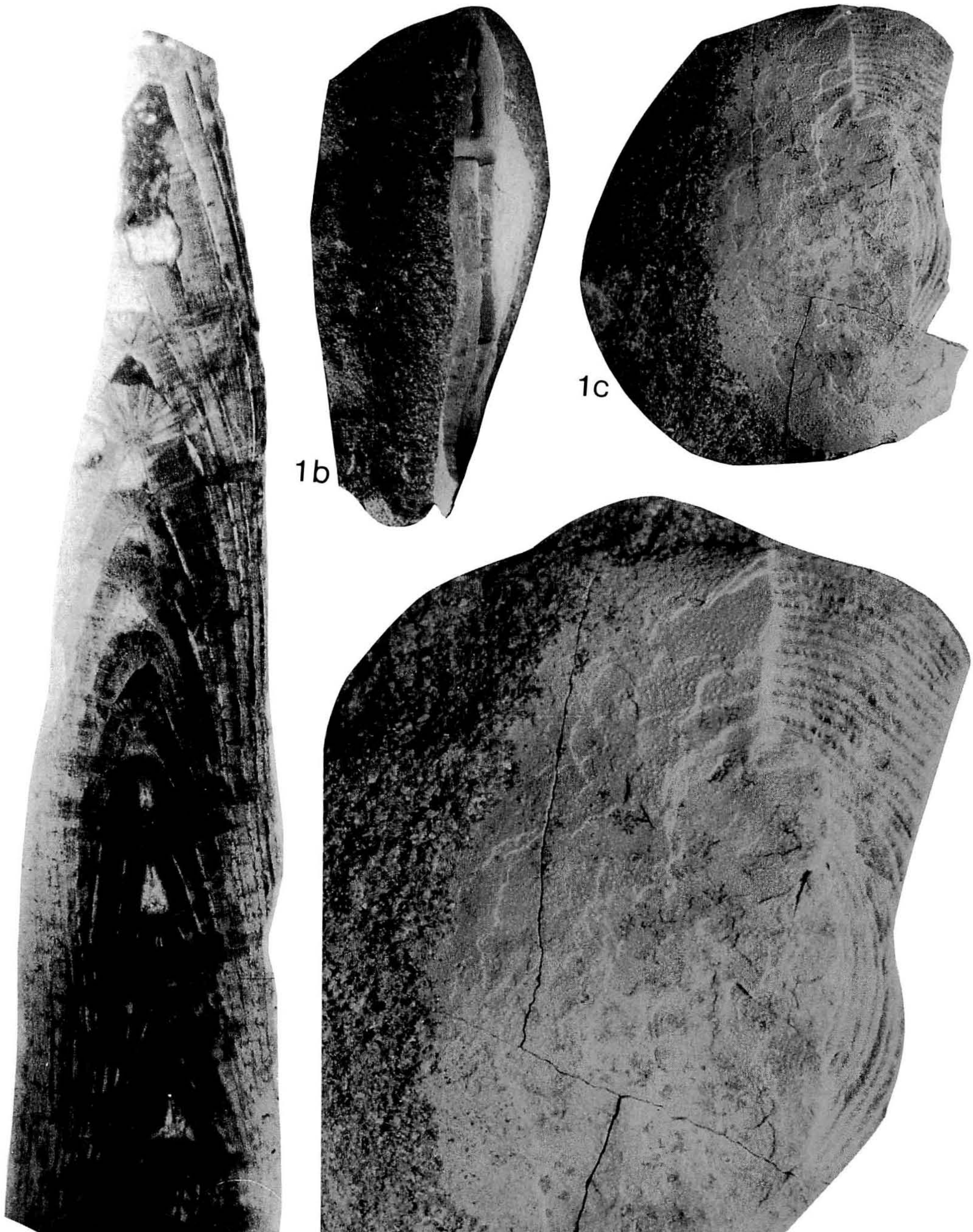
According to Doornink (1932), *Nummulites bagelensis* Verbeek, 1891, has a vast species variation, from a test with central columns to one without them. Also, he described that the megalospheric form with columns of *Nummulites bagelensis* is similar to the megalospheric form of *Nummulites gizehensis* (Forskål), while the megalospheric form without columns is retained as *Nummulites bagelensis* Verbeek. The latter is, however, similar to *Nummulites millecaput* Boubée, while the microspheric form of *Nummulites bagelensis* Verbeek by Doornink (op. cit., pl. 2, fig. 9) seems to be *Nummulites beaumonti* d'Archiac and Haime.

Explanation of Plate 20

Nummulites millecaput Boubée

1a. Axial section of microspheric form, ×20. 1b. Oblique view. ×1.5, 1c–d. Side views. 1c. ×1.5, 1d. ×3. Yusan Formation; Locality: US81701B (Yusankaigan Section).

Plate 20



Therefore, the author considers *Nummulites bagelensis* Verbeek to be subdivided into *Nummulites gizehensis* (Forskål), *N. millecaput* Boubée, and *N. beaumonti* d'Archiac and Haime.

Nummulites pengaronensis Verbeek, 1871

Plate 21, figures 3–5; Plate 23, figures 3–4; Plate 27, figures 1–2; Fig. 26–5; Fig. 28.

Nummulites pengaronensis Verbeek, 1871, p. 3–6, pl. 1, figs. 1a–k; Hanzawa, 1957, p. 43, pl. 1, fig. 8.
Nummulites nanggoelani Verbeek, 1891, p. 116, 118, pl. 1.
Camerina pengaronensis (Verbeek). Doornink, 1932, p. 283–284, pl. 4, figs. 1–3, pl. 6, fig. 12; Henrici, 1934, p. 29–30, pl. 1, fig. 10; Cole, 1957b, p. 753–754, pl. 231, figs. 1–17.
Camerina semiglobula Doornink, 1932, p. 292–295, pl. 7, figs. 1–14, text-figs. d–e.
Camerina saipanensis Cole. Cole and Bridge, 1953, p. 20–21, pl. 2, figs. 7–19.
Nummulites striatus (Bruguiere). Hanzawa, 1957, p. 41–42, pl. 1, figs. 1–3, 9–11.

Description: Both megalospheric and microspheric test small, biconvex, regularly sloping, and rather steeply, from umbo to periphery; 1.5 to 7.8 mm in diameter, and 1.0 to 3.5 mm in thickness; form ratio of diameter to thickness, 1.5 to 2.2; surface umbo smooth, with axial plug (310 to 490 μm across) composed of dark shell materials; sutures, straight and radial, becoming bifurcate toward periphery. Megalospheric embryonic apparatus, biloculine; spherical to subspherical protoconch; of diameter 38 × 30, 40 × 40, 42 × 42, 48 × 48, 52 × 50, 89 × 65, and 96 × 89 μm, in 7 specimens; and reniform deuteroconch; of diameter 24 × 16, 40 × 32, 46 × 42, 75 × 52, and 90 × 70 μm, in 5 specimens; microspheric nucleoconch, proloculus small, spherical, of diameter 24 × 24 μm; and second chamber, reniform, of diameter 16 × 16 μm; both megalospheric and microspheric embryonic chambers, followed by planispirally coiled, involuted whorls. Spire tight coiled, 5 to 6 whorls in megalospheric form; a radius of 214 to 312 μm in the first whorl, with 7 to 8 chambers; 364 to 498 μm in the second whorl, with 10 to 15 chambers; 540 to 725 μm in the third whorl, with 13 to 18 chambers; 728 to 905 μm in the 4th whorl, with 16 to 23 chambers; 885 to 978 μm in the 5th whorl, with 18 to 20 chambers; and 1144 μm in the 6th whorl, with 26 to 27 chambers. Spire tight coiled, 8 to 9 whorls in microspheric form; a radius of 102 to 145 μm in the first whorl, with 7 to 8 chambers; 190 to 312 μm in the second whorl, with 9 to 15 chambers; 344 to 416 μm in the third whorl, with 14 to 21 chambers; 506 to 760 μm in the 4th whorl, with 18 to 26 chambers;

Explanation of Plate 21

Nummulites gizehensis (Forskål)

1–2. Side views of megalospheric form. ×10, 8–11. Axial sectons of megalospheric form. 8, 10–11. ×15, 9. ×20. Yusan Formation; Localities: 1–2. MI81806 (Miyukihama Section), 8. OT72111 (Ōtani Section), 9. NK81902 (Nankinhama Section), 10–11. US81701B (Yusankaigan Section).

Nummulites pengaronensis Verbeek

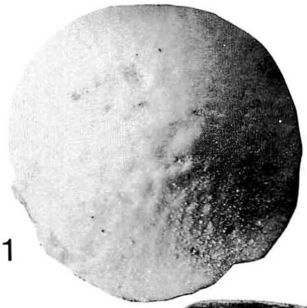
3–4. Side views of megalospheric form. ×10, 5. Axial section of megalospheric form. ×40. Yusan Formation; Locality; MI81806 (Miyukihama Section).

Nummulites millecaput Boubée

6. Axial section of megalospheric form. ×20. Yusan Formation; Locality: OT72111 (Ōtani Section).

Nummulites perforatus (Montfort)

7. Axial section of megalospheric form. ×15. Yusan Formation; Locality: NH72205 (Ninohashi Section).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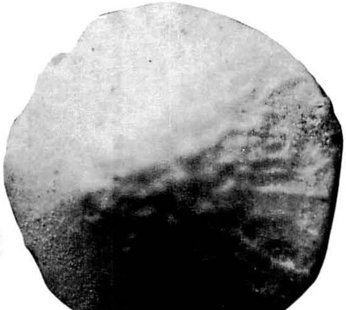
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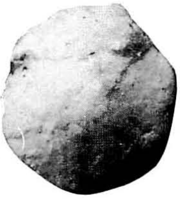
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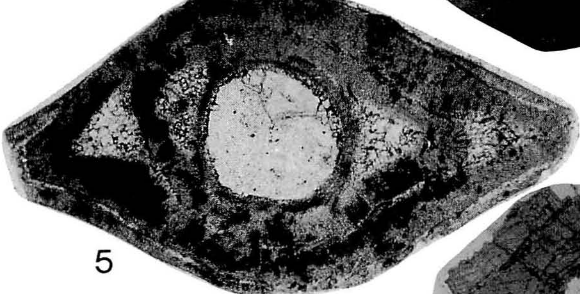
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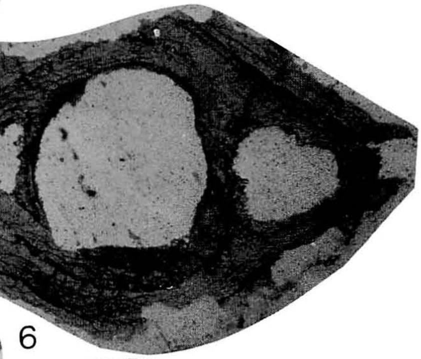
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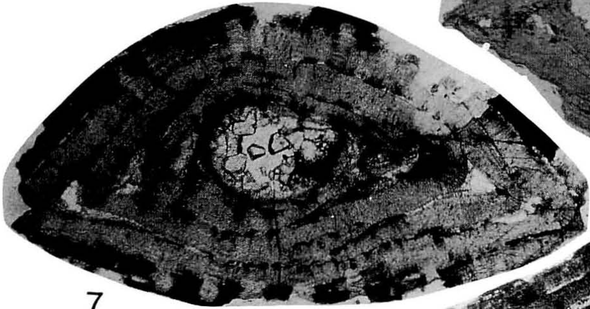
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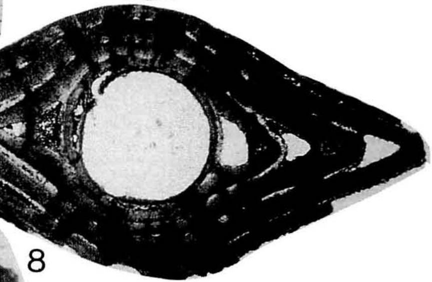
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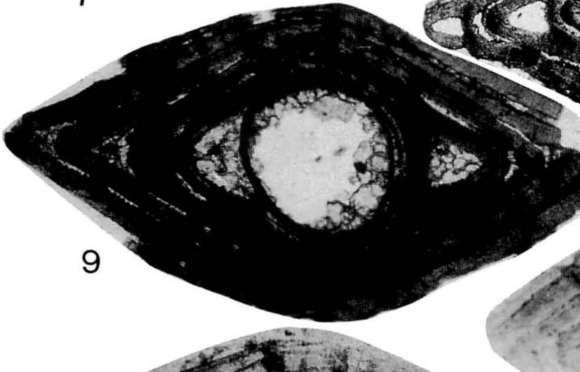
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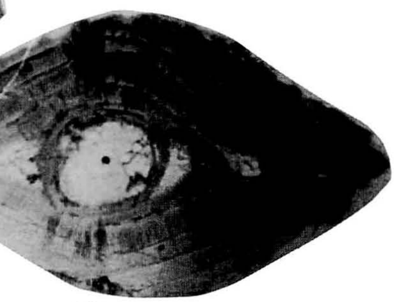
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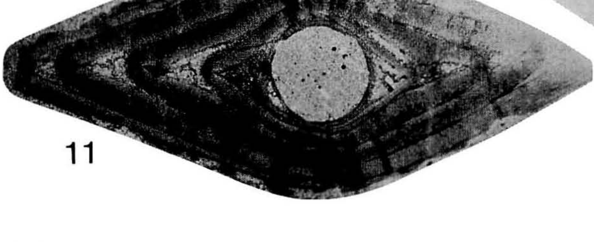
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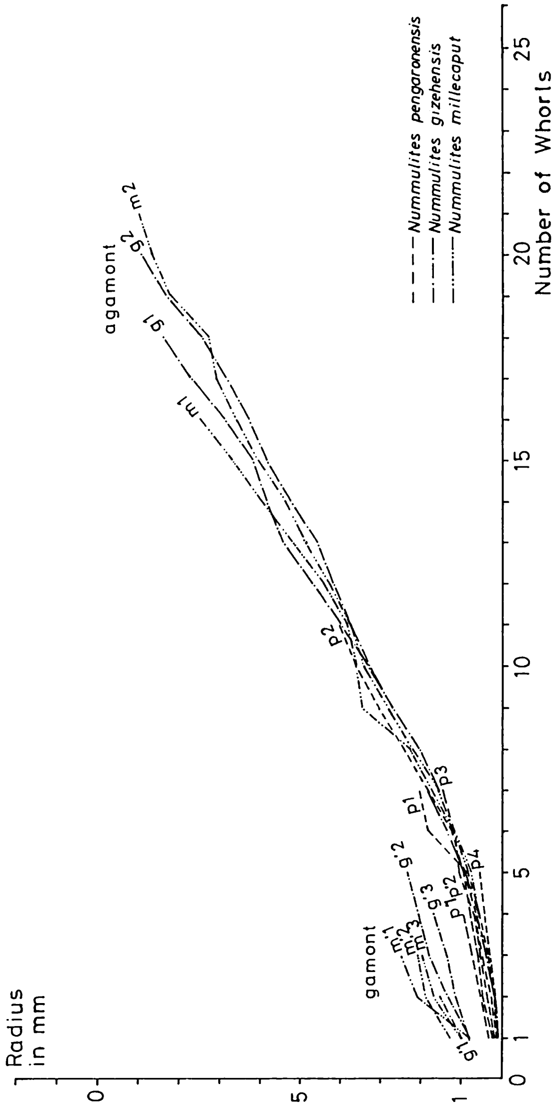


Fig. 28. Spira-diagram of gamont megalospheric and agamont microspheric forms of *Nummulites pengaronensis* Verbeek, *Nummulites gizehensis* (Forskål), and *Nummulites millecaput* Boubée from the Yusan Formation, Haha-Jima, Ogasawara Islands. p'1. US81717 a1 specimen; p'2. US81710 a36 specimen (Plate 27, fig. 2); g'1. NH c28 specimen (Plate 24, fig. 3); g'2. US81716 b1 specimen (Plate 26, fig. 7); g'3. US81703 a4 specimen (Plate 26, fig. 5); m'1. MI81805 b8 specimen (Plate 24, fig. 7); m'2. MI81802a4 specimen (Plate 24, fig. 4); m'3. MI81807 a8 specimen (Plate 26, fig. 2); p1. US81709 a13 specimen (Plate 23, fig. 4); p2. MI q31 specimen; p3. US81706 a6 specimen (Plate 23, fig. 3); p4, US81706 a10 specimen; g1. US81709−1 specimen (Plate 22, fig. 4); g2. UN82202−1 specimen (Plate 27, fig. 2); m1. MI81805 AH5 specimen (Plate 23, fig. 1); m2, US81707−3 specimen (Plate 20, fig. 1a).

Explanation of Plate 22

(All figures ×42)

Nummulites aturicus Joly and Leymerie

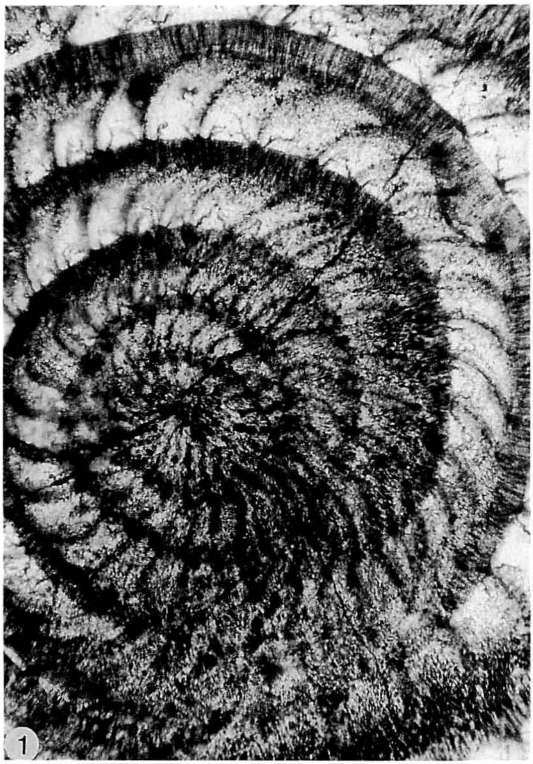
1. Central part of equatorial section shown in Figure 4 in Plate 15 showing near center and early whorls.

Nummulites perforatus (Montfort)

2. Central part of equatorial section showing microspheric proloculus, and early whorls. Yusan Formation; Locality: US81701B (Yusankaigan Section).

Nummulites gizehensis (Forskål)

3, 4. Central parts of equatorial section showing microspheric proloculus, and early whorls. 3. Enlarged central part of equatorial section shown in Figure 2 in Plate 15. Yusan Formation; Localities: 3. UN82202, 4. US81709 (Yusankaigan Section).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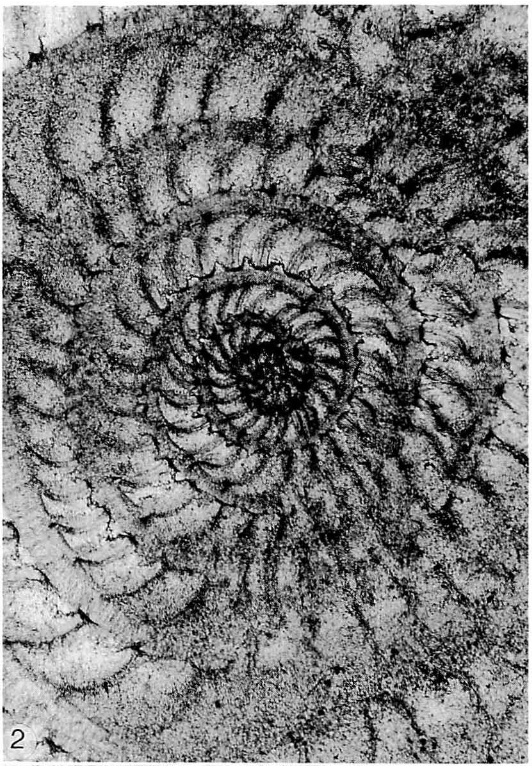
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768 to 1165 μm in the 5th whorl, with 21 to 34 chambers; 1019 to 1477 μm in the 6th whorl, with 24 to 37 chambers; 1600 to 1680 μm in the 7th whorl, with 28 to 38 chambers; 2080 to 2100 μm in the 8th whorl, with 43 to 47 chambers; and 2440 μm in the 9th whorl, with 44 chambers. Septa, straight for one-third to three-fourths of their length, and then recurving near distal end, and radial; wall lamellar, finely perforate; intraseptal, marginal, and vertical canals present.

Stratigraphic horizon: Yusan and Okimura Formations.

Remarks: The present form is characterized by striate and radial septal sutures in the ornamentation of the biconical test, the development of a central plug, nearly straight and radial septa, except near their distal ends, tight coiling of a spiral wall, and small embryonic chambers. Thus the present form is referred to *Nummulites pengaronensis* Verbeek, 1871. Doornink (1932) separated *Camerina pengaronensis* from *C. semiglobula* Doornink, based on the development of the central plug, which is much smaller in the latter. The figures of a vertical section of *Nummulites pengaronensis* by van der Vlerk (1929, fig. 35b) and Hanzawa (1957, pl. 1, fig. 8) show, however, that a distal axial plug is present and developed.

As the author considers that *Nummulites nanggoelani* Verbeek from the Nanggoelan bed, Java, should belong to *Nummulites* with striate septal sutures, he accepts Doornink's view that *Nummulites nanggoelani* is synonymous with *N. pengaronensis*. Also the author accepts that Cole (1957b) referred *Camerina saipanensis* Cole to *C. pengaronensis* (Verbeek), because the author could recognize a distal axial plug in *Camerina saipanensis* from Saipan (Cole, 1957a, pl. 102, fig. 20) and Eniwetok (Cole, 1957b, pl. 231, figs. 2–4, 6, 9), although Cole and Bridge's (1953) *Camerina saipanensis* from Saipan does not have distinct axial plugs. Hanzawa's (1957) *Nummulites striatus* (Bruguiere) from Saipan should be referred to *Nummulites pengaronensis* Verbeek in every respect of the external and internal features, and also the former species from Saipan could be distinguised from *Nummulites striatus* (Bruguiere) from Europe (Blondeau, 1972, p. 148), based on the number of chambers per whorl and size.

The present form from Haha-Jima described as *Nummulites pengaronensis* Verbeek is similar to *Nummulites beaumonti* d'Archiac and Haime, 1853, from a viewpoint of tight coiling of the spiral wall, chamber form, and septa, but it is distinguished from the latter in having fewer septa that are gently curved toward the distal ends. Nagappa (1959) described that *Nummulites pengaronensis* Verbeek from the Khirthar Stage evolved from *Nummulites*

Explanation of Plate 23

(All figures ×42)

Nummulites millecaput Boubée

1. Central part of equatorial section shown in Figure 3 in Plate 15 showing near center, and early whorls.

Nummulites aturicus Joly and Leymerie

2. Central part of equatorial section shown in Figure 7 in Plate 15 showing microspheric proloculus, and early chambers.

Nummulites pengaronensis Verbeek

3–4. Equatorial sections showing microspheric proloculus, and whole whorls. Yusan Formation; Localities: 3. US81706, 4. US81709 (Yusankaigan Section).


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atacicus Leymerie from the Laki to lower Khirthar Stages, whereas *Nummulites beaumonti* d'Archiac and Haime from the Khirthar Stage evolved from *Nummulites pinfoldi* Davies, 1940, from the Laki to lower Khirthar Stage, which evolved from *Nummulites atacicus* Leymerie from the lower Laki Stage. Therefore both *Nummulites pengaronensis* and *N. beaumonti* could be regarded as descendant species from *Nummulites atacicus*. The present form (pl. 27, fig. 2) seems to be a megalospheric form of *Nummulites djokdjokartae* Martin, but it is different from the latter by having small proloculus.

Nummulites perforatus (Montfort, 1808)

Plate 15, figures 1, 5–6, 8–9; Plate 16, figures 2–3; Plate 21, figure 7; Plate 22, figure 2; Plate 24, figures 1–2, 5–6, 8; Plate 25, figures 1–3; Plate 26, figures 1, 3–4, 6; Fig. 26–2; Fig. 27.

Egeon perforatus Montfort, 1808, p. 166, figs. 1–2.

Nummulites perforata d'Orbigny. Bellardi, 1852, p. 274–275; d'Archiac and Haime, 1853, p. 115–120, pl. 6, figs. 1–12; de la Harpe, 1877, p. 822–823, pl. 17, fig. 4.

Nummulites perforatus (Montfort). Boussac, 1911, p. 29–30, pl. 4, figs. 1, 5, 8, pl. 22, fig. 1; p. 66, partim, fig. 9; pl. 3, figs. 7, 13, 16; Schaub, 1963, p. 290, fig. 2; Hanzawa, 1967, p. 174–176, p. 16, figs. 1–6; Blondeau, 1972, p. 161, pl. 34, figs. 6–11; Rahagni and Schaub, 1976, p. 775, pl. 4, fig. 5, pl. 5, fig. 1; Schaub, 1981, p. 88–90, pl. 17, figs. 1–10, pl. 18, figs. 1–31, pl. 19, figs. 1–8, text-figs. 76–77, tab. 2m; Serra-Kiel, 1984, p. 124–128, pl. 23, figs. 1–7, pl. 24, figs. 1–3, text-figs. 4–148–151, 153–154; Matsumaru, 1984, p. 418–419, text-figs. 5, 7–8; Matsumaru, 1994, p. 162–165, p. 1, figs. 1–2.

Camerina perforatus Montfort. Doornink, 1932, p. 273–274, pl. 1, figs. 1–5; Henrici, 1934, p. 21–25, pl. 1, figs. 1–4, 9.

Nummulites boninensis Hanzawa, 1947a, p. 256–259, pl. 39, figs. 12–13, pl. 40, fig. 2 (non pl. 39, figs. 1–11, pl. 40, figs. 1, 3–9).

Description: Megalospheric test, lenticular to inflated lenticular, with sharp margin; 4.1 to 5.6 mm in diameter, and 2.1 to 3.3 mm in thickness; form ratio of diameter to thickness, 1.7 to 2.0; surface smooth, septal filaments, thin, radial, gently curved, flush from central boss to periphery; round granules, usually found between septal filaments and on septal filaments. Embryonic apparatus, biloculine, spherical to subspherical protoconch; 732 × 732, 840 × 840, 880 × 672, 880 × 808, 916 × 716, 920 × 1000, 948 × 856, 960 × 748, 960 × 844, 1000 × 824, 1000 × 832, and 1068 × 812 μm in diameter, in 12 specimens, and reniform deuteroconch; 540 × 92, 760 × 168, 800 × 120, 600 × 92, 660 × 144, 880 × 160, 490 × 76, and 880 × 160 μm in diameter, in 8 specimens. Spire tight coiled, 4 to 5 and 1/2 whorls; the first whorl, divided by radial and curved septa into 7 to 9 chambers; the second, into 13 to 16

Explanation of Plate 24

(All figures ×12)

Nummulites perforatus (Montfort)

1–2, 5–6, 8. Equatorial sections of megalospheric form. Yusan Formation; Localities: 1, 5–6. NK81902 (Nankinhama Section), 2. US81709 (Yusankaigan Section), 8. OT72111 (Ōtani Section).

Nummulites gizehensis (Forskål)

3. Equatorial section of megalospheric form. Yusan Formation; Locality: NH72205 (Ninohashi Section).

Nummulites millecaput Boubée

4, 7. Equatorial sections of megalospheric form. Yusan Formation; Localities: 4. MI81802, 7. MI81805 (Miyukihama Section).

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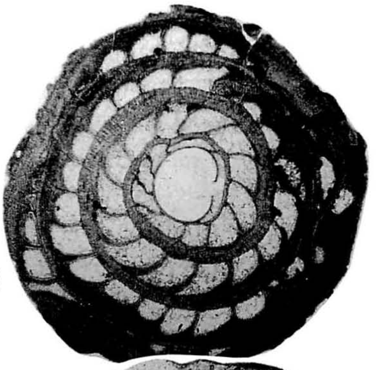

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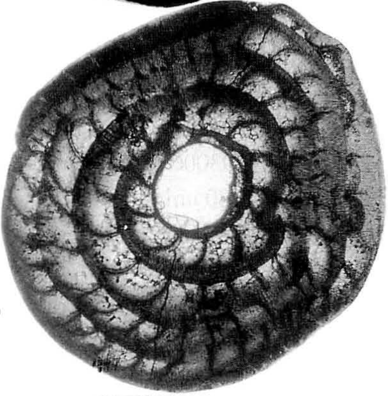

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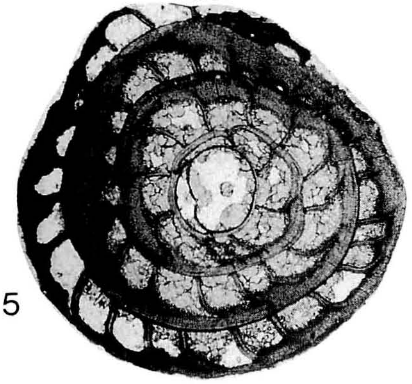

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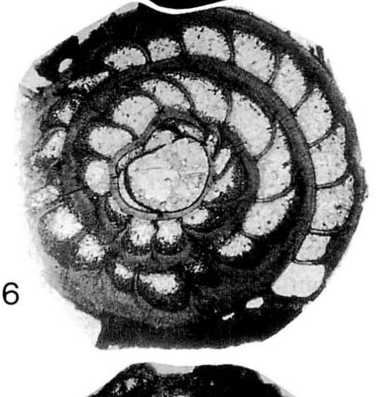

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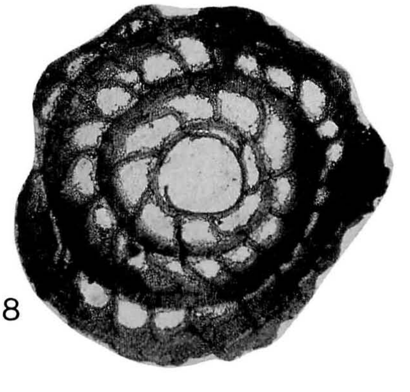

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chambers; the third, into 20 to 25 chambers; the fourth, into 27 to 33 chambers; and the fifth, into 23 to 24 chambers. Microspheric test, lenticular with rounded margin; 22 to 42 mm in diameter, and 5 to 8 mm in thickness; form ratio of diameter to thickness, 3.8 to 5.8; surface smooth, marked with meandering septal filaments running from center to periphery; numerous round granules, distributed over whole surface of test. Mature forms, of minute proloculus, 32 μm in diameter; and closely and regularly coiled whorls, 18 to 32 in number; a radius of 51 to 85 μm in the first whorl, 100 to 180 μm in the second whorl, 200 to 340 μm in the third whorl, 400 to 500 μm in the 4th whorl, 620 to 780 μm in the 5th whorl, 920 to 1280 μm in the 6th whorl, 1100 to 1620 μm in the 7th whorl, 1560 to 2450 μm in the 8th whorl, 1710 to 3120 μm in the 9th whorl, 2100 to 3620 μm in the 10th whorl, 2430 to 4200 μm in the 11th whorl, 2950 to 4650 μm in the 12th whorl, 3360 to 5180 μm in the 13th whorl, 4100 to 5500 μm in the 14th whorl, 4500 to 5900 μm in the 15th whorl, 4820 to 6480 μm in the 16th whorl, 5300 to 7130 μm in the 17th whorl, 5770 to 7340 μm in the 18th whorl, 6180 to 7830 μm in the 19th whorl, 6700 to 8580 μm in the 20th whorl, 7240 to 8833 μm in the 21th whorl, 7750 to 9130 μm in the 22th whorl, 8120 to 9400 μm in the 23th whorl, 8200 to 9570 μm in the 24th whorl, 8400 to 9090 μm in the 25th whorl, 8600 to 9370 μm in the 26th whorl, 8930 to 9960 μm in the 27th whorl, 9300 to 10500 μm in the 28th whorl, 1110 μm in the 29th whorl, 1160 μm in the 30th whorl, 1180 μm in the 31th whorl, and 1210 μm in the 32th whorl, respectively. Spiral wall, rather thick in adult stage, lamellar, finely perforate; septa, regular, curve, and oblique; chambers, rather isometric in width and height in the first whorl, then larger in width than in height in later whorls.

Stratigraphic horizon: Yusan and Okimura Formations.

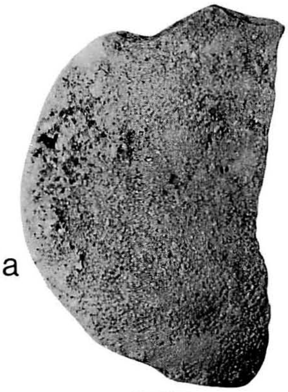
Remarks: As the author (1984, 1994) has stated, both megalospheric and microspheric specimens from Haha-Jima, in addition to the third specimen of megalospheric schizont form, have been critically compared with topotype specimens of *Nummulites perforatus* (Montfort) from Leghis, Cluj (Klausenburg), Rumania. As a result of the investigation, it was concluded that all of the characteristic features, such as granular test, external form, number of whorls, chamber shape, number of chambers in whorls, and spira-diagram of Haha-Jima specimens, is in satisfactory with those of topotype specimens.

As Doornink (1932) has already pointed out, the external characteristics of *Camerina perforata* (Montfort) vary considerably. Although the microspheric form from Haha-Jima is large test and different from the thicker test with a blunt margin of *Camerina obtusa* (Sowerby), which Doornink (op. cit.) described as a junior synonym of *Camerina perforata*, the present form from Haha-Jima is assigned to *Nummulites perforatus* (Montfort), based mainly on the spira-diagram assignment and chamber shape.

Explanation of Plate 25

Nummulites perforatus (Montfort)

1a, 2a, 3a, 3c. Side views of microspheric form. 1a. ×1.5, 2a, 3a, 3c. ×2, 1b–c. Axial sections. 1b. ×1.5, 1c. ×2. 2b, 3d. Axial views. ×2. 2c, 3b. Equatorial sections. 2c. ×2, 3b. ×3. Yusan Formation; Localities: 1. US81706, 2. US81704, 3. US81701 (Yusankaigan Section).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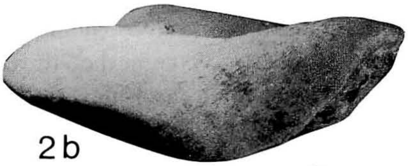
1b


1c


2a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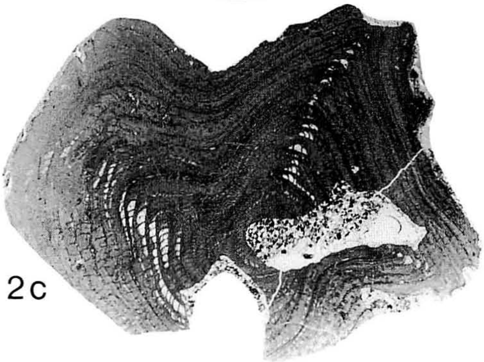
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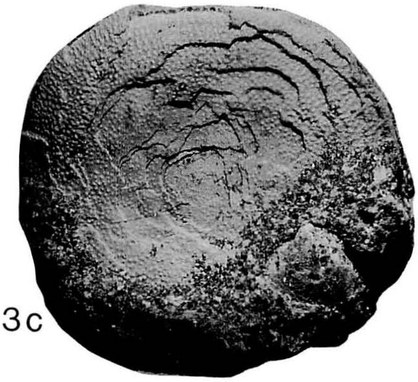
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Nummulites sp.

Plate 27, figure 4.

Description: Test lenticular, with sharp margin; 11.2 mm in diameter, and 2.48 mm in thickness; form ratio of diameter to thickness, 4.52; surface ornamented by several prominent pillars, 160 to 200 μm in diameter. Minute proloculus, not observed; and closely coiled volutions, 12 in number; radius of 73 μm in the first volution, 177 μm in the second volution, 227 μm in the third volution, 606 μm in the 4th volution, 926 μm in the 5th volution, 1300 μm in the 6th volution, 2532 μm in the 7th volution, 3000 μm in the 8th volution, 3560 μm in the 9th volution, 4492 μm in the 10th volution, 5260 μm in the 11th volution, and 5600 μm in the 12th volution; thickness of test, 83 μm in the first volution, 135 μm in the second volution, 333 μm in the third volution, 645 μm in the 4th volution, 884 μm in the 5th volution, 1123 μm in the 6th volution, 1539 μm in the 7th volution, 1680 μm in the 8th volution, 1860 μm in the 9th volution, 1960 μm in the 10th volution, 2200 μm in the 11th volution, and 2480 μm in the 12th volution, respectively. Spiral lamellar gradually increasing in thickness until the 7th volution, then thinner from the 8th to the 12th volution; distinct marginal cord on periphery. Pillars, regularly distributed and extend from surface toward early volutions.

Stratigraphic horizon: Yusan Formation.

Remarks: This species is found in the present collection from accidental vertical sections, and is characterized by a lenticular test, tightly coiled and regularly distributed pillars. As such, this species is compared with *Nummulites yawensis* Cotter from the upper Eocene Yaw Stage, Kyetubok, Burma (Nagappa, 1959, pl. 9, figs. 11–12). The former is, however, a large-sized and thin lenticular test, but the latter has a markedly small-sized and thick lenticular one. Therefore, the two are not identical. *Nummulites* sp. from Haha-Jima is similar to *Nummulites acutus* (Sowerby) from the middle to lower upper Eocene Prang Stage of Norang River, Garo Hills, Assam, India (Nagappa, 1959, pl. 10, figs. 1–2). However, *Nummulites acutus* is slightly different in that the pillars appear heavier and more pronounced on *Nummulites* sp. in the present collection.

Genus *Heterostegina* d'Orbigny, 1826

Heterostegina borneensis van der Vlerk, 1929

Explanation of Plate 26

(All figures ×12)

Nummulites perforatus (Montfort)

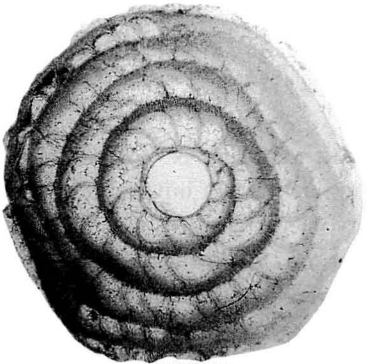
1, 3–4, 6. Equatorial sections of megalospheric form. Yusan Formation; Localities: 1. US81701B (Yusankaigan Section). 3. MI81801B, 4, 6. MI81802 (Miyukihama Section).

Nummulites millecaput Boubée

2. Equatorial section of megalospheric form. Yusan Formation; Locality: MI81807 (Miyukihama Section).

Nummulites gizehensis (Forskål)

5, 7–8. Equatorial sections of megalospheric form. Yusan Formation; Localities: 5, 8 US81703, 7. US81716 (Yusankaigan Section).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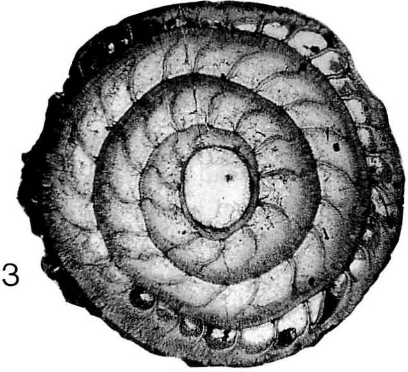
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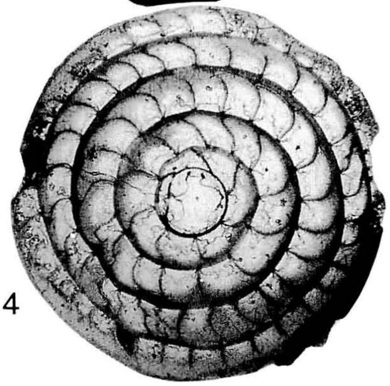
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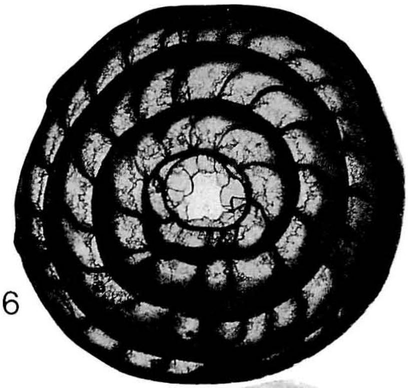
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Plate 28, figures 1–7.

Heterostegina borneensis van der Vlerk, 1929, p. 16, figs. 6a–c, 25a–b; Cole and Bridge, 1953, p. 23, pl. 2, figs. 1–3, 5; pl. 4, figs. 16–18; Hanzawa, 1957, p. 44–45, pl. 2, figs. 12–17; pl. 6, fig. 12; Matsumaru, 1976b, p. 199, pl. 3, figs. 17–19, 21–22.

Description: Test evolute, inflated lenticular with wide rim; 2.3 to 2.9 mm in diameter, 1.5 to 1.7 mm in diameter of central boss, 0.7 mm in thickness of inflated portion, and 0.2 to 0.3 mm in thickness of flange. Megalospheric embryonic apparatus, biloculine; subspherical protoconch, 125 × 100, and 250 × 215 μm in diameter, and reniform deuteroconch, 175 × 90, and 215 × 210 μm in diameter; followed by one operculine chamber of radial diameter 58 and 100 μm, and of tangential diameter 75 and 225 μm, respectively. In vertical section, embryonic apparatus, biloculine; the initial protoconch, subcircular; of diameter 104 to 162 μm, and height 133 to 144 μm, and the second deuteroconch, subcircular; of diameter 69 μm and height 83 μm. Prominent pillars, present on central boss of test; and of diameter 83 to 125 μm on central boss, and 62 μm on flange. Pillars penetrating to outer wall of embryonic apparatus and equatorial layer. Thickness of side wall over embryonic apparatus, 270 to 290 μm. Rudimentary open spaces, present in alar prolongation of last two whorls; of dimension 58 × 18, 60 × 15, 83 × 20, and 104 × 20 μm, in internal length and height.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: As the present form has only one operculine chamber and exhibits the peculiar features of rudimentary open spaces between the side walls of the test, this form is assigned to *Heterostegina borneensis* van der Vlerk, 1929, from Borneo. *Heterostegina nigripustula* Cole, 1954, from the Tertiary b Stage in Bikini Atoll, is a junior synonym of *Heterostegina borneensis* van der Vlerk, because of the same features.

Heterostegina borneensis occurs from the lower member of the Minamizaki Limestone, whereas *Spiroclypeus margaritatus* occurs from the upper member of the Minamizaki Limestone. It should be noted that if we consider both the development proportions of the lateral chambers and stratigraphic distribution of *Heterostegina borneensis* and *Spiroclypeus margaritatus* in the Minamizaki Limestone, the former is an ancestor of the latter and evolved into the latter.

Explanation of Plate 27

(All figures ×42, except Figure 4 of 11 times of natural size)

Nummulites pengaronensis Verbeek

1–2. Equatorial sections of megalospheric form. Yusan Formation; Localities: 1. US81717, 2. US81710 (Yusankaigan Section).

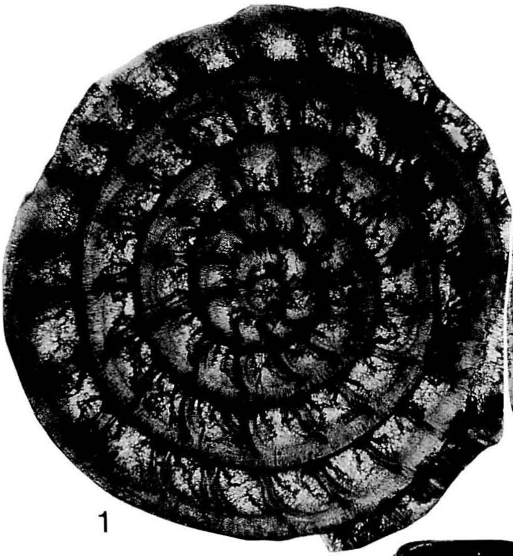
Nummulites millecaput Boubée

3. Equatorial section of megalospheric form showing division of spiral wall. Yusan Formation; Locality: MI81807 (Miyukihama Section).

Nummulites sp.

4. Axial section of microspheric form. Yusan Formation; Locality: US81709 (Yusankaigan Section).

Plate 27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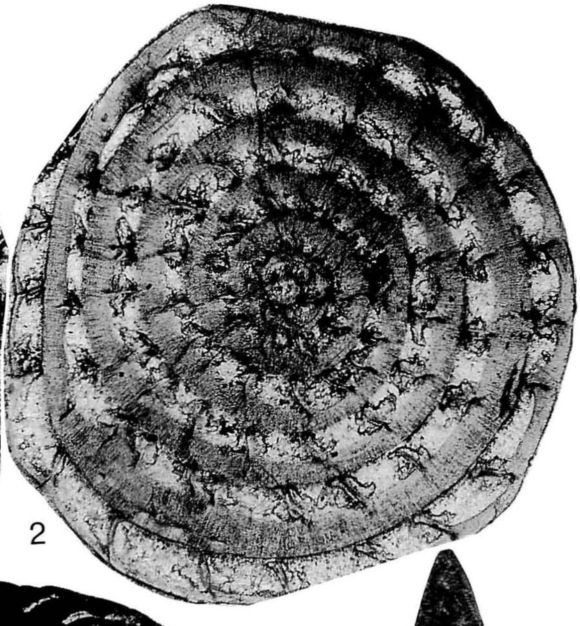
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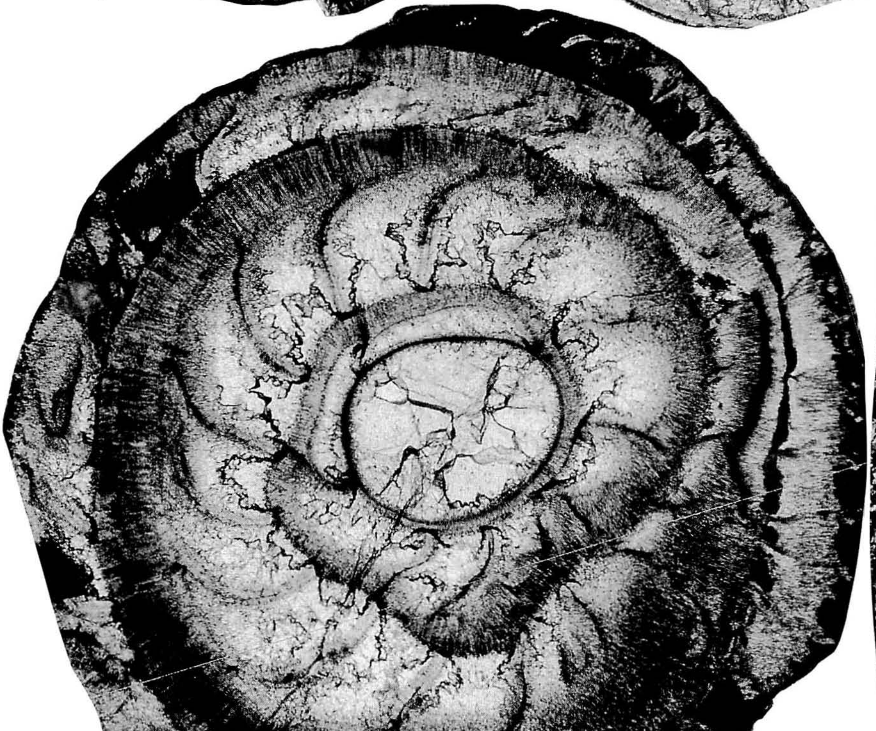
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Heterostegina duplicamera Cole, 1957b

Plate 29, figures 1–7.

Heterostegina duplicamera Cole, 1957b, p. 759–760, pl. 236, figs. 1–23.

Description: Test evolute, inflated lenticular with moderately wide, thin flange on distal part; lightly elevated central boss, covered with pillars or without pillars; wide rim; smooth and, in places, beaded sutures on curved chamber walls. Megalospheric form, 2.4 to 3.9 mm in diameter, 1.8 to 2.0 mm in diameter of central boss, 0.8 to 1.0 mm in thickness, and 0.2 to 0.3 mm in thickness of flange; microspheric form, similar to megalospheric form, but large; 3.0 to 7.0 mm in diameter, 1.9 to 2.2 mm in diameter of central boss, 1.2 to 1.5 mm in thickness, and 0.4 to 0.5 mm in thickness of flange. Umbonal pillars, present, and extended from embryonic chambers to surface of test; of diameter 100 to 150 μm in megalospheric form, and of diameter 120 to 280 μm in microspheric form. Megalospheric embryonic apparatus, biloculine; protoconch, spherical to subspherical; with internal diameter of 140 × 146, 208 × 177, 229 × 208, 229 × 229, and 270 × 260 μm; deuteroconch reniform; with inner diameter of 177 × 52, 200 × 114, 250 × 104, 250 × 208, and 155 × 223 μm; embryonic apparatus, 146 to 237 μm high in vertical section; microspheric proloculus measuring 42 × 42, 52 × 48, 60 × 52, and 62 × 62 μm in inner diameter, and second chamber measuring 50 × 20, 52 × 30, 62 × 30, and 102 × 54 μm in inner diameter. Megalospheric embryonic apparatus, followed by 2 to 3 undivided operculine chambers, and microspheric apparatus, followed by 3 to 4 operculine chambers; following chambers, divided into heterostegine chambers, formed by complete secondary septa. Megalospheric form, with 2 to 3 whorls; a radius of 500–850 μm in the first whorl, with 8 to 10 chambers; and 1320 to 1540 μm in the second whorl, with 15 to 22 chambers; and microspheric form, with 2 and 1/2 to more than 3 whorls; a radius of 170–280 μm in the first whorl, with 7 chambers; 480–730 μm in the second whorl, with 10 to 12 chambers; and 940 μm in the third whorl, with 13 chambers. Wall calcareous, finely perforate; and heterostegine chambers having Y-shaped supplementary radial stolons at distal tip of secondary septula in equatorial plane. Secondary canals in secondary septa from chamberlets, branching off from lateral canals in main septum, and communicating with intraseptal canals from part of former marginal canals. Flange having either no pillars or very small ones; of diameter 50 to 60 μm.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present specimens in the Minamizaki Limestone vary from the inflated test with coarse pillars to the test without pillars. There is complete gradation between these

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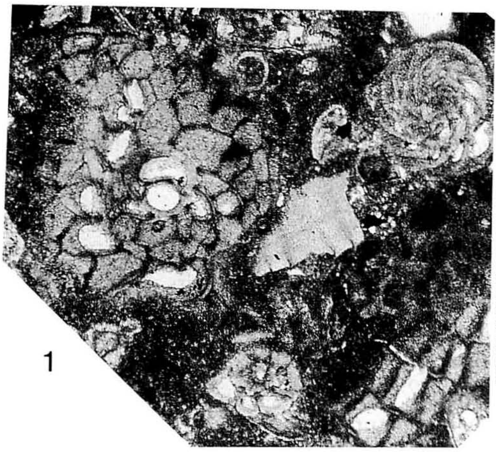
Explanation of Plate 28

(All figures ×40)

Heterostegina borneensis van der Vlerk

1–4. Equatorial sections. 1. Megalospheric form, 2–4. Microspheric forms, 5–6. Axial sections of megalospheric form showing rudimentary open spaces in the alar prolongation of last two whorls, 7. Oblique sections of megalospheric form showing central pillars. Minamizaki Limestone; Localities: 1–2. 12, 3. 20, 4. 17.5, 7. 35 (All belonging to 1304 Section). 5–6. 9709 (Minami-Jima).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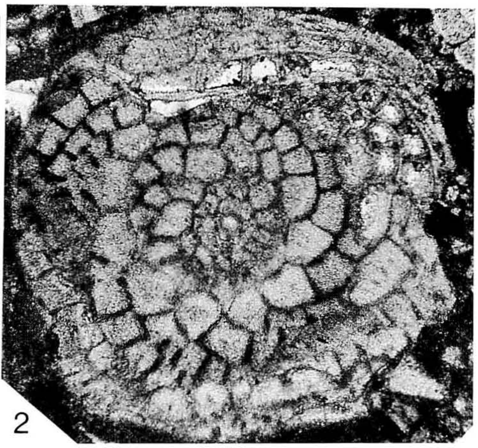
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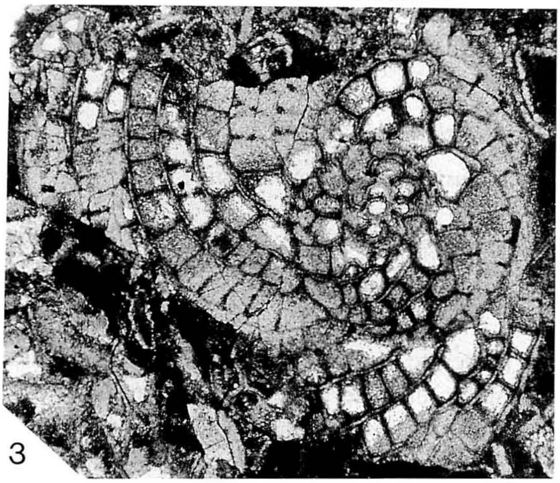
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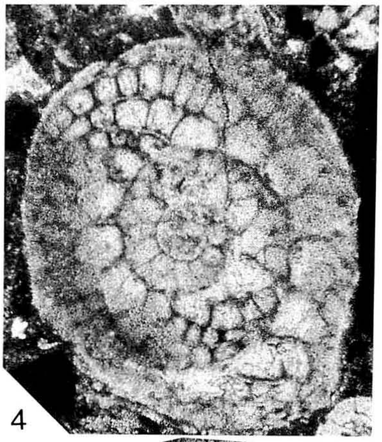
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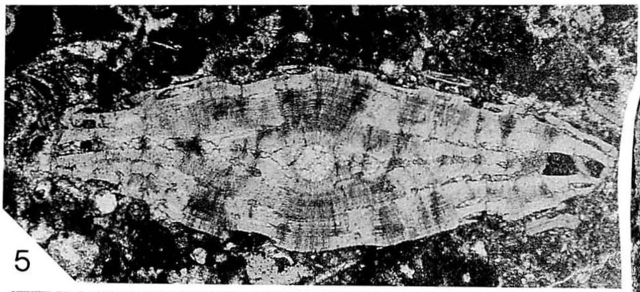
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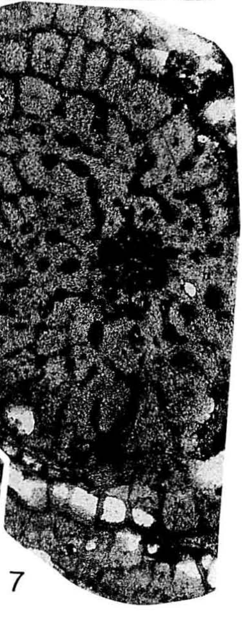
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two types, and all of the specimens have more than 2 operculine chambers. Thus the Minamizaki specimens are assigned to *Heterostegina duplicamera* Cole, 1957, although Cole designates the latter as an inflated test with large pillars. *Heterostegina duplicamera* differs from *Heterosteginsa praecursor* Tan, 1932, *H. bantamensis* Tan, 1932, *H. borneensis* van der Vlerk, 1929, and *H. pusillumbonata* Cole, 1954, from the Oligocene beds in the Pacific Region, in having 2 to 4 operculine chambers. *Heterostegina duplicamera* resembles *H. saipanensis* Cole, 1953, from the upper Eocene Hagman and Densinyama Formations, and the Matansa Limestone in Saipan, and from the upper Eocene Tertiary b stage in Eniwetok Atoll, in the test shape and numbers of operculine chambers and whorls, but it differs from the latter in having larger embryonic chambers. According to Cole (1957b), *Heterostegina duplicamera* and *Heteroategina saipanensis* in Eniwetok Atoll occur from the cores from 1925 to 2688 feet and those from 3052 to 4341 feet, respectively. Inasmuch as these two species are very closely related in the external and internal features and close occurrences in the stratigraphic distribution, it may be possible to consider a more logical evolution from *Heterostegina saipanensis* to *H. duplicamera*.

Genus *Grzybowskia* Bieda, 1950

Grzybowskia boninensis Matsumaru, n. sp.

Plate 30, figures 1–7.

Type material: Holotype, equatorial section of megalospheric form, Saitama University coll. no. 8822 (Plate 30, fig. 1).

Description: Test lenticular, with moderate rim; 1.4 to 3.64 mm in diameter, with slightly elevated central boss, 1.0 to 2.0 mm in diameter, and 0.61 to 0.86 mm in thickness; form ratio of diameter to thickness, 1.6 to 4.2; surface rather smooth, but with tiny granules on chamberlets sutures, 24 to 62 μm in diameter. Mature forms, biloculine embryonic chambers; protoconch, spherical to subspherical, 88 × 88 and 160 × 144 μm, deuteroconch, reniform, 92 × 20 and 120 × 68 μm; following two or three operculine chambers in initial part of first whorl; chamberlets appearing until more than two whorls, but not arranged in regular rows, and even irregular ones, rectangular, pentagonal, or hexagonal in shape; wall finely perforate; without lateral chambers; marginal cord, and stolon system present.

Stratigraphic horizon: Sekimon Limestone.

Remarks: The present form is similar to both *Grzybowskia multifida* Bieda, 1950, from the Eocene Tatra Limestone, Poland, and *Heterostegina aequatoria* Cole from the Tertiary b beds in Eniwetok Atoll, in having chamberlets in irregular rows, but it is different from

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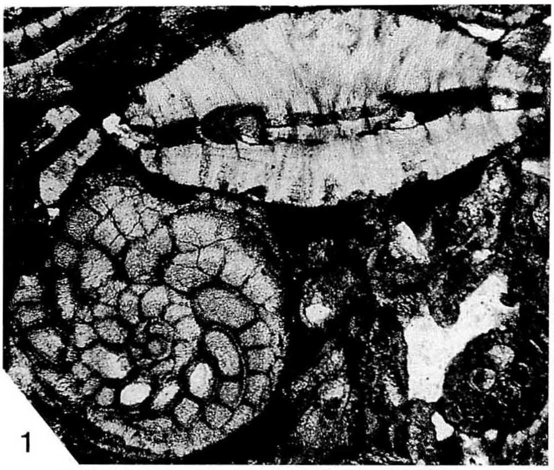
Explanation of Plate 29

(All figures ×40)

Heterostegina duplicamera Cole

1 (lower), 2–5, 7. Equatorial sections of microspherical form, 1 (upper), 6. Axial sections of microspheric form. Minamizaki Limestone; Localities: 1. 12, 2–4. Base, 5. 15, 6. 25.5, 7.16 (All belonging to 1301 Section).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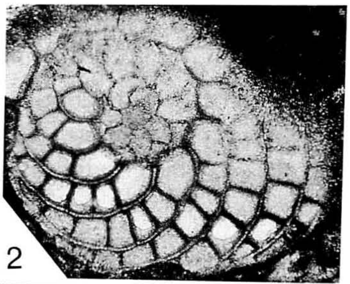
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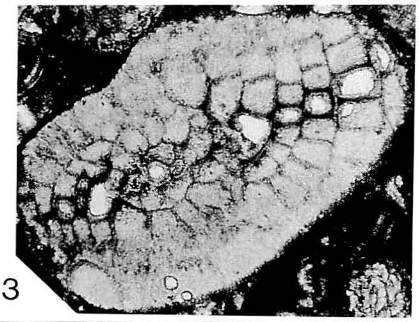
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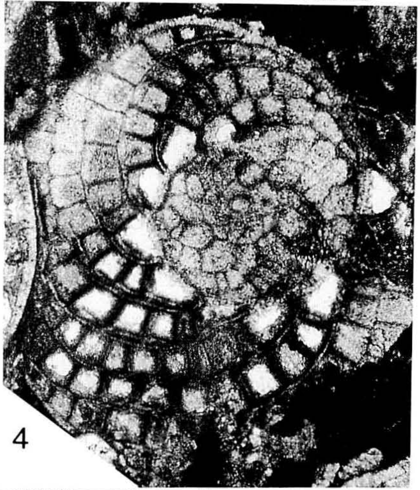
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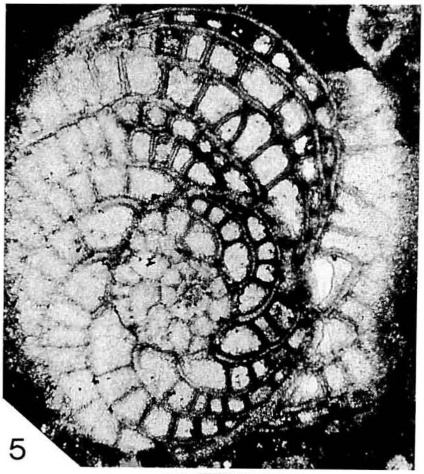
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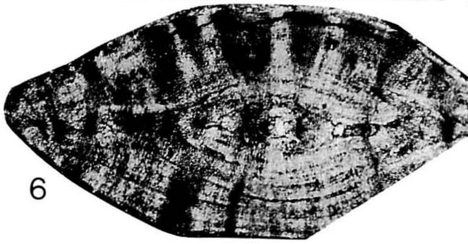
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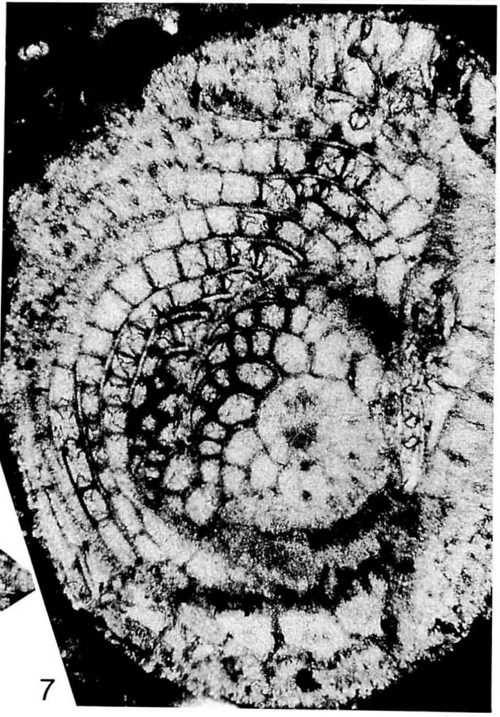
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the latter two in having fewer operculine chambers. Also the present form is similar to *Heterostegina saipanensis* Cole from the Eocene Matansa Limestone, Saipan, in having fewer operculine chambers, but it is different from the latter in having chamberlets in irregular rows. Although Loeblich and Tappan (1988, p. 684) regarded *Grzybowski* Bieda, 1950 as a synonym of *Heterostegina* d'Orbigny, 1826, the irregular arrangement of chamberlets formed by the secondary septa, which is recognized in *Grzybowskia*, seems to represent the generic character. As such, the present form is identifiable with *Grzybowskia boninensis*, n. sp. Also, *Heterostegina aequatoria* Cole may be a junior synonym of *Grzybowskia multifida* Bieda. Although Bieda (1963) identified *Grzybowskia reticulata* (Rütimeyer) from the Tatra Limestone, *Heterostegina reticulata* Rütimeyer from the Priabonian type section does not have hexagonal chamberlets (Hottinger, 1977, figs. 44A–D). Bieda's *Grzybowski reticulata* is included in a variation of *G. multifida*, whereas *Heterostegina reticulata* is a senior synonym of *H. saipanensis*.

Genus *Spiroclypeus* H. Douvillé, 1905

Spiroclypeus granulosus Boussac, 1906

Plate 31, figures 1–5.

Spiroclypeus granulosus Boussac, 1906, p. 96–97, pl. 2, figs. 15–18, pl. 3, fig. 19; Bieda, 1963, p. 198, pl. 17, figs. 9–11; Hottinger, 1977, p. 114, figs. 48G–H.

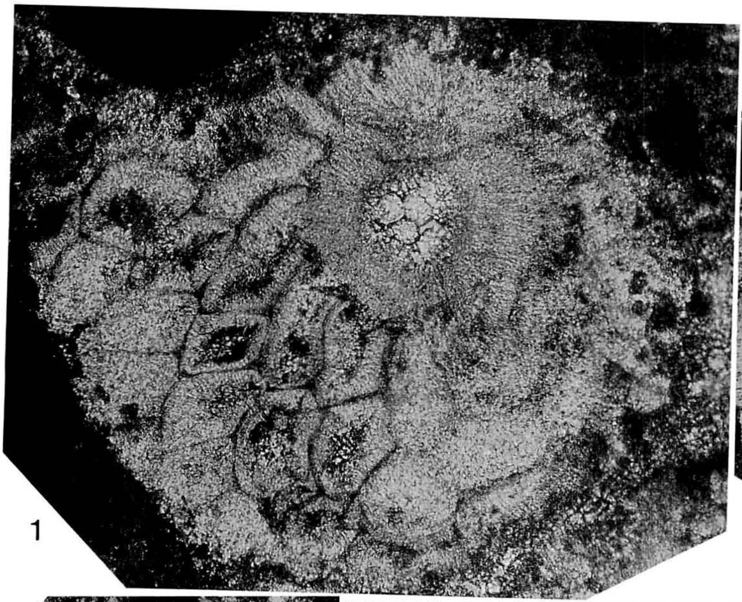
Spiroclypeus vermicularis Tan, 1937, p. 187–190, pl. 1, figs. 7–8, pl. 2, figs. 6–10, pl. 3, figs. 13–23, pl. 4, figs. 11–18; Cole and Bridge, 1953, p. 18, pl. 14, fig. 7; Cole. 1957b, p. 764, pl. 238, figs. 1–6, 8–12; Hanzawa, 1957, p. 47–48, pl. 4 figs. 2–7, pl. 5, fig. 15.

Description: Test lenticular, with slight flange; 2.3 to 3.4 mm in diameter, and 0.7 to 1.2 mm in thickness; form ratio of diameter to thickness, 2.4 to 3.6; pillars, heavy; and of diameter 110 to 208 μm in central area, smaller pillars, of diameter 40 to 80 μm in marginal area. Embryonic chambers, biloculine; circular to subcircular protoconch; of diameter 72 and 109 μm, and of height 72 and 102 μm, respectively; deuteroconch incompletely recognized; wall surrounding embryonic chambers, thickness of 12 and 14 μm. Two to three whorls, discernible; height of whorls increasing toward periphery; rectangular, pentagonal, or hexagonal chamberlets varying from 40 to 45 μm in radial diameter, and 36 to 104 μm in tangenital diameter in adult stage; 7 to 12 lateral chamberlets present, in a tier on either side of embryonic chambers in vertical section; of 42 to 112 μm in length, and 16 to 24 μm in height. Floors and roofs, 8 to 72 μm in thickness; wall lamellar, finely perforate; marginal cord, and stolon system present.

Explanation of Plate 30

Grzybowskia boninensis Matsumaru, n. sp.

1. Equatorial section of megalospheric form. Holotype, Saitama University coll. no. 8822. Sekimon Limestone: OK 23.95 (Okiko/Tsukigaoka Shrine Section). ×100, 2, 4–5, 7. Axial sections. 2, 4, 7. Microspheric forms, 2, 7. ×43, 4. ×23, 5. Megalospheric form. ×43, 3. Tangential section. ×43, 6. Oblique sections of megalospheric form. ×43. Sekimon Limestone; Localities: 1, 5. OK23.95, 2, 3. OK25.95, 4, 6. OK19.95 (Okiko/Tsukigaoka Shrine Section), 7. cl (Chibusa Dam).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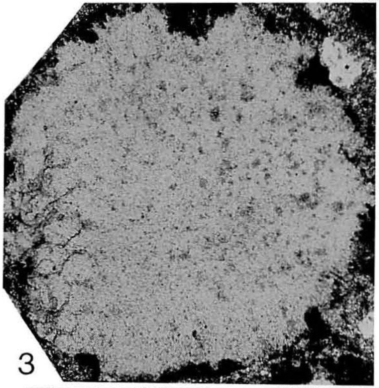
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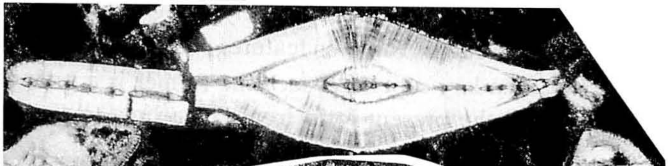
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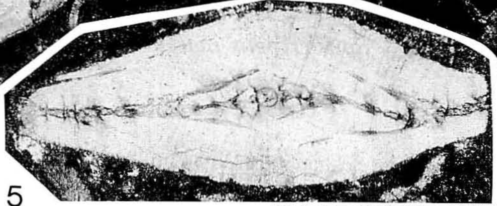
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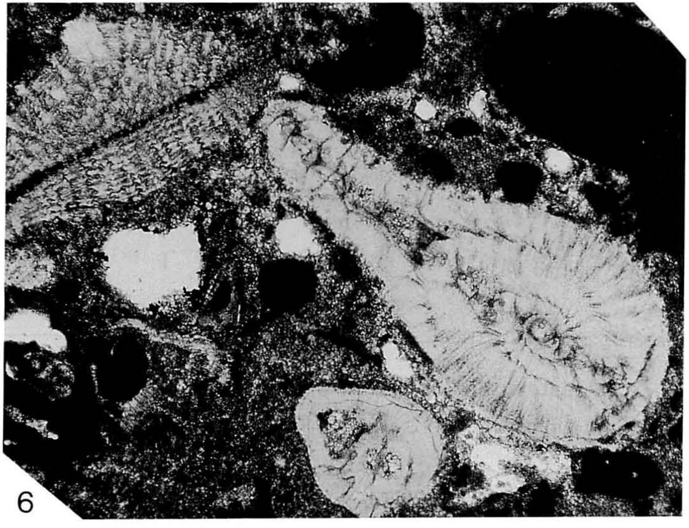
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Stratigraphic horizon: Sekimon Limestone.

Remarks: The present form is characterized by having pillars traversing lateral chambers in the central portion of the test, reticulate chamberlets in the equatorial chambers in 2 to 3 whorls, and at places hexagonal or pentagonal chamberlets, which were formed by septal fluting, and 7 to 12 lateral chambers. Although Tan (1937) described a new species of *Spiroclypeus vermicularis* from the upper Eocene beds of East Borneo, and Cole (1957b) and Hanzawa (1957) supported Tan's new species, and described *Spiroclypeus vermicularis* from the upper Eocene Limestone of Eniwetok Atoll and Saipan, no one made a comparison with *Spiroclypeus granulosus* Boussac, 1906, from the Priabonian type section, Italy.

The two topotype specimens of *Spiroclypeus granulosus* (Hottinger, 1977, figs. 48G and H), and one topotype specimens of the same species (Bieda, 1963, pl. 17, fig. 11), having only one operculine chamber, while *Spiroclypeus vermicularis* by Tan (1937, p. 88) and Cole (1957b, p. 764) shows normally one operculine chamber, except for an example of two operculine chambers. Hanzawa (1957, p. 47) described that *Spiroclypeus vermicularis* Tan is characterized by lateral chambers with a vermicular in tangential section, as Tan has indicated, but Cole (op. cit.) neither showed this character in his illustration nor mentioned it. The state of lateral chamber may be varied by the rate of growth or seen by the orientation of thin section. Both *Spiroclypeus granulosus* Boussac, 1906, and *S. vermicularis* Tan, 1937, represent the common features of reticulate, hexagonal, or pentagonal chamberlets divided by secondary septa. As such the former is a senior synonym of the latter, and the author referred the present form from Haha-Jima to *Spiroclypeus granulosus* Boussac.

Spiroclypeus margaritatus (Schlumberger, 1902)

Plate 32, figures 1–8; Plate 33, figures 1–9.

Heterostegina margaritata Schlumberger, 1902, p. 252–253, pl. 7, fig. 4.

Spiroclypeus orbitoideus H. Douvillé, 1905, p. 460–462, pl. 14, figs. 1–6; Tan, 1937, p. 183–184, pl. 1, figs. 2–4, pl. 2, figs. 1–13, pl. 3, figs. 1–7 (non figs. 8, 24), pl. 4, fig. 1; Cole, 1957a, p. 332–333, pl. 95, figs. 6–12; Matsumaru, 1976b, p. 200, pl. 1, figs. 1, 8, 10; Hashimoto, Matsumaru, and Sugaya, 1981, p. 59, pl, 13, fig. 8.

Spiroclypeus leupoldi van der Vlerk, 1925, p. 14–15, pl. 2, fig. 16, pl. 5, figs. 41, 48; Yabe and Hanzawa, 1929, p. 188, pl. 24, fig. 9; Cole, 1954, p. 577–578, pl. 208, figs. 1–19; Hanzawa, 1957, p. 45–46, pl. 5, figs. 7–13; Matsumaru, 1974, p. 108 pl. 15, figs. 2–4, 10, 13–15, 21–23, 28; Matsumaru, 1976b, p. 199–200, pl. 1. figs. 4–7, 14–15, 21, 23–24; Hashimoto. Matsumaru, and Alcantara, 1982, p. 34–36, pl. 10, figs. 18–20, pl. 11, figs. 1–7, 9.

Spiroclypeus wolfgangi van der Vlerk, 1925, p. 15–15, pl. 2, fig. 15, pl. 5, figs. 39, 49; Tan, 1937, p. 183, pl. 1 fig. 1.

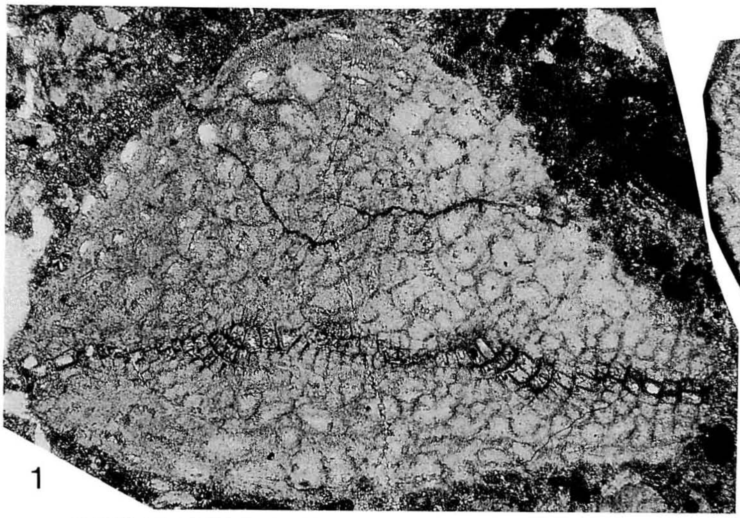
Spiroclypeus yabei van der Vlerk, 1925, p. 16, pl. 2, fig. 19, pl. 5, figs. 40, 50; Tan, 1937, p. 183, pl. 1, figs.

Explanation of Plate 31

(All figures ×40)

Spiroclypeus granulosus Boussac

1, 3, 5. Oblique sections. 1, 3. Microspheric forms, 5. Megalospheric form. 2, 4. Axial sections. 2. Megalospheric form. 4. Microspheric form. Sekimon Limestone; Localities: 1, 4. cl (Chibusa Dam), 2–3, 5. 9381403 (Sekimon Karst Section).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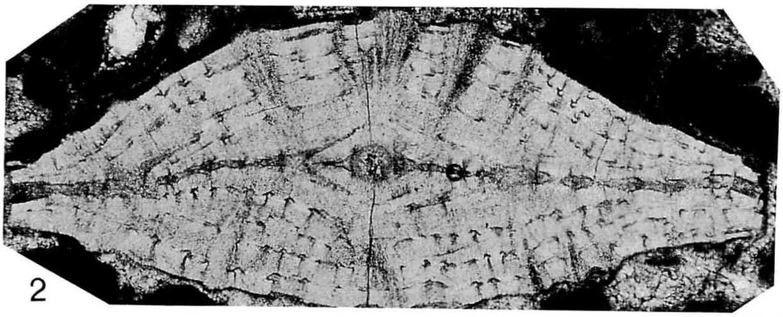
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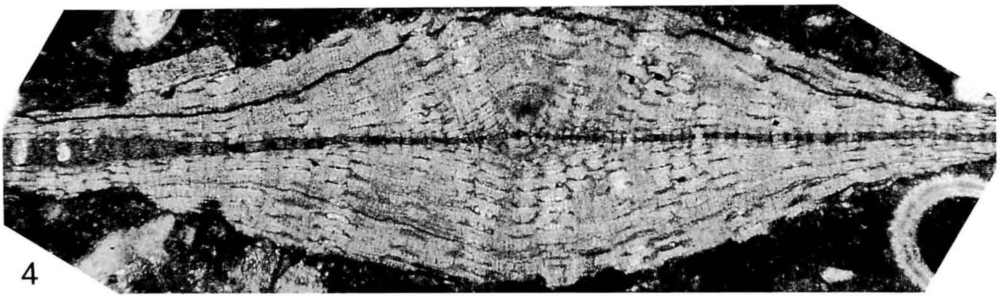
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5–6, pl. 3, figs. 10–11, pl. 4, figs. 8–10, text-fig. 1; Cole, 1954, p. 580–581, pl. 207, figs. 1–14, pl. 208, figs. 20–26; Cole, 1957b, p. 764, pl. 239, figs. 9.10.

Spiroclypeus tidoenganensis van der Vlerk, 1925, p. 16–17, pl. 1, fig. 12, pl. 5, figs. 42, 47; Tan, 1937, p. 183, pl. 1, fig. 10, pl. 2, figs. 4–5, pl. 3, fig. 12, pl. 4, figs. 2–5, 19–21; Hanzawa, 1957, p. 46–47. pl. 3, figs. 1–6, pl. 4, figs. 1, 8–10; Cole, 1957a, p. 332. pl. 95, figs. 13–15 Matsumaru, 1976b, p. 200. pl. 1, figs. 3, 9, 12, 18–20, 22, pl. 6, fig. 15; Hashimoto and Matsumaru, 1978, p. 85–86, pl. 11, fig. 2; Hashimoto, Matsumaru, and Sugaya, 1981, p. 60–61, pl. 13, figs. 9, 12.

Spiroclypeus margaritata (Schlumberger). Yabe and Hanzawa, 1925a, p. 627–630, pl. 2, figs. 10, pl. 3, figs. 8–9, pl. 4, figs. 3–8, text-figs. 1–4; Yabe and Hanzawa, 1929, p. 187, pl. 23, figs. 1, 3–4, pl. 24, figs. 1–5; Krijnen, 1931, p. 89, pl. 1, figs. 1–3; Tan, 1937, p. 182–183, pl. 2, fig. 12, pl. 3, fig. 9, pl. 4, figs. 6–7; Hanzawa, 1940, p. 789–790, pl. 42, figs. 3–9; Cole, 1954, p. 578–580, pl. 206, figs. 10–25, pl. 207, figs. 15–16; Matsumaru, 1974, p. 108, pl. 15, figs. 16, 24, 26; Hashimoto and Matsumaru, 1975b, p. 122, pl. 13, figs. 11–12; Hashimoto, Matsumaru, and Sugaya, 1981, p. 59–60, pl. 13, fig. 3; Hashimoto, Matsumaru, and Alcantara, 1982, p. 34–36, pl. 11, fig. 8; Matsumaru, Myint Thein, and Ogawa, 1993, p. 10–11, figs. 2–1–9, 3–1.

Spiroclypeus margaritata (Schlumberger) var. *umbonata* Yabe and Hanzawa, 1929, p. 187–188, pl. 124, figs. 5–8.

Spiroclypeus higginsi Cole, 1939, p. 185, pl. 23, figs. 10–15, pl. 23, fig. 13; Hanzawa, 1957, p. 45, pl. 5, figs. 1–6, 14: Cole, 1957a, p. 332, pl. 95, figs. 1–5, pl. 109, fig. 16; Cole, 1957b, p. 763–764, pl. 239, figs. 11–12, 14; Matsumaru, 1974, p. 108, pl. 15, figs. 1, 5, 8, 12, 18–19; Matsumaru, 1976b, p. 109, pl. 1, figs. 2, 11, 16–17.

Description: Test moderately large, thin to thick, with eccentrically umbonal area surrounded by gently sloping rim; megalospheric form, 2.6 to 3.9 mm in diameter, 1.9 to 2.6 mm in diameter of umbo, and 0.87 to 1.30 mm in thickness; microspheric form, 4.2 to 5.0 mm in diameter, 2.2 to 3.7 mm in diameter of umbo, and 1.25 to 1.80 mm in thickness; minute to small pillars, present on umbonal portion; of diameter 60 to 125 μm in megalospheric form, and 83 to 166 μm in microspheric form; umbonal pustule, large; and of diameter 208 to 500 μm in some microspheric specimens. Megalospheric embryonic apparatus, biloculine, diameter of whole embryonic apparatus 187 to 254 μm across both protoconch and deuteroconch chambers; protoconch subspherical; of internal diameters 156 × 125, 173 × 156, and 218 × 194 μm; deuteroconch reniform; of inner diameter 156 × 72, 193 × 83, and 250 × 92 μm; thickness of outer wall of embryonic chambers, from 12 to 30 μm; height of embryonic apparatus, from 177 to 196 μm in vertical section. Embryonic chambers, followed by only one undivided operculine chamber; and following chambers, divided into heterostegine chamberlets. Chamberlets near periphery of test, rectangular; of dimension 114 × 70, 125 × 83, 146 × 90, and 146 × 135 μm, in inner radial and tangential diameters; 6 to 9 lateral chambers present, in a tier on each side of median layer at center of megalospheric form, and 10 to 12 lateral chambers in a tier on each side of median layer of microspheric form; of dimension 62 × 20, 70 × 27, 83 × 12, 83 × 27, 83 × 33, 83 × 48, 94 × 15, 94 × 20, 94 × 30,

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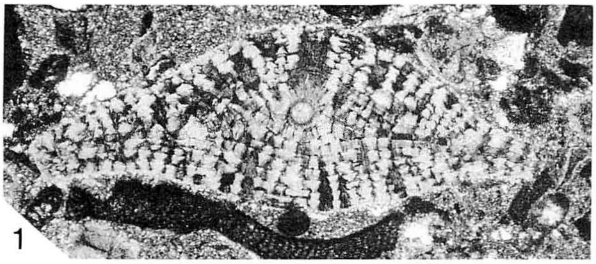
Explanation of Plate 32

(All figures ×20)

Spiroclypeus margaritatus (Schlumberger)

1–2, 6, 8. Axial sections. 1–2, 8. Megalospheric forms. 6. Microspheric form. 3–5, 7. Oblique sections. 3, 5. Megalospheric forms, 4. Microspheric form, 7. This form is in association with *Paleomiogypsina boninensis* Matsumaru, n. gen., n. sp. Minamizaki Limestone; Localities: 1, 3, 7. 43 (801S Section). 2, 5. 57, 4. 43, 6. 55, 8. 49 (All belonging to 1304 Section).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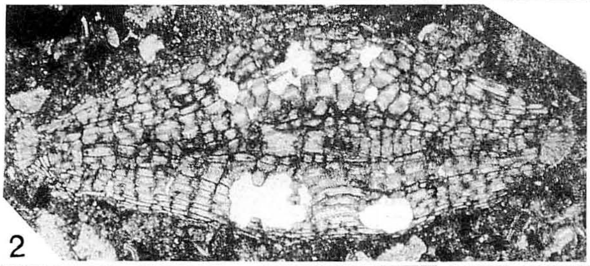
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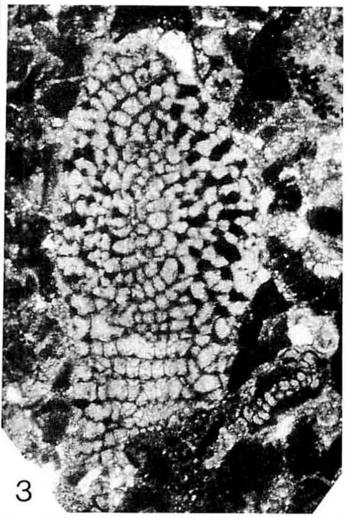
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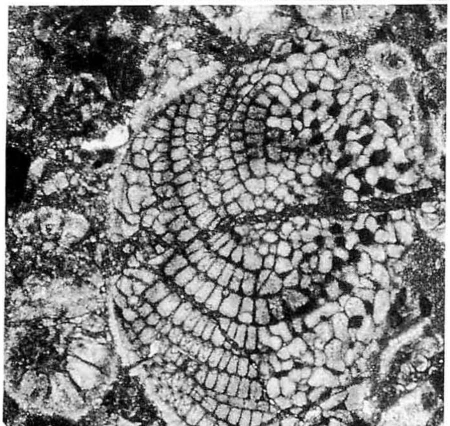
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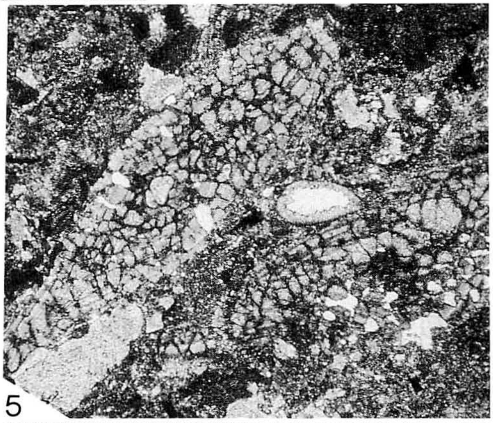
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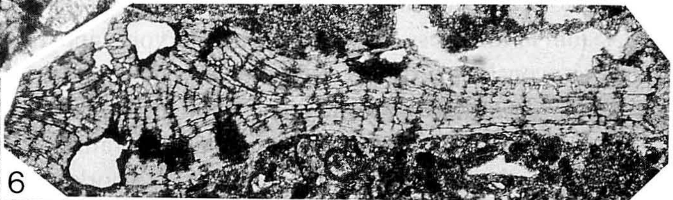
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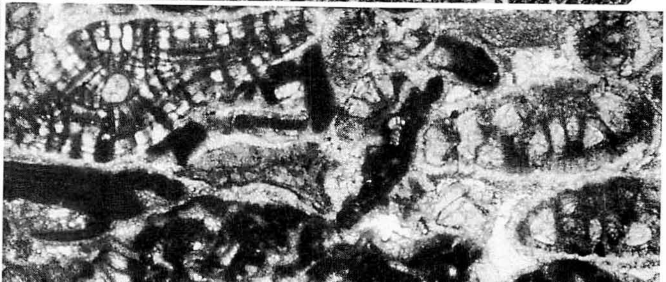
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94 × 37, 104 × 20, 114 × 27, 120 × 15, 123 × 27, 125 × 20, 125 × 27, 146 × 62, 187 × 52, and 208 × 42 μm, in inner length and height; thickness of floors and roofs of lateral chambers, 12 to 146 μm thick.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: The author described that all *Spiroclypeus* species in the west Pacific Region were a junior synonym for *Spiroclypeus margaritatus* (Schlumberger) (Matsumaru *et al.*, 1993, p. 11). *Spiroclypeus margaritatus* from Chichi-Jima is restricted to the upper member of the Minamizaki Limestone, in associated with *Miogypsinella boninensis*, n. sp., *Peelella boninensis*, n. gen., n. sp., *Boninella boninensis*, n. gen., n. sp., and *Cycloloculina boninensis*, n. sp.

Genus *Cycloclypeus* W. B. Carpenter, 1856

Cycloclypeus eidae Tan, 1932

Plate 34, figures 1–6.

Cycloclypeus neglectus Martin, 1880, p. 156–157, pl. 27, fig. 3; van der Vlerk, 1925, p. 18–19, pl. 1, fig. 11, pl. 2, fig. 20, pl. 4, figs. 36–37, text-fig. a and b; Whipple, 1934, p. 143, pl. 19, fig. 2.

Cycloclypeus (Cycloclypeus) eidae Tan, 1932, p. 50–59, pl. 5, fig. 6; pl. 12, figs. 2–3, pl. 13, figs. 1–2, 4–6; Cole, 1945, p. 280, pl. 14, figs. A–D; Cole and Bridge, 1953. p. 27, pl. 5, figs. 13–19; Cole, 1957a, p. 334, pl. 101, fig. 15; Chaproniere, 1984, p. 35–37, pl. 16. figs. 1–5, pl. 25, figs. 8–10 (non pl. 5, figs. 6a–b).

Cycloclypeus neglectus Martin var. *eidae* Tan. Caudri, 1932, p. 186–187, figs. 15–16; Hanzawa, 1957, p. 49–50, pl. 6, figs. 1–2.

Cycloclypeus eidae Tan Matsumaru, 1976b, p. 200, pl. 5, figs. 13, 16–17.

Description: Test moderately large, lenticular in shape, with low central umbo and wide peripheral flange; megalospheric form, 2.5 to 3.5 mm in diameter, 1.2 to 1.5 mm in diameter of umbo, and 0.3 to 0.5 mm in thickness; surface ornamented small round pillars, ranging from 42 to 83 μm in diameter; microspheric form, from 2.7 to 4.1 mm in diameter, and 0.35 to 0.45 mm in thickness. Megalospheric embryonic apparatus, nephrolepidine type of biloculine; protoconch spherical to subspherical, internal diameter 80 × 80, 104 × 94, 125 × 116, and 146 × 125 μm; deuteroconch reniform, largest inner diameter 114 × 83, 166 × 100, 187 × 104, and 187 × 125 μm; height of embryonic apparatus, 73 to 85 μm in vertical sections. 15 to 18 nepionic chambers arranged in about 2 whorls, in 5 mature specimens. In typical specimen, biloculine embryonic chambers, protoconch subspherical; 130 × 125 μm in diameter, and deuteroconch reniform, 166 × 100 μm in diameter; followed by undivided arcuate nepionic chamber, and total of 10 subquadrangular chamberlets in the 4th and 5th precyclic nepionic chambers, within 18 nepionic chambers; quadrangular chamberlets in the cyclic

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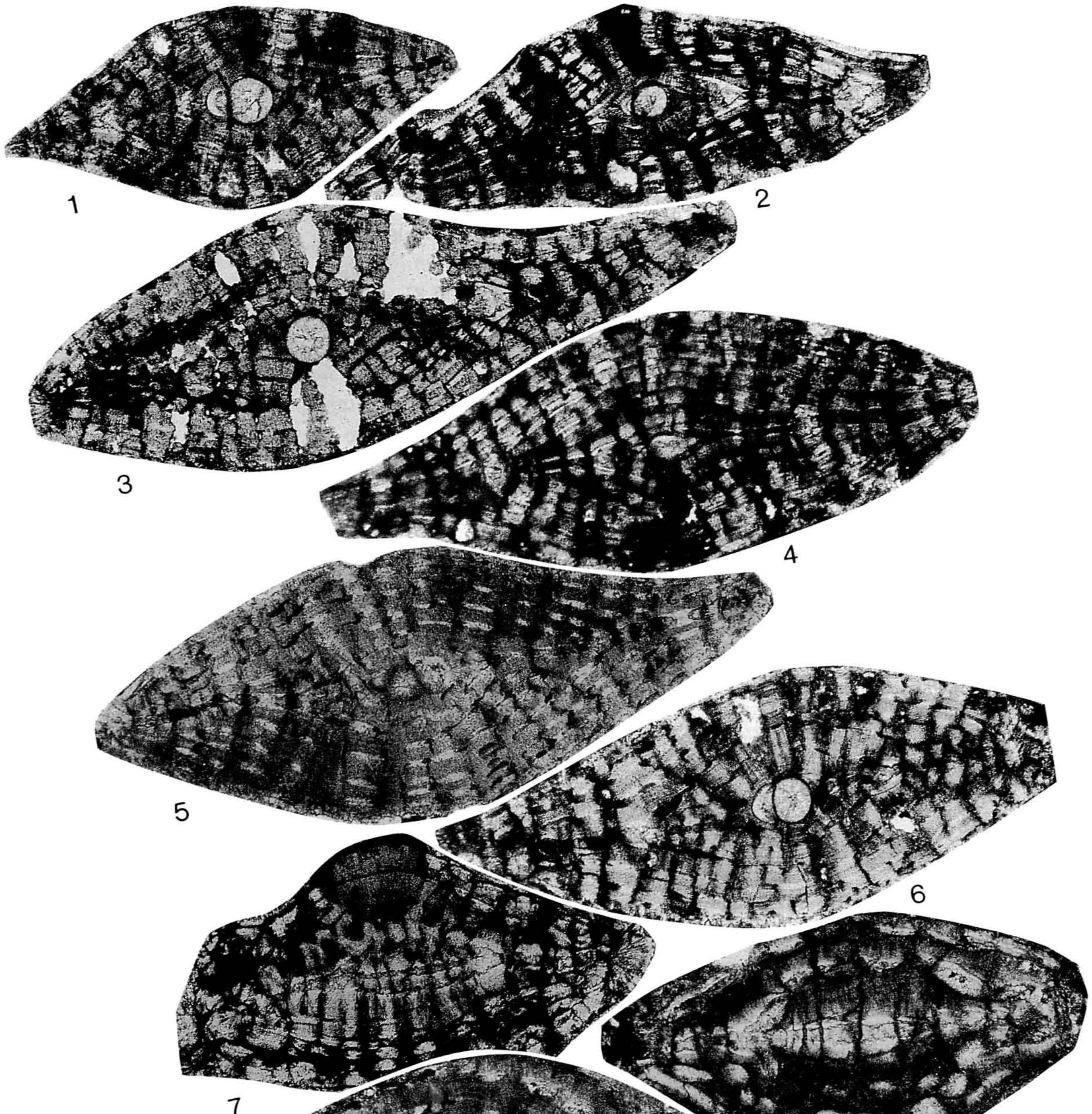
Explanation of Plate 33

(All figures ×40)

Spiroclypeus margaritatus (Schlumberger)

1–9. Axial sections. 1–6, 8–9. Megalospheric forms, 7. Microspheric form. Minamizaki Limestone; Localities: 1–2, 4, 6, 8–9. 49, 3. 57, 7. 43 (All belonging to 1304 Section), 5. 9716 (Minami-Jima).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chamber; of dimension 88 × 112, 90 × 130, 116 × 160, 128 × 168, 156 × 156, and 166 × 146 μm, in inner radial and tangential diameter. Both primary and secondary septa present; pierced by longitudial canals, called interseptal canal system, communicating with vertical canals through side walls; thickness of side walls, 170 × 225 μm.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: Tan (1932) classified various species of the genus *Cycloclypeus* in the Indo-Pacific Region, and found all three subgenera: *Cycloclypeus* sensu stricto, *Radiocycloclypeus*, and *Katacycloclypeus*. *Cycloclypeus communis* and *C. neglectus* described by Martin (1880) have, however, been abandoned by Tan (op. cit.) without sufficient reason. Tan's biometrical pioneer work has produced an excellent classification concerning large number of perfectly preserved specimens. Tan's classification of the genus *Cycloclypeus* Carpenter, 1856 is mainly based on the number of nepionic chambers (septa) and protoconch size. According to Tan (op. cit.), the former parameter was from 16 to 34 for *Cycloclypeus oppenoorth* Tan, and from 4 to 21 for *Cycloclypeus eidae* Tan, while the latter parameter was from 110 to 230 μm in the diameter for *Cycloclypeus oppenoorth*, and from 50 to 266 μm in the diameter for *Cycloclypeus eidae*; e.g. three specimens with 18 nepionic chambers for *Cycloclypeus oppenoorth* are 130, 190, and 190 μm in the diameter of protoconch, while 4 specimens with those for *Cycloclypeus eidae* are 65, 100, 100, and 105 μm in the diameter of protoconch. Chichi-Jima specimens are still too fragmental, and these specimens from the Minamizaki Limestone cannot be successfully identified. As such, there remains more or less a question whether *Cycloclypeus eidae* Tan from Chichi-Jima is correct or not. For the present paper, Chichi-Jima specimens from some available oriented thin sections are, however, identical with figures given for *Cycloclypeus eidae* Tan, based on the number of nepionic chambers and size of protoconch.

Family Pellatispiridae Hanzawa, 1937

Genus *Biplanispira* Umbgrove, 1937

Biplanispira absurda Umbgrove, 1937

Plate 35, figures 1–4; Plate 36, figures 1–6.

Pellatispira crassicolumnata Umbgrove, 1928, p. 66–67, fig. 79 (non figs. 75–78, 80).
Biplanispira absurda Umbgrove, 1938, p. 82–89, text-figs. 1–17; Hanzawa, 1957, p. 52, pl. 11, figs. 1–5, pl. 12, figs. 4–5.

Description: Test discoidal or thin lenticular, with thick marginal periphery; 4.2 to

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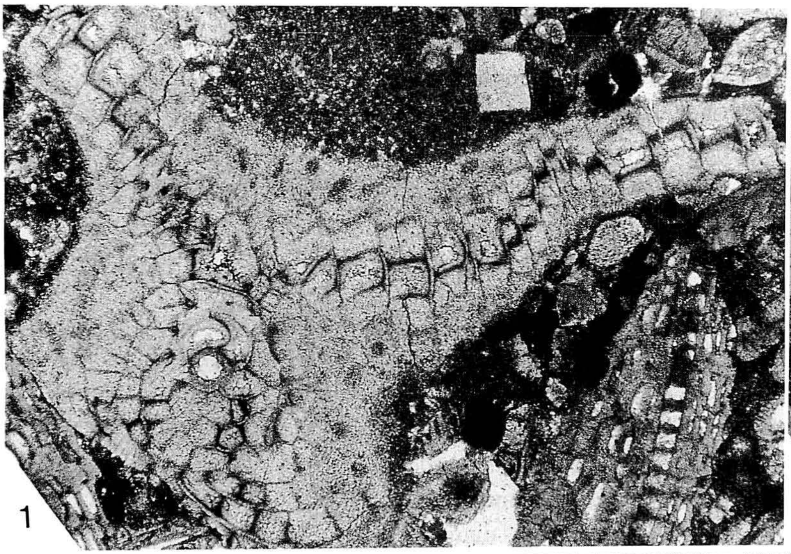
Explanation of Plate 34

(All figures ×40)

Cycloclypeus eidae Tan

1. Equatorial section of megalospheric form. 2, 4–6. Oblique sections. 2, 4. Megalospheric forms, 5–6. Microspheric forms. 3. Tangenital section. Minamizaki Limestone; Localities: 1. 15. 2, 4–5. 32. 3. 17.5, 6. 28 (All belonging to 1304 Section).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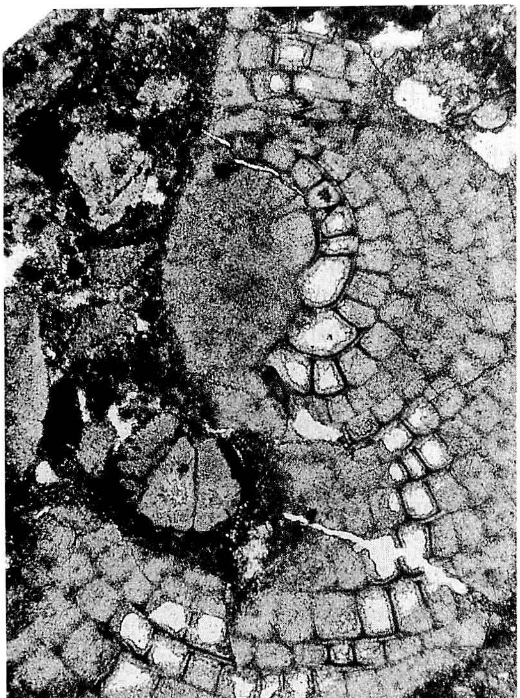
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8.1 mm in diameter, and 0.8 to 1.1 mm in thickness; form ratio of diameter to thickness, 3.1 to 8.1; surface coarsely granulate with pillars; of diameter 125 to 270 μm. Megalospheric apparatus, biloculine; spherical to subspherical protoconch, 146 × 146, 156 × 156, and 229 × 218 μm in diameter, and second reniform deuteroconch, 135 × 83 and 160 × 136 μm in diameter; microspheric spherical proloculus, very small, 32 × 32 μm in diameter. Distinct primary coil after embryonic apparatus, planispirally, in central part of infant stage, after which this coil meeting with the second coil, emerged from primary coil in adult stage. Mature forms, of a radius 645 to 1000 μm in the first coil, with 9 to 11 primary chambers; 1165 to 1520 μm in the second coil, with 19 primary chambers; and 1664 to 1900 μm in the third coil, with 3 primary chambers, and probable 27 secondary chambers. Primary and secondary chambers, increased toward periphery of test, with chamber height of 240 to 440 μm. In vertical section, single median layer of primary chambers present, in central part of test, after which those subdivided into irregularly arranged secondary chamber layer toward the periphery. Lateral layers present, superposed above and below both primary and secondary chamber layers, pierced by numerous vertical canals; of diameter 20 to 25 μm. Pore openings of vertical canals, of diameter 27 to 42 μm; closed by roofs of numerous surface chambers, superposed above lateral layers, 125 to 374 μm in width, and 42 to 94 μm in height in megalospheric form, and 80 to 120 μm in width, and 24 to 28 μm in height in microspheric form. Wall thick, fibrous, and perforate; canal system present, of radial, simple marginal, and interseptal canals; dorsal and umbilical pillars present over lateral walls; aperture, longitudinal grooves, at base of apertural face.

Stratigraphic horizon: Sekimon Limestone.

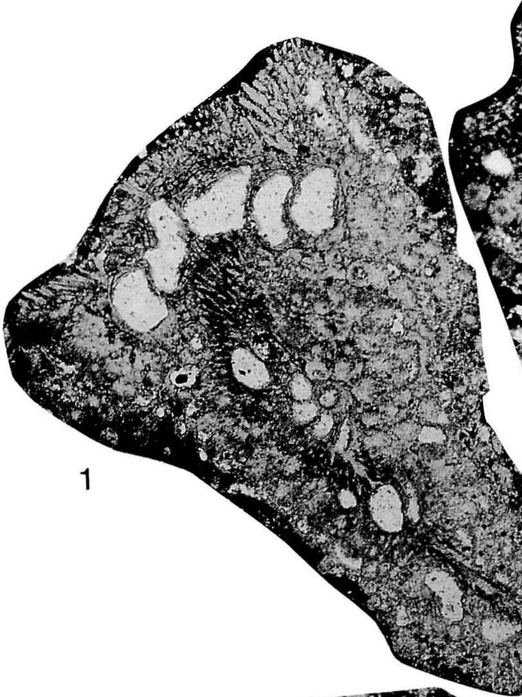
Remarks: The present form is apparently similar in all respects of both external and internal features to *Biplanispira absurda* Umbgrove from the upper Eocene Matansa Limestone, Saipan, described by Hanzawa (1957), but differs in being smaller. As Umbgrove (1938, p. 82–89) has stated that there is at least a single illustration of Figure 79 to be transferred to *Biplanispira absurda* in *Pellatispira crassicolumnata* Umbgrove (1928, p. 66–67, figs. 75–79), the author could confirm a transition form in his collections from the Sekimon Limestone, and then it is evident that *Biplanispira absurda* Umbgrove has evolved from *Pellatispira crassicolumnata* Umbgrove by an acquired character of secondary median chambers. Although Cole and Bridge (1953, p. 333) mentioned that Umbgrove's illustrations of *Biplanispira absurda* in 1938 were similar to those of Whipple (1934) of *Pellatispira fulgeria*, the latter should be studied based on the detailed observation to confirm whether or not *Biplanispira absurda* is a synonym of *Pellatispira fulgeria*.

Explanation of Plate 35

(All figures ×22)

Biplanispira absurda Umbgrove

1–4. Oblique sections. 1–2, 4. Megalospheric forms, 3. Microspheric form. Sekimon Limestone; Localities: 1–2, 4. OK23.95, 3. OK19.95 (Both of Okiko/Tsukigaoka Shrine Section).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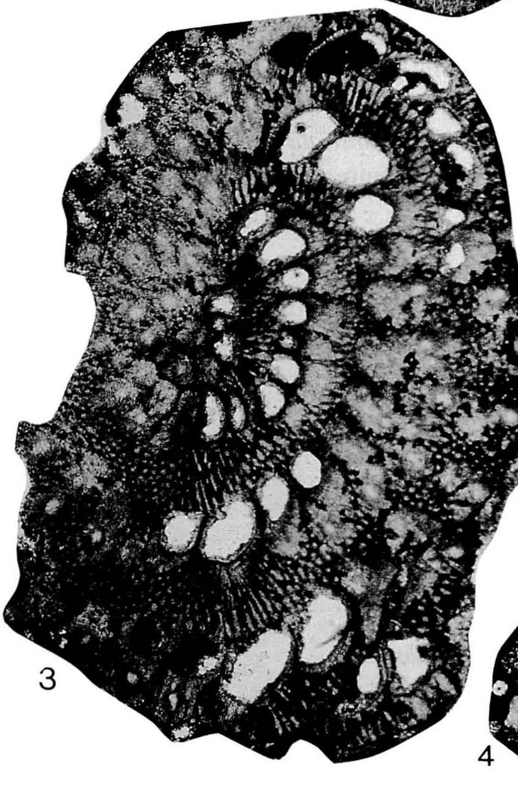
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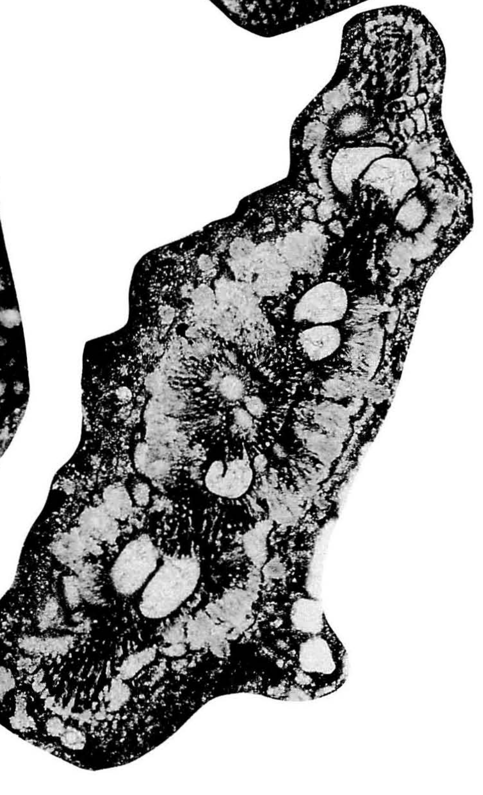
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Biplanispira mirabilis (Umbgrove, 1936)

Plate 37, figures 1–5.

Heterospira mirabilis Umbgrove, 1936, p. 155–159, pl. 1, figs. 1–11.
Biplanispira mirabilis (Umbgrove), 1937, p. 309; Crespin, 1938, p. 6, pl. 2, figs. 9–18; Cole and Bridge, 1953, p. 22–23, pl. 6, figs. 9–19; Cole, 1957a, p. 334, pl. 99, figs. 1–6, pl. 100, figs. 1–3.
Biplanispira mirabilis (Umbgrove) forma *elliptica* Hanzawa, 1957, p. 51, pl. 10, figs. 2a–e.
Biplanispira inflata Hanzawa, 1957, p. 52, pl. 8, figs. 3, 5–6, pl. 9, fig. 8.

Description: Test thick lenticular, with bluntly rounded periphery; 4.0 to 5.7 mm in diameter, and 1.6 to 1.8 mm in thickness; form ratio of diameter to thickness, 2.4 to 2.6. Megalospheric embryonic apparatus, biloculine; subspherical protoconch, 208 × 187 μm in diameter, and reniform deuteroconch, 239 × 135 μm in diameter; followed by succeeding primary chambers developed in a planispiral involuted coil in central part of test; beyond which the primary chamber coil, concealed by the secondary chamber coils, lying above and below the primary chamber coil. Mature forms, of a radius 603 μm in the first coil, with 10 primary chambers; 957 μm in the second coil, with 20 primary chambers; and 1206 μm in the third coil, with two primary chambers, one symmetrical chamber, and 27 secondary chambers. Primary and secondary chambers, increased toward marginal areas, 200 to 360 μm in height in the chamber. Wall thick and fibrous layer, perforate; with canal system present, of radial and simple marginal cord, and interseptal canals present; dorsal and umbilical pillars present over lateral walls; aperture at base of apertural face.

Stratigraphic horizon: Sekimon Limestone.

Remarks: The present form is assigned to *Biplanispira mirabilis* (Umbgrove) from the upper Eocene Matansa Limestone, Saipan, described by Cole and Bridge (1953) and Hanzawa (1957). *Biplanispira mirabilis* differs from *B. absurda* Umbgrove in the prominent development of the secondary and surface chambers into a marginal zone of the test.

Genus *Pellatispira* Boussac, 1906

Pellatispira orbitoidea (Provale, 1908)

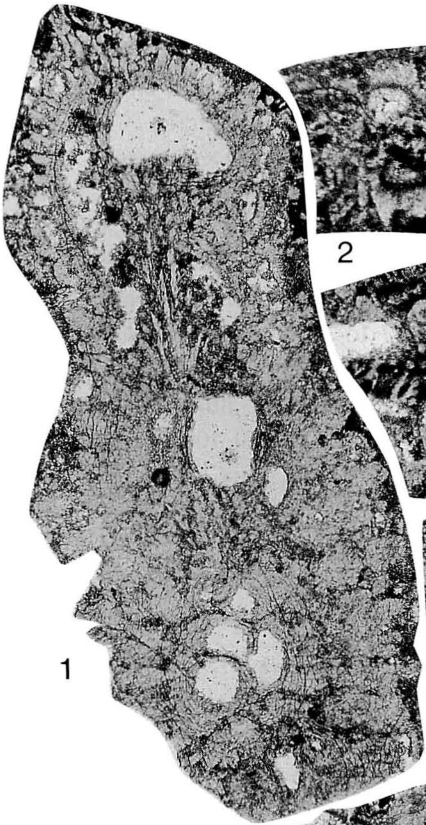
Plate 38, figures 1–8.

Assilina madaraszi von Hantken var. *orbitoidea* Provale, 1908, p. 71, pl. 5, fig. 5.
Pellatispira orbitoidea (Provale). Umbgrove, 1928, p. 18–19, figs. 2–3, 5, 7, 9, 11–26, 34–41; Henrici, 1934, p. 34–35, pl. 2, fig. 9; Cole, 1957a, p. 333. pl. 96, figs. 3–5, 7–9, pl. 97, figs. 1–12, pl. 99, figs. 7–11; Hanzawa, 1957, p. 53, pl. 7, figs. 1–8.
Pellatispira rutteni Umbgrove, 1928, p. 20–21, figs. 57–61; Cole and Bridge, 1953, p. 22, pl. 6, figs. 1–8;

Explanation of Plate 36

(All figures ×42)

Biplanispira absurda Umbgrove
1. Oblique section of megalospheric form, 2–6. Axial sections. 2–5. Megalospheric forms, 6. Microspheric form. Sekimon Limestone; Localities: 1, 3, 6. OK23.95, 5. OK25.95 (Both of Okiko/Tsukigaoka Shrine Section). 2, 4. cl (Chibusa Dam).



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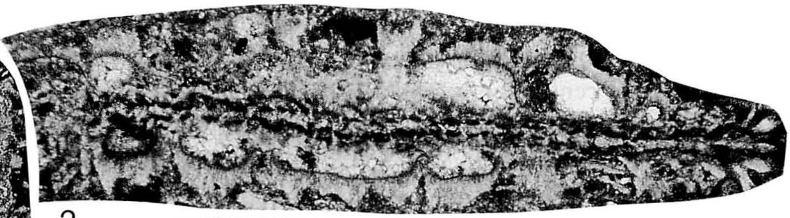

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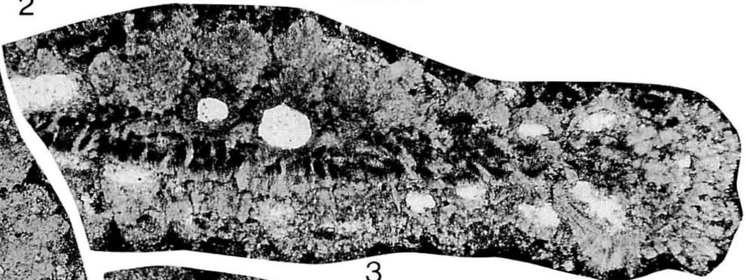

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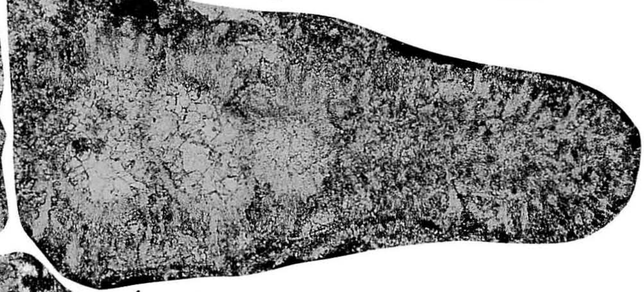

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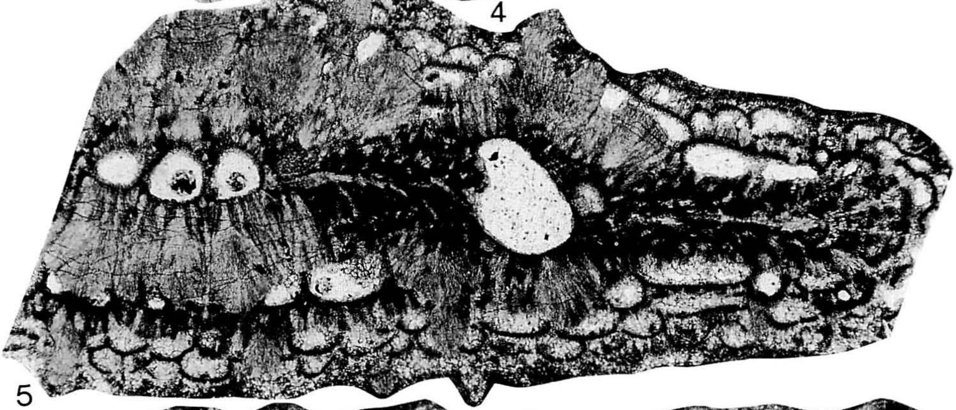

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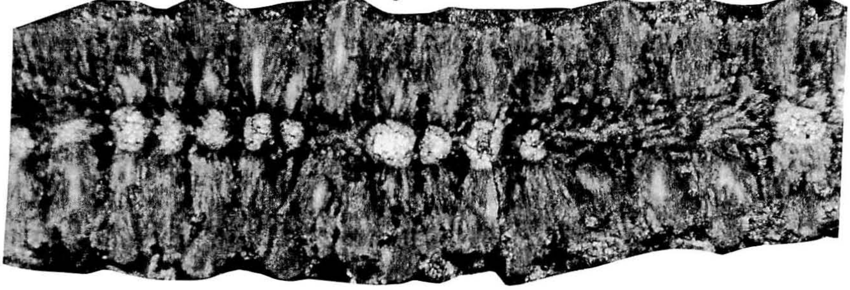

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Hanzawa, 1957, p. 53–54, pl. 8, figs. 1–2, 7–8.

Description: Test thick, lenticular, with inflated central boss; 2.9 to 5.8 mm in diameter, and 1.2 to 1.8 mm in thickness; form ratio of diameter to thickness, 2.0 to 3.3; large pillars distributed on central boss, and of diameter 120 to 200 μm. Megalospheric embryonic chambers, biloculine; subspherical protoconch; 180 × 150, 208 × 188, 230 × 220, and 240 × 204 μm in diameter, and reniform deuteroconch; 146 × 125, 176 × 116, 176 × 166, and 260 × 188 μm in diameter; total distance across embryonic chambers, 312 to 438 μm; followed by regularly coiled whorls of chambers. Adult form, of a radius 540 to 686 μm in the first whorl, with 9 to 11 chambers; 600 to 820 μm in the first and a half whorl, with 9 to 12 chambers; 1160 to 1200 μm in the second whorl, with 17 to 20 chambers; and 1600 to 1840 μm in the third whorl. In vertical section, lateral layers present, thickest at center of test, and gradually attenuate toward peripheral margin; pierced by numerous vertical canals, of diameter 24 to 52 μm; numerous remarkable vertical pillars, 100 to 200 μm in width; wall fibrous, lamellar, with thin inner layer, finely perforate, 8 to 24 μm thick, and thick outer layer, coarsely perforate, 200 to 310 μm thick.

Stratigraphic horizon: Sekimon Limestone.

Remarks: The present form is characterized by a thick lenticular test, three closely coiled whorls, and thick lateral layers pierced by numerous remarkable vertical pillars; and it is identical as *Pellatispira orbitoidea* (Provale).

Pellatispira provalei Yabe, 1921

Plate 39, figures 1–5.

? *Calcarina* sp. H. Douvillé, 1905, p. 451.

Assilina madaraszi Provale, 1908, p. 66–70, pl. 4, figs. 21–24; pl. 5, figs. 1–4.

Pellatispira madaraszi von Hantken var. *provalei* Yabe, 1921, p. 108; Umbgrove, 1928, p. 17–18, figs. 27–33; Henrici, 1934, p. 33–34, pl. 2, figs. 10–11.

Pellatispira madaraszi von Hantken var. *douvillei* (Boussac). Yabe, 1921, p. 108, pl. 4, figs. 3, 7–8, pl. 5, figs. 2, 5–6.

Pellatispira crassicolumnata Umbgrove, 1928, p. 66–67, figs. 75–79 (non fig. 80); Henrici, 1934, p. 35, pl. 2, fig. 8; Cole and Bridge, 1953, p. 21–22, pl. 15, figs. 3–7.

Pellatispira provalei Yabe. Cole, 1957a, p. 333, pl. 96, figs. 1–2, 6, pl. 98, figs. 1–12.

Description: Test thin, discoidal, lenticular, with thick marginal periphery; 2.8 to 6.4 mm in diameter, 0.56 to 1.33 mm in thickness in central portion of test, and 0.58 to 1.36 mm in thickness in the periphery; form ratio of diameter to thickness, 3.13 to 6.57 in

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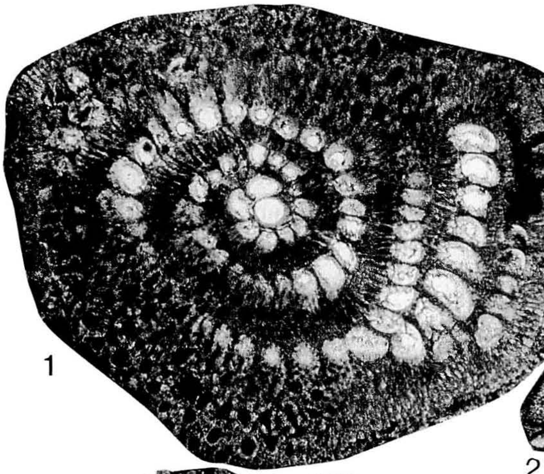
Explanation of Plate 37

Biplanispira mirabilis (Umbgrove)

1. Equatorial section of megalospheric form. ×22, 2, 5a–b. Oblique sections. 2. ×42, 5a. ×22, 5b. Central part of oblique section shown in Figure 5a showing complicated arrangement of primary chamber coil and secondary chamber coil. ×42. 3–4. Axial sections showing surface chambers. ×22. Sekimon Limestone; Localities: 1, 3–4. 72203 (Sekimon Karst Section), 2, 5. OK25.95 (Okiko/Tsukigaoka Shrine Section).



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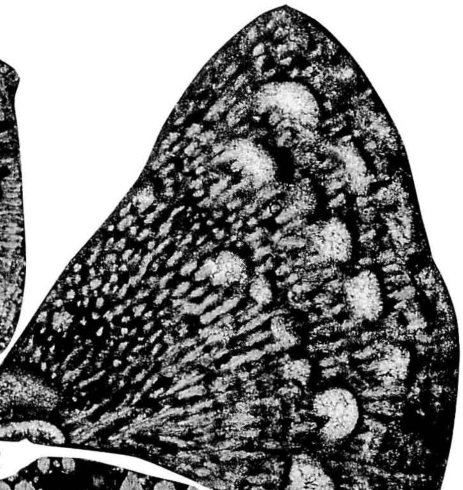

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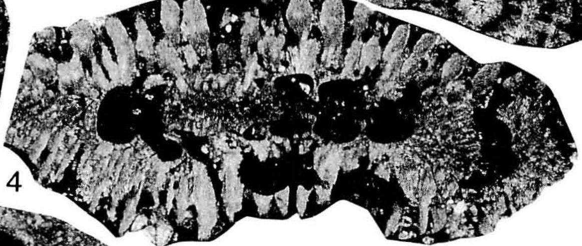

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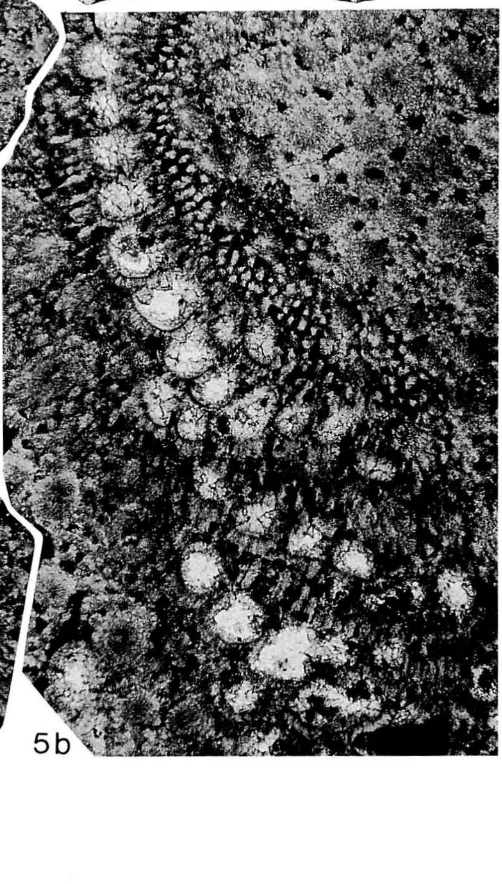


5b

center, and 2.91 to 6.34 in periphery; surface, pustulated densely with pillars of two different sizes, larger one, of diameter 180 to 240 μm, and smaller one, of diameter 80 to 160 μm. Megalospheric embryonic apparatus, biloculine; subspherical protoconch, 135 × 125, 144 × 128, 166 × 135, 240 × 192, and 240 × 192 μm in diameter, and reniform deuteroconch, 192 × 168 μm in diameter; total distance across embryonic chambers, 304 μm in equatorial section. In vertical section, nucleoconch, 135 to 240 μm in diameter, 166 to 218 μm in height, and outer wall of nucleoconch, 14 to 25 μm in thickness. Median chambers, in loose evoluted planispiral coil after embryonic apparatus, and increased in width toward periphery of test; their width, 340 to 426 μm. Adult form, of a radius 603 to 680 μm in the first coil, with 10 chambers; 720 to 960 μm in the first and a half coil, with 10 chambers; and 1240 μm in the second coil. Revolving wall between chambers with double septa, composed of thin inner layer, 10 to 12 μm thick, with finely perforate pores, 4 to 6 μm across, and thick outer layer, 230 to 240 μm thick, with vertical canals, 24 to 35 μm across. In vertical section, both large pore-like canal openings among pillars and outer layer, and many minute pores between inner layers present, communicated with median layer; surface chambers superposed above lateral layers, 94 to 198 μm in width, and 42 to 94 μm in height; and outer wall of roofs of surface chamber, 12 to 16 μm in thickness; wall calcareous, fibrous, lamellar.

Stratigraphic horizon: Sekimon Limestone.

Remarks: Although free specimens were not available for study to observe the distribution of pustules or granules on the surface of the test, the present form has a more densely pustulated surface than *Pellatispira orbitoidea* (Provale), and is assigned to *Pellatispira provalei* Yabe. Following Cole's (1957a) opinion, the author considers that *Pellatispira provalei*, without a thin fibrous keel beyond the main part of the test, may be a senior synonym of *Pellatispira crassicolumnata* Umbgrove, with a thin one, or both species may have a very close phylogenetic relation.

Superfamily Orbitoidacea Schwager, 1876

Family Orbitoclypeidae Pokorný, 1958

Genus *Orbitoclypeus* Silvestri, 1907

Orbitoclypeus kimurai Matsumaru, 1989

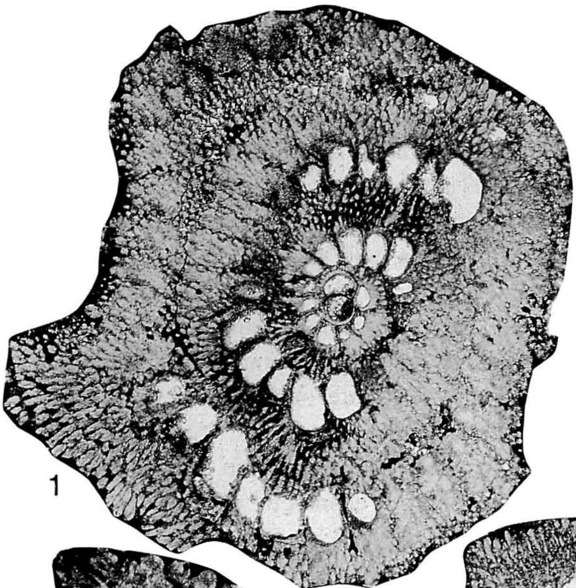
Plate 40, figures 8–9; Plate 49, figure 3.

Explanation of Plate 38

(All figures ×22)

Pellatispira orbitoidea (Provale)

1–5. Equatorial sections of megalospheric form. 6, 8. Axial sections of megalospheric form, 6. This form shows poor development of surface chambers, 8. This form shows remarkable development of surface chambers, and finely perforated thin floors and roofs, 7. Tangential section of megalospheric form. Sekimon Limestone; Localities: 1–2, 4. OK23.95, 5, 7. OK19.95 (Both of Okiko/Tsukigaoka Shrine Section), 3, 6, 8. 72203 (Sekimon Karst Section).



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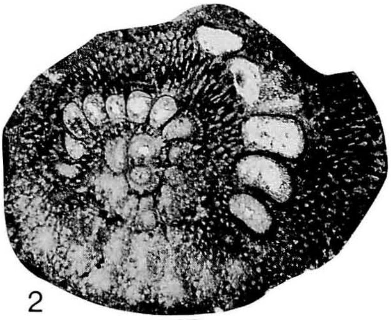

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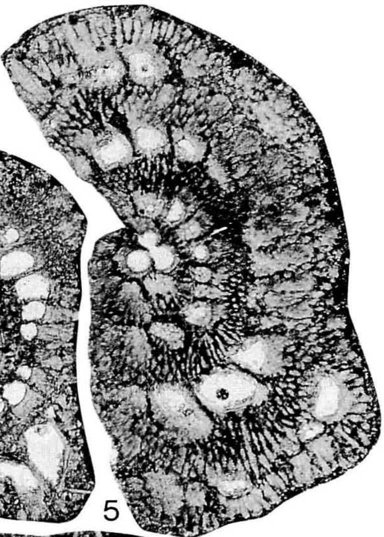

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Orbitoclypeus kimurai Matsumaru. Matsumaru and Kimura, 1989, p. 260, 262, 264, figs. 3–1–2, 4–7, 9–10, 12, 5–1–2, 5.

Description: Test thick, lenticular, with umbonal central part surrounded by narrow rim; 2.5 to 5.0 mm in diameter, and 0.9 to 3.3 mm in thickness; form ratio of diameter to thickness, 1.5 to 2.8; surface covered by network of lateral chambers; polygonal granules, surrounded by 5 to 7 lateral chambers, 120 to 208 μm in diameter in umbo, and 48 to 100 μm in diameter in periphery. Megalospheric embryonic chambers, trybliopidine type; subspherical protoconch, 164 × 156, and 240 × 168 μm in diameter, and reniform deuteroconch, 204 × 196, and 408 × 240 μm in diameter; outer wall of embryonic chambers, 12 to 13 μm in thickness. Periembryonic chambers, with about 24 semi-hexagonal chambers in periembryonic ring, with radial diameters of 30 to 40 μm, and tangential diameters of 26 to 30 μm. Equatorial chambers, arranged in irregular rings, spatulate or hexagonal in form; 22 to 59 μm in radial diameter, and 20 to 31 μm in tangential diameter; and tendency for rings to become stellate, with eight rays. Lateral chambers, rectangular in shape; arranged in regular tiers in vertical section; spaceous over embryonic chambers; of length 64 to 160 μm, and height 16 to 26 μm; thickness of floors and roofs, 8 to 24 μm; number of lateral chambers per tier over embryonic chambers, 20 to 25 layers; pillars present, prominent in central part of test in vertical section.

Stratigraphic horizon: Yusan and Okimura Formations, and Sekimon Limestone.

Remarks: The present specimens are composed with the type specimens from the Eocene Kurusuno Formation (Matsumaru and Kimura, 1989; Matsumaru *et al.*, 1993) at Takahata village, Tosa Shimizu City, Kochi Prefecture, Japan. Although the former has larger embryonic chambers and more lateral chambers than the latter, the other features of the former are similar to those of the latter. Thus the author identified the present specimens from Haha-Jima as *Orbitoclypeus kimurai* Matsumaru.

The author (Matsumaru and Kimura, 1989, p. 262) has, however, described that *Orbitoclypeus kimurai* Matsumaru is distinguished from *Orbitoclypeus chudeaui* (Schlumberger) by its small embryonic, small adauxiliary chambers, and many lateral chambers. The present form from Haha-Jima may be assigned to *Orbitoclypeus chudeaui*, but the embryonic chambers of the former were destroyed by recrystallization and ill preservation, and their embryonic chambers characteristics could not be determined, except trybliolepidine type. The embryonic chambers of the former could not be completely compared with those of *Orbitoclypeus chudeaui* (Schlumberger). Therefore, the present form from Haha-Jima is assigned to *Orbitoclypeus kimurai*.

Explanation of Plate 39

(All figures ×40)

Pellatispira provalei Yabe

1–2. Equatorial sections of megalospheric form. 3, 5. Oblique sections of megalospheric form. 4. Axial section of megalospheric form. Sekimon Limestone; Localities: 1, 3, 5. OK19.95, 2, 4. OK25.95 (Both of Okiko/Tsukigaoka Shrine Section).

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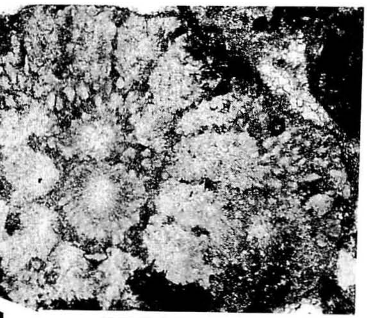

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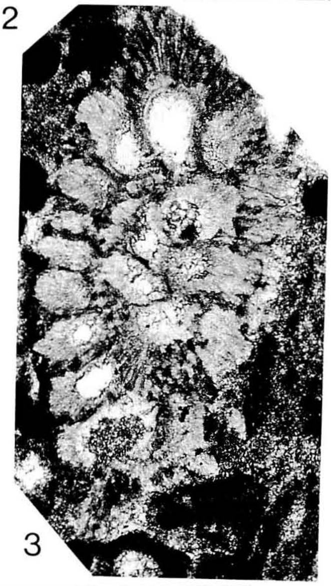

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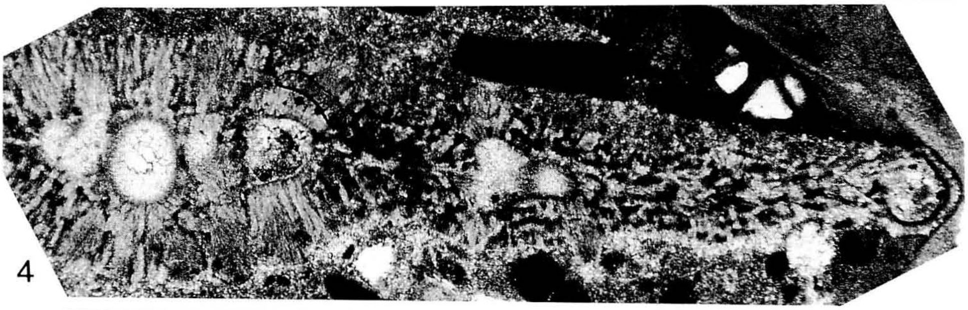

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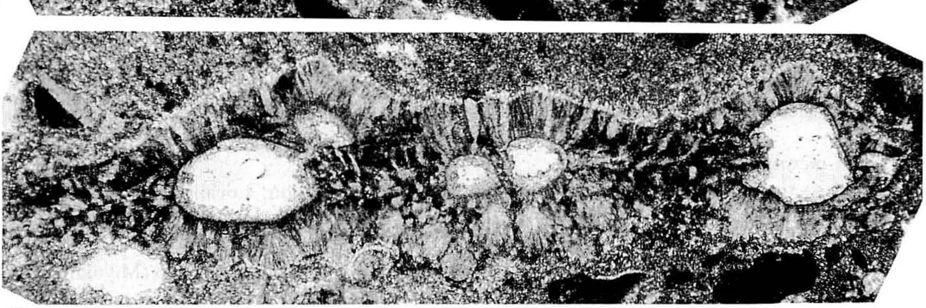

5

Family Asterocyclinidae Brönnimann, 1951

Genus *Asterocyclina* Gümbel, 1870

Asterocyclina asterodisca Matsumaru, n. sp.

Plate 40, figures 2, 4; Plate 41, figures 1–4, 6–8; Plate 42, figures 1, 3, 5; Fig. 29–3.

Type material: Holotype, equatorial section of megalospheric form, Saitama University coll. no. 8818 (Plate 42, fig. 5); Paratype, exterior, Saitama University coll. no. 8819 (Plate 41, fig. 4).

Description: Test small, lenticular, asteroid form of cross type with only four long distinct rays; 2.3 to 4.2 mm in diameter, and 0.9 to 1.1 mm in thickness; form ratio of diameter to thickness, 3.0 to 3.7; surface smooth, covered with slightly raised round granules, surrounded by 7 to 12 lateral chambers; 42 to 146 μm in diameter. Megalospheric embryonic chambers, biloculine, semiisolepidine to primitive nephrolepidine type; spherical to subspherical protoconch; 56 × 56, 64 × 62, 72 × 54, 72 × 56, 72 × 68, and 92 × 74 μm in diameter, in 6 specimens, and reniform deuteroconch; 80 × 54, 75 × 52, 92 × 56, 88 × 48, 96 × 42, and 92 × 61 μm in diameter, in 6 specimens; total distance across embryonic chambers, 112 to 125 μm in diameter; and outer wall of embryonic chambers, 5 to 12 μm in thickness. Two principal auxiliary chambers, 16 to 24 μm in radial diameter, and 32 to 44 μm in tangential diameter; while two to six adauxiliary chambers, 8 to 13 μm in radial diameter, and 14 to 36 μm in tangential diameter. Microspheric proloculus, very small, about 20 μm in diameter. Equatorial chambers in interray areas, small and square near center of test, but large and square in the periphery; 14 to 24 μm in radial diameter, and 20 to 48 μm in tangential diameter; while those in ray areas, small and square near center to large and square in the periphery; 24 to 61 μm in radial diameter, and 16 to 32 μm in tangential diameter. Lateral chambers, arranged in regular tiers; and number of lateral chambers, from 16 to 18 layers over embryonic chambers; low, and open cavities between floors and roofs; 24 to 58 μm in

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Explanation of Plate 40

Asterocyclina pentagonalis (Deprat)

1, 3. Axial sections of microspheric form. ×32. Okimura Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).

Asterocyclina asterodisca Matsumaru, n. sp.

2, 4. Axial sections. 2. Megalospheric form. ×26, 4. Microspheric form. ×20. Okimura Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).

Discocyclina augustae van der Weijden

5. Axial section of microspheric form. ×24. Yusan Formation; Locality: UN82204 (Yusankaigan Section).

Asterocyclina incisuricamerata Cole

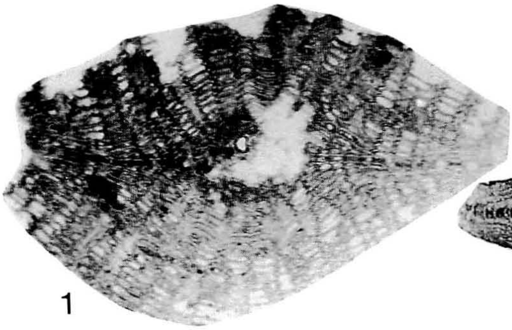
6. Axial section of megalospheric form. ×38. Okimura Formation; Locality: TJ82402–2 (Toeijūtaku Section).

Discocyclina dispansa (Sowerby)

7. Axial section of microspheric form. ×12. Yusan Formation; Locality: MI81806 (Miyukihama Section).

Orbitoclypeus kimurai Matsumaru

8. Oblique section. ×24, 9. Axial section. ×20. Yusan Formation; Locality: MI81806 (Miyukihama Section).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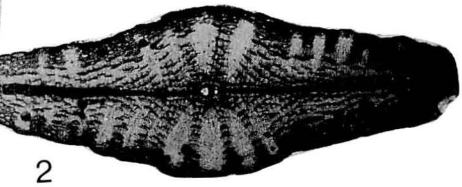
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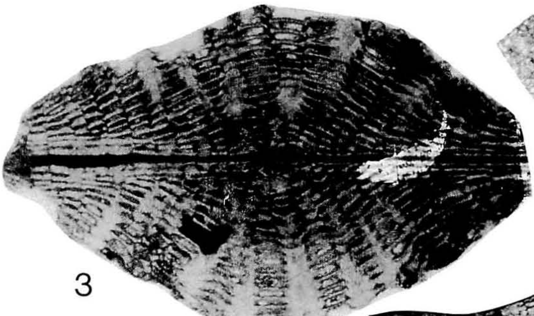
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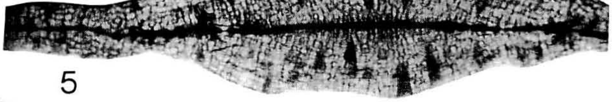
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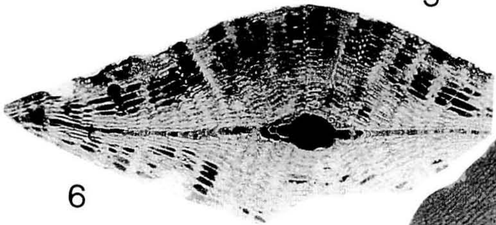
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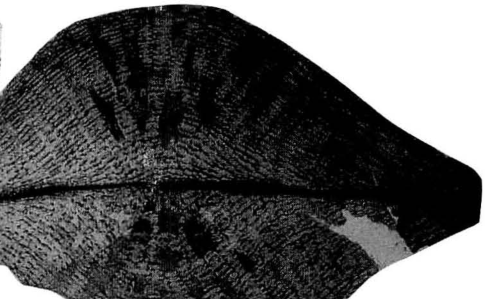
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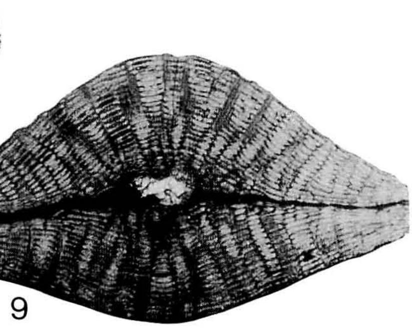
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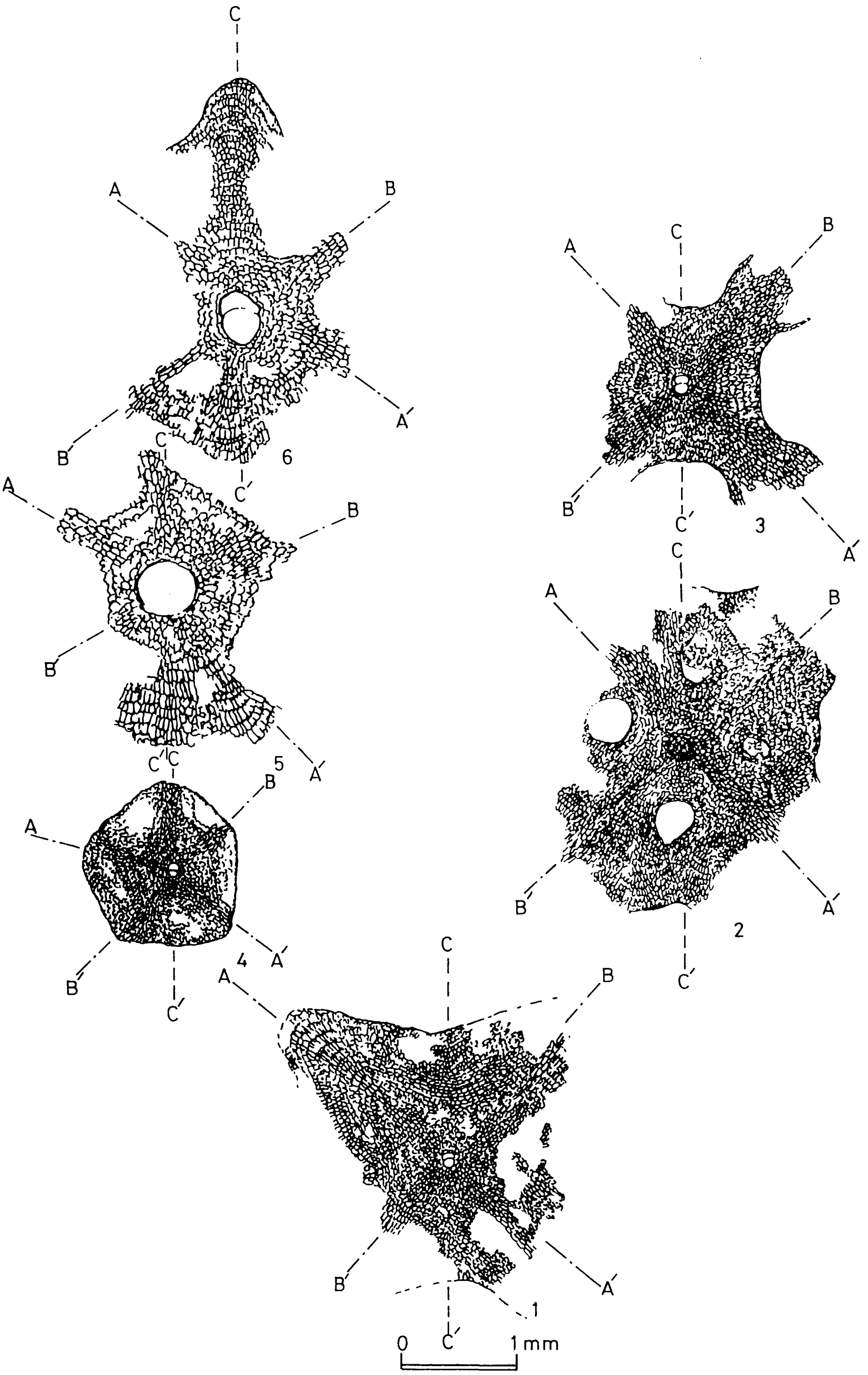
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length, and 12 to 20 μm in height; and thickness of floors and roofs, 5 to 24 μm. Heavy pillars present, in central umbonate area, 115 to 154 μm in diameter.

Stratigraphic horizon: Yusan and Okimura Formations.

Remarks: The present form is compared with the Cuban species of *Asterocyclina habanensis* Cole and Bermúdez, 1947, in the America-Caribbean region, because of some minor differences in external and internal structures between them. The former is, however, different from the latter in having only a stellate form of cross type and an isolepidine to primitive nephrolepidine structure of embryonic chambers, whereas the latter has a wide variation, from the stellate form of cross type to one with five to eight rays and typical nephrolepidine embryonic chambers. As such, the author identified the present form as *Asterocyclina asterodisca*, n. sp.

Asterocyclina hahajimensis Matsumaru, n. sp.

Plate 42, figures 6a–b; Plate 43, figure 6; Fig. 29–2.

Type material: Holotype, equatorial section of microspheric form, Saitama University coll. no. 8820 (Plate 42, fig. 6); Paratype, exterior, Saitama University coll. no. 8821 (Plate 43, fig. 6).

Description: Test compressed lenticular to lenticular, stellate, with four rays; 3.3 to 4.0 mm in diameter, and 0.6 to 0.8 mm in thickness through the center; and form ratio of diameter to thickness, 4.1 to 6.7; surface, covered with reticulate mesh of lateral chambers, but in interrays area, certain inflated small ellipsoidal mounds; of diameter of 230 × 225, and 400 × 380 μm; and becoming hollow cheeks. Round granules (50 to 150 μm across), distributed in the entire test, and surrounded by 7 to 12 lateral chambers. In equatorial section of microspheric form, proloculus, very small, about 20 μm in diameter; and equatorial chambers in interray areas except those central parts, small and square near the center, to large and square in periphery; 16 to 44 μm in radial diameter, and 24 to 40 μm in tangential diameter; and four ellipsoidal hollow spaces in central part of interray areas; of diameter 243 × 139, 451 × 243, 417 × 382, and 392 × 313 μm; and bounded by lateral chambers. Equatorial chambers in ray areas, small and square near center, to large and square in periphery; 48 to 80 μm in radial diameter, and 16 to 24 μm in tangential diameter.

Fig. 29. Growth pattern of rays of the *Asterocyclina* from the Yusan Formation, Okimura Formation, and Sekimon Limestone, Haha-Jima, Ogasawara Islands. A-A′, B-B′: Rays axis; C-C′: Symmetric axis. A scale is applicable to all *Asterocyclina* forms. 1. *Asterocyclina incisuricamerata* Cole. OK82001–1 specimen (Plate 42, fig. 2). 2. *Asterocyclina hahajimensis*, n. sp. Holotype, TJ82402–1 specimen (Plate 42 fig. 6). 3. *Asterocyclina asterodisca*, n. sp., Holotype, OK82001–8 specimen (Plate 42, fig. 5). 4. *Asterocyclina stella* (Gümbel). HY2115–1 specimen (Plate 45, fig. 3). 5–6. *Asterocyclina pentagonalis* (Deprat). 5. OK82001–8 specimen (Plate 45, fig. 4). 6. OK82001–7 specimen (Plate 45, fig. 1). *Asterocyclina incisuricamerata*, *A. hahajimensis*, and *A. asterodisca* belong to the stellate form with 4 rays group. *Asterocyclina hahahjimensis* is considered to be a transitional form from *Asterocyclina incisuricamerata* to *Asterocyclina asterodisca*. *Asterocyclina stella* and *A. pentagonalis* belong to the stellate form with 5 to 6 rays group, in addition to the fundamental stellate form with 4 rays. By growing interray chambers between two sets of intersection axes of A-A′ and B-B′, respectively, the *Asterocyclina* could become the stellate form with 8 rays.

Stratigraphic horizon: Okimura Formation.

Remarks: Only two curious and one half broken stellate specimens with four rays were discovered in the sample from OK82001 station of the Okimura Formation. Although the present form does not permit sufficient specific identification, the author considers that the present form should be easy to warrant describing it as a new species, due to its having a peculiar internal structure of ellipsoidal hollow spaces in the interray areas of the test. Judging from the degrees of the development of the interray areas of *Asterocyclina* Gümlel, 1870, *Asterocyclina hahajimensis*, n. sp., would be a transitional species between *Asterocyclina incisuricamerata*, of stellate form with four rays, and *Asterocyclina asterodisca*, n. sp., or *A. habanensis* Cole and Bermúdez of cross form, with four long and distinct rays (Fig. 29–1–3).

Asterocyclina incisuricamerata Cole, 1957

Plate 40, figure 6; Plate 41, figure 5; Plate 42, figures 2, 4a–b; Plate 43, figures 1–5, 7–9; Plate 44, figures 3a–b; Plate 50, figure 8; Fig. 29–1.

Asterocyclina incisuricamerata Cole, 1957a, p. 349–350, pl. 117, figs. 1–5; Cole, 1957b, p. 776–777, pl. 245, figs. 3–10, 13–15, 17.

Asterocyclina matanzensis Cole, 1957a, p.350, pl. 117, figs. 6–10, pl. 118, figs. 9–18; Cole, 1957b, p. 777–778, pl. 249, figs. 1–17; Konda and Okuda, 1977, p. 363–364, fig. 2.

Asterocyclina centripilaris Cole, 1957b, p. 775–776, pl. 248, figs. 1–7, 9–11.

Asterocyclina praecipua Cole, 1957b, p. 780, pl. 245, figs. 11–12, 16, 18–20; Cole, 1963a, p.E 24, pl. 9, figs. 12–13, 18.

Asterocyclina elongaticamera Cole, 1959b, p. 11–12, pl. 1, fig. 5. pl. 3, figs. 5–14.

Description: Test small, thin to thick lenticular, with inflated central umbonate area, surrounded by narrow to wide brims, and with typical radiate four elevated rays and at places five rays; 1.7 to 5.0 mm in diameter, and 0.5 to 2.4 mm in thickness; form ratio of diameter to thickness, 1.67 to 4.20; surface covered by network of lateral chambers; round granules, surrounded by 7 to 12 lateral chambers; and of diameter of 30 to 210 μm. Megalospheric embryonic chambers, biloculine, semiisolepidine to primitive nephrolepidine type; spherical to subspherical protoconch; 46 × 46, 63 × 47, 63 × 57, 63 × 59, 74 × 65, 80 × 64, 80 × 65, 84 × 59, and 107 × 77 μm in diameter, in 9 specimens, and reniform deuteroconch; 88 × 29, 114 × 45, 118 × 41, 105 × 39, 130 × 46, 80 × 36, 92 × 36, 107 × 36, and 170 × 52 μm in diameter, in 9 specimens; total distance across embryonic chambers, 87 to 145 μm in diameter; outer wall of embryonic chambers, 5.4 to 12.8 μm in thickness. Two principal auxiliary chambers, 16 to 19 μm in radial diameter, and 22 to 24 μm in tangential diameter.

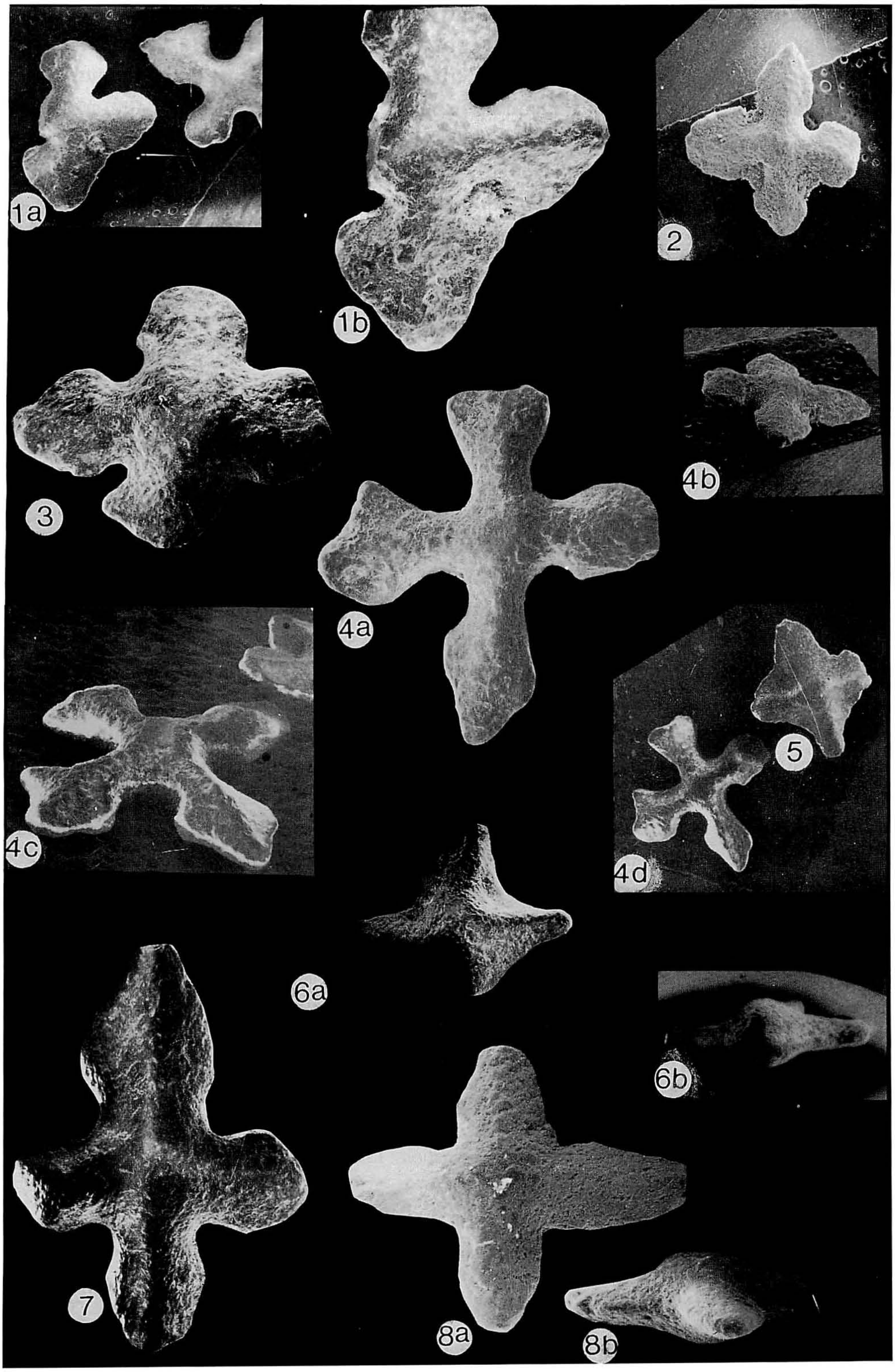
Explanation of Plate 41

Asterocyclina asterodisca Matsumaru, n. sp.

1–4, 6–8. Exteriors. 1a. ×9, 1b. ×19, 2, 4b. ×7, 3, 4a. ×17, 4a. Paratype, Saitama University coll. no. 8819. 4c. ×12, 4d, 6a–b. ×8, 7. ×18, 8a–b. ×16. Yusan Formation; Localities: 1–4, 6–7. MI81806 (Miyukihama Section). Okimura Formation; Locality: 8. OK82001 (Okiko/Tsukigaoka Shrine Section).

Asterocyclina incisuricamerata Cole

5. Exterior. ×8. Yusan Formation; Locality: MI81806 (Miyukihama Section).


1a
1b
2
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4a
4b
4c
4d
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6a
6b
7
8a
8b

Microspheric proloculus, very small, about 20 μm in diameter; equatorial chambers in interray areas, small, open-arcuate or short-hexagonal near center of test, but large square in periphery; 16 to 32 μm in radial diameter, and 24 to 48 μm in tangential diameter, while those in ray areas, small arcuate or square in center, becoming large spatulate or elongated square toward the periphery; 32 to 88 μm in radial diameter, and 16 to 43 μm in tangential diameter. Lateral chambers, arranged irregularly in regular tiers; and number of lateral chambers, 10 to 24 layers over embryonic chambers. Chamber cavities, low and slit-like between thick floors and roofs, and low and open between moderately thick floors and roofs; 50 to 100 μm in length, and 5 to 10 μm in height; and thickness of floors and roofs, 8 to 50 μm.

Stratigraphic horizon: Yusan and Okimura Formations, and Sekimon Limestone.

Remarks: Although there is a considerable range in the diameter and thickness of the test, the diameter of pillars, the diameter of embryonic chambers, and the number of lateral chambers, the present form is characterized by being a stellate form with originally 4 rays, and in some specimens 5 rays, and small embryonic chambers of semiisolepidine to primitive nephrolepidine type. Thus the present form is very similar to *Asterocyclina incisuricamerata* Cole and *A. matanzensis* Cole, from Saipan, by Cole (1957a), and to *Asterocyclina praecipua* Cole from Eniwetok Atoll, by Cole (1957b). According to Cole (1957a, b), *Asterocyclina incisuricamerata* from Saipan and Eniwetok Atoll is a stellate form with four and five rays, whereas *Asterocyclina matanzensis* from Saipan and Eniwetok Atoll and *A. praecipua* from Eniwetok Atoll are a stellate form only with four rays. Further, *Asterocyclina matanzensis* and *A. praecipua* are included into a species variation of *A. incisuricamerata*, and the former two are synonymous with *A. incisuricamerata*. Moreover, both *Asterocyclina centripilaris* Cole from Eniwetok Atoll (Cole, 1957b) and *A. elongaticamera* Cole from a seamount near Tuamotu Archipelago, French Oceania (Cole, 1959b), are very similar to *Asterocyclina praecipua* Cole, in forming heavy pillars, and the former two are small in size of the test, and they would be a juvenile form of the latter. As a whole, the present form from Haha-Jima is considered alone and is assigned to *Asterocyclina incisuricamerata* Cole.

Asterocyclina incisuricamerata Cole from Haha-Jima is similar to *Asterocyclina stella* (Gümbel, 1861) from many localities in the Tethys region, in both external and internal

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Explanation of Plate 42

Asterocyclina asterodisca Matsumaru, n. sp.

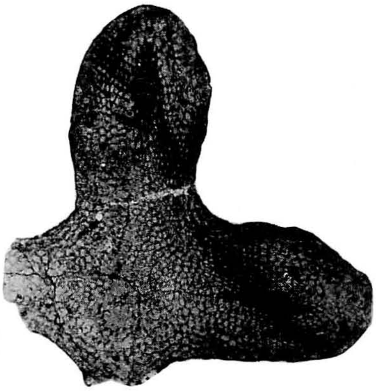
1, 3, 5. Equatorial sections. 1, 3. Microspheric forms. ×25, 5. Megalospheric form. Holotype, Saitama university coll. no. 8818. ×20. Okimura Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).

Asterocyclina incisuricamerata Cole

2, 4a–b. Equatorial sections. 2. Megalospheric form. ×25, 4a. Microspheric form. ×11, 4b. Microspheric form enlarged twice of Figure 4a showing the development of equatorial chambers in interray areas. Okimura Formation; Localities: 2. OK82001 (Okiko/Tsukigaoka Shrine Section), 4. TJ82402–1 (Toeijūtaku Section).

Asterocyclina hahajimensis Matsumaru, n. sp.

6. Equatorial section of microspheric form. Holotype, Saitama University coll. no. 8820. 6a. ×14, 6b. Enlarged central part of Figure 6a. ×28. Okimura Formation; Locality: TJ82402–1 (Toeijūtaku Section).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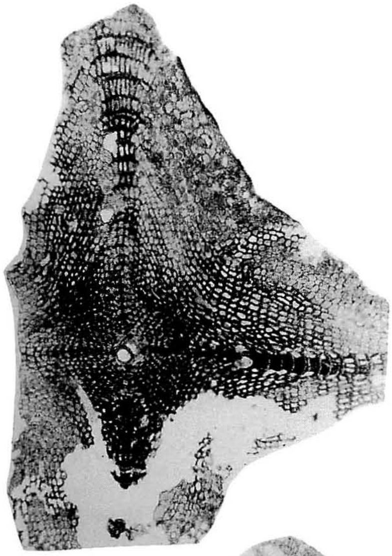
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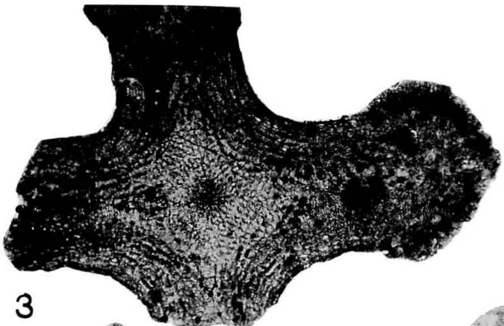
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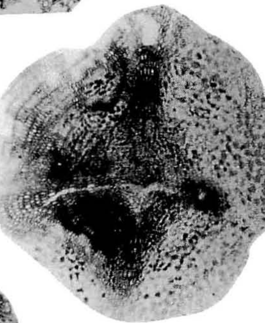
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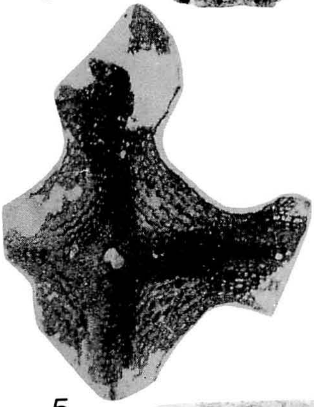
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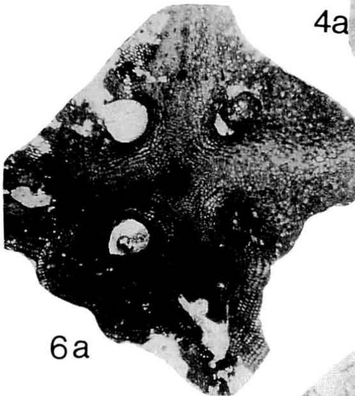
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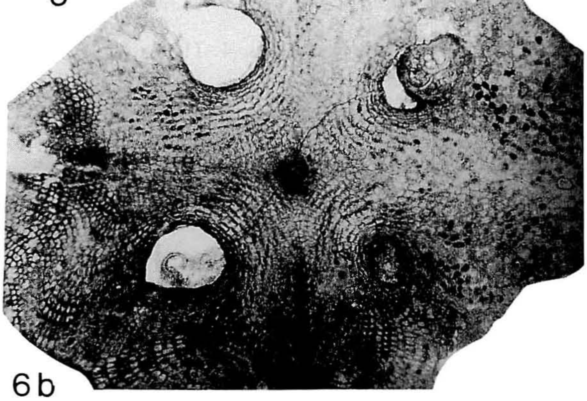
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4b

structures, but the former is distinguished from the latter in having a more primitive form of embryonic chambers. The stratigraphic range of these two species from Haha-Jima, Ogasawara Islands, is common between them in the Yusan and Okimura Formations, but the stellate form with four rays of *Asterocyclina incisuricamerata* seems to be relatively strong in occurrence in the Yusan Formation, while the stellate form with five rays of *Asterocyclina incisuricamerata* and *A. stella* is strong in occurrence in the Okimura Formation. As such, the author considers that *Asterocyclina incisuricamerata* Cole may evolve into *Asterocyclina stella* (Gümbel).

Generally, the stellate form of *Asterocyclina* Gümbel, 1870 will progress from the fundamental stellate form with four rays through five to six rays, or further through six to eight rays (Fig. 29).

Asterocyclina pentagonalis (Deprat, 1905)

Plate 40, figures 1, 3; Plate 44, figures 2a–b; Plate 45, figures 1, 4, 6–7; Plate 47, figure 1; Plate 49, figures 1–2; Plate 50, figure 5; Fig. 29–5–6.

Orthophragmina pentagonalis (Schafhautl). Deprat, 1905, p. 507–508, pl. 18, figs. 24–25, pl. 19, fig. 27 (non *Asterodiscus pentagonalis* Schafhautl, 1863, p. 107, pl. 15, fig. 2).

Orthophragmina nummulitica (Gümbel). Deprat, 1905, p. 506, pl. 18, fig. 23 (non *Orbitoides (Rhipidocyclina) nummulitica* Gümbel, 1870).

Actinocyclina alticostata Nuttall, 1926a, p. 151, pl. 8, figs. 6–8.

Orthocyclina suruaensis van der Vlerk. Henrici, 1934, p. 48, pl. 4, fig. 8.

Asterocyclina sp. aff. *A. pentagonalis* Deprat. Caudri, 1934, p. 97–99, pl. 3, figs. 1, 9.

Discocyclina (Isodiscocyclina) pentagonalis (Deprat). Weijden, 1940, p. 38–39, pl. 5, fig. 1.

Discocyclina sp. B. Cole and Bridge, 1953, pl. 12, fig. 4.

Asterocyclina sp. Cole and Bridge, 1953, p. 37, pl. 15, fig. 8–9 (non pl. 14, figs. 1–2).

Asterocyclina penuria Cole, 1957a, p. 350–351, pl. 116, figs. 1–10; Cole, 1957b, p. 778–780, pl. 246, figs. 1–11, pl. 247, figs. 1–15, pl. 248, figs. 8, 12–17; Cole, 1959b, p. 12–14, pl. 1, figs. 1–4, 6–11, pl. 12, figs. 1–9, pl. 3, figs. 1–4; Konda and Okuda, 1977, p. 363–364, fig. 3.

Discocyclina (Discocyclina) dispansa (Sowerby). Hanzawa, 1957, p. 83–84, pl. 14, figs. 2–3, 8–9 (non pl. 13, figs. 1, 3?, 4).

Discocyclina (Asterocyclina) stellaris (Brunner). Hanzawa,1957, p. 84, pl. 14, figs. 1, 5–7.

Asterodiscus cuvillieri Neumann, 1958, p. 119–120, pl. 31, figs. 1–8, pl. 32, fig. 5, text-fig. 40.

Asterocyclina alticostata (Nuttall) *gallica* Less, 1987, p. 241–242, pl. 43, figs. 9–12, pl. 44, figs. 1–2, text-figs. 32o–p.

Asterocyclina alticostata (Nuttall) *cuvillieri* (Neumann). Less, 1987, p. 242, pl. 44, figs. 3–9, text-fig. 32q.

Asterocyclina alticostata alticostata (Nuttall). Less, 1987, p. 243, pl. 44, figs. 10–11, pl. 45, figs. 1–3, text-fig. 32r.

Asterocyclina alticostata (Nuttall) *danubica* Less, 1987, p. 243–244, pl. 45, figs. 4–11, text-fig. 32s.

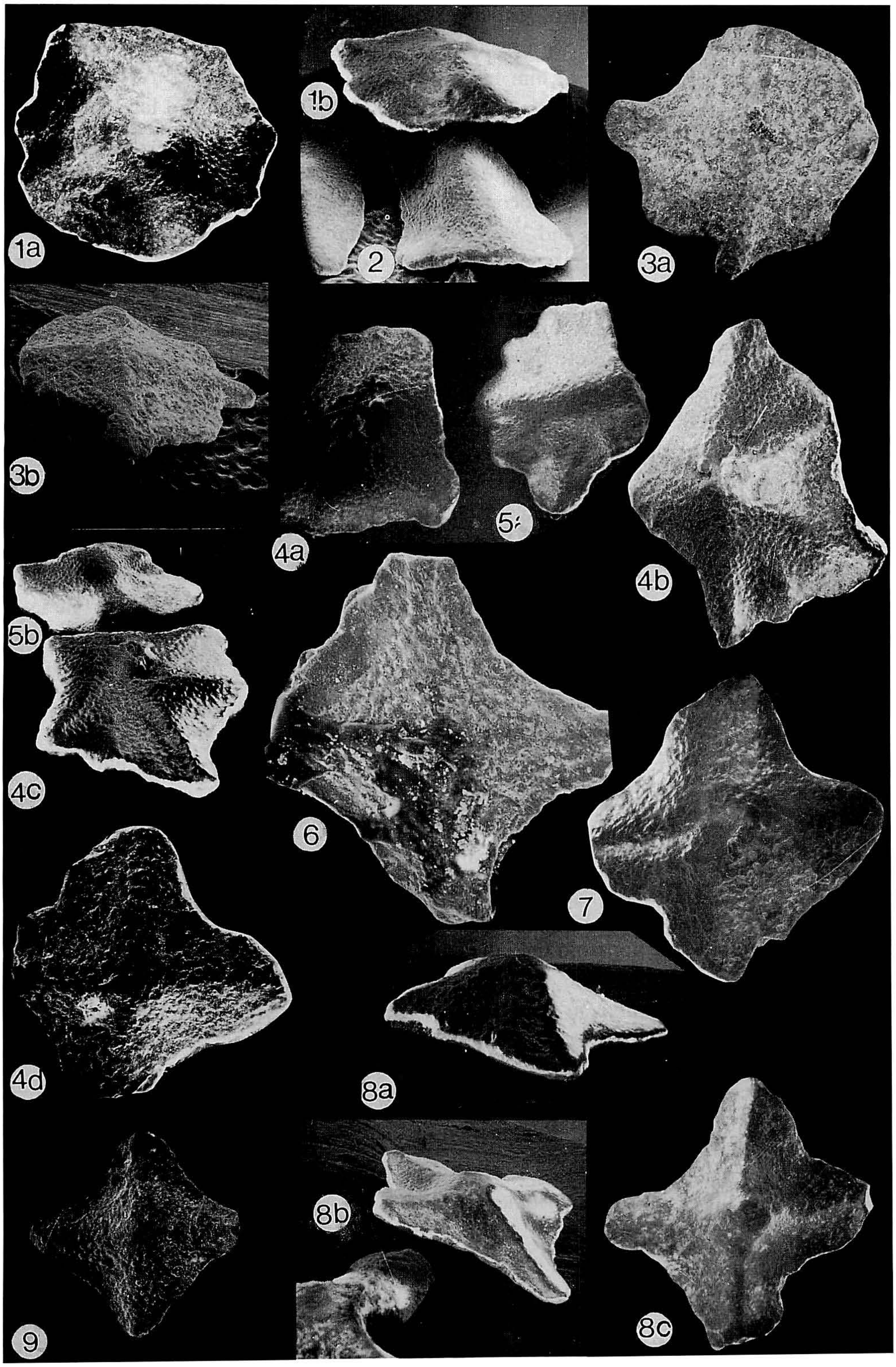
Explanation of Plate 43

Asterocyclina incisuricamerata Cole

1–5, 7–9. Exteriors. 1–3. ×8, 4–5, 7, 9. ×16, 8. ×14. Okimura Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).

Asterocyclina hahajimensis Matsumaru, n. sp.

6. Exterior. Paratype, Saitama University coll. no. 8821. ×14. Okimura Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).


1a
1b
2
3a
3b
4a
5a
4b
5b
4c
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4d
8a
9
8b
8c

Description: Test medium size, lenticular to inflated lenticular, with umbo surrounded by thin flange; asteroidal form, with five rays ordinarily, but sometimes interrays present between principal rays; 2.1 to 7.2 mm in diameter, and 1.1 to 2.6 mm in thickness; form ratio of diameter to thickness, 1.80 to 2.46; surface covered by network of lateral chambers; polygonal granules, surrounded by 5 to 7 lateral chambers; and of diameter of 45 to 200 μm. Megalospheric embryonic chambers, large, biloculine, typical nephrolepidine type, with deuteroconch slightly embracing protoconch; subspherical protoconch; 152 × 200, 200 × 168, 210 × 170, 232 × 168, 237 × 166, and 298 × 240 μm in diameter, in 6 specimens, and reniform deuteroconch; 296 × 200, 320 × 212, 256 × 208, 264 × 128, 343 × 114, and 320 × 196 μm in diameter, in 6 specimens; total distance across embryonic chambers, 294 to 450 μm in diameter; and outer wall of embryonic chambers, 8 to 24 μm in thickness. Embryonic chambers, surrounded completely by distinct ring of two principal auxiliary chambers and other elongated or nearly square periembryonic chambers; the former, 24 to 48 μm in radial diameter, and 48 to 80 μm in tangential diameter; the latter, 35 to 56 μm in radial diameter, and 40 to 125 μm in tangential diameter. Microspheric proloculus, very small, but not measured; equatorial chambers in interray areas, small square or hexagonal near central part of test, but large square near the periphery; 24 to 100 μm in radial diameter, and 20 to 48 μm in tangential diameter, while those in ray areas, small square in central part, and become large square toward periphery; 40 to 115 μm in radial diameter, and 22 to 44 μm in tangential diameter. Lateral chambers, arranged in regular tiers; and number of lateral chambers, 18 to 38 layers over embryonic chambers. Chamber cavities, low and open between straight floors and roofs; 40 to 125 μm in length, and 10 to 24 μm in height; and thickness of floors and roofs, 7.2 to 11.2 μm.

Stratigraphic horizon: Yusan and Okimura Formations, and Sekimon Limestone.

Remarks: The present form is characterized by the medium-sized test and asteroidal form with typically five rays and large embryonic chambers of the nephrolepidine type, which are surrounded completely by peculiar periembryonic chambers of two principal auxiliary chambers and other auxiliary chambers. As such, the present form is assigned to *Asterocyclina pentagonalis* (Deprat) from the Eocene beds of New Caledonia. Cole (1957a, p. 350–351) compared *Asterocyclina* specimens from Saipan with *Asterocyclina pentagonalis*, and distinguished the former from the latter mainly by its degree of inflation, the number of lateral chamber layers, and the thickness of floors and roofs, whereas Cole (op. cit.) assigned the Saipan specimens to *Asterocyclina penuria* Cole. The discrimination of *Astero-*

Explanation of Plate 44

Asterocyclina stella (Gümbel)

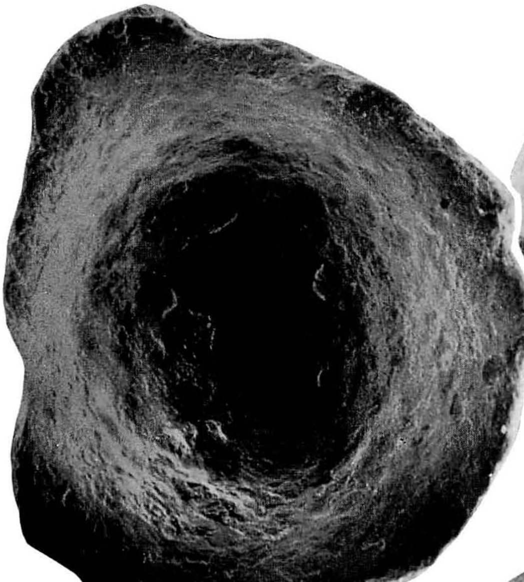
1a. Side view of exterior, 1b. Axial view of exterior. ×34. Yusan Formation; Locality: MI81806 (Miyukihama Section).

Asterocyclina pentagonalis (Deprat)

2a. Oblique view of exterior, 2b. Side view of exterior. ×20. Yusan Formation; Locality: MI81806 (Miyukihama Section).

Asterocyclina incisuricamerata Cole

3a. Side view of exterior, 3b. Oblique view of exterior. ×26. Yusan Formation; Locality: MI81806 (Miyukihama Section).



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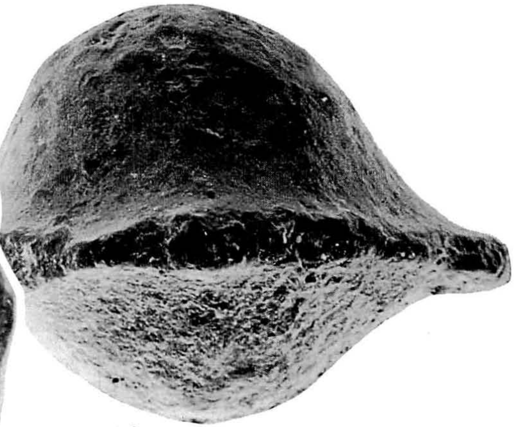
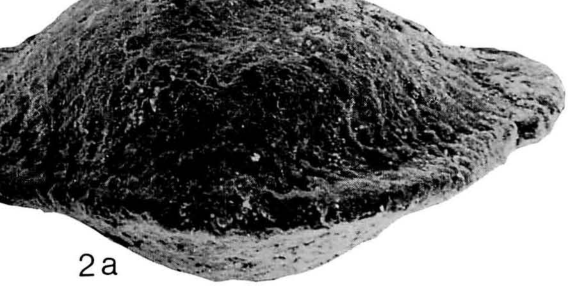


1b



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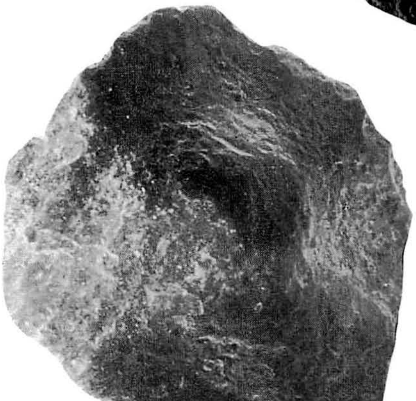

3a

2b

3b

cyclina penuria from *A. pentagonalis* is, however, difficult, and the author considers that the former is a junior synonym of *Asterocyclina pentagonalis* (Deprat). Also, as *Asterocyclina pentagonalis* has a tendency to become an asteroidal form with six to eight rays, this species has transitional forms to *Asterocyclina alticostata* (Nuttall) and/or *A. cuvillieri* (Neumann).

Asterocyclina stella (Gümbel, 1861)

Plate 44, figure 1a–b; Plate 45, figures 2–3, 5; Plate 50, figures 7; Fig. 29–4.

Hymenocyclus stella Gümbel, 1861, p. 653.
Orbitoides stella Gümbel, 1870, p. 138–139, pl. 2, figs. 117a–c, pl. 4, figs. 8–10, 19.
Orthophragmina stella (Gümbel). Schlumberger, 1904, p. 132–133, pl. 6, figs. 47–50, 53–56.
Asterodiscus stella (Gümbel). Douvillé, 1922, p. 76–77, 93, text-fig. 13; Neumann, 1958, p. 112–114, pl. 28, figs. 1–6, text-figs. 36a-b.
Discocyclina (Discocyclina) stella (Gümbel), Weijden,1940, p. 50–53, pl. 8, figs. 1–3.
Asterocyclina stella (Gümbel). Brönnimann, 1940, p. 28–29, pl. 1, figs. 3, 7, pl. 2, fig. 2; Schweighauser, 1953, p. 90–91, pl. 13, figs. 6–8; Bieda, 1963, p. 215, pl. 26, figs. 4–6; Sirotti, 1978, p. 62, 64, pl. 4, figs. 11–15; Matsumaru and Kimura, 1989, p. 259–260, figs. 3–3, 8, 11, 4–1–5.
Asterocyclina stella stella (Gümbel). Less, 1987, p. 231–232, pl. 42, figs. 7–10, text-fig. 32c.

Description: Test small, inflated lenticular, asteroidal forms, with five fundamental rays, and rarely other forms in addition with interrays between principal rays, to form six rays and eight rays; 1.5 to 3.1 mm in diameter, maximum up to 4.9 mm in diameter, and 0.7 to 1.7 mm in thickness; form ratio of diameter to thickness, 1.47 to 2.73; surface suture, covered by network of lateral chambers; round granules, surrounded by 7 to 12 lateral chambers, and of diameter of 60 to 190 μm. Megalospheric embryonic chambers, biloculine, nephrolepidine type; subspherical protoconch; 64 × 53, 64 × 58, and 64 × 64 μm in diameter, and reniform deuteroconch; 90 × 54, and 104 × 32 μm in diameter; total distance across embryonic chambers, 92 to 114 μm in diameter, and outer wall of embryonic chambers, 6 to 8 μm in thickness; two principal auxiliary chambers, 18 to 20 μm in radial diameter, and 35 to 45 μm in tangential diameter. Microspheric proloculus, very small, but not measured; equatorial chambers in interray areas, small, open-arcuate, and square or hexagonal near center of test, but large and square or hexagonal to periphery; 10 to 72 μm in radial diameter, and 13 to 48 μm in tangential diameter. Those in ray areas, small, and arcuate or square in center, and large and spatulate or square toward periphery; 26 to 80 μm in radial diameter, and 21 to 48 μm in tangential diameter. Lateral chambers, arranged in regular tiers; and number of lateral chambers, 18 to 20 layers over embryonic chambers. Chamber

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Explanation of Plate 45

Asterocyclina pentagonalis (Deprat)
1, 4, 6–7. Equatorial sections. 1, 4, 6. Megalospheric forms. ×26, 7. Microspheric form. ×17. Okimura Formation; Localities: 1, 4, 6. OK82001 (Okiko/Tsukigaoka Shrine Section), 7. TJ82402–1 (Toeijūtaku Section).

Asterocyclina stella (Gümbel)
2–3, 5. Equatorial sections. 2–3. Megalospheric forms. 2. ×30, 3. ×37, 5. Microspheric form. ×11. Yusan Formation; Localities: 2. MI81802 (Miyukihama Section), 3. HY21151 (Hyōgidaira Section), 5. UN82204 (Yusankaigan Section).


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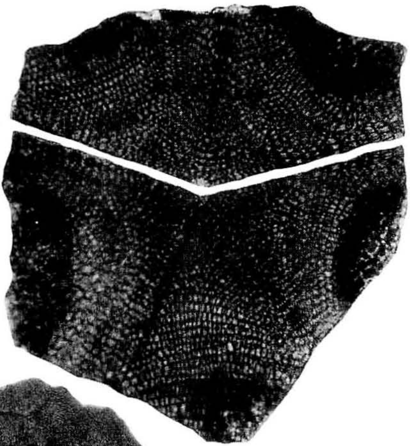
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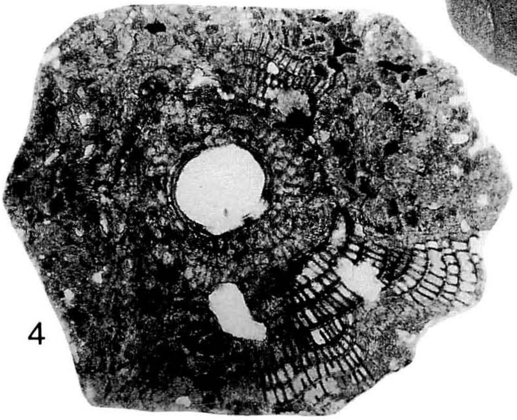
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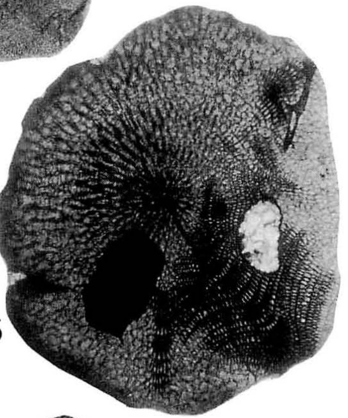
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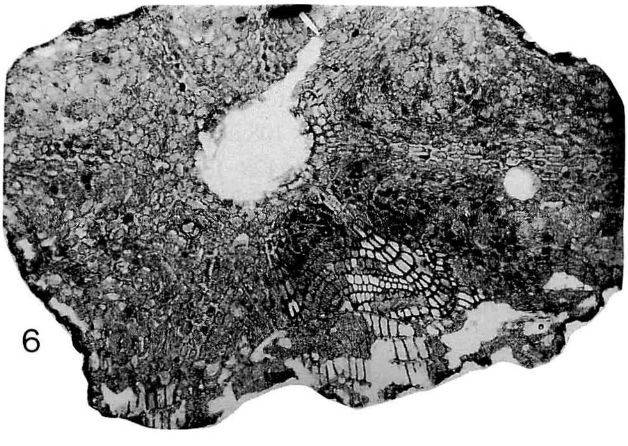
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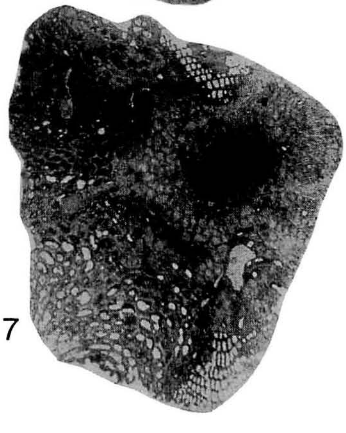
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cavities, low and open between floors and roofs; 40 to 56 μm in length, and 10 to 18 μm in height; and thickness of floors and roofs, 5 to 18 μm.

Stratigraphic horizon: Yusan and Okimura Formations, and Sekimon Limestone.

Remarks: The present form is assigned to *Asterocyclina stella* (Gümbel), because of the clear morphology of both external and internal features.

Family Discocyclinidae Galloway, 1928

Genus *Discocyclina* Gümbel, 1870

Discocyclina augustae van der Weijden, 1940

Plate 40, figure 5; Plate 46, figures 1–2, 4–5; Plate 47, figures 6–7.

Orbitoides (Discocyclina) papyracea Boubée. Gümbel, 1870, p. 112–118.

Orbitoides (Discocyclina) *applanata* Gümbel, 1870, p. 122–123, pl. 3, figs. 17–18, 35–37; Hantken, 1875, p. 71, pl. 11, fig. 2.

Orthophragmina pratti (Michelin). Schlumberger, 1903, p. 274–277, pl. 8, figs. 2–3, 8–10 (non fig. 1), pl. 9, fig. 17?

Orthophragmina applanata (Gümbel). Prever, 1912, p. 139–141, pl. 1, fig. 6, pl. 3, fig. 6

Discocyclina archiaci (Schlumberger). Douvillé, 1922, p. 57, 65, 67, text-fig. 2.

Discocyclina (Discocyclina) augustae van der Weijden, 1940, p. 23–26, pl. 1, figs. 4–8, pl. 2, figs. 1–2.

Discocyclina augustae van der Weijden. Brönnimann, 1940, p. 253–260, pl. 14, figs. 7–12, pl. 15, figs. 1–2, text-figs. 1–5; Schweighauser, 1953, p. 49–51, pl. 8, figs. 1–3, pl. 13, fig. 4; Neumann, 1958, p. 84–86, pl. 12, figs. 1–6, pl. 26, figs. 1–2, text-fig. 21; Samanta, 1965, p. 421–422, pl. 3, figs. 7–13, pl. 14, fig. 12.

Discocyclina cf. *augustae* van der Weijden. Bursch, 1947, p. 59–60, pl. 5, fig. 8.

Discocyclina augustae van der Weijden var. *olianae* (Almela and Rios). Neumann, 1958; p. 86, pl. 12, figs. 7–10, text-fig. 22.

Discocyclina applanata (Gümbel). Sirotti, 1978, p. 53–54, pl. 1, figs. 1–5.

Discocyclina augustae van der Weijden *sourbetensis* Less, 1987, p. 152–153, pl. 9, figs. 7, 9–12, pl. 10, fig. 1, pl. 17, fig. 4, text-fig. 27f.

Discocyclina augustae van der Weijden *atlantica* Less, 1987, p. 153–154, pl. 10, figs. 2–4, text-fig. 27g.

Discocyclina augustae van der Weijden *olianae* Almela and Rios. Less, 1987, p. 154–155, text-fig. 27h.

Discocyclina augustae augustae van der Weijden. Less, 1987, p. 155–156, pl. 10, figs. 5–6, 8–12, pl. 11, figs. 1–4, text-fig. 27i.

Description: Test small, thin lenticular to flattened discoidal with small umbo; 2.0 to 6.2 mm in diameter, 1.8 to 2.1 mm in diameter in umbo, and 0.6 to 1.0 mm in thickness; form ratio of diameter to thickness, 3.0 to 7.5; surface covered by network of lateral chambers; granules, fine, 48 to 93 μm in diameter. Embryonic chambers of nephrolepidine to trybliolepidine types, biloculine; spherical to subspherical protoconch; 65 × 60, 72 × 48, 72 × 66, 72 × 72, 80 × 72, 82 × 82, 84 × 88, 92 × 80, and 128 × 108 μm in diameter, in 9 specimens, and reniform deuteroconch; 168 × 124, 136 × 104, 155 × 128, 136 × 124, 160 × 120,

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Explanation of Plate 46

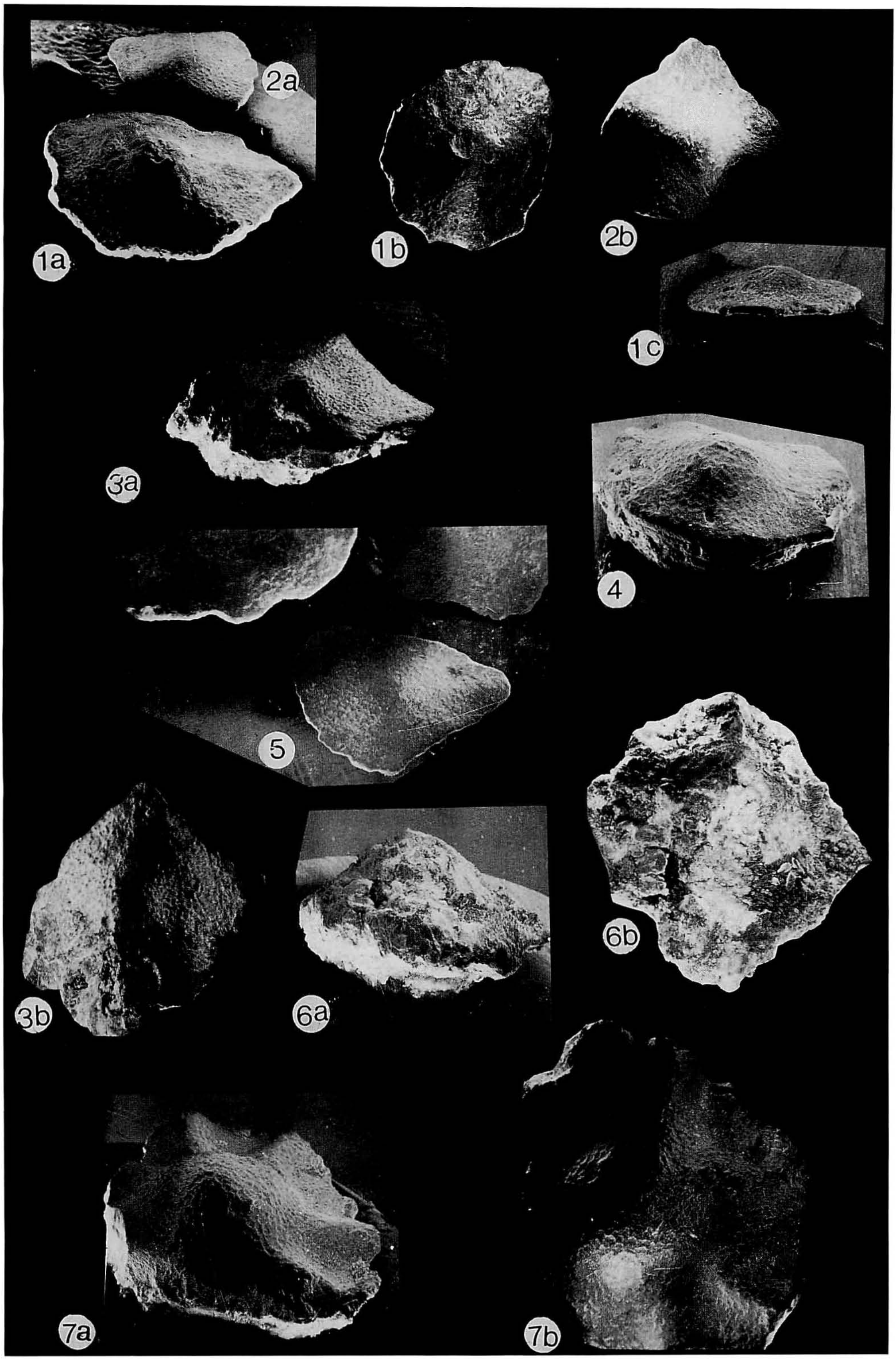
Discocyclina augustae van der Weijden

1–2, 4–5. Exteriors. ×8. Yusan Formation; Locality: UN82204 (Yusankaigan Section)

Discocyclina javana (Verbeek)

3, 6–7. Exteriors. 3. ×10, 6. ×8, 7. ×6. Yusan Formation; Locality: MI81806 (Miyukihama Section).

Plate 46



170 × 152, 180 × 149, 140 × 136, and 224 × 208 μm in diameter, in 9 specimens; total distance across embryonic chambers, 128 to 260 μm in diameter; outer wall of embryonic chambers, 6 to 10 μm in thickness; two main principal periembryonic chamberlets, 24 to 40 μm in radial diameter, and 32 to 84 μm in tangential diameter. Microspheric proloculus, very small, but not measured; equatorial chambers, narrow, relatively low, and concentric; number of equatorial chamber layers, 25 to 47 in the adult form; equatorial chamberlets, nearly square within the first two or three rings; 20 × 12, 22 × 30, and 24 × 24 μm in radial and tangential diameters, while those lengthened and rectangular in the final stage; 60 × 24, 80 × 26, 83 × 20, 84 × 32, 98 × 32, and 104 × 42 μm in radial and tangential diameters. Lateral chambers, arranged in regular tiers; number of lateral chambers, 19 to 20 layers over embryonic chambers; chamber cavities, low and open between floors and roofs; 32 to 64 μm in length, and 10 to 16 μm in height; and thickness of floors and roofs, 8 to 12 μm.

Stratigraphic horizon: Yusan Formation.

Remarks: The present form is compared with the topotype specimens of *Discocyclina applanata* (Gümbel) from Priabona, Italy, and was also checked with Sirotti's (1978) description and illustration. Although *Discocyclina applanata* is a senior synonym of *Discocyclina augustae* van der Weijden, the latter has been widely used in the literature, while the former was not used for 66 years, until Sirotti (1978) described it. The law of priority should be used to promote stability, and *Discocyclina augustae* has been used as a valid species for a long time. As such, the author refers the present form to *Discocyclina augustae* van der Weijden, and also this idea coincides with Sirotti's personal communication.

Discocyclina dispansa (Sowerby, 1840)

Plate 40, figure 7; Plate 48, figures 1–3.

Lycophris dispansa Sowerby, 1840, p. 327, pl. 24, figs. 16a–b.

Discocyclina dispansa (Sowerby). Nuttall, 1926a, p. 145–147, pl. 7, figs. 1–3, 5; Hanzawa, 1957, p. 83–84, pl. 13, figs. 1, 3–4 (non pl. 14, figs. 2–3, 8–9); Nagappa, 1959, pl. 10, figs. 6–8; Samanta, 1965, p. 422, pl. 1, figs. 9–11; Less, 1987, p. 163–164, pl. 13, figs. 9, 12, pl. 14, figs. 3, 6, text-fig. 27q.

Discocyclina cf. *dispansa* (Sowerby). Henrici, 1934, p. 45–46, pl. 1, fig. 12.

Discocyclina (Discocyclina) omphala (Fritsch). Cole, 1957a, p. 347–349, pl. 115, figs. 1–11, 12?

Discocyclina (Discocyclina) indopacifica Hanzawa, 1957, p. 82–83, pl. 12, figs. 1–2, pl. 13, figs. 2, 5–6.

Discocyclina dispansa (Sowerby) *umbilicata* (Deprat). Less, 1987, p. 164–165, pl. 14, figs. 4–5, 7–8, text-fig. 27r.

Explanation of Plate 47

Asterocyclina pentagonalis (Deprat)

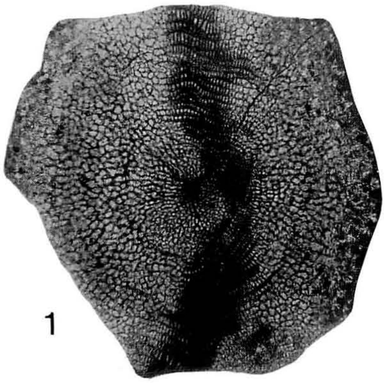
1. Oblique section of microspheric form. ×10. Yusan Formation; Locality: UN82204 (Yusankaigan Section).

Discocyclina javana (Verbeek)

2–5. Equatorial sections. 2. Microspheric form. ×10, 3–5. Megalospheric forms. 3, 5. ×27, 4. ×10. Yusan Formation; Localities: 2, 3. UN82204, 5. UN82203 (Yusankaigan Section), 4. MI81806 (Miyukihama Section).

Discocyclina augustae van der Weijden

6–7. Equatorial sections of megalospheric form. 6. ×28, 7. ×24. Yusan Formation; Locality: US81810 (Yusankaigan Section).



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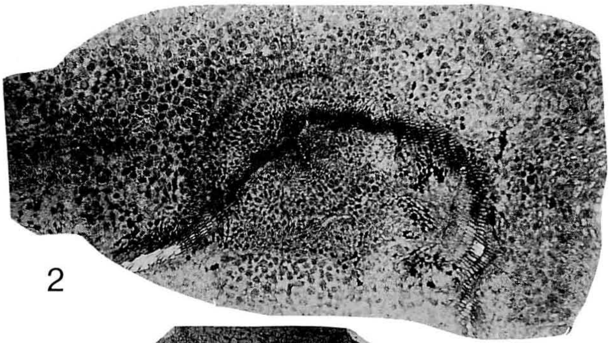

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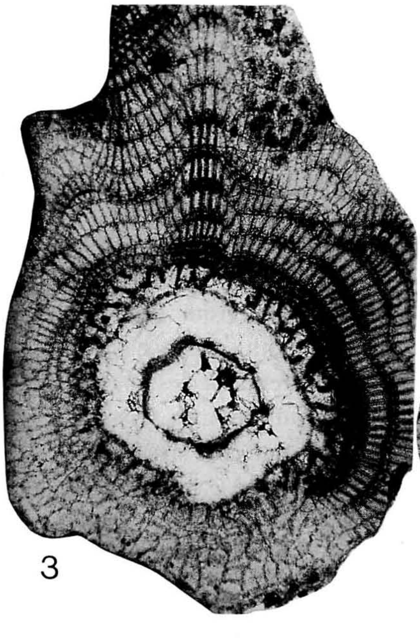

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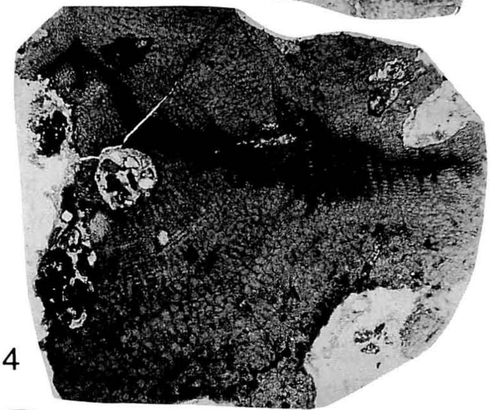

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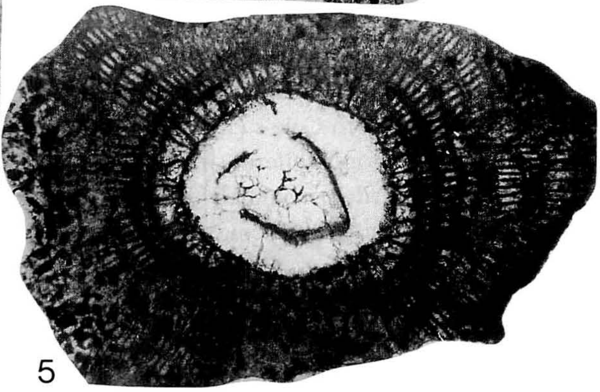

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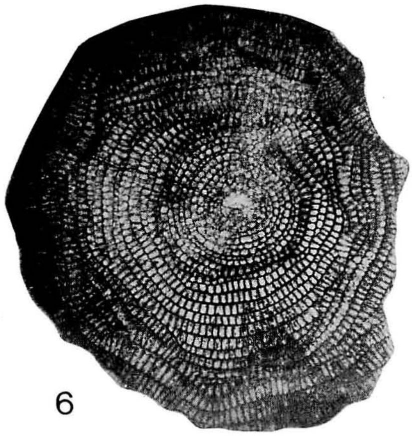

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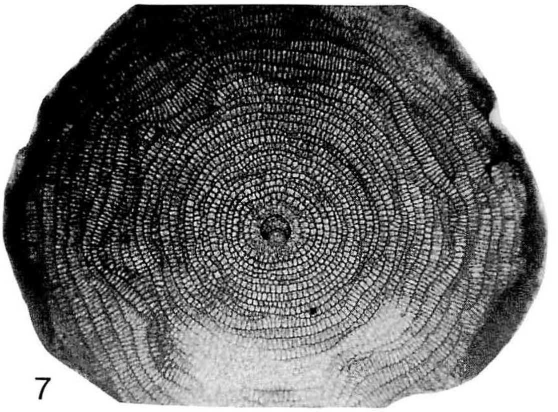


7

Description: Test moderate, lenticular, with or without central umbo; 2.5 to 9.3 mm in diameter, 1.6 to 2.6 mm in diameter in umbo, and 0.8 to 2.7 mm in thickness; form ratio of diameter to thickness, 2.7 to 6.2; surface smooth, covered by network of lateral chambers; round granules, slightly raised; 40 to 229 μm in diameter. Megalospheric embryonic chambers, trybliolepidine type, biloculine; spherical protoconch, of dimeter 171 μm, and reniform deuteroconch, of diameter 541 μm in centered oblique section; outer wall of embryonic chambers with 10 to 14 μm in thickness; height of embyronic chambers, 148 to 188 μm in two vertical sections. Periembryonic chamberlets rectangular; 64 to 71 μm in radial diameter, and 38 to 52 μm in tangential diameter. Microspheric proloculus, very small, but not measured; equatorial chambers, narrow and low, and number of equatorial chambers, more than 26 in the adult form; equatorial chamberlets, nearly square near center; 40 × 30, 40 × 32, and 48 × 36 μm in radial and tangential diameters, while those lengthened and rectangular in final stage; 57 × 38, 64 × 38, 74 × 30, and 88 × 48 μm in radial and tangential diameters. Lateral chambers, arranged in regular tiers, and number of lateral chambers, 20 to 28 layers over embryonic chambers in megalospheric form, and 30 to 38 layers in microspheric form. Chamber cavities, low and open between thin floors and roofs; 80 to 107 μm in length, and 7 to 12 μm in height; and thickness of floors and roofs, 7 to 16 μm.

Stratigraphic horizon: Yusan and Okimura Formations, and Sekimon Limestone.

Remarks: The present form is assigned to *Discocyclina dispansa* (Sowerby), because of having the same external and internal features. The present form is similar to *Discocyclina omphala* (Fritch) from Saipan, described by Cole (1957a). Both *Discocyclina dispansa* (Sowerby, 1840) from Cutch, India, and *D. omphala* (Fritch, 1875) from Tempotok, near Bintot, Borneo, are, however, different in external shape, and both species have variously been interpreted by many authors as a large synonym, a different species, or one to be abolished. According to Cole's (1957a, p. 349) interpretation, that the main reliance for the definition of larger foraminiferal species should be based on the internal structures, *Discocyclina omphala* (Fritch) could be a junior synonym of *D. dispansa* (Sowerby). Thus the present form is regarded as being *Discocyclina dispansa* (Sowerby).

Discocyclina javana (Verbeek, 1892)

Plate 46, figures 3, 6–7; Plate 47, figures 2–5; Plate 49, figures 4–5; Plate 50, figures 1–4, 6.

Orbitoides ephippium (Schlotheim) var. *javana* Verbeek, 1892, p. 109, pl. 1, fig. 1; Verbeek and Fennema, 1896, p. 1168–1171, pl. 9, figs. 138–143, pl. 10, figs. 152–154.

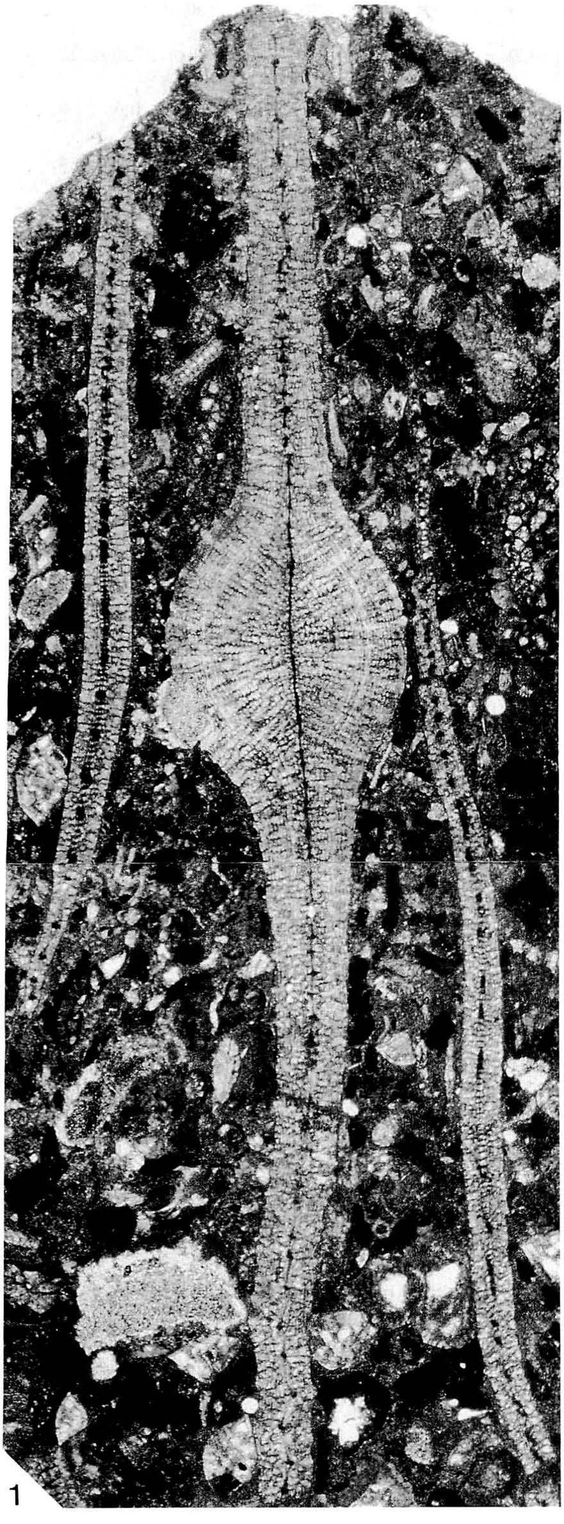
Orbitoides papyracea (Boubée) var. *javana* Verbeek, 1892, p. 119, fig. 8; Verbeek and Fennema, 1896, p. 1171–1173, pl. 9, figs. 144–147, pl. 10, figs. 155–157.

Orbitoides dispansa (Sowerby). Verbeek, 1892, p. 120, fig. 9; Verbeek and Fennema, 1896, p. 1173–1174, pl. 9, figs. 148–149, pl. 10, figs. 158–160.

Explanation of Plate 48

Discocyclina dispansa (Sowerby)

1. Axial section of microspheric form. ×22, 2–3. Oblique sections. 2. ×22, 3. ×40. Sekimon Limestone; Localities: 1–2. 72203 (Sekimon Karst Section), 3. OK25.95 (Okiko/Tsukigaoka Shrine Section).



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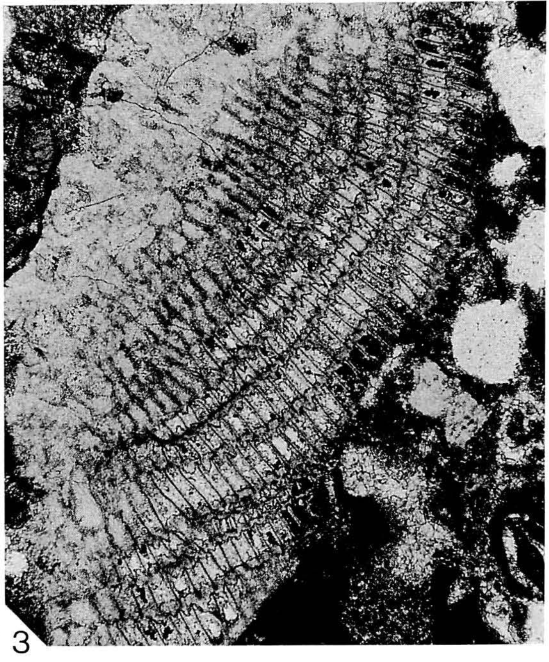

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Orthophragmina dispansa (Sowerby). Schlumberger, 1903, p. 285–287, pl. 11, figs. 42–44, pl. 12, figs. 51–52.

Discocyclina aff. *javana* (Verbeek). Yabe and Hanzawa, 1929, p. 161, pl. 16, fig. 7, pl. 22, fig. 6, pl. 27, figs. 1?, 2–3, 4?

Discocyclina sowerbyi Nuttall. Nagappa, 1959, pl. 11, figs. 1–2; Samanta, 1965, p. 426, 428, pl. 3, figs. 1–6, pl. 4, fig. 10.

Discocyclina omphala (Fritch). Nagappa, 1959, pl. 11, figs. 3–5; Samanta, 1964, p. 343–345, pl. 3, figs. 3–4, 9; Samanta, 1965, p. 424, pl. 2, figs. 10–11.

Discocyclina sijuensis Samanta, 1963, p. 39–40, figs. 1–4.

Discocyclina javana (Verbeek). Samanta, 1964, p. 340–343, pl. 1, figs. 1–12, pl. 2, figs. 1–7; Samanta, 1965, p. 422, 424, pl. 4, figs. 6–9; Less, 1987, p. 141–143, pl. 6, figs. 7, 9, text-figs. 260p.

Description: Test moderate to large, lenticular, with indistinct umbo; 3.4 to 12.2 mm in diameter, 2.5 to 4.6 mm in diameter in umbo, and 1.7 to 3.1 mm in thickness; form ratio of diameter to thickness, 1.7 to 5.0; surface smooth, covered by network of lateral chambers; granules distributed in the entire test, surrounded by 4 to 7 triangular to polygonal lateral chambers; of diameter of 42 to 280 μm. Megalospheric embryonic chambers, concentric to multilepidine type, biloculine; polygonal protoconch; 520 × 478, 555 × 491, 594 × 543, 800 × 457, and 1029 × 571 μm in diameter, and large polygonal deuteroconch; 1102 × 928, 1144 × 936, 1029 × 800, 971 × 829, and 1142 × 914 μm in diameter, with outer wall of embyronic chambers, thin, 15 to 17 μm in thickness; height of embryonic chambers, 286 to 370 μm, in three vertical sections. Periembryonic chamberlets, large and rectangular; 128 × 53, 128 × 64, and 137 × 94 μm in radial and tangential diameters; and number of periembryonic chamberlets, 50 to 56. Microspheric proloculus, very small, but not measured; equatorial chambers, narrow and low, and concentric, but of polygonal arrangement in the early stage in both megalospheric and microspheric forms. Equatorial chamberlets, rectangular to radially elongated; 30 to 80 μm in radial diameter, and 24 to 42 μm in tangential diameter. Lateral chambers, arranged in regular tiers, and number of lateral chambers, 20 to 23 layers over embryonic chambers in megalospheric form, and 38 to 40 layers in microspheric form. Chamber cavities, low and open between floors and roofs; 56 to 160 μm in length, and 14 to 40 μm in height; and thickness of floors and roofs, 12 to 20 μm.

Stratigraphic horizon: Yusan Formation.

Remarks: As the present form is characterized by large and irregular embryonic chambers, concentric to multilepidine types of embyronic chambers, and numerous narrow

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Explanation of Plate 49

Asterocyclina pentagonalis (Deprat)

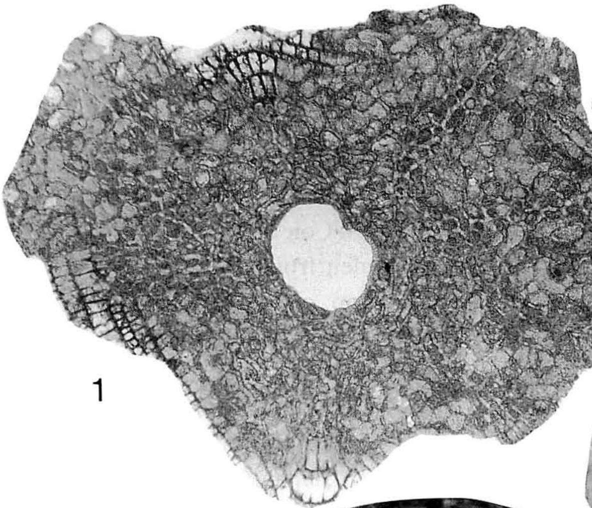
1. Tangential section of megalospheric form. ×34, 2. Axial section of microspheric form. ×18. Okimura Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).

Orbitoclypeus kimurai Matsumaru

3. Tangential section of megalospheric form. ×34. Yusan Formation; Locality: MI81804 (Miyukihama Section).

Discocyclina javana (Verbeek)

4. Axial section of microspheric form. ×20, 5a. Equatorial section of microspheric form. ×10, 5b. Central part of equatorial section shown in Figure 5a showing small proloculus, rectangular nepionic chambers, and equatorial chambers in polygonal arrangement in the early stage. ×95. Yusan Formation; Locality: UN82204 (Yusankaigan Formation).



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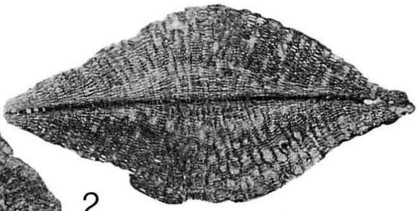

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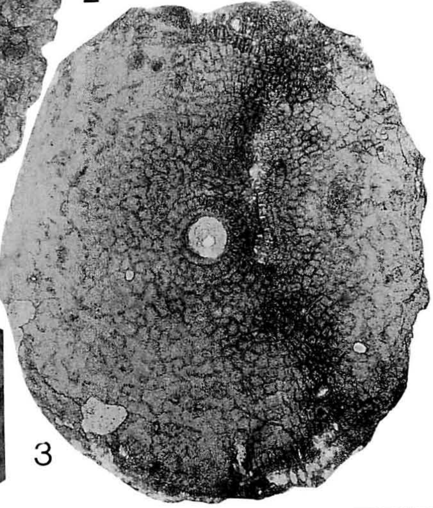

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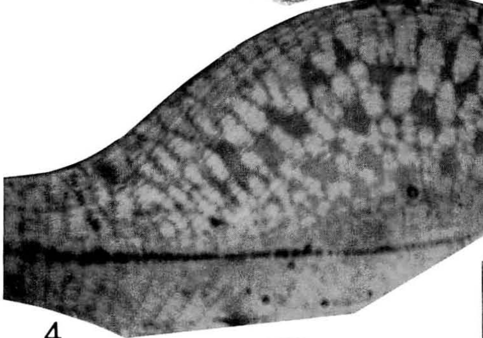

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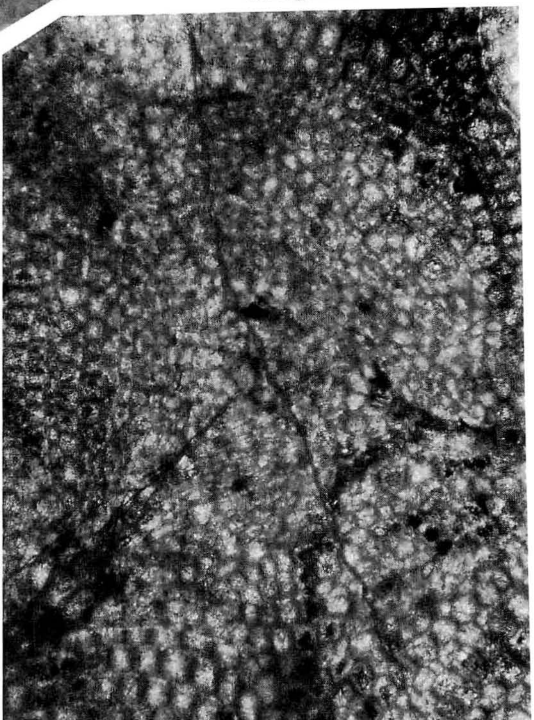
5a



5b

to broad granules distributed in the entire medium to large test, the present form is assigned to *Discocyclina javana* (Verbeek).

Cole (1957a, p. 348) regarded both *Orthophragmina umbilicata* Deprat, 1905, from New Caledonia, and *Discocyclina (Discocyclina) indopacifica* Hanzawa from Saipan, to *Discocyclina (Discocyclina) omphala* (Fritch) from Saipan. Later Cole (1960) transferred *Discocyclina (D.) omphala* to *Discocyclina (D.) javana* (Verbeek), for reason of a synonym. Less (1987) abolished *Discocyclina omphala*, because although Cole (1957a, p. 348) described the internal structure of Douvillé's (1905) topotype specimen from Borneo, his statement cannot be accepted without the available figure. Then less (op. cit., p. 164) regarded Cole's *Discocyclina omphala* (Fritch) to *Discocyclina dispansa* (Sowerby) *umbilicata* (Deprat). According to Less (op. cit., p. 142, 157), *Discocyclina dispansa* is characterized by the seminephrolepidine type of embyronic chambers, while *Discocyclina javana* is characterized by the polylepidine (= multilepidine) to umbilicolepidine (= concentric) type. As *Discocyclina omphala* from Saipan (Cole, 1957a) and *D. indopacifica* from Saipan (Hanzawa, 1957) have the trybliolepidine or the eulepidine type of embryonic chambers, they may not be included into *Discocyclina javana*. According to Samanta (1964, 1965), as *Discocyclina javana* from Assam, India, has large eulepidine to multilepidine types of embryonic chambers, *Discocyclina omphala* and *D. indopacifica* from Saipan can be included into *D. javana*. Hanzawa (1957, p. 82) described that the nucleoconch of both *Discocyclina javana* from Nanggoelan, Java, and *D. indopacifica* from Saipan, are variable in structure of nephrolepidine to eulepidine forms. Hanzawa (op. cit.) regarded *Discocyclina* aff. *javana* from Palawan (Yabe and Hanzawa, 1929, p. 161) to *D. indopacifica*, and the nucleoconch of the former clearly shows a multilepidine form. Then it is evident from Hanzawa's examination that *Discocyclina javana* and its allied form have a nephrolepidine to multilepidine types of embryonic chambers. Weijden (1940, pl. 4, fig. 8) showed a concentric form in the nucleoconch of *Discocyclina javana*.

Discocyclina javana was originally described by Verbeek (1892) and Verbeek and Fennema (1896), based on a large microspheric form. Caudri (1934, p. 90, 94) described that the megalospheric form of *Discocyclina javana* would belong to *D. dispansa* (Sowerby)

Explanation of Plate 50

Discocyclina javana (Verbeek)

1–2, 4. Equatorial sections of megalospheric form. ×18, 3, 6. Axial sections of megalospheric form. 3. ×18, 6. ×12. Yusan Formation; Locality: UN82204 (Yusankaigan Section).

Asterocyclina pentagonalis (Deprat)

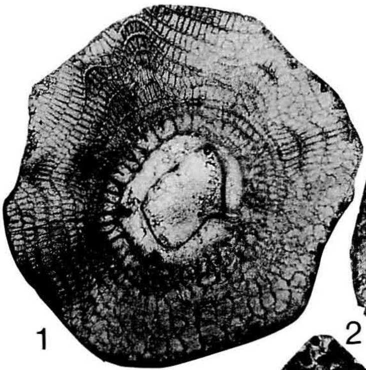
5. Equatorial section of microspheric form. ×11. Yusan Formation; Locality: UN82204 (Yusankaigan Section).

Asterocyclina stella (Gümbel)

7. Central part of equatorial section shown in bisymmetric with Figure 3 in Plate 45, showing embryonic chambers, peri-embryonic chambers, and neanic equatorial chambers in both ray and interray areas. ×100. Yusan Formation; Locality: HY21151 (Hyōgidaira Section).

Asterocyclina incisuricamerata Cole

8. Central part of equatorial section shown in Figure 2 in Plate 42, showing embryonic chambers, nepionic chambers, and neanic chambers in both ray and interray areas, ×95. Yusan Formation; Locality: OK82001 (Okiko/Tsukigaoka Shrine Section).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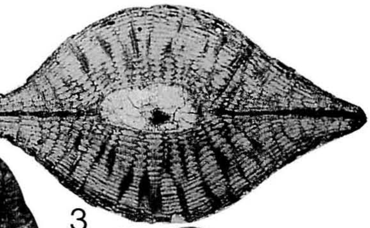
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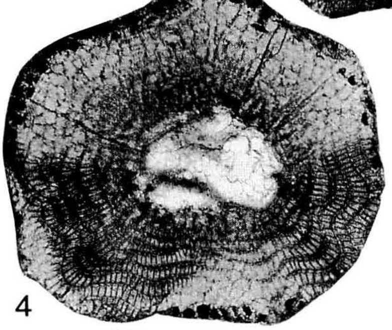
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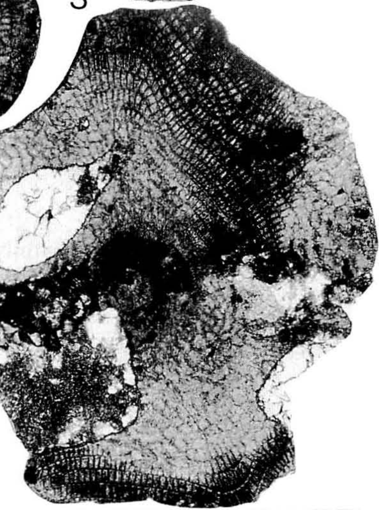
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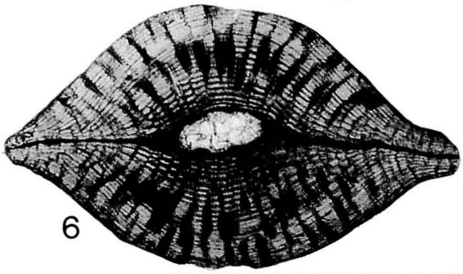
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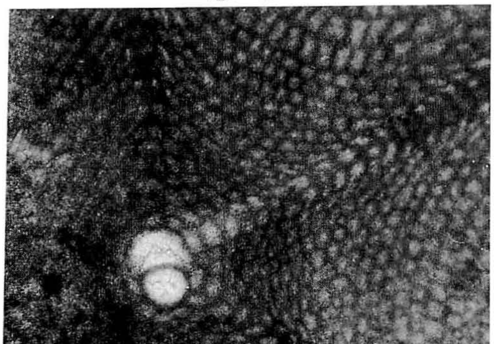
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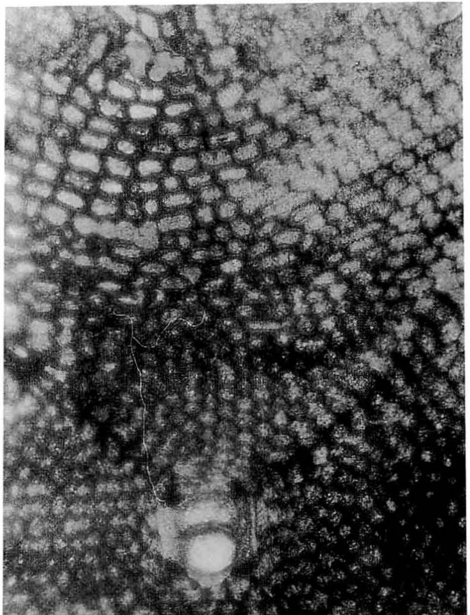
⑧

or have a great resemblance to *D. dispansa* from the Nanggoelan (Nanggulan) Bed, Java. Schlumberger's (1903) examination about Nanggoelan form corresponded to the megalospheric form of *Discocyclina javana*. Less (1987, p. 142) described *Discocyclina javana* based on Schlumberger's (op. cit.) megalospheric form of *D. dispansa*, which has Less's polylepidine embryo (rarely with transition toward the umbilicolepidine type). There are a series of interpretations about the megalospheric form of *Discocyclina javana* (Verbeek). However, the author regards Schlumberger's megalospheric form as a megalospheric form of *Discocyclina javana*, because the author has collected many megalospheric specimens in association with the microspheric specimens of *Discocyclina javana* from the Nanggoelan Bed, Java, and confirmed the megalospheric form to have concentric to multilepidine types of embryonic chambers, as shown in Figures 1–2 and 4 in Plate 50, and Figures 3 and 5 in Plate 47.

Superfamily Planorbulinacea Schwager, 1877

Family Cymbaloporidae Cushman, 1927

Subfamily Fabianiinae Deloffre and Hamaoui, 1973

Genus *Fabiania* Silvestri, 1924

Fabiania cassis (Oppenheim, 1896)

Plate 51, figures 1–6.

Patella (Cymbiola) cassis Oppenheim, 1896, p. 55–56, pl. 2, figs. 2–3.

Fabiana cassis (Oppenheim). Silvestri, 1926, p. 15–21, pl. 1, figs. 1–8; Hanzawa, 1959, p. 120–121, pl. 9, figs. 1–15.

Pseudorbitolina cubensis Cushman and Bermúdez, 1936, p. 59, figs. 27–30; Cole, 1944, p. 35–36, pl. 2, fig. 7, pl. 8, figs. 14–15, pl. 13, figs. 1–2.

Eodictyoconus cubensis (Cushman and Bermúdez). Cole and Bermúdez, 1944, p. 6–10, pl. 1, fig. 1, pl. 2, figs. 1–12, pl. 3, figs. 1–5.

Fabiania saipanensis Cole. Cole and Bridge, 1953, p. 28, pl. 15, figs. 1–2; Cole, 1957a, p. 337, pl. 102, figs. 7–9, pl. 118, fig. 8; Cole, 1957b, p. 767–768, pl. 245, figs. 1–2; Hanzawa, 1957, p. 62–64, pl. 28, figs. 1–6, pl. 29, figs. 1–2, pl. 30, figs. 1–7.

Fabiania indica Nagappa, 1956, p. 192–195, pl. 30, figs. 1–9, text-figs. 1–3.

Description: Test low to high conical, with deeply excavated umbilicus, or irregularly compressed conical; 1.02 to 5.26 mm in diameter, 0.53 to 1.75 mm in basal diameter in umbilicus, 0.29 to 1.01 mm in height, and 0.06 to 0.40 mm in basal height of umbilicus; form ratio of diameter to thickness, 2.57 to 3.52. Embyronic apparatus located at apex of test; 53 and 106 μm in diameter, and 73 and 93 μm in height, respectively, in one specimen; 88 and

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Explanation of Plate 51

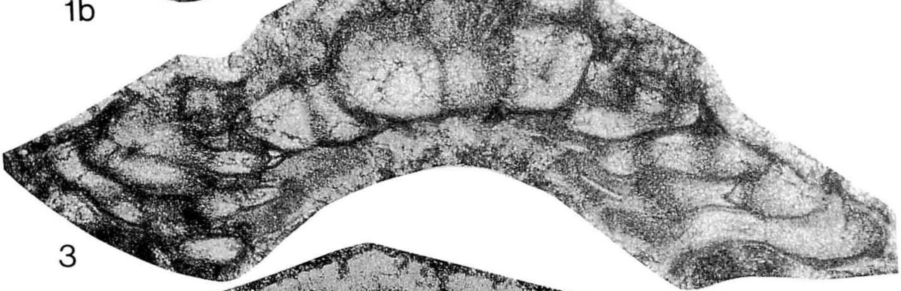
Fabiania cassis (Oppenheim)

1, 3–6. Axial sections. 1, 3–4, 6. Megalospheric forms. 1a, 6. ×40, 1b, 3–4. ×110, 5. Microspheric form. ×40, 2. Horizontal section of megalospheric form. ×110. Sekimon Limestone; Localities: 1, 3. 72203 (Sekimon Karst Section), 2. OK19.95, 4, 6. OK23.95, 5. OK25.95 (Okiko/Tsukigaoka Shrine Section).

1a

2

1b



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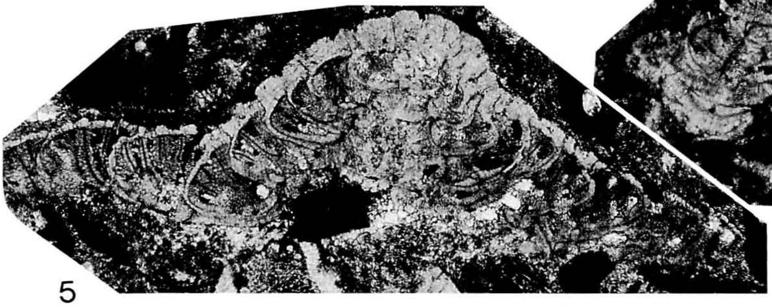

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6

150 μm in diameter, and 100, and 138 μm in height, respectively, in the other specimen. Two or three embryonic chambers in centered oblique section, in three specimens; subspherical protoconch, 225 × 200 μm in diameter, and reniform deuteroconch, 208 × 200 μm in diameter, in one specimen; probable protoconch, subspherical, 250 × 215 μm in diameter, and probable deuteroconch, subspherical, 250 × 238 μm in diameter, in the second specimen; subspherical protoconch, 82 × 73 μm in diameter, and two reniform deuteroconchs, 140 × 73, and 136 × 100 μm in diameter, in the third specimen. Embryonic chambers surrounded by thick wall (20 to 25 μm across); followed by a few chambers spirally coiled in short length, and later chambers added in cycles or tiers; entire interior with short horizontal and vertical partitions; pierced by stolons communicating with adjacent chambers; and projected from outer wall to form numerous coarse alveoli; 150 to 200 μm in length, and 125 to 200 μm in height, and smaller alveoli subdivided by second-order partitions; 60 to 80 μm in length, and 50 to 70 μm in height; wall calcareous, outer wall coarsely or finely perforate, internal partitions imperforate; surface smooth to rugose, owing to ridges and pits; openings of vertical canals (8 to 17 μm across); aperture, simple openings in umbilicus.

Stratigraphic horizon: Sekimon Limestone.

Remarks: Some of the present form from Haha-Jima resembles *Fabiania saipanensis* Cole, 1953, from the Eocene Matansa Limestone, Saipan, whereas others from Haha-Jima resemble *Fabiania cubensis* (Cushman and Bermúdez) from the middle Eocene Pinar del Rio Province, Cuba, in every respect, except that the present form from Haha-Jima consists of more differentiated coarse and finner alveoli of the cortial layer than both *Fabiania saipanensis* and *F. cubensis*. However, there seem to be many transitional forms among them. Hanzawa (1959) described that all of the *Fabiania* species were seemingly synonyms of *Fabiania cassis* (Oppenheim) from Europe and the author supports his observation. The present form from Haha-Jima is referred to *Fabiania cassis* (Oppenheim).

Subfamily Halkyardiinae Kudo, 1931

Genus *Halkyardia* Heron-Allen and Earland, 1918

Halkyardia minima (Liebus, 1911)

Plate 52, figures 1–4.

Cymbaropora radiata Hagenou var. *minima* Liebus, 1911, p. 88–89, pl. 3, fig. 7.

Halkyardia minima (Liebus). Heron-Allen and Earland, 1918, p. 110, pl. 6, figs. 8–9; Renz, 1936, p. 54, 66, 83, 114–116, 124–125, pl. 15, figs. 7–8; Bursh, 1947, p. 29–34, pl. 1, figs. 12, 21, 28, pl. 12, figs. 12–16, figs. 9–14; Furrer, 1949, p. 130–131, fig. 5; Hanzawa, 1957, p. 61–62, pl. 6, fig. 10.

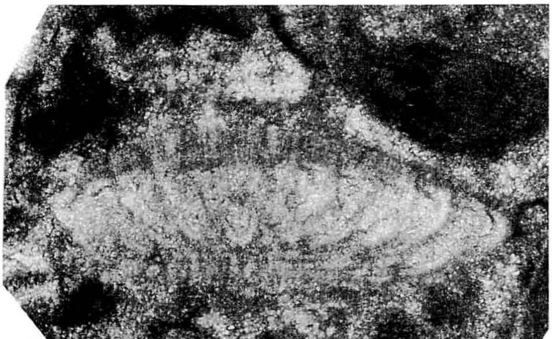
Explanation of Plate 52

Halkyardia minima (Liebus)

1–4. Axial sections. 1a. ×100, 1b. ×210, 2–4. ×112. Minamizaki Limestone; Locality: 1. 15 (1301 Section). Sekimon Limestone; Localities: 2. 72203 (Sekimon Karst Section), 3. OK25.95, 4. OK19.95 (Okiko/Tsukigaoka Shrine Section).


1a


1b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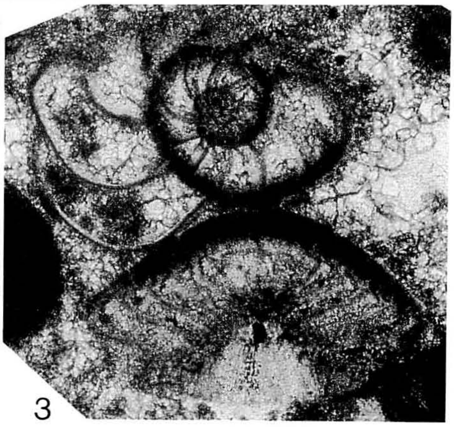
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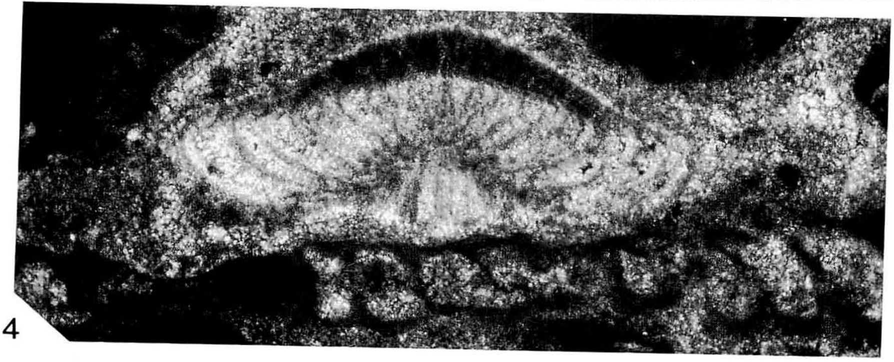
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Description: Test concavoconvex to planoconvex, dorsal side evenly convex, ventral side low umbilicus to nearly flat base; 0.47 to 0.48 mm in diameter, and 0.20 mm in thickness; form ratio of diameter to thickness, 2.4; dorsal side covered with thick and finely perforated lamellae; 16 to 20 μm in thickness. Proloculus located at apical portion of test; with diameter of 38 μm, and height of 28 μm in vertical section; chambers arranged in ventral side beneath proloculus, mostly filled with perforate plugs, formed by horizontal lamellae and connecting pillars. Single conical layers, of alternating annular series of 12 to 13 annuli of chambers; those of adult stage, of length 90 to 95 μm, and height about 16 μm; floors and roofs, of thickness 8 to 16 μm; wall calcareous, optically radial in structure; numerous appertures with small pores on the surface of the test.

Stratigraphic horizon: Okimura Formation, Sekimon Limestone and lower member of Minamizaki Limestone.

Remarks: The present form occurs commonly from the Okimura Formation and Sekimon Limestone, and rarely from the Minamizaki Limestone, and is assigned to *Halkyardia minima* (Liebus) in every respect of the test shape and chamber arrangement. The present form is close to *Halkyardia bikiniensis* Cole, 1954, from the Oligocene Limestone of Bikini Atoll, and seems to be identical except smaller in size.

Family Cibicididae Cushman, 1927

Subfamily Annulocibicidinae Saidova, 1981

Genus *Cycloloculina* Heron-Allen and Earland, 1908

Cycloloculina boninensis Matsumaru, n. sp.

Plate 53, figures 1–6.

Type material: Holotype, equatorial section of megalospheric form, Saitama University coll. no. 8836 (Plate 53, fig. 1); Paratype, axial section, Saitama University coll. no. 8837 (Plate 53, fig. 2); Paratype oblique section, Saitama University coll. no. 8838 (Plate 53, fig. 3).

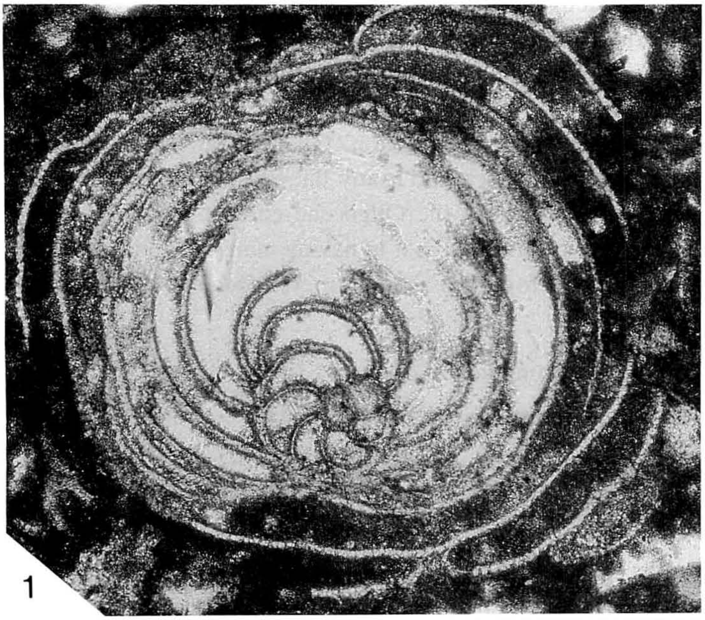
Description: Test discoidal; 0.5 to 0.8 mm in diameter, and thickness, 0.2 to 0.3 mm; form ratio of diameter to thickness, 2.3 to 3.5; peripheral margin smoothly rounded, central portion depressed; megalospheric embryonic chambers, biloculine; subspherical protoconch, 40 × 32 μm in diameter, and reniform deuteroconch, 36 × 34 μm in diameter; followed by five arcuate chamber planispirally; and later flabelliform chambers uncoiled, up to 10 in number; final two to three chambers annular; wall calcareous, thin perforation, 3 to 14 μm thick; aperture, irregularly scattered pores on the surface.

Explanation of Plate 53

(All figures ×100)

Cycloloculina boninensis Matsumaru, n. sp.

1. Equatorial section of megalospheric form. Holotype, Saitama University coll. no. 8836, 2, 4. Axial sections. 2. Paratype, Saitama University coll. no. 8837, 3, 5–6. Oblique sections. 3. Paratype, Saitama University coll. no. 8838, 5. Present form associated with *Asterigerina tentoria* Todd and Post. Minamizaki Limestone; Locality: 81702 (9308S Section).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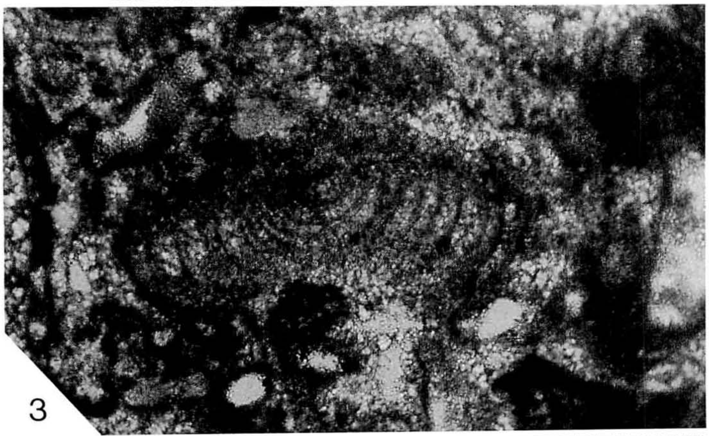
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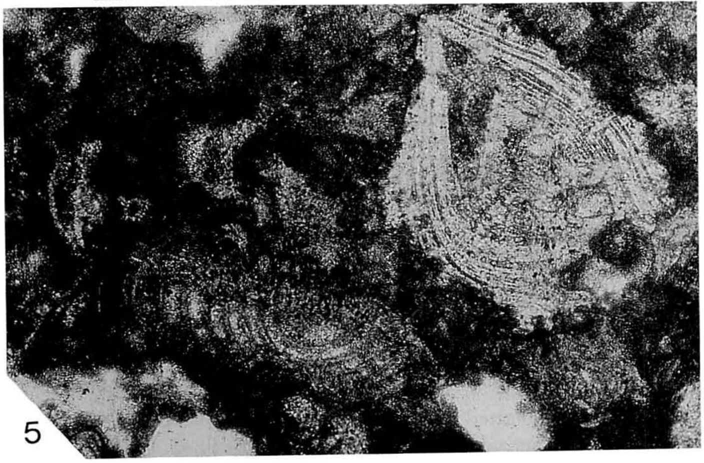
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6

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: The present form is similar to *Cycloloculina annulata* Heron-Allen and Earland, 1908, from the Tertiary of England, but differs from the latter in having many flabelliform chambers. The present form resembles *Cycloloculina cubensis* Cushman and Bermúdez, 1936, from the Oligocene Mahlac Formation, Guam (Todd, 1966), but differs from the latter in having a smaller protoconch and many flabelliform chambers. Also the present form resembles *Cycloloculina* sp. from the Oligocene core at 1891.5 to 1902 feet, Bikini Atoll (Todd and Post, 1954), but differs from it in having many flabelliform chambers and few annular chambers. The present form is assigned to *Cycloloculina boninensis*, n. sp.

Family Planorbulinidae Schwager, 1877

Subfamily Planorbulininae Schwager, 1877

Genus *Neoplanorbulinella* Matsumaru, 1976

Neoplanorbulinella saipanensis Matsumaru, 1976

Plate 54, figures 8–12; Plate 55, figures 1, 4–7.

Neoplanorbulinella saipanensis Matsumaru, 1976b, p. 201–202, pl. 6, figs. 1–12.

Description: Test attached, discoidal, conical to concavoconvex; 0.90 to 1.27 mm in diameter, and 0.30 to 0.37 mm in thickness; form ratio of diameter to thickness, 3.4 to 3.5; dorsal side of test, covered with irregularly thickened lamellar walls, sutures, and pustules; diameter of pustules, 50 to 60 μm, and ventral side of test, with lateral chambers differentiated from equatorial layer; megalospheric embryonic chambers, protoconch-deuteroconch-the third chamber arrangement with proximal stolon only; and one principal auxiliary chamber with proximal and distal stolons in opposite side of the third chamber; inner diameter of spherical to subspherical protoconch; 76 × 82, 77 × 88, and 80 × 82 μm, that of reniform deuteroconch; 64 × 80, 40 × 83, and 88 × 96 μm, and that of the third chamber; 54 × 104, 24 × 48, and 64 × 88 μm; embryonic apparatus, 68 μm high in vertical section; outer wall of embryonic apparatus, 8 to 26 μm thick. Principal auxiliary chamber, large; of dimension 56 × 96, and 60 × 64 μm in inner radial and tangential diameters. Microspheric proloculus, small, but not measured. Periembryonic chambers, arcuate shape, with two sets of slit-like

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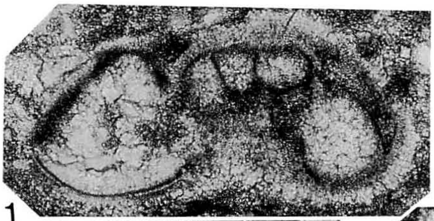
Explanation of Plate 54

Mississippina concentrica (Parker and Jones)

1–3, 5–7. Axial sections. 1–3. ×116, 5–7. ×43, 4. Oblique section. ×116. Minamizaki Limestone; Localities: 1, 3–4. 9704 (Minami-Jima), 2. 37 (1304 Section). Sekimon Limestone; Localities: 5.72203 (Sekimon Karst Section), 6–7. OK19.95 (Okiko/Tsukigaoka Shrine Section).

Neoplanorbulinella saipanensis Matsumaru

8–10. Axial sections of megalospheric form. 8–9. ×40, 10a. ×100, 10b. Enlaged form of Figure 10a showing lateral chambers in ventral side connected by nucleoconchal stolons. ×200, 11–12. Horizontal sections of megalospheric form. ×116. Minamizaki Limestone; Localities: 8–9. 43, 10, 12, 12. 49 (Both of 1304 Section), 11. 43 (801S Section).



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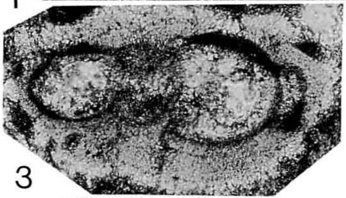

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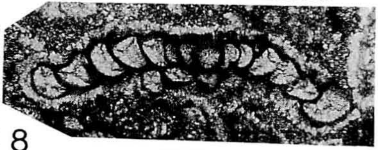

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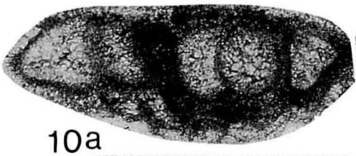

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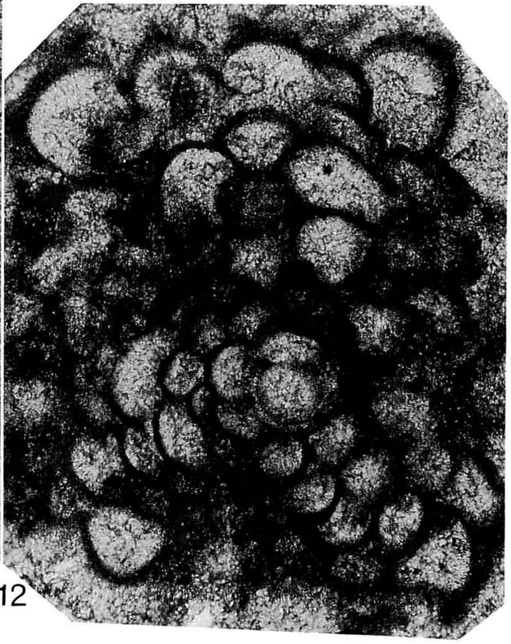

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peripheral apertures to each chamber; in low trochoid spire, of 4 nepionic spirals; and of dimension 32 × 72, 40 × 96, 48 × 80, 50 × 100, 52 × 64, 56 × 76, 56 × 80, 64 × 72, 64 × 104, and 68 × 112 μm in inner radial and tangential diameters. Later arcuate equatorial chambers, planispirally to low trochoid spirally arranged, and then those of successive annuli alternating in position near periphery, nearly symmetrical; of dimension 60 × 96, 64 × 64, 64 × 128, 72 × 80, 72 × 100, 80 × 112, 80 × 150, 92 × 136, and 104 × 144 μm in inner radial and tangential diameters; and having two arched apertures, each with short imperforate lip. Rectangular lateral chambers in ventral side irregularly arranged; and of dimension 24 × 16, 88 × 64, 88 × 80, 92 × 80, 104 × 40, 112 × 80, and 128 × 74 μm in inner width and height in vertical section. One to three layers of lateral chambers present, over embryonic and equatorial chambers. Floors and roofs, 8 to 16 μm thick; and diameter of pores in floors and roofs, 6 to 8 μm. Wall calcareous, bilamellid, coarsely perforate, in outer lamella of thickness 4 to 44 μm, and imperforate in inner lamella of thickness 4 to 5 μm, respectively.

Stratigraphic horizon: Sekimon and Minamizaki Limestone.

Remarks: The present specimen is assigned to *Neoplanorbulinella saipanensis* Matsumaru in all respects. In *Neoplanorbulinella saipanensis* from the Minamizaki Limestone, the only principal auxiliary chamber is highly developed and grows out from the embryonic apparatus, with deuteroconchal stolon, in addition to the occurrence of lateral chambers in the vental side of the test (Plate 54, figs. 11–12; Plate 55, fig. 1). This species resembles *Planorbulina acervalis* Brady, 1884, in having lateral chambers in the ventral side (Reiss and Hottinger, 1984, p. 252, fig. G32b), but the latter is of obscure whether or not in having one principal auxiliary chamber. *Planorbulina acervalis* may, however, belong to the genus *Neoplanorbulinella*.

Genus *Peelella* Matsumaru, n. gen.

Type species: *Peelella boninensis* Matsumaru, n. sp.

Diagnosis: Test small, discoidal, flat to concavoconvex; up to 1.4 mm in diameter; megalospheric apparatus, biloculine; spherical to subspherical protoconch, and reniform deuteroconch; the entire apparatus, surrounded by thick wall, followed by principal auxiliary chamber with proximal stolon only, and low trochospirally coiled periembryonic chambers, later planispiral and nearly symmetrical; microspheric proloculus tiny, spherical to subspherical, and second chamber, followed by trochospirally coiled 8 to 9 nepionic chambers

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Explanation of Plate 55

Neoplanorbulinella saipanensis Matsumaru

1. Enlarged form of Figure 11 in Plate 54 showing embryonic, and periembryonic chambers in low trochoid spire giving 4 nepionic spirals. ×230, 4–7. Axial sections of megalospheric form showing lateral chambers in ventral side. 4, 7. ×116, 5–6. ×100. Minamizaki Limestone; Localities: 1. 43 (801S Section), 4. 9 (1302 Section). 5. Base, 6. 43 (Both of 1304 Section), 7. (Minami-Jima).

Miniacina miniacea (Pallas)

2–3. Horizontal sections. ×116. 2. Megalospheric form showing bilocular embryonic chambers, and two nepionic spirals, 3. Microspheric form showing proloculus, and peri-embryonic chambers arranged with raspberry type. Minamizaki Limestone; Localities: 2. 1305 (Minamizaki Cape), 3. 9703 (Minami-Jima).


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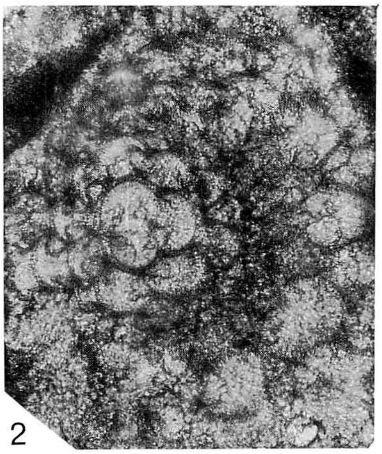
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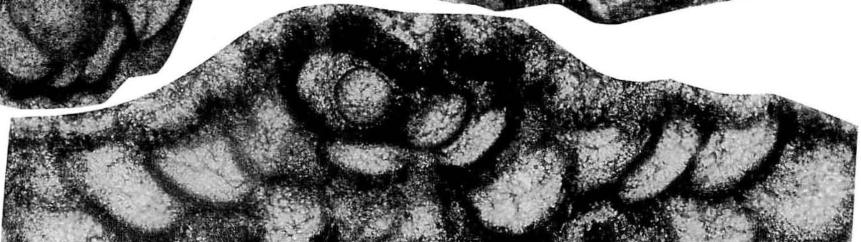
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with proximal stolons only. Both generations, followed by equatorial chambers in annular series, those of successive annuli alternating in position; each chamber with two interiomarginal stolons or stoloniferous apertures; lateral chambers irregular, rounded, well differentiated from the equatorial layer through stolons and coarse perforations on the ventral side of the test; those of successive layers alternating; wall calcareous, lamellae, inner lamella thin, imperforate, and outer lamella thick, coarse perforate.

Comparison: The present genus resembles *Neoplanorbulinella* Matsumaru, 1976, but differs from it in lacking the third embryonic chamber with proximal stolon, and in having well differentiated lateral chambers in ventral side of the test.

Peelella boninensis Matsumaru, n. sp.

Plate 56, figures 1–8; Plate 57, figures 1–10.

Type material: Holotype, horizontal section of megalospheric specimen, Saitama University coll. no. 8814 (Plate 56, fig. 1); Paratype, horizontal section of microspheric specimen, Saitama University coll. no. 8815 (Plate 56, fig. 8).

Description: Test attached, discoidal, flat to concavoconvex; 0.48 to 1.20 mm in diameter, and 0.12 and 0.33 mm in thickness; form ratio of diameter to thickness, 2.72 to 4.15; megalospheric embryonic apparatus of protoconch and deuteroconch, isolepidine type; protoconch spherical to subspherical; internal diameter 48 × 48, 56 × 44, 60 × 56, and 64 × 52 μm, and deuteroconch reniform; internal diameter 44 × 34, 48 × 36, 48 × 40, and 72 × 62 μm; embryonic apparatus 48 to 59 μm high in vertical section; wall of embryonic apparatus 8 to 22 μm thick; spherical to subspherical proloculus in microspheric generation; of inner diameter 22 × 18, and 24 × 24 μm, and reniform second chamber; of inner diameter of 18 × 16 and 24 × 8 μm; followed by subquadrate nepionic chambers disposed in trochoid spire. Periembryonic chambers of both generations, arranged in low trochoid spire; megalospheric principal auxiliary chamber, with proximal stolon only; and of dimension 24 × 72, 28 × 72, 30 × 60, and 32 × 40 μm in inner radial and tangential diameters; megalospheric and microspheric auxiliary chamber, with proximal and distal stolons; and of dimension 18 × 24, 20 × 36, 20 × 40, 22 × 35, 24 × 28, 28 × 72, 29 × 59, 32 × 58, 40 × 53, 40 × 56, 42 × 68, 44 × 48, 48 × 72, 52 × 60, 52 × 66, 52 × 84, 56 × 56, and 79 × 60 μm in inner radial and tangential diameters. Equatorial chambers of both generations arcuate, with two sets of slit-like peripheral apertures to each chamber, arranged in annular series, those of successive

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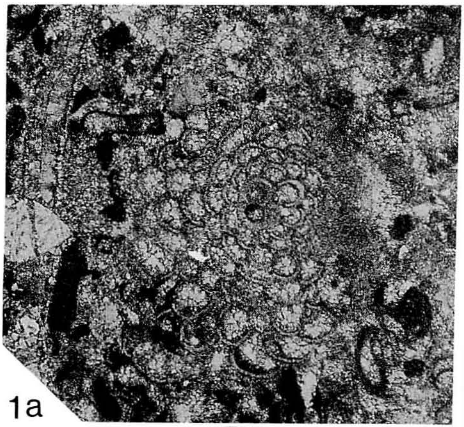
Explanation of Plate 56

Peelella boninensis Matsumaru, n. gen., n. sp.

1, 7–8. Horizontal sections. 1a. Holotype, Saitama University coll. no. 8814, ×43, 1b. Enlarged megalospheric form of Figure 1a showing bilocular embryonic chambers, one principal auxiliary chamber with proximal stolon only, and peri-embryonic chambers arranged with 2 nepionic spirals, and arcuate equatorial chambers. ×100, 7. Megalospheric form. ×100, 8. Microspheric form. Paratype, Saitama University coll. no. 8815. ×200, 2, 4–6. Axial sections showing low trochoid spire in the early stage, and planispiral coil in the adult stage. 2. ×43, 4, 6–7. ×100, 5. ×116, 3. Oblique section of microspheric form. ×43. Minamizaki Limestone; Locality: 9709 (Minami-Jima).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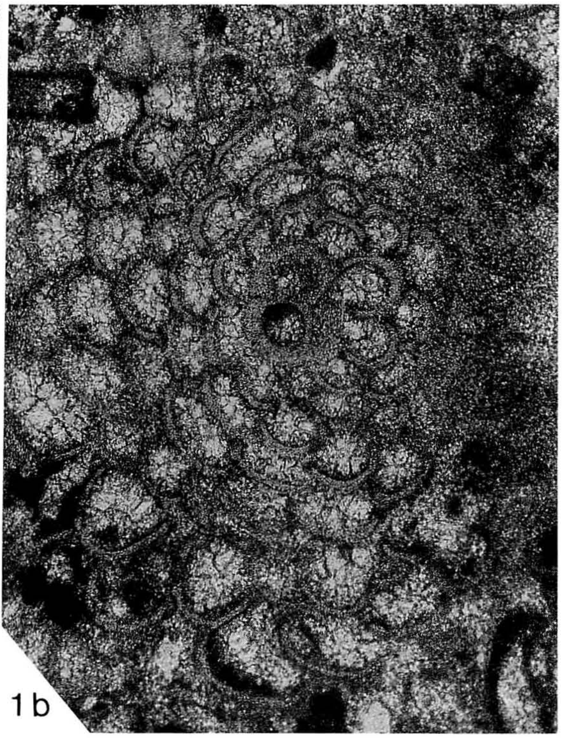
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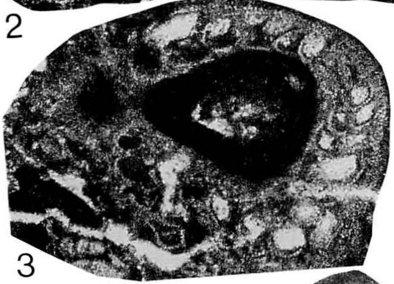
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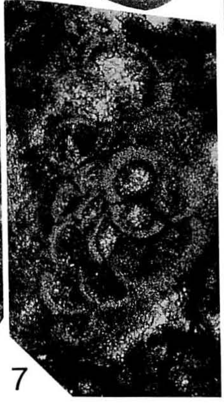
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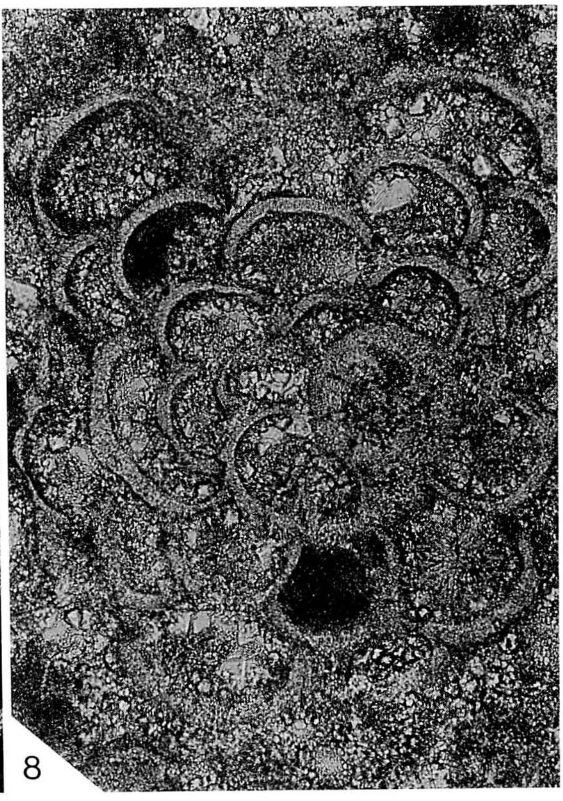
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annuli alternating in position; of dimension 24 × 24, 37 × 64, 42 × 60, 42 × 68, 44 × 76, 46 × 60, 48 × 60, 50 × 60, 50 × 80, 53 × 70, 60 × 78, 60 × 80, 77 × 124, and 80 × 144 μm in inner radial and tangential diameters. In vertical section, equatorial layer of lobulate chambers, with 24 × 80, and 32 × 59 μm in inner width and height, and numerous chambers well differentiated from equatorial layer on ventral side of test; of dimension 36 × 16, 48 × 27, 56 × 24, 60 × 40, 68 × 108, 84 × 128, 88 × 50, 104 × 56, and 144 × 78 μm in inner width and height. 5 to 7 layers of lateral chambers present, over embryonic chambers; floors and roofs, 4 to 10 μm thick; and diameter of pores in floors and roofs, 3 to 4 μm. Wall calcareous, bilamellid in dorsal side of test, coarsely perforate in outer lamella, 20 to 32 μm thick, and imperforate in inner lamella, 4 to 5 μm thick.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: The present form resembles *Neoplanorbulinella saipanensis* Matsumaru, 1976, but differs from it in having no third embryonic chamber and having well differentiated lateral chambers. The present form is assigned to *Peelella boninensis*, n. sp.

Genus *Planorbulinella* Cushman, 1927

Planorbulinella larvata (Parker and Jones, 1865)

Plate 58, figures 1–10.

Planorbulina vulgaris d'Orbigny var. *larvata* Parker and Jones, 1865, p. 380, pl. 19, figs. 3a–b.

Planorbulina larvata Parker and Jones. Brady, 1884, p. 568, pl. 92, figs. 5–6; Cushman, 1915, p. 27, pl. 8, fig. 2; Cushman, 1921, p. 310; Hofker, 1927, p. 6, pl. 1, figs. 1–5, pl. 2, figs. 1–10.

Planorbulinella larvata (Parker and Jones). Cushman, 1927, p. 96, pl. 20, fig. 9; Yabe and Hanzawa, 1929, p. 177, pl. 15, fig. 5, pl. 16, fig. 6, pl. 20, fig. 6, pl. 23, fig. 8; Hanzawa, 1957, p. 69, pl. 38, fig. 2; Freudenthal, 1969, p. 82–84, pl. 4, figs. 3–4, pl. 5, figs. 1–2, pl. 6, fig. 4, pl. 12, figs. 4–5.

Description: Test attached, discoidal, planoconvex or slightly concavoconvex; of diameter 0.67 to 1.5 mm, and thickness 0.20 to 0.30 mm; both sides of test, covered with irregularly thickened walls, sutures, and pustules; 20 to 30 μm across at periphery. Megalospheric embryonic chambers, protoconch-deuteroconch-the third chamber arrangement; spherical to subspherical protoconch; 58 × 76, 80 × 88, and 104 × 136 μm in diameter, reniform deuteroconch; 64 × 80, 56 × 72, and 80 × 112 μm in diameter, and the third chamber, with proximal stolon only; 52 × 80, 48 × 56, and 64 × 132 μm in diameter; embryonic apparatus, 72 μm high in vertical section; wall of embryonic apparatus, 13 to 20 μm thick. Periembryonic chambers, arcuate shape, with two sets of slit-like peripheral apertures to each chamber; 2 nepionic spirals; and of dimension 32 × 66, 32 × 84, 40 × 84, 42 × 80, 64 × 72, and 68 × 76 μm in inner radial and tangential diameter, in the 4th nepionic chamber, and 36 × 56,

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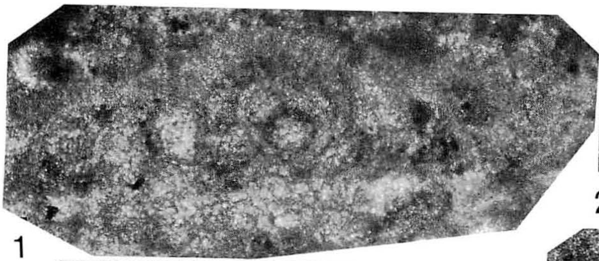
Explanation of Plate 57

(All figures ×116)

Peelella boninensis Matsumaru, n. gen., n. sp.

1–2. Oblique sections, 3, 5–8, 10. Axial sections. 4, 9. Tangential sections. Minamizaki Limestone; Localities: 1, 3–4, 8, 10. 9709. 2, 5–7, 9. 9706 (Both of Minami-Jima).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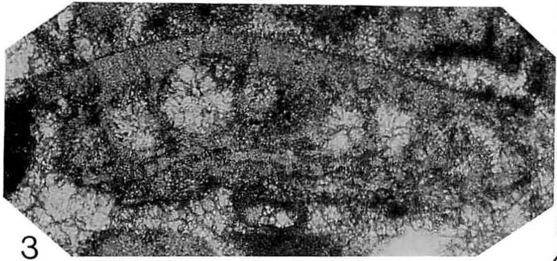
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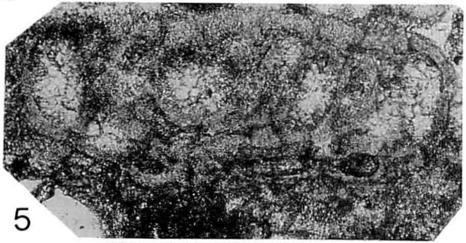
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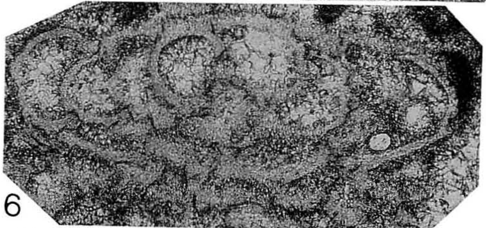
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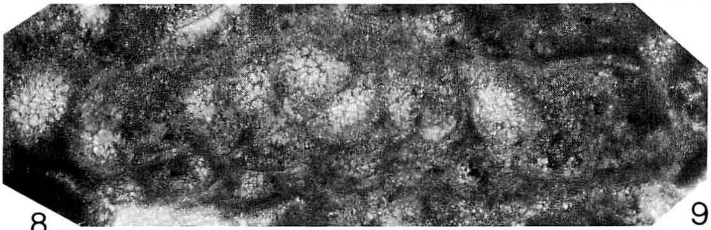
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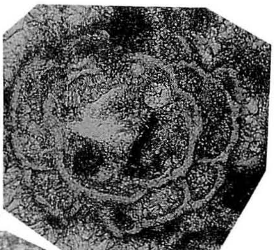
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40 × 36, 40 × 64, 40 × 101, 56 × 88, 64 × 72, 72 × 128, and 80 × 144 μm in inner radial and tangential diameter, in other nepionic chambers. Later arcuate equatorial chambers, planispirally arranged to low trochoid spirals, nearly symmetrical, and each with small imperforate lip; of dimension 48 × 92, 52 × 96, 56 × 80, 62 × 96, 72 × 80, 72 × 120, 80 × 112, and 80 × 120 μm in inner radial and tangential diameters. Wall calcareous, bilamellid, coarsely perforate in outer lamella of thickness 4 to 32 μm and imperforate in inner lamella of thickness 3 to 8 μm, respectively.

Stratigraphic horizon: Sekimon and Minamizaki Limestones.

Remarks: In all respects, the present specimen is assigned to *Planorbulinella larvata* (Parker and Jones), described by many authors.

Family Victoriellidae Chapman and Crespin, 1930

Subfamily Victoriellinae Chapman and Crespin, 1930

Genus *Eorupertia* Yabe and Hanzawa, 1925

Eorupertia boninensis (Yabe and Hanzawa, 1922)

Plate 59, figures 1–3.

Uhligina boninensis Yabe and Hanzawa, 1922, p. 72–75, pl. 12, figs. 1–11.
Eorupertia boninensis (Yabe and Hanzawa). Yabe and Hanzawa, 1925b, p. 77.

Description: Test cylindrical to subconical; 1.6 to 3.5 mm in longitudinal diameter, and 0.68 to 2.35 mm in transverse diameter; form ratio of longitudinal diameter to transverse diameter, 0.98 to 1.53; enrolled in trochospirally coiled, attached at spiral side of early stage. Megalospheric apparatus, biloculine; protoconch subspherical, 112 × 88 μm in diameter, and deuteroconch reniform, 136 × 86 μm in diameter; partition between protoconch and deuteroconch, imperforate and thin, 8 μm in thickness; outer wall of embryonic apparatus, thick and perforate, 40 to 44 μm thick. Chambers coiled about axial hollow, inflated, 5 to 9 chambers per whorl; wall thick, coarsely perforate, bilamellar, with dark organic lining; pillars developed in the wall, 80 to 136 μm in diameter; aperture umbilical, interiomarginal, slitlike with thick lip.

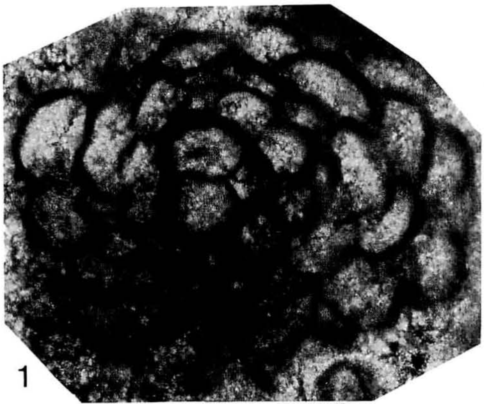
Stratigraphic horizon: Yusan and Okimura Formations, and Sekimon Limestone.

Remarks: The present form is assigned to *Eorupertia boninensis* (Yabe and Hanzawa), based on detailed observation of the topotype specimens.

Explanation of Plate 58

Planorbulinella larvata (Parker and Jones)

1–5, 9. Horizontal sections. 1–5. Megalospheric forms, 9. Microspheric form, 1, 4. ×100, 2–3, 5, 9. × 116, 6, 8, 10. Axial sections of megalospheric form. 6. ×40, 8. ×100, 10. ×116, 7. Oblique section of microspheric form. ×43. Minamizaki Limestone; Localities: 1, 5, 8. 49, 3. 46 (Both of 1304 Section), 2. 9704 (Minami-Jima), 4. 21.5, 6. 15 (Both of 1301 Section). Sekimon Limestone; Localities: 7, 9–10. 72203 (Sekimon Karst Section).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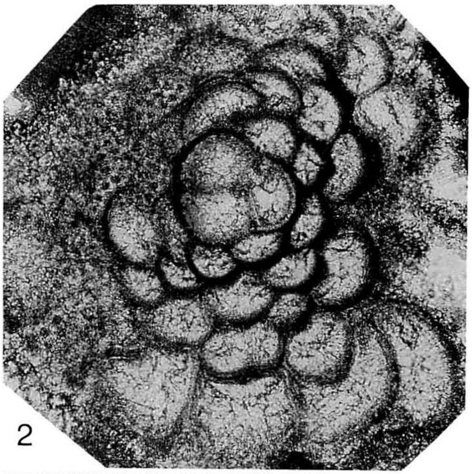
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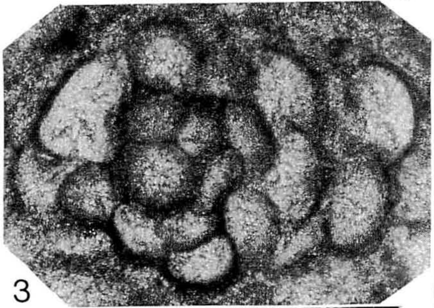
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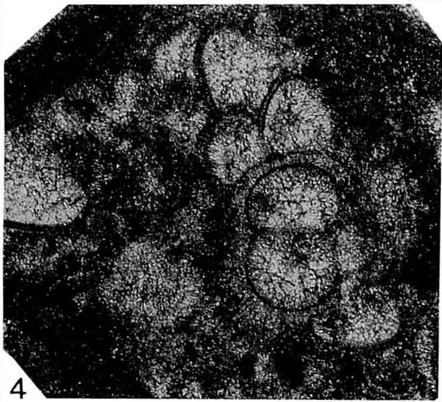
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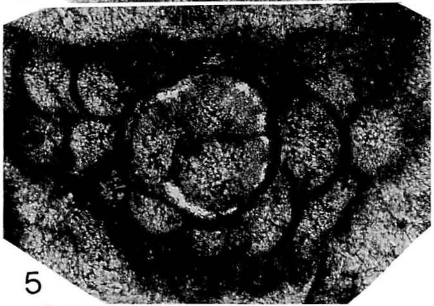
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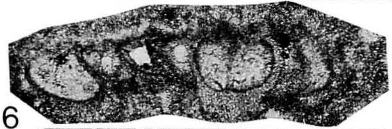
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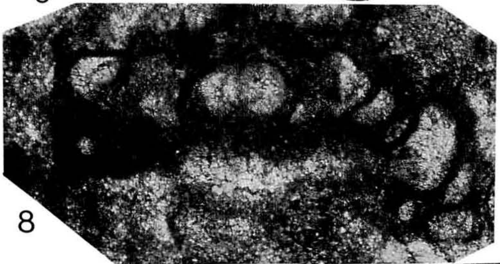
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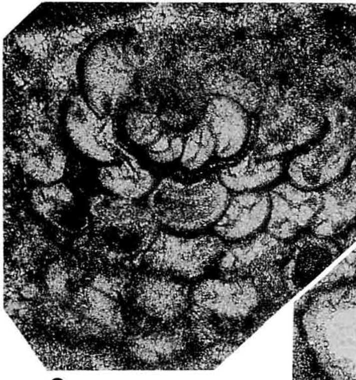
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Genus *Victoriella* Chapman and Crespin, 1930

Victoriella conoidea (Rutten, 1914)

Plate 59, figures 4–5.

Carpenteria conoidea Rutten, 1914a, p. 47, pl. 7, figs. 7–9.
Carpenteria proteiformis Goës var. *plecte* Chapman, 1921, p. 320, pl. 51, fig. 3
Victoriella plecte (Chapman). Chapman and Crespin, 1930, p. 110–112, pl. 7, figs. 1–4.
Victoriella conoidea (Rutten). Glaessner and Wade, 1959, p. 194–196, 198, 203, pl. 1, figs. 1–5, pl. 2, figs. 1–5, 7–10, pl. 3, fig. 3.

Description: Test conical, with small attachment area at apex of the cone; 1.27 to 1.98 mm in length, and 0.96 to 1.15 mm in width; form ratio of length to width, 1.32 to 1.59. Early chambers trocospiral, later extending upward from base, and high-spired around axis hollow; chambers inflated; three to four per whorl; sutures depressed; wall, calcareous, bilamellar, 88 to 96 μm thick; with some interlocular spaces, 10 to 16 μm in diameter; and coarsely perforate, except imperforate around aperture; pillars present, on outer lamella, 104 to 146 μm in diameter; aperture umbilical, bordered by thick lip.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form differs from *Carpenteria balaniformis* Gray, 1858, of the type species of *Carpenteria* Gray, 1858 in its form, without carinate at the periphery, and in having fewer chambers per whorl. The present form is assigned to *Victoriella conoidea* (Rutten), described by Glaessner and Wade (1959). *Victoriella conoidea* greatly resembles *Victoriella hamiltonensis* Glaessner and Wade, 1959, type species of *Wadella* Srinivasan, 1966, in every respect of similar shell form, trochospiral coil, wall structure, and apertural situation, and the former may be a senior synonym of the latter.

Superfamily Asterigerinacea d'Orbigny, 1839

Family Lepidocyclinidae Scheffen, 1932

Subfamily Eulepidininae Matsumaru, 1991

Genus *Eulepidina* H. Douvillé, 1911

Eulepidina dilatata (Michelotti, 1861)

Explanation of Plate 59

Eorupertia boninensis (Yabe and Hanzawa)

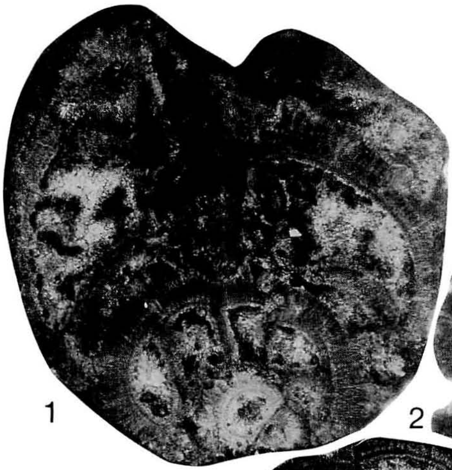
1–2. Vertical sections of megalospheric form, 3. Horizontal section. ×43. Yusan Formation; Localities: 1. MI81804, 2. MI81805, 3. MI81807 (Miyukihama Section).

Victoriella conoidea (Rutten)

4–5. Vertical sections. ×40. Minamizaki Limestone; Localities: 4. 3.5 (1304 Section), 5. 5.4 (1301 Section).

Lenticulina sp.

6, 8–9. Oblique sections. 6. ×43, 8–9. ×100, 7. Axial section. ×43. Minamizaki Limestone; Localities: 6. 37.5 (801S Section), 7. 13 (1302 Section), 8–9. 5 (1304 Section).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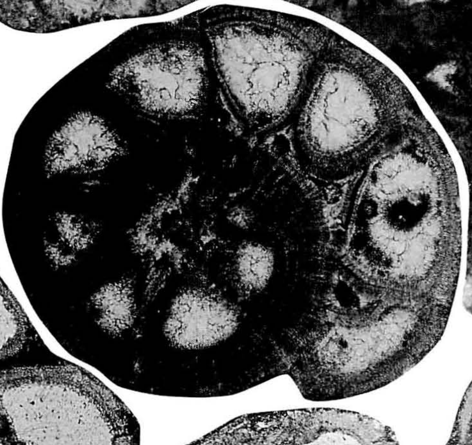
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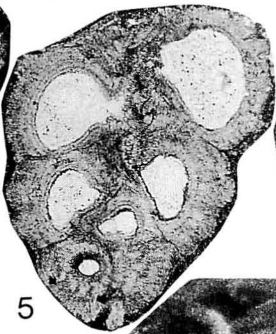
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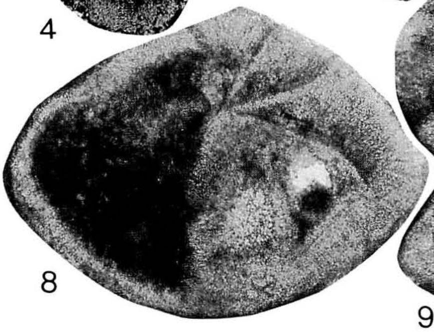
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Plate 60, figures 1–6; Plate 61, figures 1–6; Plate 62, figures 1–7; Plate 63, figures 1–6; Plate 64, figures 1–2; Fig. 20–2, 4; Fig. 30.

Orbitoides dilatata Michelotti, 1861, p. 17, pl. 1, figs. 1–2.

Orbitoides (Lepidocyclina) dilatata (Michelotti), Gümbel, 1870, p. 139–140, pl. 4, figs. 45a–b, 46–47.

Lepidocyclina elephantina Munier-Chalmas, 1891, p. 76; Lemoine and R. Douvillé, 1904, p. 13–14, pl. 2, figs. 13, 19.

Lepidocyclina dilatata (Michelotti), Lemoine and R. Douvillé, 1904, p. 12–13, fig. 13, pl. 1, fig. 2; pl. 2, figs. 8, 21; pl. 3, figs. 10, 15; Checchia-Rispoli, 1909, p. 56, 60, 99, 130, pl. 5, fig. 53, pl. 7, fig. 15; Silvestri, 1910, p. 139–156, fig. 19–20, 22–25, pl. 1, figs. 4–10; Checchia-Rispoli, 1911, p. 298, pl. 1, figs. 23–24; Silvestri, 1924b, p. 7–29, pl. 1, figs. 22–25; Silvestri, 1937, p. 176, pl. 22, fig. 3.

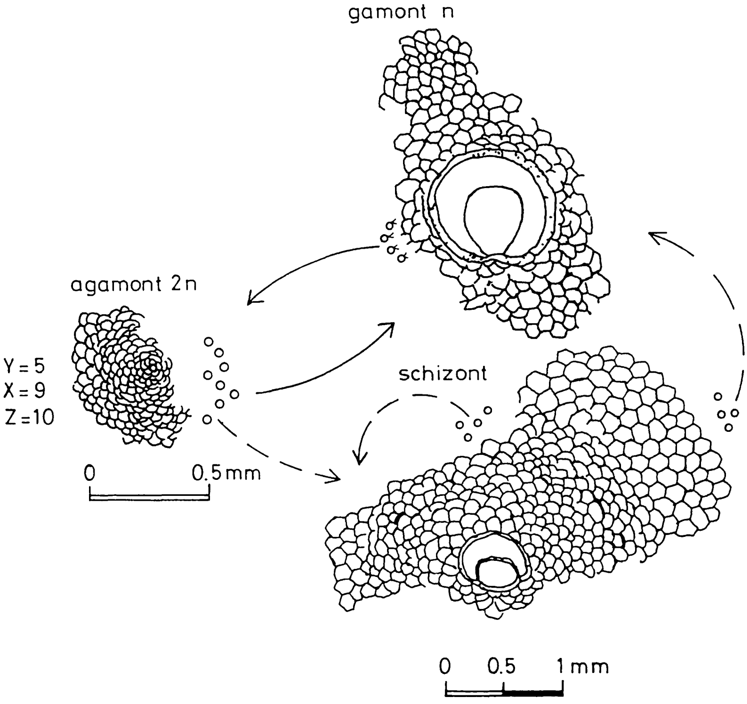

Fig. 30. Hypothetical trimorphic life cycle of *Eulepidina dilatata* (Michelotti). n: haploid; 2n: diploid. The scale is applicable to all three forms. The microspheric agamont, megalospheric gamont, and megalospheric schizont are sketched from A. Sirotti's specimen (Matsumaru, 1991, fig. 4), 1304–17.5–3 specimen (Plate 61, fig. 2), and 1304–25–11 specimen (Plate 60, fig. 2), respectively.

Explanation of Plate 60

(All figures ×40)

Eulepidina dilatata (Michelotti)

1–6. Equatorial sections of megalospheric form. 1, 3–6. Gamont megalospheric forms, 2. Schizont megalospheric form. Minamizaki limestone; Localities: 1. 12, 2–3. 25, 4. 35, 5–6. 15 (All belonging to 1304 Section).


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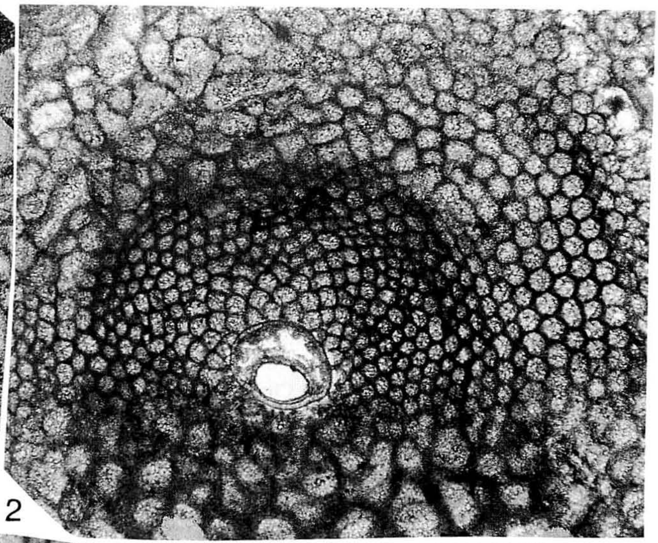
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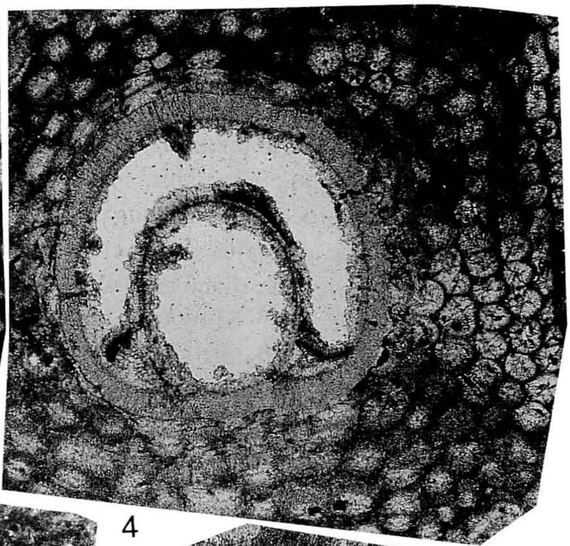
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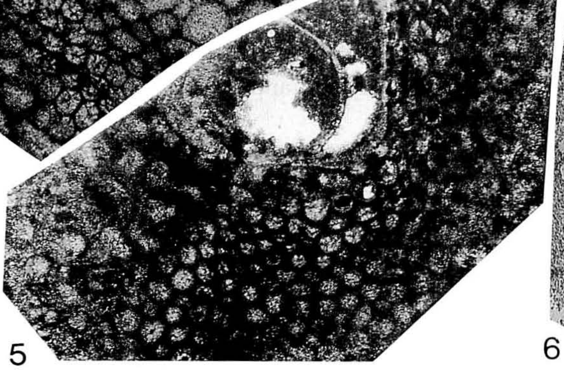
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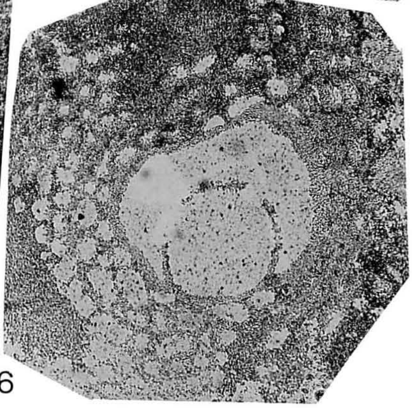
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Lepidocyclina raulini Lemoine and R. Douvillé, 1904, p. 11–12, pl. 1, figs. 3, 6, 9, 13, 16, pl. 2, figs. 3, 10, pl. 3, figs. 4, 14.

Lepidocyclina schlumbergeri Lemoine and R. Douvillé, 1904, p. 14, pl. 1, fig. 10, pl. 2, fig. 6.

Eulepidina formosolideus H. Douvillé, 1925, p. 71, pl. 3, figs. 2–4; Llueca, 1929, p. 339–340, pl. 30, figs. 7–13, pl. 31, figs. 1–3.

Eulepidina dilatata (Michelotti). H, Douvillé, 1925, p. 71, 99, figs. 56a–b, pl. 4, figs. 1–4, pl. 5, figs. 1–4; Llueca, 1929, p. 340–341, pl. 31, figs. 4–10, pl. 33, figs. 41–43; Bourcart and David, 1933, p. 49, pl. 1, fig. 4, pl. 7, figs. 1–2.

Eulepidina eodilateta H. Douvillé, 1925, p. 73; Lange, 1968, p. 49, pl. 2, fig. 1.

Eulepidina roberti H. Douvillé, 1925, p. 73, fig. 57, pl. 3, fig. 5; Flandrin, 1938, p. 104, figs. 16–17, pl. 11, figs. 9–11, pl. 12, figs. 2–5.

Lepidocyclina (Eulepidina) dilatata (Michelotti). van der Vlerk, 1928, p. 193, pl. 7, figs. 3a–c; Brönnimann, 1940, p. 44–46, fig. 11, pl. 4, figs, 4, 6, 10, pl. 5, figs. 15–17, pl. 6, figs. 6–7.

Eulepidina dilatata dilatata (Michelotti). Lange, 1968, p. 51–55, pl. 3, fig. 1; Matsumaru, 1971b, p. 184–185, pl. 22, figs. 28–38.

Eulepidina ephippioides (Jones and Chapman). Lange , 1968, p. 45, 47–49, pl. 2, fig. 3 (non fig. 2).

Description: Test large, thin to thick lenticular; outline circular through subcircular to polygonal; generally with pillars and pseudopillars distributed on general surface of megalospheric test, and with stout pillars on surface of microspheric test. Megalospheric gamont test, diameter 5.6 to 13.0 mm, diameter of central boss 3.8 to 4.8mm, and thickness at central portion 1.0 to 2.4 mm; small pillar, 25 to 90 μm in diameter; megalospheric schizont test, diameter 5.0 to 6.5 mm, and thickness at center 1.0 to 1.3 mm in vertical sections; microspheric agamont test, diameter 11.0 to 16.0 mm, diameter of central boss 9.0 mm, thickness at central portion 3.8 to 4.5 mm; stout pillar, 100 to 130 μm in diameter. Gamont and schizont embryonic apparatus, biloculine; eulepidine type in terms of megalospheric nucleoconch, deuteroconch embracing protoconch along its circumference; both surrounded by thick embryonic apparatus wall; pierced by many big stoloniferous foramina and stolons; led to the periembryonic chambers radially on equatorial plane. Gamont form very rarely having protoconch, followed by trochospirally arranged deuteroconch and successive periembryonic chambers (Plate 61, fig. 6). Gamont and schizont periembryonic chambers, followed by radially and concentrically arranged arcuate, ogival to short-spatulate or short-hexagonal equatorial chambers, through ontogeny in equatorial section. Gamont embryonic chambers, protoconch subspherical; internal diameter 290 × 275, 363 × 375, 425 × 450, 490 × 590, 525 × 640, and 625 × 675 μm, from 6 specimens, and deuteroconch reniform; internal diameter 638 × 265, 675 × 193, 700 × 200, 960 × 270, 1000 × 263, and 1100 × 350 μm, from 6 specimens. Schizont embryonic chambers, protoconch subspherical; internal diameter 188 × 133, and 190 × 134 μm, and deuteroconch reniform; internal diameter 325 × 110, and 325 × 115 μm; wall of gamont and schizont embryonic apparatus, 25 to 125 μm and 17 to 18 μm thick, respectively; height of gamont and schizont embryonic apparatus, 190 to 700 μm in

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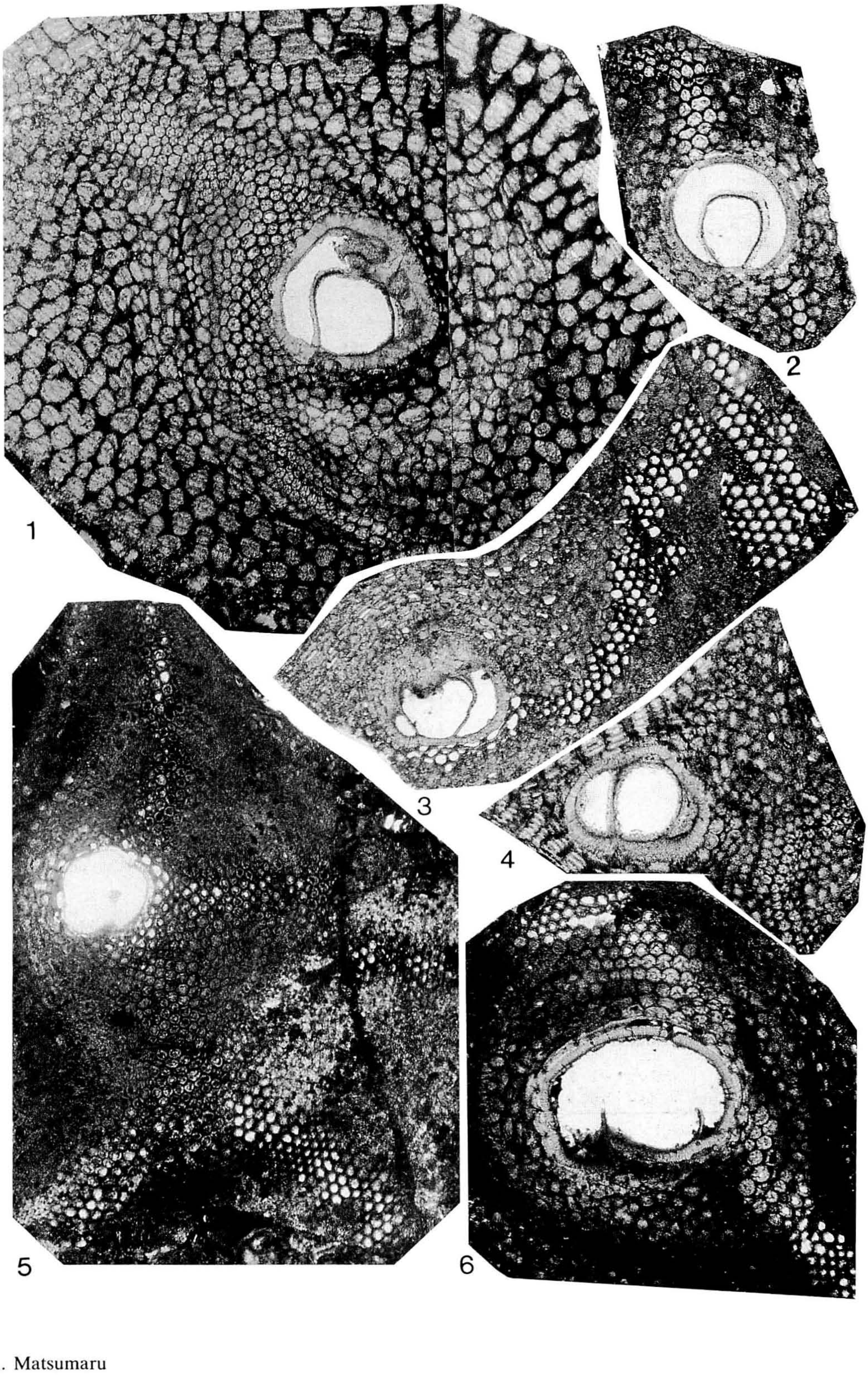
Explanation of Plate 61

(All figures ×20)

Eulepidina dilatata (Michelotti)

1–6. Equatorial sections of gamont megalospheric form. 1. Showing the mature stage of gamont form shown in Figure 3 in Plate 60. Minamizaki Limestone; Localities: 1, 5. 25, 2, 4. 17.5, 3. 32, 6. 35 (All belonging to 1304 Section).



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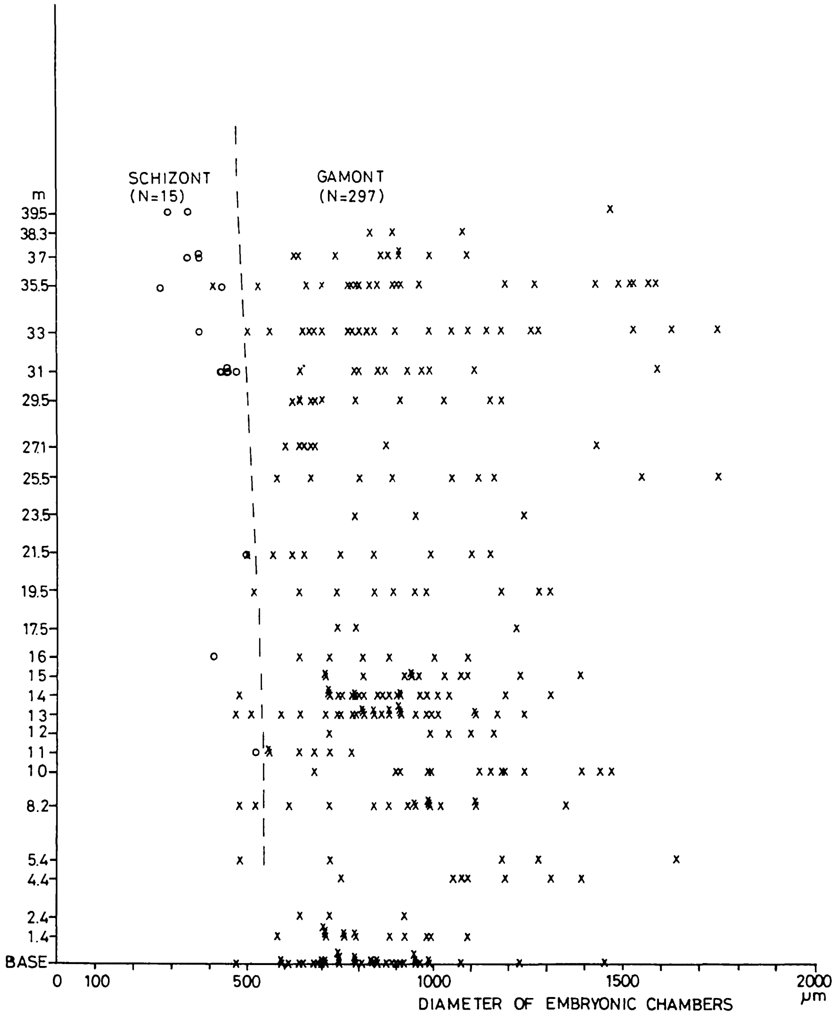


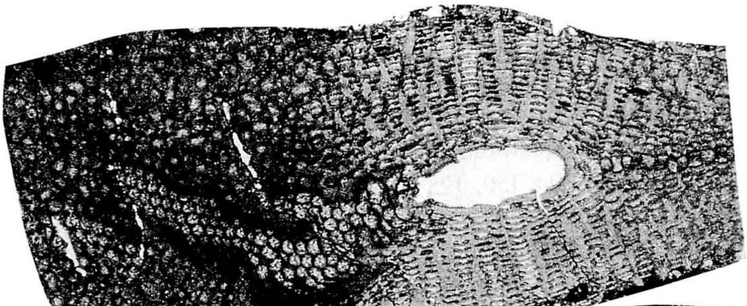
Fig. 31. Scattergram showing the relation between the maximum diameter of embryonic chambers of the schizont form (circles) and the gamont form (crosses) of *Eulepidina* in equatorial, oblique, and vertical sections, and their stratigraphic occurrences in 1301 section, Minamizaki Cape, Chichi-Jima, Ogasawara Islands. The dotted line separates the main fields of schizont and gamont forms. The schizont form is 4.8% of the total number of forms. N is the number of specimens.

Explanation of Plate 62

(All figures ×20)

Eulepidina dilatata (Michelotti)

1. Equatorial to axial transitional section showing twisted megalospheric form, 2–7. Axial sections of megalospheric form. Minamizaki Limestone; Localities: 1. 17.5, 2. 25, 3. Teratological megalospheric form with three nucleoconchs. 11, 4. 23, 5. 10, 6. Base (All belonging to 1304 Section), 7. 9707 (9308 Section).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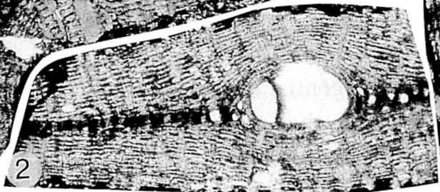
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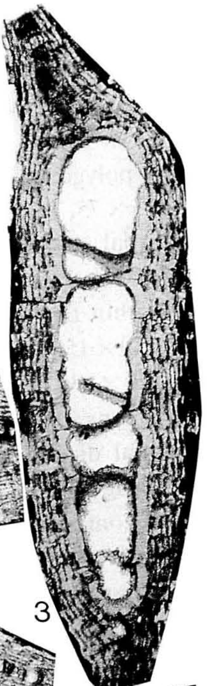
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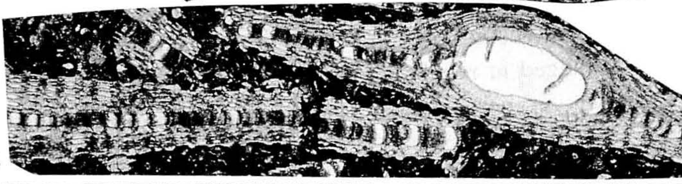
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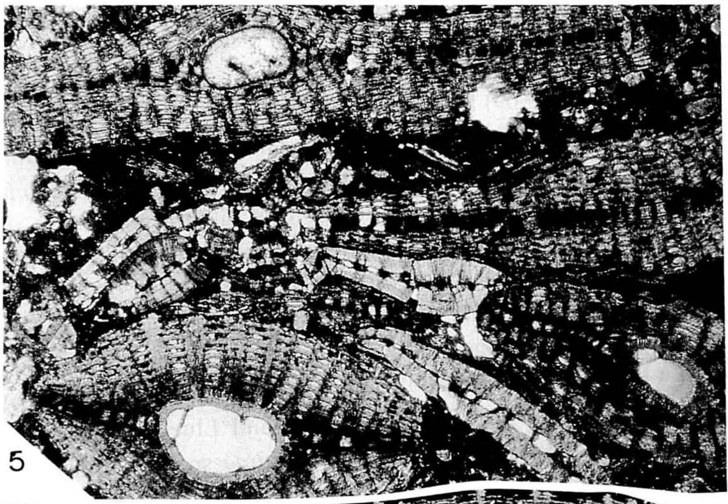
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vertical section. Arcuate principal auxiliary chamber of gamont and schizont, formed directly from deutroconch by big deuterostolon; of dimmension 38 × 63, 38 × 68, 50 × 125, 55 × 100, 63 × 75, and 90 × 125 μm, and 25 × 40 μm to 30 × 40 μm, in inner radial and tangential diameters, respectively. Equatorial chambers of gamont, schizont, and agamont, arcuate in infant stage at center, but spatulate to hexagonal near adult stage through ontogeny, and circular to polygonal arrangement in equatorial section; of dimension 48 × 50, 50 × 75, 60 × 120, 75 × 75, 80 × 100, 88 × 100, 100 × 150, 125 × 150, and 50 × 55 μm, in inner radial and tangential diameter within a radius of 1 mm; 50 × 50, 83 × 75, 100 × 75, 100 × 85, 100 × 100, 100 × 125, 110 × 125, 160 × 175, and 65 × 75 μm, in inner radial and tangential diameter within that of 2 mm; 65 × 50, 85 × 85, 85 × 105, 105 × 80, 110 × 125, 125 × 105, 135 × 100,150 × 150, and 110 × 125 μm, in inner radius and tangential diameter within that of 3 mm; 120 × 130 μm in inner radius and tangential diameter within that of 4 mm; 125 × 140 μm in inner radius and tangential diameter within that of 5 mm; 150 × 135 μm in radius and tangential diameter within that of 6 mm, and 140 × 150, and 205 × 140 μm, in inner radial and tangential diameter within that of 7 mm, respectively. Equatorial chambers of gamont, schizont, and agamont, gradually increasing height of equatorial chambers from central part to periphery in vertical section. Lateral chambers of gamont, schizont, and agamont, rectangular cavities arranged in regular tiers; 6 to 26 layers of lateral chambers over central portion in vertical section in gamont and schizont, and more than 36 layers in agamont; of dimension 100 × 13, 110 × 25, 125 × 25, 125 × 30, 130 × 12, 130 × 25, 150 × 38, 165 × 30, 170 × 25, 200 × 18, 210 × 40, 250 × 30, and 250 × 40 μm, in inner length and height, respectively. Floors and roofs, 8 to 35 μm thick.

Stratigraphic horizon: Minamizaki limestone.

Remarks: H. Douvillé (1925, p. 68–69) has classified 7 species: *levis*, n. sp., *elephantina* (Munier-Chalmas), *raulini* (Lemoine and R. Douvillé), *formosoides*, n. sp., *eodilatata*, n. sp., *dilatata* (Michelotti), and *roberti*, n. sp., belonging to *Lepidocyclina (Eulepidina)* from Europe, based on the characteristics of the development of pillars, similar test shape, height of equatorial chamber, thickness of its chamber wall, and the size of embryonic chambers. Moreover, Llueca (1927, 1929) described three species from Spain: *Lepidocyclina (Eulepidina) pachecoi*, *L.(E.) hernandezi*, and *L. (E.) royoi*, in addition to Douvillé's 7 species. Although the description of the most species stated above is fragmental, critical reading of the description and illustration has enabled the author to conclude that there is a gradation among these species, except for *Eulepidina levis* and Llueca's three species. Comparing Chichi-Jima *Eulepidina* species with Europe *Eulepidina* species critically, they

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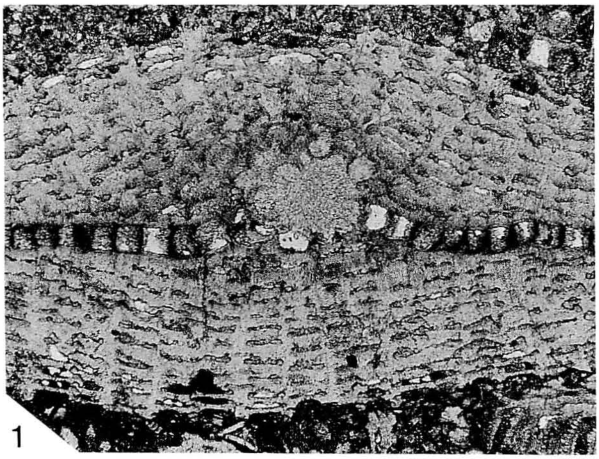
Explanation of Plate 63

(All figures ×40)

Eulepidina dilatata (Michelotti)

1–3. Parts of axial section of megalospheric form showing trochospiral arrangement of embryonic to nepionic chambers. 4. Part of axial section of megalospheric form showing two rows of big stoloniferous foramina (15–20 microns across) in the nucleoconch wall, 5–6. Parts of axial section showing pectinations which develop on distal side of equatorial chamber wall, and some division of equatorial layer in peripheral zone. Minamizaki Limestone; Localities: 1, 3–6. 23 (1304 Section), 2. 33 (1301 Section).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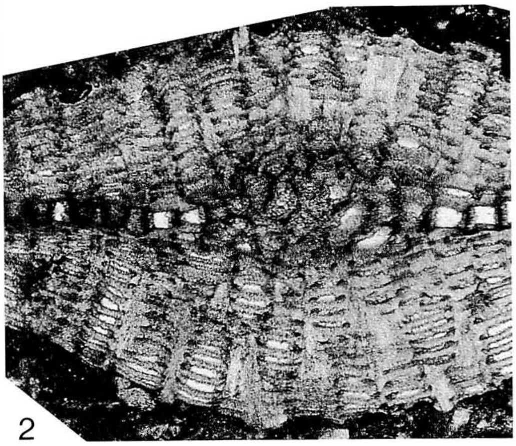
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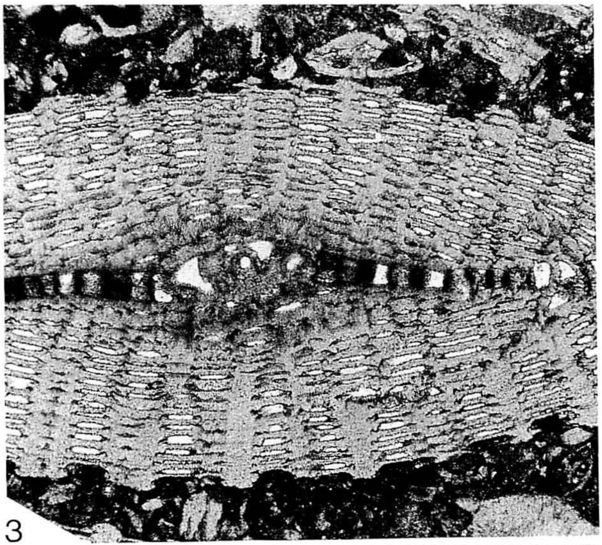
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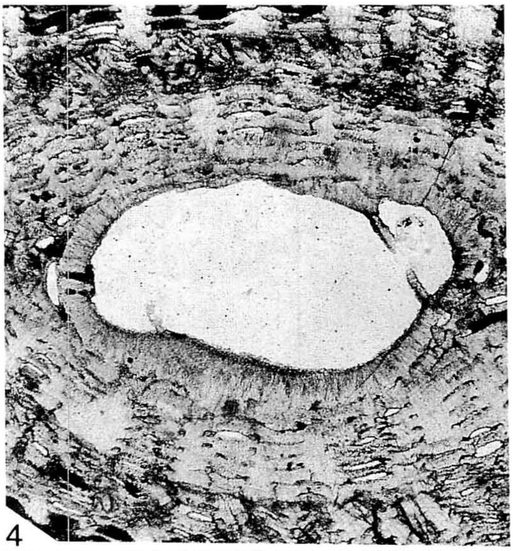
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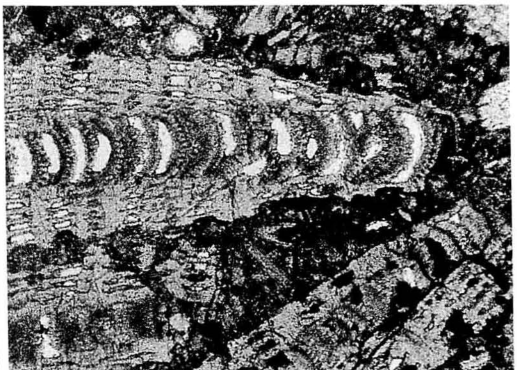
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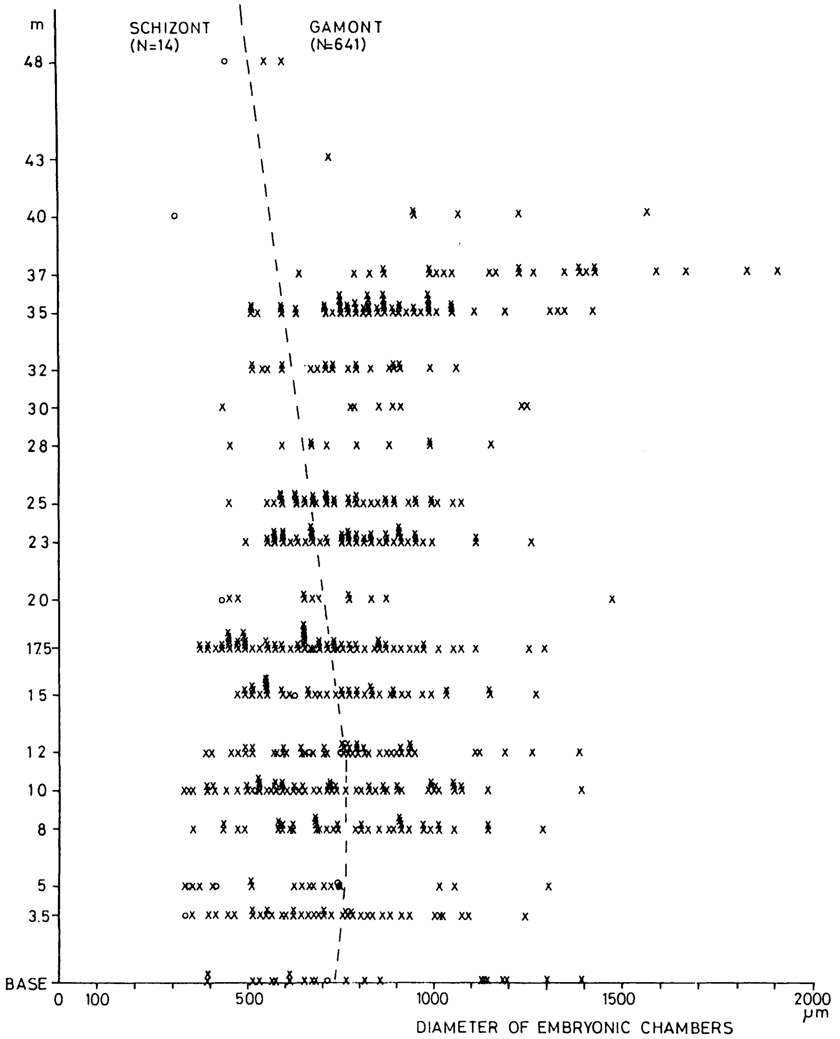

Fig. 32. Scattergram showing the relation between the maximum diameter of embryonic chambers of schizont and gamont forms of *Eulepidina*, and their stratigraphic occurrence in 1304 section, Minamizaki Cape, Chichi-Jima, Ogasawara Islands. The schizont form is 2.1% of the total number of forms.

Explanation of Plate 64

(All figures ×20)

Eulepidina dilatata (Michelotti)

1. Axial section of agamont microspheric form, 2. Oblique section of agamont microspheric form. Minamizaki Limestone; Localities: 1. 25, 2. 32 (Both of 1304 Section).

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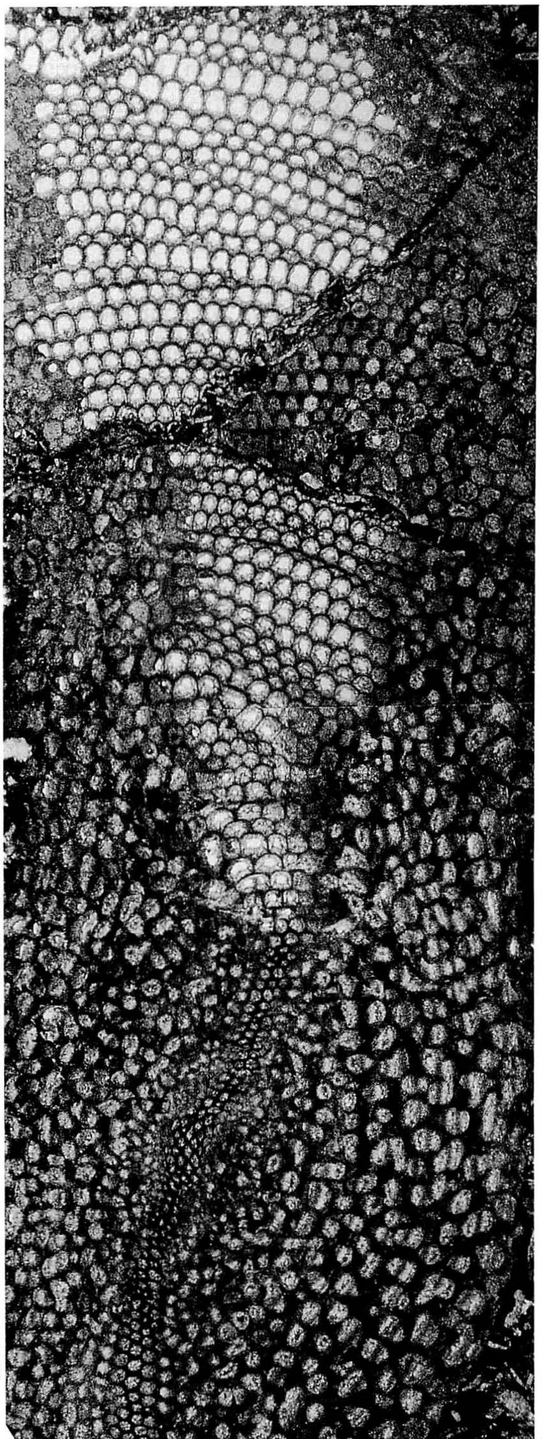

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are all combined under the name *Eulepidina dilatata* (Michelotti, 1861), because Douvillé described apparently based on not a specific character, but an ecological character recognized in the morphological variation, which occurs under the ecological condition from lagoonal or sand shoals to reef flat, from reef and reef-front to deep fore-reefs, and from reef slope to reef talus.

According to Frost and Langenheim (1974, p. 170–172), Caribbean species of *Lepidocyclina (E.) undosa* Cushman in inter-reef facies is described as a lenticular test of no more than 10 mm in diameter, embryonic chambers completely eulepidine, but exceptionally slight nephrolepidine, small in diameter of all embryonic chambers, and thin in thickness of embryonic apparatus wall. In contrast, the same species in reef-facies is described as a large lenticular test to variably selliform, generally of 10 to 25 mm in diameter; embryonic

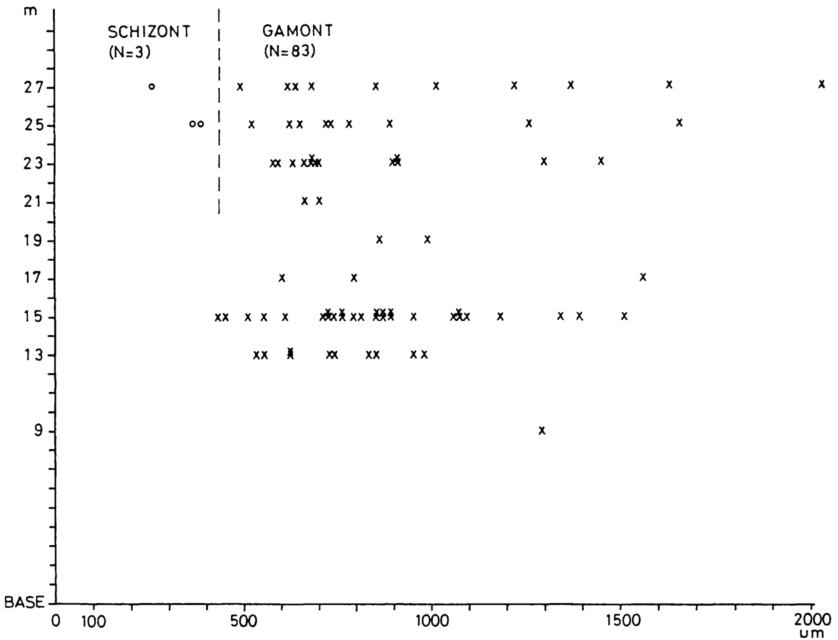


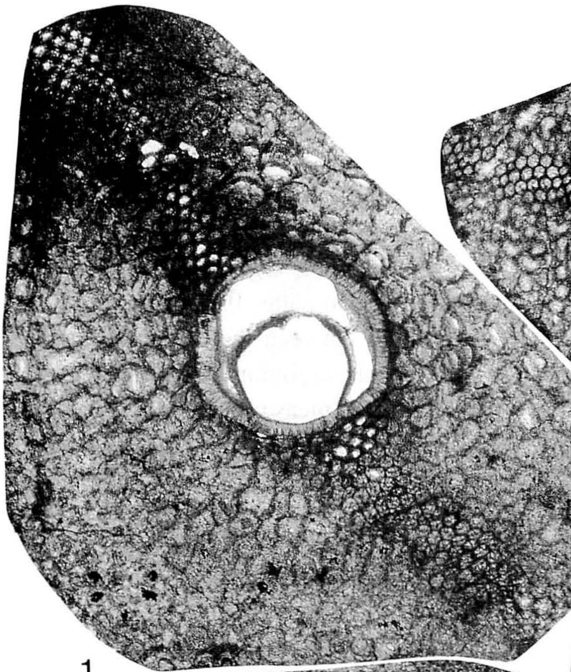
Fig. 33. Scattergram showing the relation between the maximum diameter of embryonic chambers of schizont and gamont forms of *Eulepidina*, and their stratigraphic occurrence in 71801 section, Minamizaki Cape, Chichi-Jima, Ogasawara Islands. The schizont form is 3.5% of the total number of forms.

Explanation of Plate 65

(All figures ×20)

Eulepidina ephippioides (Jones and Chapman)

1–6. Central oblique sections of gamont megalospheric form. Minamizaki Limestone; Localities: 1, 3. 12, 4, 5. Base (All belonging to 1301 Section), 2, 6. 17.5 (1304 Section).



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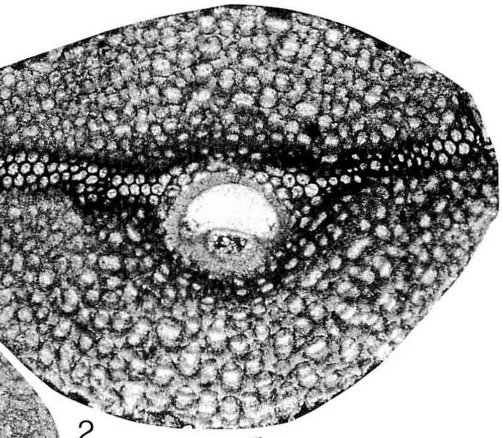

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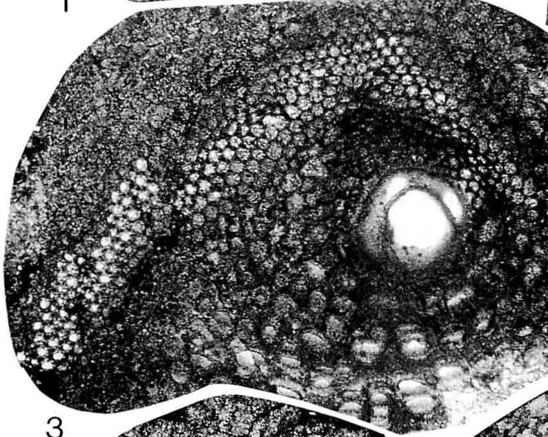

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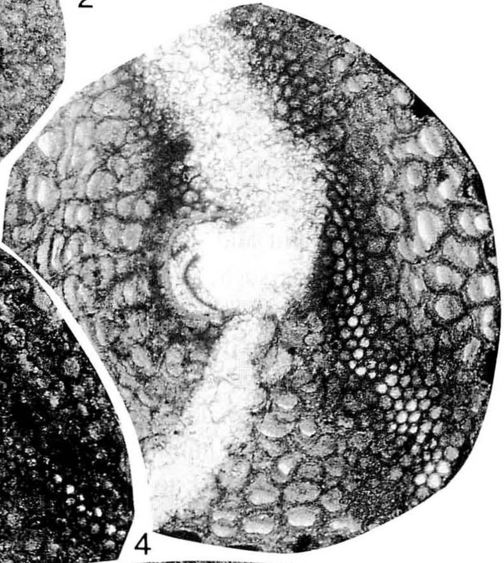

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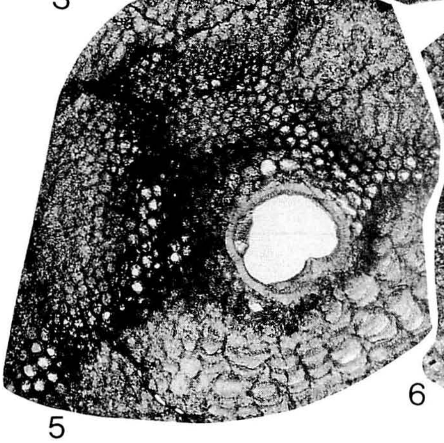

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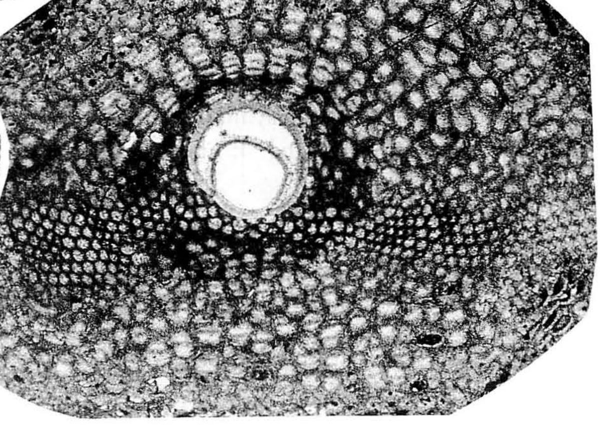

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chambers of many specimens are half as large as the largest chambers of inter-reef specimens, and lateral chambers are of the same diameter as larger megalospheric inter-reef specimens. Although a worldwide comparison of the genus *Eulepidina* species should be made as based on Cole's opinion (1957a, p. 347), the author retained two species of *Eulepidina dilatata* (Michelotti) and *E. ephippioides* (Jones and Chapman) from Chichi-Jima, referring to many literature sources.

The author investigated, at first, the size of embryonic chambers of *Eulepidina dilatata* and *E. ephippioides* from the Minamizaki Limestone, Chichi-Jima, Ogasawara Islands, in order to examine the embryonic acceleration of *Eulepidina* H. Douvillé, 1911 with the lapse of time. Figures 31–33 are scattergrams showing the relation between the maximum inner diameter of embryonic chambers of all the *Eulepidina* and their stratigraphic occurrences in 1301, 1304, and 71801 sections. The size of embryonic chambers measured from about 2000 preparations of available thin sections of *Eulepidina* specimens was plotted, and discrimination of species identification was not necessary. As a result, the size of embryonic chambers of all the *Eulepidina* was shown to tend to slightly increase with the lapse of time (Fig. 31–33). It is assumed that this conclusion is almost the same tendency of inceasing that Lange (1968) examined regarding *Eulepidina ephippioides* (Jones and Chapman), *E. eodilatata* H. Douvillé, *E. dilatata* (Michelotti), and *E. dilatata* (Michelotti) *concentrica* (Silvestri) from the Oligocene beds, Aphales-Bucht, Greece. Moreover, from the present examination of Ogasawara *Eulepidina*, gamont and schizont forms of the genus *Eulepidina* were newly discriminated (Figs. 31–33). As such, it becomes clear that the occurrence frequency of schizont form varies from 2.1 to 4.8% for the total.

Secondary, the genus *Eulepidina* species are classified into two, as follows: Specimens with both large embryonic apparatus, spatulate to hexagonal equatorial chambers of cyclical arrangement and alternate in position from one annulus to another in equatorial section, and a large test that is thin and lenticular in vertical section, were identified as *Eulepidina dilatata* (Michelotti). Thick to inflated lenticular specimens with features both small embryonic apparatus and spatulate and hexagonal equatorial chambers arranged typically in cyclical curves that are composed of radially reduced and tangentially progressed actual size, were identified as *Eulepidina ephippioides* (Jones and Chapman). As there are no exact equatorial sections of both microspheric forms of *Eulepidina dilatata* and *E. ephippioides* from Chichi-Jima, the author could not examine the nepionic types of the microspheric juvenarium. However, microspheric *Eulepidina dilatata* from Scicca, Sicily, has 5 spirally disposed chambers (= Y), 9 chambers developed from a pair of primary and secondary spires (= X), and 10 first symmetrical chambers, counting from the proloculus (= Z) (Matsumaru, 1991, p. 889, fig. 4; Fig. 30). Also, microspheric *Eulepidina ephippioides* from

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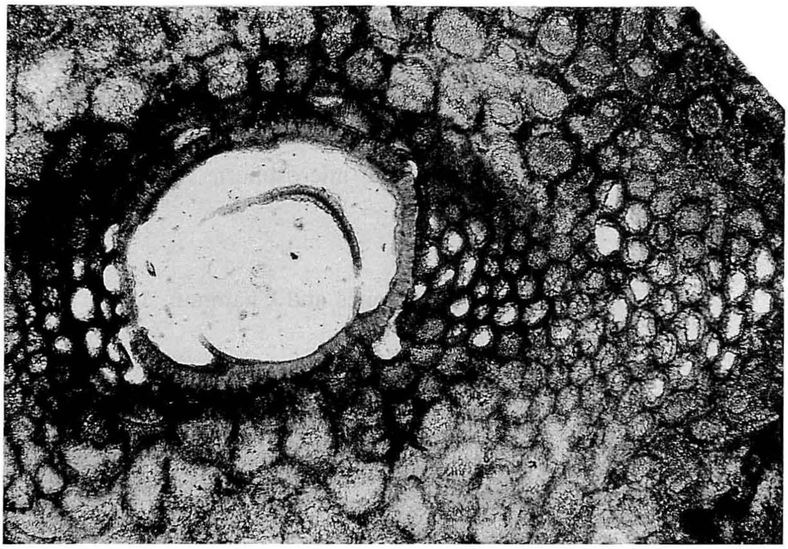
Explanation of Plate 66

(All figures ×40)

Eulepidina ephippioides (Jones and Chapman)

1–2. Centered oblique sections of gamont megalospheric form showing embryonic, and nepionic chambers, 3. Part of oblique section showing development and arrangement of equatorial chambers. Minamizaki Limestone; Localities: 1. 12, 3. 21.5 (Both of 1301 Section), 2. 25 (1304 Section).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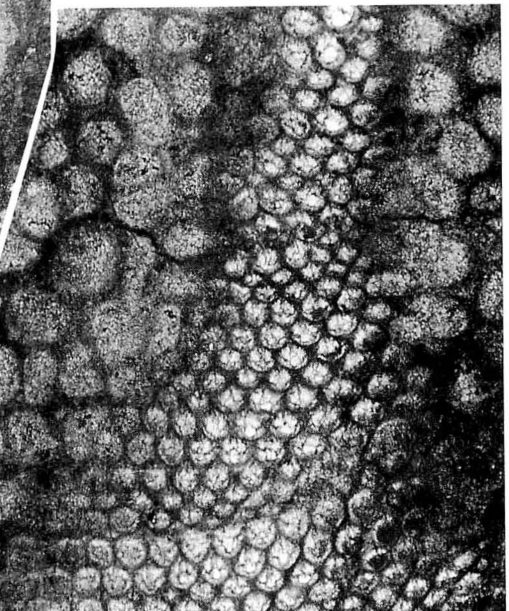
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North West Cape, Australia, has the following chamber budding formation: 6 as Y parameter, 10 and 12 as X parameter, and 12 as Z parameter, for 1j specimen; 7 as Y parameter, 10 and 12 as X parameter, and 13 as Z parameter, for 2g specimen; and 6 as Y parameter, 9 as X parameter, and 10 as Z parameter, for 2h specimen (Chaproniere, 1984, fig. 19-1j, -2g, and -2h). Therefore microspheric *Eulepidina dilatata* can be regarded as being of minor difference in chamber budding formation from microspheric *Eulepidina ephippioides*. As such, both species is separated.

Eulepidina ephippioides (Jones and Chapman, 1900)

Plate 65, figures 1–6; Plate 66, figures 1–3; Plate 67, figures 1–6; Plate 68, figures 1–3; Plate 69, figures 1–4; Plate 70, figures 1–5, Fig. 20–5.

Orbitoides (Lepidocyclina) ephippioides Jones and Chapman, 1900, p. 251–252, pl. 20, fig. 9.
Orbitoides (Lepidocyclina) murrayana Jones and Chapman, 1900, p. 252–253, pl. 21, fig. 10.
Lepidocyclina (Eulepidina) formosa Schlumberger, 1902, p. 251, pl. 7, figs. 1–3; Yabe, 1919, p. 43–46, pl. 6, figs. 1b, 2, 4b, 6–7b, 8b, pl. 7, figs. 1b?, 4, 12b, 14b; Yabe and Hanzawa, 1925c, p. 105, pl. 25, figs. 1–2; Yabe and Hanzawa, 1929, p. 163–164, pl. 2, fig. 4, pl. 3, figs. 1–3, pl. 5, figs. 5–6, pl. 7, fig. 6, pl. 8, fig. 3, pl. 9, fig. 4, pl. 12, fig. 9; Cole and Bridge, 1953, p. 34–35, pl. 7, figs. 10, figs, 1–2?, 3–6; Cole, 1954, p. 594–597, pl. 216, figs. 1–16, pl. 217, figs. 9–11, pl. 218, figs. 1, 3–4; Hanzawa, 1957, p. 72–73, pl. 16, figs. 1a, b–2a, b, 6, pl. 17, figs. 1?–6.
Orbitoides richthofeni Smith, 1906, p. 205, pl. 1, fig. 1.
Lepidocyclina (Eulepidina) monstrosa Yabe, 1919, p. 43–43, pl. 6, fig. 5a, pl. 7, figs. 11–12a, 13.
Lepidocyclina (Eulepidina) gibbosa Yabe, 1919, p. 46, pl. 6, figs. 3, 4c, 7c?
Lepidocyclina ephippioides Jones and Chapman. Nuttall, 1926b, p. 34–36, pl. 5, figs. 1–3, 8, 10.
Lepidocyclina (Eulepidina) ?formosa Schlumberger. Nuttall, 1926b, p. 22–30.
Lepidocyclina (Eulepidina) badjirraensis Crespin, 1952, p. 29–30, pl. 6, figs. 1–2, 5, pl. 7, figs. 1–2, 4, pl. 8, figs. 1–5; Cole, 1957a, p. 345–346, pl. 108, figs. 1–3, pl. 109, figs. 9–10; Chaproniere, 1984, p. 53–54, pl. 1, fig. 6, pl. 12, figs. 1–3, 5, pl. 18, figs. 11–15, pl. 25, figs. 15–16, text-figs. 19–2a–h.
Lepidocyclina (Eulepidina) abdopustula Cole, 1954, p. 594, pl. 215, figs. 9–10, pl. 218, figs. 7–11.
Lepidocyclina (Eulepidina) ephippioides (Jones and Chapman). Cole, 1957a, p. 346–347, pl. 108, figs. 4–13, pl. 109, figs. 11–15; Cole, 1957b, p. 775, pl. 239, figs. 5–6; Coleman, 1963, p. 15–16, pl. 4, figs. 6–12, pl. 5, figs. 1–3; Adams and Belford, 1974, p. 500–502, pl. 74, figs. 4–6, 9, 12, 14, text-fig. 12; Chapronier, 1983, p. 40–41, pl. 3, fig. 10, pl. 5, figs. 5–8, pl. 6, fig. 1, text-fig. 19-1a-j.
Eulepidina ephippioides (Jones and Chapman). Lange, 1968, p. 45, 47–49, pl. 2, fig. 2 (non fig. 3).

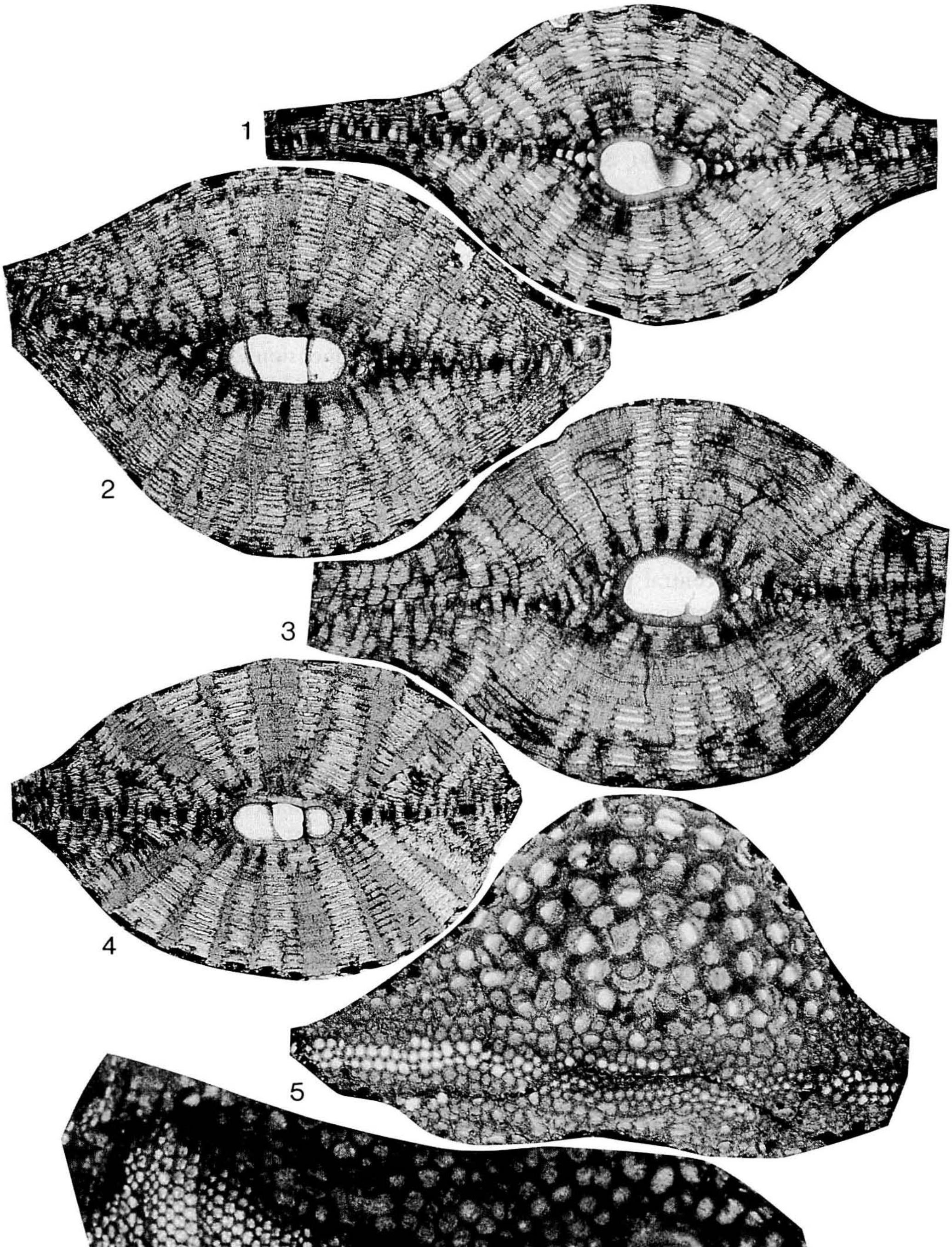
Description: Test large, lenticular to strongly inflated, surrounded by narrow rim to wide thin brim; diameter 4.2 to 13.0 mm, diameter of central inflated boss from 2.7 to 6.2 mm, and thickness through center 1.2 to 4.0 mm; outline subcircular to rounded; surface smooth, umbonal part covered by polygonal mesh of test materials and pillars; 10 to 217 μm in diameter, rarely 450 to 625 μm in diameter. Megalospheric embryonic aparatus, biloculine;

Explanation of Plate 67

(All figures ×20)

Eulepidina ephippioides (Jones and Chapman)

1–4. Axial sections of gamont megalospheric form, 5–6. Oblique sections, 5. Megalospheric form, 6. Agamont microspheric form. Minamizaki Limestone; Localities: 1, 5. Base, 6. 21.5 (Both of 1301 Section), 2, 4. 17.5, 3. 25.5 (Both of 1304 Section).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protoconch and deuteroconch, eulepidine type; inner diameter of whole embryonic apparatus, 415 to 1000 μm across both protoconch and deuteroconch; and wall of embryonic apparatus generally 50 to 125 μm thick, rarely 20 to 30 μm thick. Protoconch spherical to subspherical; internal diameter 275 × 210, 435 × 348, 488 × 425, 543 × 543, 560 × 450, 565 × 475, 590 × 550, 625 × 575, and 665 × 600 μm, from 9 specimens, and deuteroconch reniform; internal diameter 520 × 210, 670 × 209, 875 × 225, 913 × 157+, 870 × 340, 913 × 185, 980 × 300, 975 × 200, and 1000 × 340 μm, from 9 specimens, respectively. Embryonic apparatus 190 to 600 μm high in vertical section; primary periembryonic chamber arcuate shape; of dimension 50 × 125, 63 × 113, 70 × 125, 75 × 120, and 88 × 105 μm, in inner radial and tangential diameters. Megalospheric and microspheric equatorial chambers arcuate in infant stage at center,but short-spatulate to short-hexagonal near adult stage through ontogeny, and subcircular to rounded arrangement in equatorial section; of dimension 75 × 100, 80 × 90, 80 × 100, 85 × 120, 100 × 120, 100 × 125, and 125 × 125 μm, in inner radial and tangential diameter within a radius of 1 mm; 65 × 65, 65 × 75, 75 × 100, 80 × 110, 80 × 130, 100 × 80, and 100 × 120 μm, in inner radial and tangential diameter within that of 2 mm; 60 × 80, and 100 × 90 μm, in inner radial and tangential diameter within that of 3 mm, and 125 × 125 μm, in inner radial and tangential diameter within that of 4 mm, respectively. Megalospheric and microspheric lateral chambers rectangularly arranged in regular tiers; 8 to 26 layers of lateral chambers over central portion in vertical section in megalospheric specimen, and more than 30 layers in microspheric specimen. Typical lateral chambers large rectangular, near periphery and over central portion in both generations; and of dimension 112 × 13, 150 × 15, 150 × 30, 165 × 60, 196 × 60, 200 × 30, 200 × 35, 200 × 55, 225 × 25, 225 × 30, 225 × 70, 240 × 22, 260 × 50, 280 × 75, 286 × 16, 290 × 80, 565 × 65, and 565 × 100 μm, in inner length and height. Floors and roofs, 8 to 50 μm thick, rarely 65 μm thick.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The discussion of this species is given in the remarks of *Eulepidina dilatata* (Michelotti). The author agrees with a conclusion in which Grimsdale (1952) and Cole (1957a) regarded *Eulepidina formosa* (Schlumberger, 1902) from the Indo-Pacific region, as being a synonym of *Eulepidina ephippioides* (Jones and Chapman, 1900) from the type locality, Christmas Island, Indian Ocean. Also *Eulepidina gibbosa* (Yabe, 1919), which is similar to *Eulepidina monstrosa* (Yabe, 1919), possess many features in common with *Eulepidina formosa*. The author considers *Eulepidina gibbosa* to be a synonym of *Eulepidina formosa*.

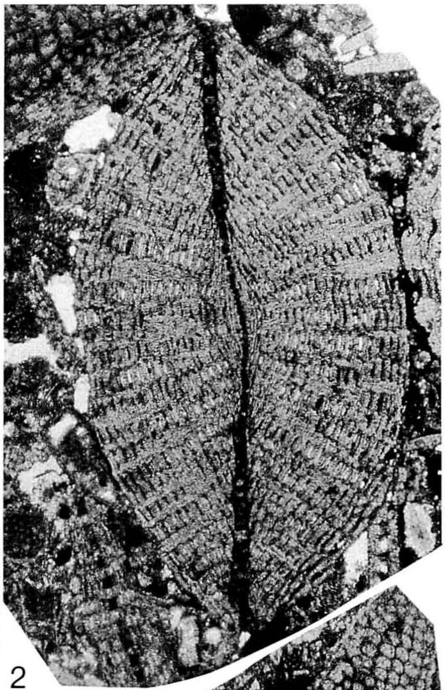
Explanation of Plate 68

(All figures ×20)

Eulepidina ephippioides (Jones and Chapman)

1, 3. Tangential sections showing circular arrangement of short spatulate to short hexagonal equatorial chambers through ontogeny, 2. Axial section of microspheric form. Minamizaki Limestone; Localities: 1. 12, 3. 31 (Both of 1301 Section), 2. 3.5 (All belonging to 1304 Section).

1



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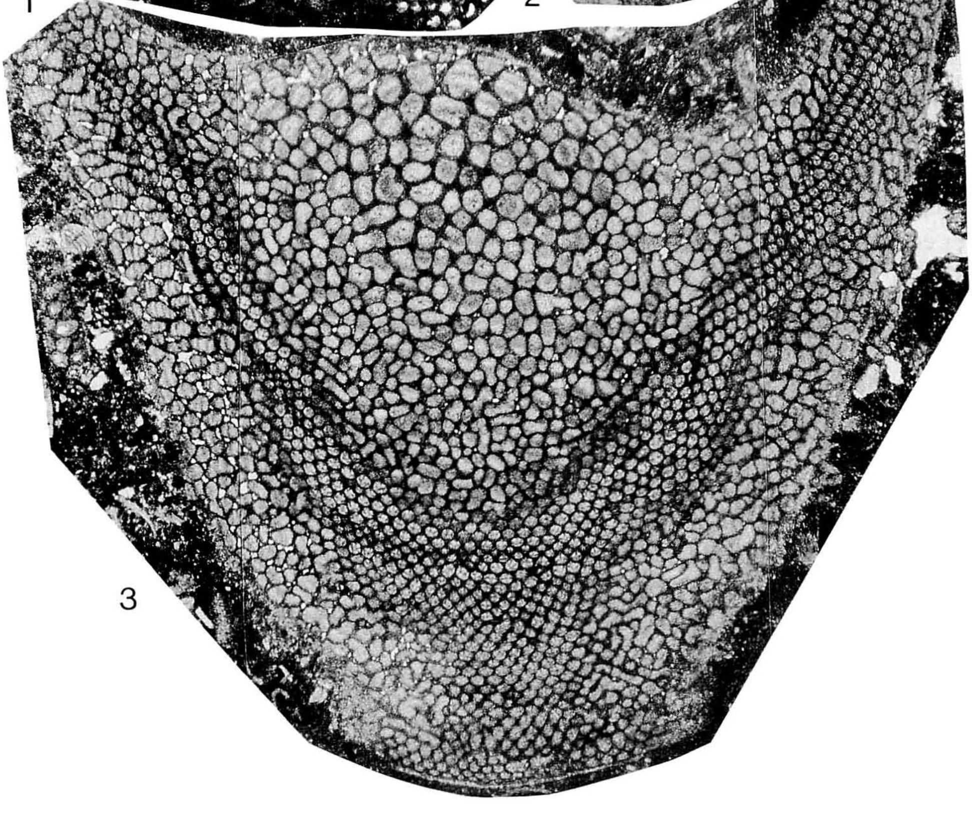

3

Subfamily Lepidocyclininae Scheffen, 1932

Genus *Nephrolepidina* H. Douvillé, 1911

Nephrolepidina marginata (Michelotti, 1841)

Plate 71, figures 1–3; Plate 72, figures 1–6; Plate 73, figures 1–5; Fig. 22–15a–c.

Nummulites marginata Michelotti, 1841, p. 297, pl. 3, figs. 4a–b.

Lepidocyclina marginata (Michelotti). Lemoine and R. Douvillé, 1904, p. 16–17, pl. 1, fig. 7, pl. 2, figs. 7, 9, 11, 20, pl. 3, figs. 3, 8–9, 13; Geyn and van der Vlerk, 1935, p. 253, figs. 25–27.

Lepidocyclina morgani Lemoine and R. Douvillé, 1904, p. 17, pl. 1, figs. 12, 15, 17, pl. 2, figs. 4, 12, pl. 3, fig. 2; Scheffen, 1932, p. 97–99, figs. 1–3.

Nephrolepidina marginata (Michelotti). H. Douvillé, 1925, p. 76–77, figs. 58–59, pl. 2, figs. 5–6; Llueca, 1929, p. 348–350, pl. 32, figs. 11–21, pl. 33, fig. 28.

Lepidocyclina (Amphilepidina) nipponica Hanzawa, 1931a, p. 151–152, pl. 25, fig. 2 (non figs. 1, 3–5, pl. 24, figs. 1–7, 11).

Lepidocyclina (Amphilepidina) scabra Hanzawa, 1931b, p. 165–166, pl. 27, figs. 14–15, pl. 28, figs. 2–4.

Lepidocyclina (Nephrolepidina) marginata (Michelotti). Brönnimann, 1940, p. 54–55, pl. 4, figs. 5, 7–8, pl. 5, figs. 13, 19–20.

Lepidocyclina (Nephrolepidina) morgani Lemoine and R. Douvillé. Hanzawa, 1957, p. 79, pl. 19, figs. 2a–d, pl. 22, figs. 9–10.

Nephrolepidina morgani (Lemoine and R. Douvillé). Lange, 1968, p. 63–65, 67–68, pl. 1, fig. 2; Matsumaru, 1971a, p. 172, pl. 18, figs. 1–4, 6–11 (non fig. 5), pl. 19, figs. 1–4, 7, 11–13 (non figs. 5–6, 8–10, 14– 15).

Nephrolepidina japonica (Yabe). Matsumaru, 1971a, p. 166, 168, pl. 14, figs. 3–6 (non figs. 1–2), pl. 17, figs. 12–18 (non figs. 7–11, 19).

Nephrolepidina angulosa (Provale). Matsumaru, 1971a, p. 168–169, (non pl. 12, figs. 1–10, pl. 13, figs. 1–11), pl. 14, figs. 16–17 (non figs. 7–15, 8–21, pl. 20, fig. 3, pl. 22, fig. 5, pl. 23, fig. 4).

Description: Test small to moderate size, lenticular to obese, with thin brim; diameter 2.6 to 5.9 mm, diameter of central inflated boss from 2.0 to 3.3 mm, and thickness through center from 1.3 to 1.4 mm; form ratio of diameter to thickness, 2.5 to 4.5; outline polygonal to rounded; conical to polygonal pillars at ridge intersections on central boss, except at outer edge of brim; measuring 75 to 160 μm in diameter in megalospheric specimen, and 160 to 320 μm in diameter in microspheric specimen. Megalospheric embryonic chambers, biloculine, nephrolepidine type; whole embryonic chambers measure 274 to 363 μm in diameter across both protoconch and deuteroconch; protoconch subspherical, 190 × 140, and 207 × 180 μm in inner diameter, and deuteroconch reniform, 310 × 125, and 336 × 146 μm in inner diameter; embryonic chambers, 144 to 230 μm high in vertical section; outer wall of embryonic chambers, 12 to 22 μm thick. Factor A value ("Grade of enclosure" of protoconch by deuteroconch; van der Vlerk, 1963; Matsumaru, 1971) varying from 32.1 to 42.6; mean value and standard deviation of Factor A in 5 specimens, 38.8 ± 4.5. Degree of curvature (= D.C.) of embryonic chambers (van der Vlerk, 1968) varying from 12.4 to 33.3; mean

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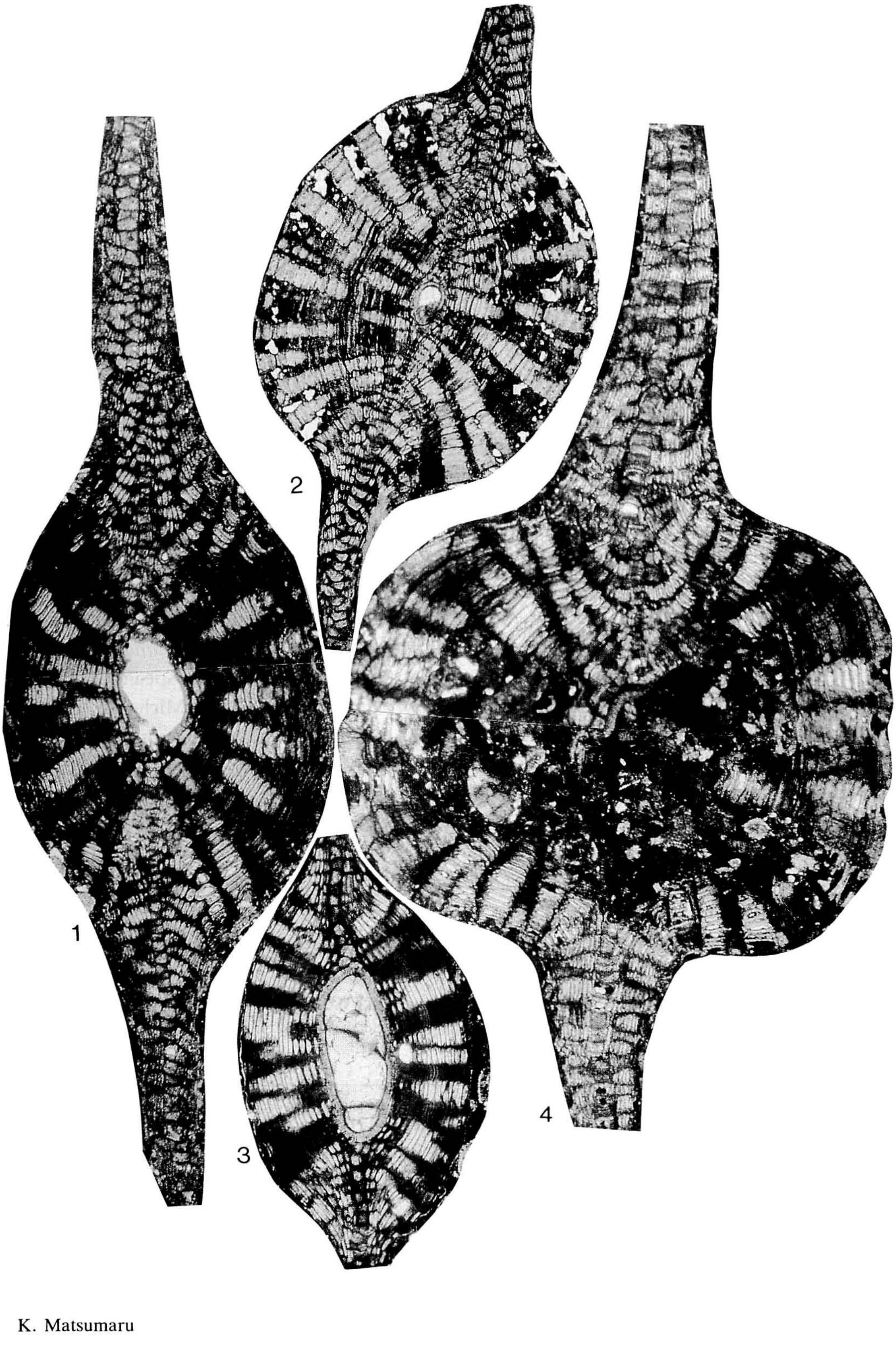
Explanation of Plate 69

(All figures ×20)

Eulepidina ephippioides (Jones and Chapman)

1–4. Axial sections of megalospheric form. 1, 3–4. Gamont, 2. Schizont. Minamizaki Limestone; Localities: 1, 4. 25, 2. 40, 3. Base (All belonging to 1304 Section).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value and standard deviation of D.C. in 5 specimens, 20.3 ± 7.8. Primary auxiliary chamber arcuate shape; of dimension 35 × 86, 35 × 95, 43 × 65, and 52 × 82 μm, in inner radial and tangential diameter; adauxiliary chambers number from 2 to 4; and its mean value in 5 specimens, 2.8. Nepionic spirals (N.S.; Matsumaru, 1971) number from 8 to 12; and its mean value in 5 specimens, 9.6. Equatorial chambers arcuate in infant stage near center, and ogival or rhombic in adult stage; arranged in intersecting curves in equatorial section; and of dimension 47 × 43, 50 × 47, 52 × 47, and 52 × 52 μm, in inner radial and tangential diameter within a radius of 0.3 mm; 56 × 47, 56 × 60, 60 × 60, and 80 × 52 μm, in inner radial and tangential diameter within a radius of 0.5 mm; 47 × 47, and 58 × 58 μm, in inner radial and tangential diameter within a radius of 0.7 mm; 70 × 58, 94 × 73, and 104 × 73 μm, in inner radial and tangential diameter within that of 1 mm; 70 × 70 μm in inner radial and tangential diameter within that of 1.3 mm; 114 × 95 μm, in inner radial and tangential diameter within that of 2 mm, and 100 × 140 μm, in inner radial and tangential diameter within that of 2.4 mm, respectively. Equatorial layer, 33 to 38 μm high near center, and 58 to 75 μm high near periphery. Lateral chambers, rectangular, open, and arranged in very regular tiers; 9 to 14 lateral chambers in a tier on each side of equatorial layer. Lateral chambers over center and at periphery; of dimension 125 × 35, 138 × 38, 138 × 40, 150 × 35, 163 × 38, 175 × 38, 175 × 50, 178 × 40, 186 × 28, 186 × 56, and 200 × 62 μm, in internal length and height; and floors and roofs, 7 to 21 μm thick.

Stratigraphic horizon: Minamizaki Limestone.

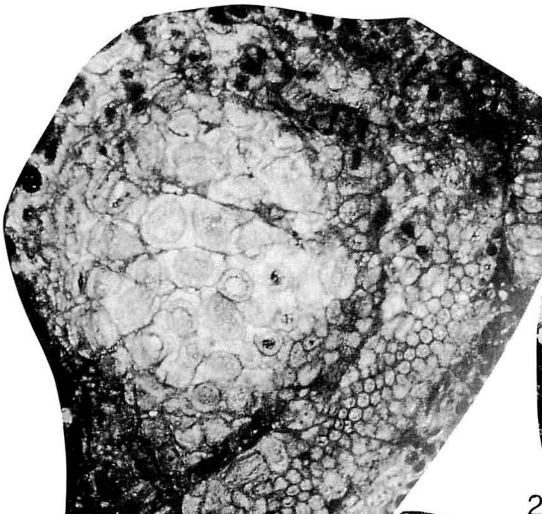
Remarks: The author (1992, p. 262) has indicated that *Nephrolepidina morgani* (Lemoine and R. Douvillé, 1940) and *N. marginata* (Michelotti, 1841) are grouped together as a dimorphous form of the same species. As such, the author regarded *Nephrolepidina morgani* as a synonym of *Nephrolepidina marginata*. The upper Oligocene Minamizaki specimens in the present collection, which were identified as *Nephrolepidina marginata* (Michelotti), have essentially the same external form, but are different in internal structure in comparison with *Nephrolepidina marginata* from the upper Miocene Shimoshiroiwa Formation, Izu Peninsula, Japan (Matsumaru, 1992, p. 260–262, figs. 2–1–4). The former is characterized by nephrolepidine embryonic chambers, fewer adauxiliary chambers, and arcuate to ogival or rhombic equatorial chambers arranged in intersecting curves, whereas the latter is characterized by trybliolepidine embryonic chambers, a large number of adauxiliary chambers, and arcuate through ogival to hexagonal equatorial chambers arranged in intersecting curves to polygonals. As such the former is assigned to *Nephrolepidina morgani* (Lemoine and R. Douvillé) and the latter is assigned to *Nephrolepidina tournoueri* (Lemoine and R. Douvillé) which evolved from *N. morgani*, respectively, in comparison with European *Nephrolepidina* species.

Explanation of Plate 70

(All figures ×20)

Eulepidina ephippioides (Jones and Chapman)

1, 4. Oblique sections, 2–3, 5. Axial sections. 2–3. Microspheric forms showing twisted form, and both thick floors and roofs and stout pillars carrying form, respectively, 5. Megalospheric form showing spaceous lateral chambers, and thin floors and roofs. Minamizaki Limestone; Localities: 1. 4.4, 2. 8.2, 4. 5.4 (All of 1301 Section), 3. 3.5, 5. 35 (Both of 1304 Section)



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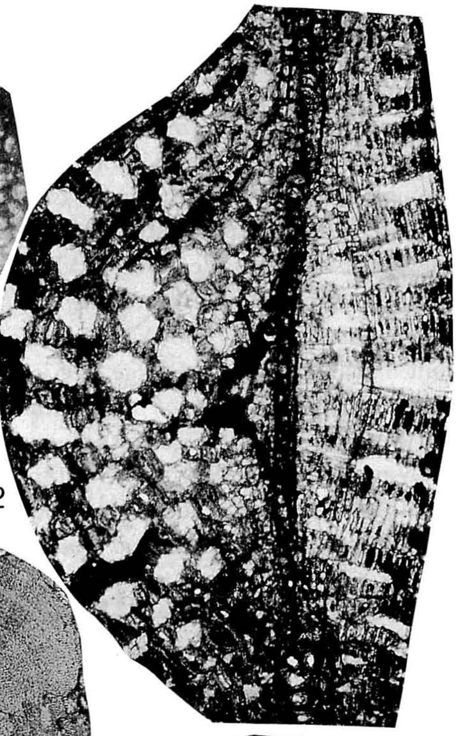

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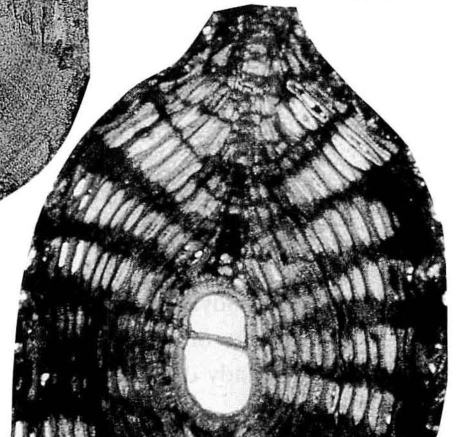

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As *Nephrolepidina praemarginata* R. Douvillé, 1908 is considered to be an ancestor species of *Nephrolepidina morgani* (Lemoine and R. Douvillé), by Vervloet (1966), Mulder (1975), and Matteucci and Schiavinotto (1977), *Nephrolepidina marginata* is regarded as only one agamont and a senior synonym for all the gamonts of *Nephrolepidina praemarginata*, *N. morgani*, and *N. tournoueri*.

Lemoine and R. Douvillé (1904, p. 18–19) recognized that *Nephrolepidina morgani* resembles *Nephrolepidina sumatrensis* (Brady, 1875), but the former is distinguished from the latter in having the pustules. Cole (1957b) found that *Nephrolepidina sumatrensis* from Eniwetok Atoll, has a compressed lenticular to nearly globular test without pillars or with pillars. As such he regarded *Nephrolepidina brouweri* (Rutten, 1923), *Nephrolepidina parva* (Oppenoorth, 1918), and *Nephrolepidina verrucosa* (Scheffen, 1932), which were found from Saipan (Cole and Bridge, 1953; Cole, 1957a) and Bikini (Cole., 1957a), as being a junior synonym of *Nephrolepidina sumatrensis* (Brady). Thus, there remains the possibility that *Nephrolepidina morgani* is a junior synonym of *Nephrolepidina sumatrensis*.

Van der Vlerk (1974) described that Hans Kugler's *Lepidocyclina* from Meijas Quarry, Penal Rock Road, Tninidad, was identified by some researchers as *Lepidocyclina yurnagunensis* Cushman, *Nephrolepidina praemarginata* R. Douvillé, or *Lepidocyclina isolepidinoides* van der Vlerk, and it was concluded that there was a great possibility to obtain the different species name. Also van der Vlerk and Postuma (1967) described that the Factor A values of *Lepidocyclina isolepidinoides* van der Vlerk and *Nephrolepidina parva* (Oppenoorth), both from Kranji locality, Java, belonging to *Globigerina ciperoensis ciperoensis* Zone to *Globorotalia kugleri* Zone (P. 22/N.3 Zone of Blow's planktonic foraminiferal zones) were 36.4 and 41.7, respectively. Moreover, Factor A parameter was found to increase persistently from 35.8 to 65.3 as one moves up in the section from *Globorotalia opima* Zone (P.21/N.2 Zone of Blow's Zone) to *Globorotalia barisanensis* Zone (N.9 Zone of Blow's Zone). According to van der Vlerk's two contributions stated above, it is satisfactory to consider the possibilities of *Nephrolepidina praemarginata* being a synonym of *Lepidocyclina isolepidinoides*, of the latter species evolving into *Nephrolepidina parva*, and of the same Factor A value being the same age.

Although there are no *Nephrolepidina marginata* free specimens from the Minamizaki Limestone, after studying the abundant thin sections available, the biometrical data of Factor A, the degree of curvature, and nepionic spirals were measured and counted from 5 specimens as already described. As a result, *Nephrolepidina marginata* (Michelotti) from

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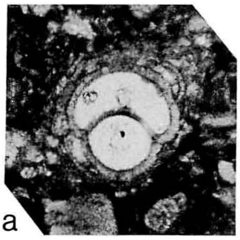
Explanation of Plate 71

Nephrolepidina marginata (Michelotti)

1a–b. Central parts of equatorial section of megalospheric form. 1a. ×43, 1b. Enlarged central part of equatorial section shown in Figure 1a, showing nephrolepidine embryonic chambers, arcuate nepionic chambers, which include two accessory auxiliary (adauxiliary) chambers, and 8 nepionic spirals. ×116, 2a–b. Centered oblique sections of megalospheric form. 2a. ×43, 2b. Enlarged centered oblique section shown in Figure 2a, showing four adauxiliary chambers, and 12 nepionic spirals. ×116, 3a–b. Axial sections of megalospheric juvenile form. 3a. ×43, 3b. Enlarged form of Figure 3a showing protoconchal foramina. ×116. Minamizaki Limestone; Locality: 9707 (9308S Section).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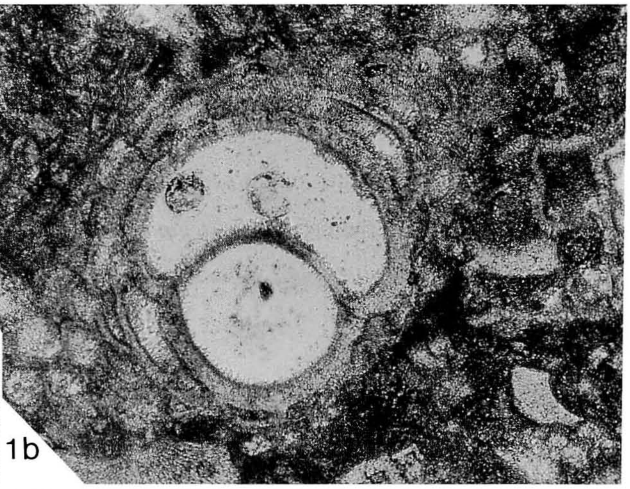
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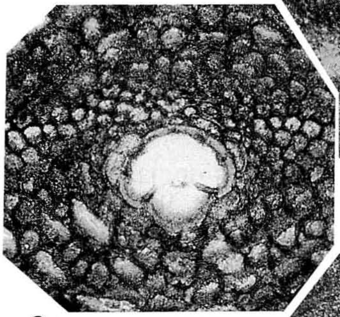
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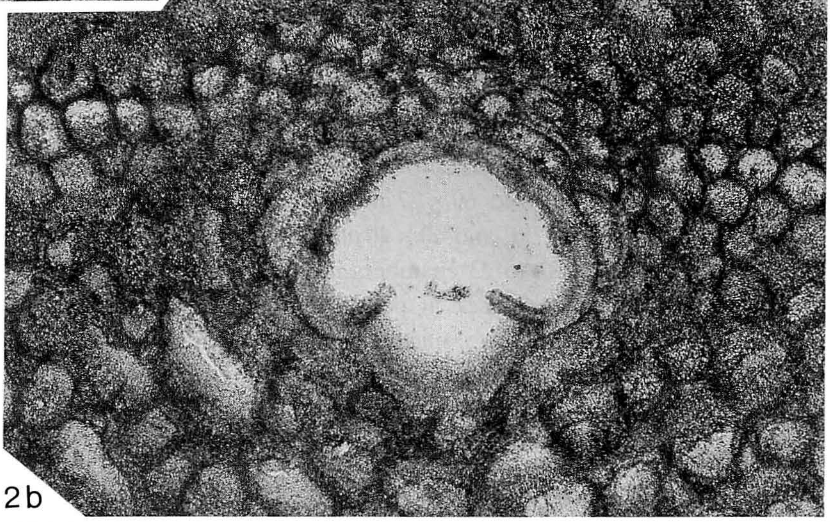
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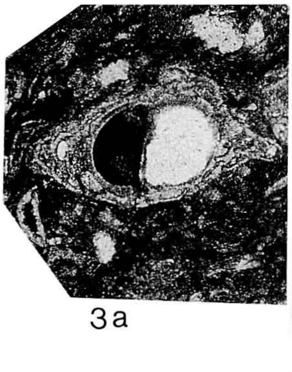

3a


3b

the Minamizaki Limestone can be correlated to *Lepidocyclina isolepidinoides* van der Vlerk or *Nephrolepidina parva* (Oppenoorth) from the Oligocene beds of *Globorotalia opima opima* Zone to *Globigerina ciperoensis ciperoensis* Zone by van der Vlerk and Postuma (1967), or *Globigerina ciperoensis ciperoensis* Zone by van der Vlerk (1968).

Family Amphisteginidae Cushman, 1927

Genus *Amphistegina* d'Orbigny, 1826

Amphistegina radiata (Fichtel and Moll, 1798)

Plate 74, figures 1–5.

Nautilus radiatus Fichtel and Moll, 1798, p. 58, pl. 8, figs. 8a–d.
Amphistegina radiata (Fichtel and Moll). Chapman, 1895, p. 45–47, pl. 1, figs. 8–10, 12; Hofker, 1927, p. 76–78, pl. 29, pl. 39, figs. 2–4, 6–7; Hanzawa, 1957, p. 60–61, p. 6, fig. 11, pl. 31, figs. 4–8, pl. 32, fig. 1; O'Herne, 1974, p. 6, pl. 1, figs. 8–11, pl. 12, figs. 1–5, pl. 13, figs. 1–3; Matsumaru, 1976c, p. 408, pl. 1, figs. 1–3, 5–13, 17, 23, 26–27, text-figs. 6–8.
Amphistegina lessoni d'Orbigny var. *radiata* (Fichtel and Moll). Cushman, 1921, p. 372–373.

Description: Test lenticular, unequal biconvex, with bluntly rounded to acute periphery; 0.98 to 1.35 mm in diameter, and 0.50 to 0.60 mm in thickness; form ratio of diameter to thickness, 1.9 to 2.6; surface umbo relatively small, ornamented numerous sutures radially arranged, almost straight at first and sharply angled near margin; megalospheric bilocular nucleoconch, spherical to subspherical protoconch, 50 × 50 to 80 × 75 μm in diameter, and reniform deuteroconch, 40 × 25 to 60 × 27 μm in diameter; and microspheric proloculus, spherical to subspherical, 32 × 30, and 40 × 40 μm in diameter. Median chambers in microspheric specimen numerous 22 to 23 chambers in last whorl; low trochospirally arranged, broad and low, strongly curved back at periphery to form chamber prolongations; wall calcareous, finely perforate; aperture, narrow slit at interiomarginal of last chamber.

Stratigraphic horizon: Sekimon and Minamizaki Limestones.

Remarks: The present form is characterized by many chambers in the last whorl, curvature of the suture and septa, and a large protoconch; and it is assigned to *Amphistegina radiata* (Fichtel and Moll).

Amphistegina vulgaris d'Orbigny, 1826

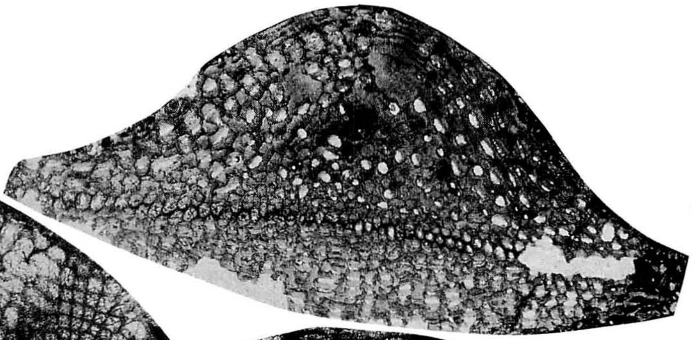
Plate 74, figure 6–8.

Amphistegina vulgaris d'Orbigny, 1826, p. 304; Parker, Jones, and Brady, 1865, p. 25, 36; Galloway, 1933, p. 315, pl. 29, fig. 2; Cushman, 1940, p. 272; Loeblich and Tappan, 1988, p. 610, pl. 677, figs. 6–8.

Explanation of Plate 72

(All figures ×43, except ×23 of Figure 1)

Nephrolepidina marginata (Michelotti)
1–6. Oblique sections. 1. Microspheric form, 2–6. Megalospheric forms. Minamizaki Limestone; Localities: 1,, 4–6. 9707 (9308S Section), 2. 9715, 3. 9709 (Both of Minami-Jima).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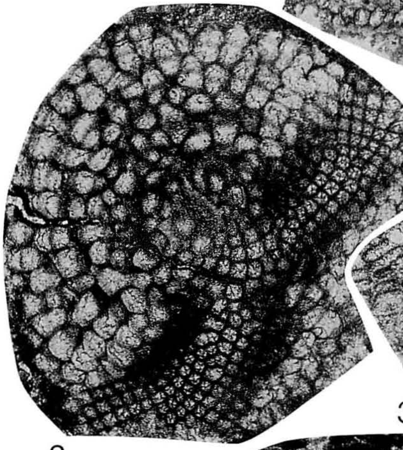
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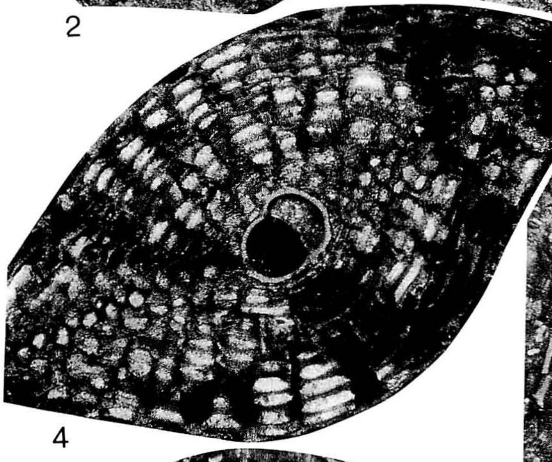
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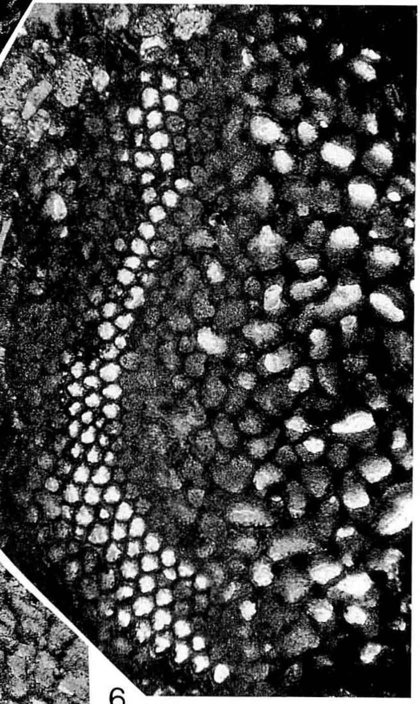
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Description: Test lenticular, unequal biconvex; 0.75 to 1.04 mm in diameter, and 0.40 to 0.53 mm in thickness; form ratio of diameter to thickness, 1.77 to 2.40; surface smooth, other than granules (15 to 20 μm in diameter) in apertural area; umbilicus filled with large plug, 120 to 187 μm in diameter; ventral septa divided by imbricate constrictions forming secondary lobes and secondary chamberlets in rosette around umbo; megalospheric embryonic chambers biloculine; protoconch subspherical, 44 × 40, and 68 × 60 μm in diameter, and deuteroconch reniform, 28 × 16 μm in diameter; chambers low, trochospirally arranged, narrow, strongly curved back at periphery to form chamber prolongations; wall calcareous, finely perforate; aperture slit opening, below periphery on ventral side.

Stratigraphic horizon: Sekimon and Minamizaki Limestones.

Remarks: Although there are no well-oriented sections of specimens, the present form is characterized by having a distinct rosette of secondary lobes on the ventral side, and it is assigned to *Amphistegina vulgaris* d'Orbigny.

Family Asterigerinidae d'Orbigny, 1839

Genus *Asterigerina* d'Orbigny, 1839

Asterigerina tentoria Todd and Post, 1954

Plate 10, figures 1–7; Plate 53, figure 5.

Asterigerina tentoria Todd and Post, 1954, p. 562–563, pl. 201, figs. 2a–c.

Description: Test small, unequal biconvex, with more elevated umbilical side; 0.56 to 0.73 mm in diameter, and 0.44 to 0.48 mm in thickness; form ratio of diameter to thickness, 1.27 to 1.52; ventral plug large, 166 to 187 μm in diameter. Megalospheric nucleoconch biloculine; spherical protoconch, 40 × 40 μm in diameter, and reniform deuteroconch, 28 × 16 μm in diameter; chambers low, trochospirally arranged, low and arcuate at center to subtriangular at peripheral margin in horizontal section; 7 chambers in second whorl; interseptal suture passage present, 6 to 8 μm in diameter; wall calcareous, finely perforate.

Stratigraphic horizon: Sekimon and Minamizaki Limestone.

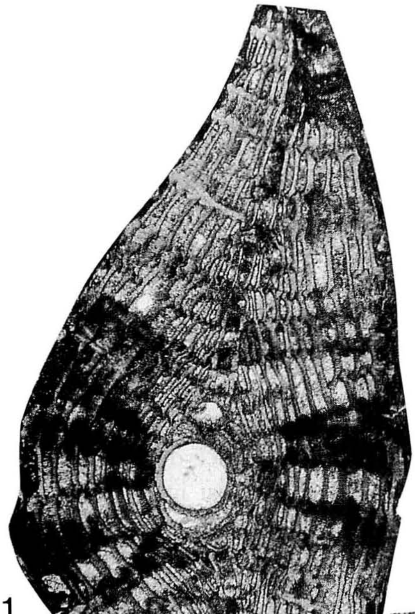
Remarks: The present form is characterized by a sharply conical on the umbilical side of a robust test, and it is assigned to *Asterigerina tentoria* Todd and Post.

Explanation of Plate 73

(All figures ×43)

Nephrolepidina marginata (Michelotti)

1–5. Axial sections of megalospheric form. Minamizaki Limestone; Locality: 9707 (9308S Section).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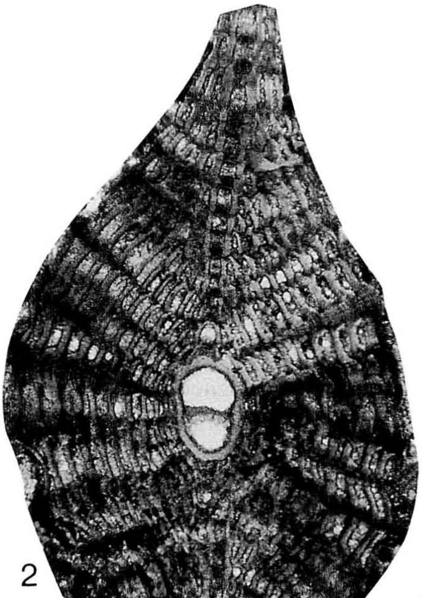
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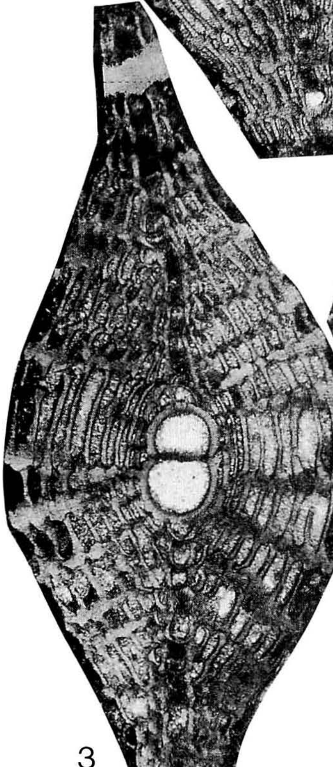
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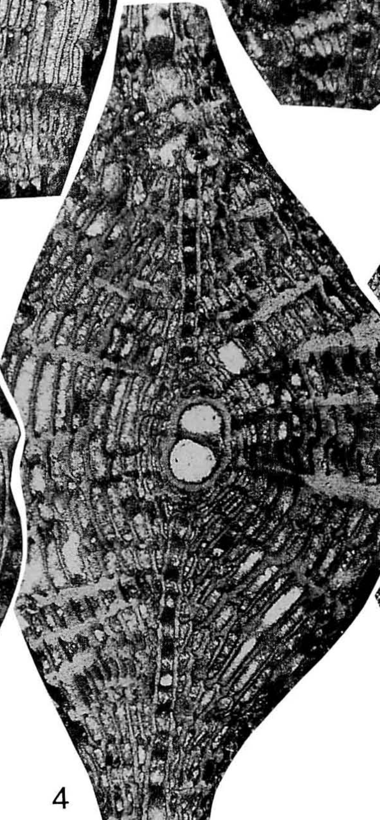
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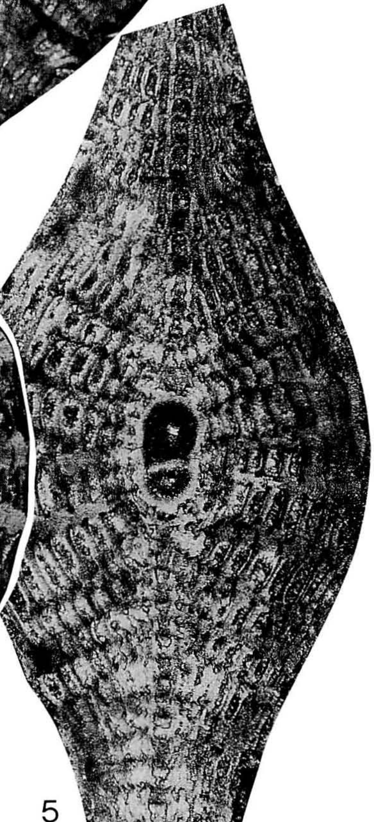
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Superfamily Acervulinacea Schultz, 1854

Family Acervulinidae Schultz, 1854

Genus *Orbitogypsina* Matsumaru, n. gen.

Type species: *Orbitogypsina vesicularis* Matsumaru, n. sp.

Diagnosis: Test small, discoidal to concavoconcave, with round periphery, and sometimes ellipsoidal, and globulus form; megalospheric embryonic chambers biloculine of protoconch and deuteroconch, followed by nepionic and equatorial chambers carrying stolon system; microspheric proloculus, followed by very low trochospiral to planispiral nepionic chambers, and then followed by planispiral large, arcuate equatoria chambers; equatorial chambers enveloped in lateral chambers on peripheral sides; those of successive lateral layers, not aligned at central part, but aligned at periphery; wall thin, calcareous, perforate; floors and roofs of lateral chambers perforate; and septa thick, elevated, and imperforate; sometimes pillars present; aperture, coarse perforations in cribrate upper surface of lateral chambers.

Comparison: The present genus has two type growths: The test in the early stage is characterized by having bilocular embryonic chambers surrounded by nepionic chambers, just like the family Lepidocyclinidae Scheffen, 1932, and the latter stage is followed by spreading and regular chambers in an discoidal or globular mass with mural pores or apertural openings in the cribrate upper surface of the chambers, like the family Acervulinidae Schultz, 1854. The new genus *Orbitogypsina* resembles *Gypsina* H. J. Carter, 1877, *Sphaerogypsina* Galloway, 1933, and *Discogypsina* A. Silvestri, 1937, but is distinguished from the latter three in having nepionic chambers whose walls are perforated by stolons, which is one of the main characteristics recognized in advanced forms of Orbitoidal Foraminifera. Although it is uncertain whether or not *Wilfordia* Adams, 1965, is a junior synonym of *Gypsina* H. J. Carter, 1877, the present new genus may have phylogenetic relation to the genus *Gypsina*, because of similar generical shape.

Orbitogypsina vesicularis Matsumaru, n. sp.

Plate 75, figures 1–3; Plate 76, figures 1–8.

Type material: Holotype, centered oblique section of megalospheric specimen, Saitama University coll. no. 8810 (Plate 75, figure 1). Paratype specimen, vertical section of micro-

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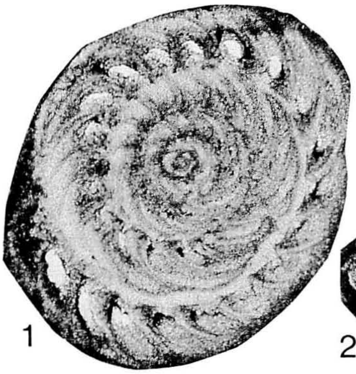
Explanation of Plate 74

Amphistegina radiata (Fichtel and Moll)

1. Equatorial section of microspheric form, 2, 4. Oblique sections of microspheric form, 3, 5. Axial sections of microspheric form. ×40. Minamizaki Limestone; Localities: 1. 37, 2, 5. 30, 3. 20, 4. 28 (All belonging to 1304 Section).

Amphistegina vulgaris d'Orbigny

6–8. Tangential sections showing ventral side of test. 6a. ×40, 6b. Enlarged form of Figure 6a showing ventral septa divided by imbricate constructions of secondary lobes, which have the appearance of secondary chamberlets in a rosette around the umbo. ×100, 7–8. ×100. Minamizaki Limestone; Localities: 6. 30, 8. 55 (Both of 1304 Section), 7. 23.6 (1301 Section).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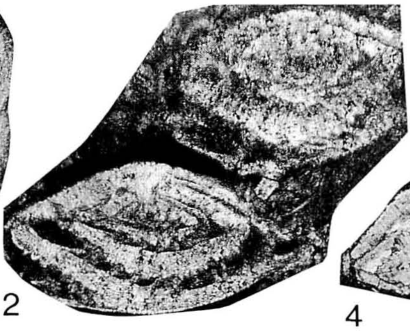
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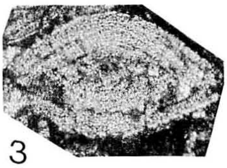
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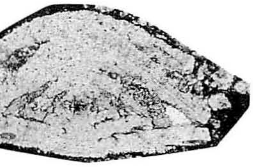
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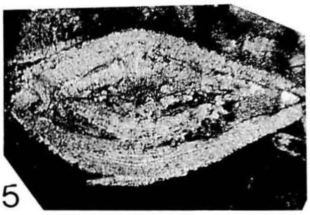
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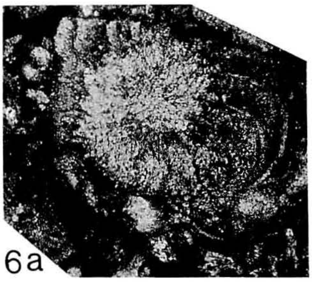
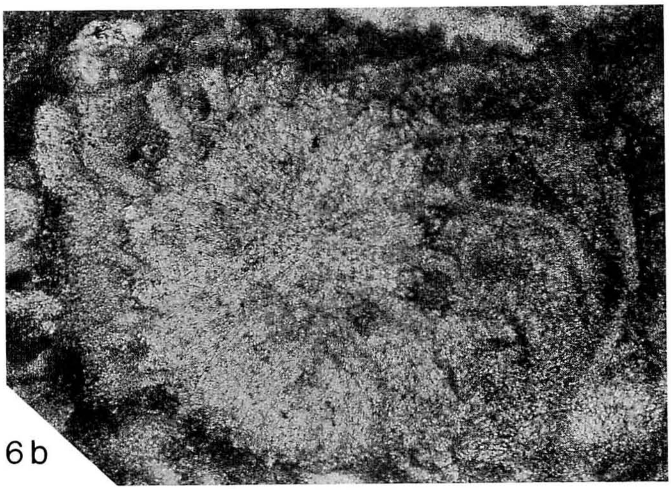
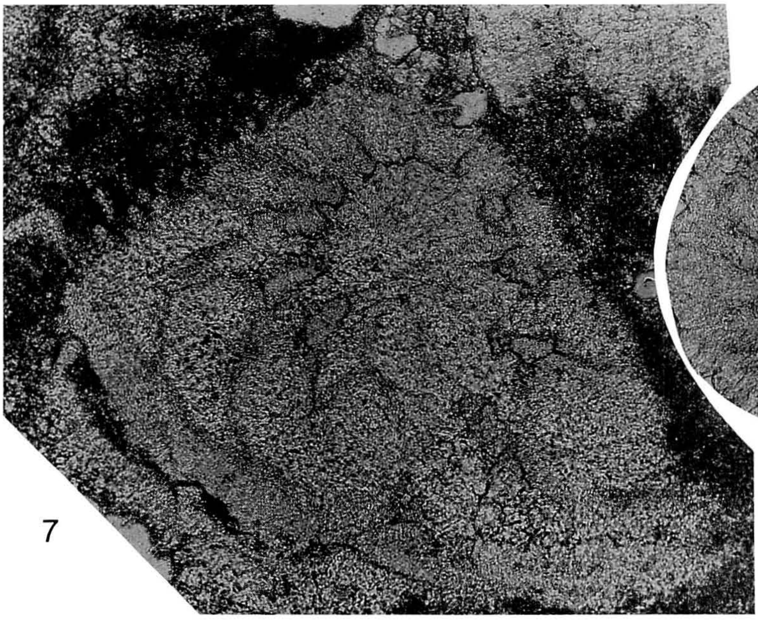

6a


6b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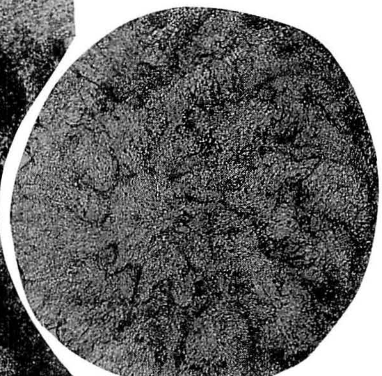
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spheric specimen, Saitama University coll. no. 8811 (Plate 76, figure 6).

Description: Test small, discoidal to concavoconcave, with round periphery; 1.04 to 1.81 mm in diameter, and 0.40 to 0.76 mm in thickness; form ratio of diameter to thickness, 2.3 to 4.0; megalospheric embryonic apparatus biloculine of protoconch and deuteroconch; nephrolepidine type; protoconch spherical to subspherical; internal diameter 56 × 56, 90 × 72, 122 × 84, and 140 × 80 μm, and deuteroconch reniform, internal diameter 48 × 24, 104 × 60, 160 × 56, and 177 × 84 μm; embryonic apparatus 76 to 166 μm high in vertical section; wall of embryonic apparatus, 8 to 16 μm thick. Embryonic apparatus followed by two primary auxiliary chambers and periembryonic (nepionic) chambers; and of dimension 40 × 56, and 56 × 88 μm; and 27 × 72, 32 × 80, and 36 × 72 μm, in inner radial and tangential diameters, respectively; consisting of 4 nepionic spirals. Spherical proloculus in microspheric generation, small, and of inner diameter 16 μm; followed by subquadrate nepionic chambers disposed in low trocoid- to planispires. Equatorial chambers arcuate in megalospheric and microspheric forms; of dimension 43 × 52, 44 × 112, 46 × 34, 46 × 48, 48 × 48, 48 × 112, 48 × 56, 56 × 62, and 56 × 96 μm in inner radial and tangential diameters. Lateral chambers of both forms, rectangular cavities arranged in regular tiers; of dimension 60 × 20, 72 × 32, 80 × 32, 84 × 32, and 104 × 36 μm in inner width and height; 6 to 11 layers of lateral chambers present, over embryonic chambers. Floors and roofs, 6 to 12 μm thick; and cribrate pores in floors and roofs, 3 to 7 μm in diameter. Pillars in microspheric form, 20 to 28 μm thick.

Stratigraphic horizon: Sekimon and Minamizaki Limestones.

Remarks: The present form resembles *Discogypsina vesicularis* A. Silvestri, 1937, and *Sphaerogypsina vesicularis* (Parker and Jones, 1860), but differs from them in having nepionic chambers, 4 nepionic spirals, and a stolon system. The present form is assigned to *Orbitogypsina vesicularis*, n. sp.

Orbitogypsina globulus Matsumaru, n. sp.

Plate 77, figures 1–3; Plate 78, figures 1–4.

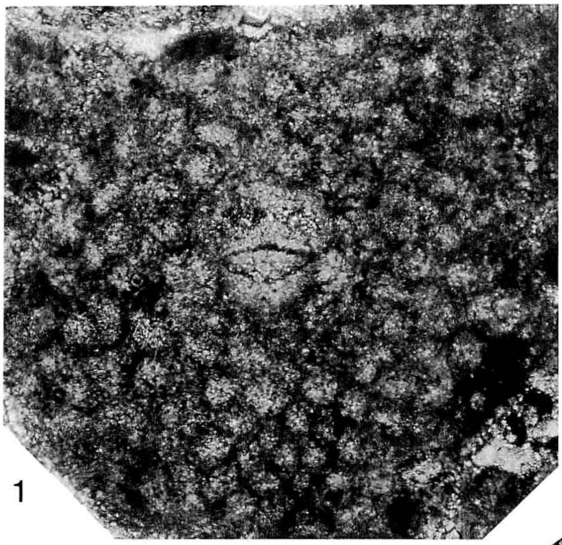
Type material: Holotype, equatorial section of megalospheric form, Saitama University coll. no. 8812 (Plate 77, fig. 1); Paratype, axial section of megalospheric form, Saitama University coll. no. 8813 (Plate 77, fig. 2).

Description: Test small, globulus to ellipsoidal; 0.42 to 1.68 mm in diameter, and 0.40 to 1.48 mm in thickness; form ratio of diameter to thickness, 1.0 to 1.2; Megalospheric bilocular embryonic chambers, nephrolepidine type; spherical to subspherical protoconch;

Explanation of Plate 75

Orbitogypsina vesicularis Matsumaru, n. sp.

1. Equatorial section of megalospheric form. Holotype, Saitama University coll. no. 8810. ×100, 2–3. Centered oblique sections of megalospheric form. 2a. ×43, 2b. Central part of Figure 2a showing bilocular embryonic chambers which are connected with nepionic chambers by stolons. ×116. 3a. ×43, 3b. Central part of Figure 3a showing embryonic chambers which are connected with nepionic chambers by stolons. ×116. Minamizaki Limestone; Localities: 1. 48 (1304 Section), 2–3. 12 (1301 Section).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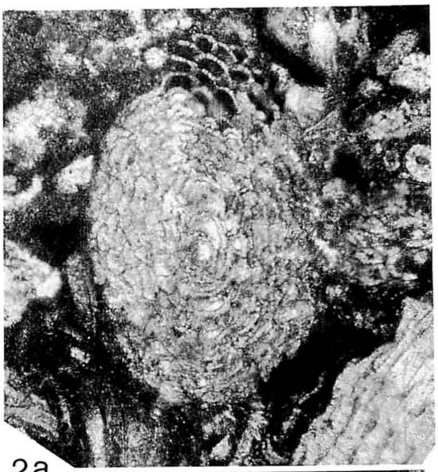
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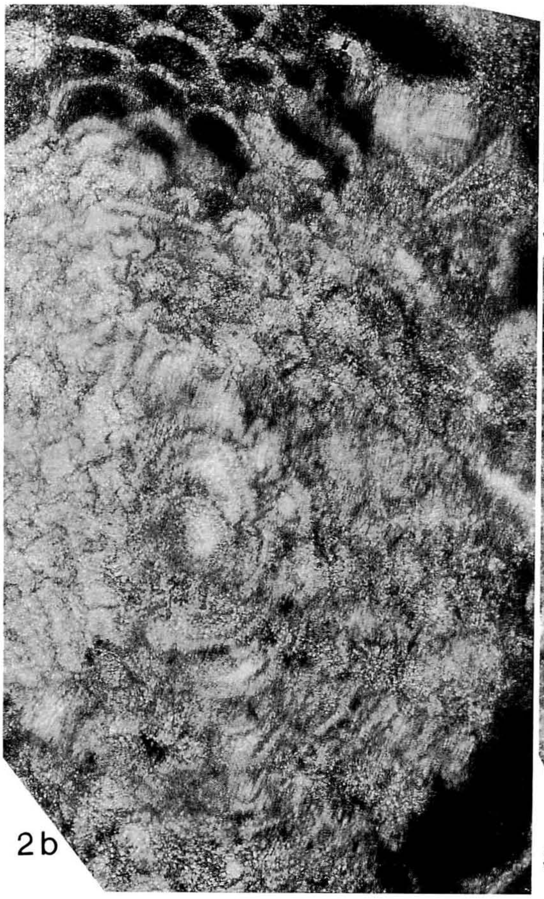
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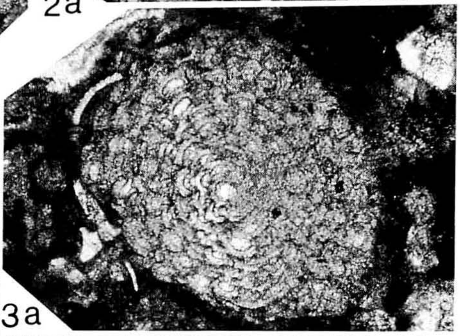
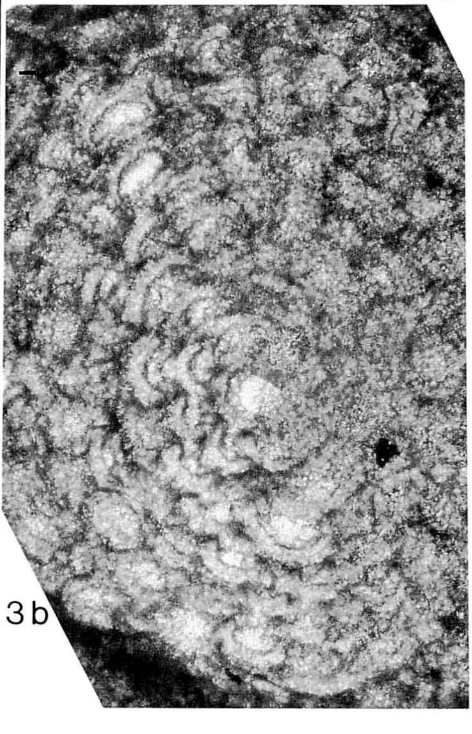

3a


3b

internal diameter 38 × 38, 50 × 64, 64 × 54, 80 × 60, 80 × 72, and 84 × 72 μm, and deuteroconch reniform; internal diameter 38 × 38, 60 × 44, 66 × 44, 72 × 40, and 104 × 40 μm; embryonic apparatus 44 to 48 μm high in vertical section; wall of embryonic chambers, 7 to 8 μm thick. Embryonic chambers followed by two primary auxiliary and other nepionic chambers, consisting of 4 nepionic spirals. Former two chambers larger, 54 × 48, and 64 × 80 μm, and latter smaller, 18 × 24, 20 × 34, 24 × 80, 32 × 40, and 40 × 52 μm, in inner radial and tangential diameters, respectively. Equatorial chambers arcuate; 16 × 48, and 36 × 46 μm in inner radial and tangential diameters; dorsal and ventral lateral chambers, well differentiated from equatorial layer, subquadrangular in axial section; 24 to 76 μm wide, and 12 to 48 μm high, and ellipsoidal in equatorial section; 8 to 32 μm in radial length, and 24 to 72 μm in tangential length, forming globular to elliptical masses; floors and roofs, 6 to 12 μm thick, pierced by cribrate pores 3 to 5 μm in diameter.

Stratigraphic horizon: Sekimon and Minamizaki Limestones.

Remarks: The present form resembles *Sphaerogypsina globulus* (Reuss, 1848), but differs in having nepionic chambers, 4 nepionic spirals, and a stolon system. According to Hofker (1970, p. 66, text-fig. 19), the embryonic and periembryonic chambers of *Sphaerogypsina globulus* from Recent, the Mediterranean, grow together into a raspberry chamber arrangement. The present form is assigned to *Orbitogypsina globulus*, n. sp.

Family Homotrematidae Cushman, 1927

Genus *Miniacina* Galloway, 1933

Miniacina miniacea (Pallas, 1766)

Plate 55, figures 2–3; Plate 79, figures 1–5.

Millepora miniacea Pallas, 1766, p. 251.

Polytrema miniacea (Pallas). Carpenter, Parker, and Jones, 1862, p. 228, 235, pl. 13, figs. 18–20.

Polytrema miniaceum (Pallas). Blainville, 1826, p. 17; Möbius, 1880, p. 85, pl. 7; Brady, 1884, p. 721, pl. 100, figs. 5–9, pl. 101, fig. 1; Hickson, 1911, p. 443–462, pl. 30, fig. 1, pl. 31, fig. 8, pl. 32, figs. 18, 23, 27, 31; Cushman, 1915, p. 75, pl. 18, fig. 6, pl. 20, fig. 4; Cushman, 1921, p.363–364; Cushman, 1924, p. 46–47; Hofker, 1927, p. 27–31, pl. 12, pl. 13, figs. 1–7, pl. 14, figs. 1–11.

Miniacina miniacea (Pallas). Galloway, 1933, p. 305–306, pl. 28, fig. 8; Cushman, 1940, p. 312, pl. 37, figs. 33–36; Cushman, Todd, and Post, 1954, p. 374, pl. 82, fig. 16; Hanzawa, 1957, p. 71–72, pl. 34, fig. 4.

Description: Test attached to substratum, branching; 1.35 to 1.58 mm in height, and

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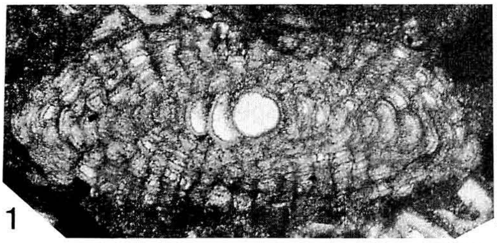
Explanation of Plate 76

(All figures ×40, except ×116 of Figure 8)

Orbitogypsina vesicularis Matsumaru, n. gen., n. sp.

1–2, 4–6, 8. Axial sections. 1–2, 8. Megalospheric forms, 4–6. Microspheric forms. 6. Paratype, Saitama University coll. no. 8811, showing very low trochospiral nepionic chambers, planispiral equatorial, and overlapping chambers. 3, 7. Oblique sections of microspheric form showing early chambers in spiral coil, and overlapping chambers. Minamizaki Limestone; Localities: 1. 33, 3. 1.4 (Both of 1301 Section), 2. 49, 4. 25, 5. 44, 6. 15 (All belonging to 1304 Section). Sekimon Limestone; Localities: 7. cl (Chibusa Dam), 8. 72203 (Sekimon Karst Section).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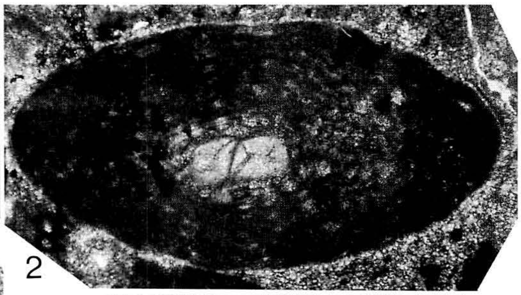
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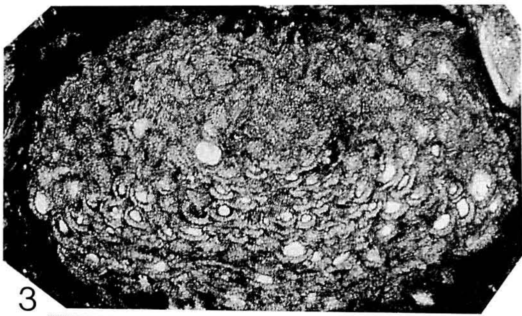
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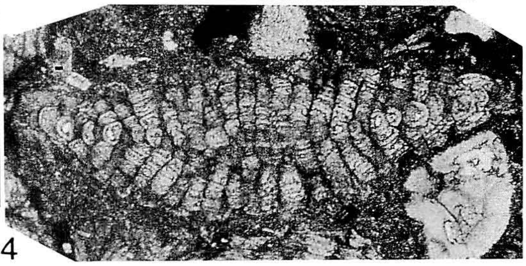
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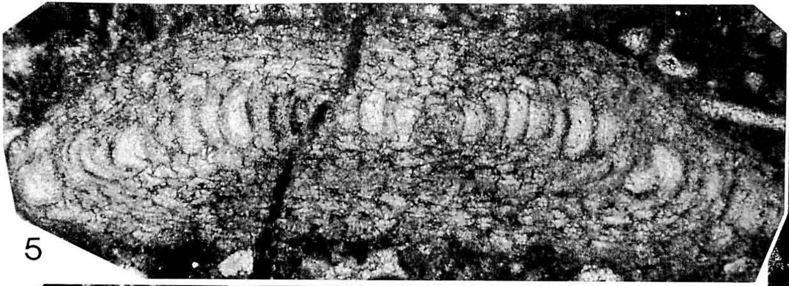
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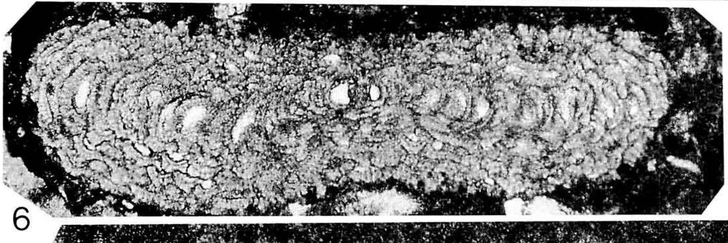
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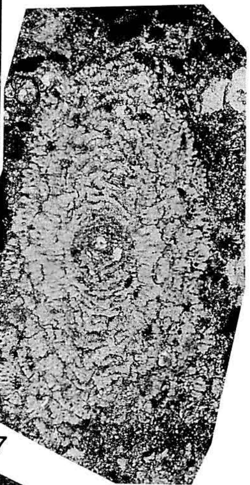
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8

1.37 to 1.73 mm in breadth; megalospheric embryonic chambers biloculine; spherical protoconch, 62 × 62 μm in diameter, and reniform deuteroconch, 78 × 38 μm in diameter, followed by the third chamber, 70 × 38 μm in diameter; two nepionic spirals from the third chamber with proximal and distal stolons. Microspheric early chambers in raspberry chamber arrangement; spherical proloculus, 28 × 28 μm in diameter, and reniform second chamber, 32 × 24 μm in diameter, and several subspherical chambers, 28 to 48 μm in tangential diameter, and 20 to 30 μm in radial diameter in equatorial section. Both megalospheric and microspheric median chambers, subdivided into reniform, elongate, and tubular chambers by several layers of perforated laminae running parallel to surface of test; layers of chambers, pierced by pillar-pores (36 to 56 μm in diameter), opened into pillar-pore tubes imperforate; chambers and pillar-pore chambers interconnected by fine wall perforations; wall calcareous, 8 to 16 μm in thickness; median chambers of early stage near center having one or more apertures at periphery; adult form, one to more apertures at ends of branches.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form growing up from the attachment to substratum is characterized by having pillar-pore chambers, and it is assigned to *Miniacina miniacea* (Pallas).

Genus *Sporadotrema* Hickson, 1911

Sporadotrema cylindricum (H. J. Carter, 1880)

Plate 80, figures 1–5.

Polytrema cylindricum H. J. Carter, 1880, p. 441.

Sporadotrema cylindricum (H. J. Carter). Hickson, 1911, p. 447–460, pl. 30, fig. 7, pl. 31, figs. 13–17, pl. 32, figs. 24, 29; Hofker, 1927, p. 22, pl. 8, figs. 3, 5–6, pl. 9, figs. 1–4, 6, pl. 10, figs. 1–10, 12–13; Yabe and Hanzawa, 1929, p. 176–177, pl. 8, fig. 7; Hanzawa, 1930, p. 94, pl. 27, figs. 1–2; Hanzawa, 1957, p. 70–71, pl. 29, figs. 1–2, pl. 36, fig. 5, pl. 37, figs. 1–5, pl. 38, figs. 7, 10–11.

Victoriella plecte (Chapman). Cole and Bridge, 1953, p. 28, pl. 14, fig. 4.

Eorupertia semiornata (Howchin). Cole, 1957a, p. 338, pl. 103, figs. 11–13, 15–16 (non fig. 14).

Carpenteria proteiformis Goës. Hanzawa, 1957, p. 70, pl. 36, figs. 9, 11, 13, pl. 38, fig. 6.

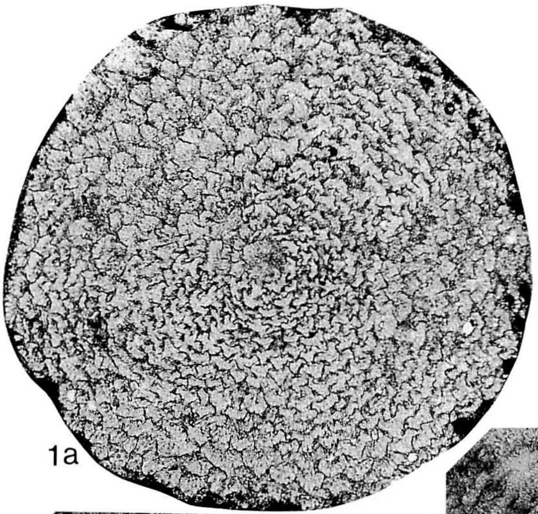
Carpenteria sp. Hanzawa, 1957, p. 70, pl. 29, figs. 1–2, pl. 36, figs. 3, 7, 10.

Sporadotrema? sp. Hanzawa, 1957, p. 71, pl. 36, figs. 4, 6, 8, 12, pl. 38, figs. 3, 5.

Explanation of Plate 77

Orbitogypsina globulus Matsumaru, n. gen., n. sp.

1a–b. Equatorial sections of megalospheric form. Holotype, Saitama University coll. no. 8812, 1a. Equatorial section showing embryonic, nepionic, and equatorial chambers, and overlapping arcuate lateral chambers through ontogeny. ×43, 1b. Enlarged central part of Figure 1a showing bilocular embryonic, nepionic, and peri-nepionic chambers. ×116, 1c. Closer central part of Figure 1a showing "grade of enclosure" of protoconch by deuteroconch, and two primary auxiliary chambers connected from deuteroconch by deuterostolon. ×230, 2–3. Axial sections. 2. Megalospheric form, Paratype, Saitama University coll. no. 8813, showing embryonic and peri-embryonic chambers in planispiral coil, and dorsal and ventral chambers in overlapping coil. 2a. ×43, 2b. ×116, 3. Microspheric form. ×43. Sekimon Limestone; Locality: 1. OK27.95 (Okiko/Tsukigaoka Shrine Section). Minamizaki Limestone; Localities: 2–3. 9704 (Minami-Jima).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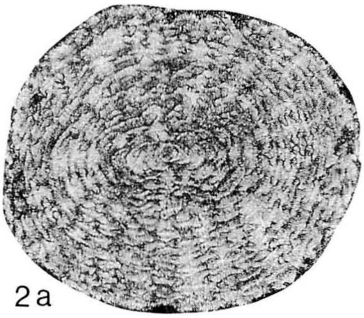
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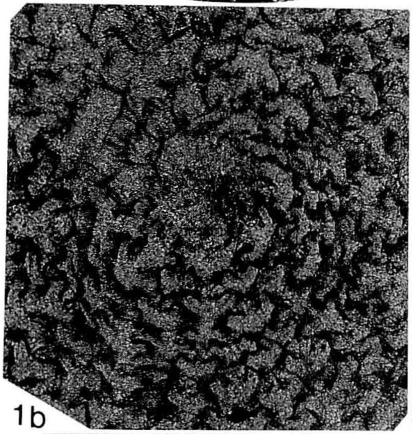
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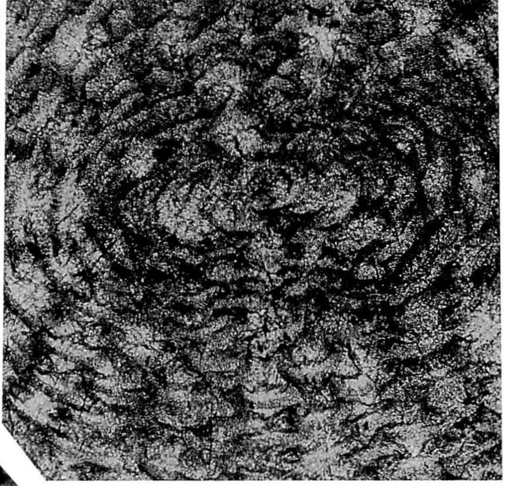
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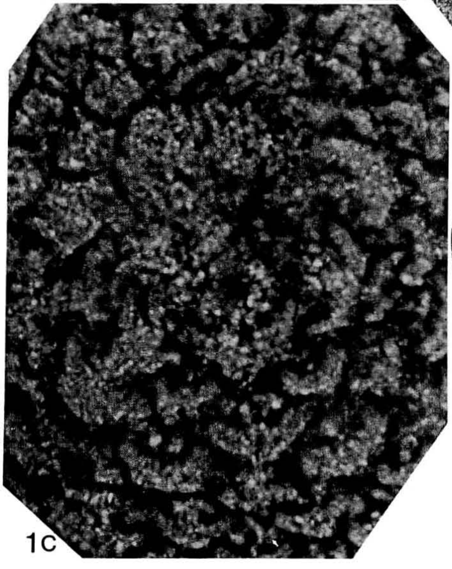
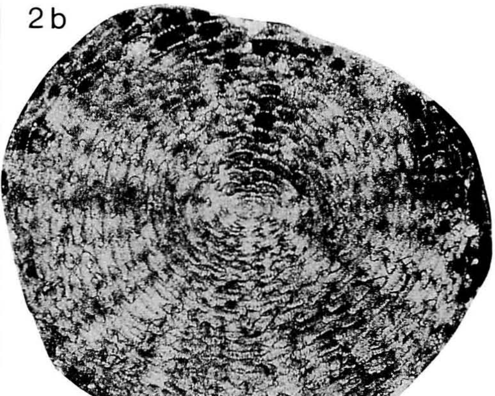

1c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Description: Test attached to substrate, cylindrical through elongate-subconical to large dendroid form; chambers disposed irregularly in elongated spiral coils separated by non-tubulous septa, and communicating by open passages, surrounded by thick cylindrical wall, with coarse pores and imperforate pustules; 1.96 to 7.84 mm high, and 1.64 to 2.40 mm broad in basal part of test, and 1.8 and 4.8 mm broad in upper part in vertical section. Embryonic chambers biloculine, spherical protoconch, 360 × 380 μm in diameter, and reniform deuteroconch, 180 × 100 μm in diameter; later periembryonic chambers in trochoidal, and then high-spired around axial hollow, formed by irregular vertical tubes; wall thick, calcareous, hyaline; 208 to 340 μm in thickness, with irregularly scattered coarse perforations at outer wall, but finer pores at inner wall; inner septal walls imperforate, double fibrous in texture; 40 to 120 μm in thickness; aperture large, terminal, covered by perforate plate.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form lacks both perforated plates at the surface surrounded by imperforate areolae of *Homotrema rubrum* (Lamarck, 1816), and the pillar-pores of *Miniacina miniacea* (Pallas, 1766). Thus the present form is assigned to *Sporadotrema cylindricum* (Carter).

Superfamily Discorbacea Ehrenberg, 1838

Family Mississippinidae Saidova, 1981

Subfamily Mississippininae Saidova, 1981

Genus *Mississippina* Howe, 1930

Mississippina concentrica (Parker and Jones, 1864MS, in Brady, 1864)

Plate 54, figures 1–7.

Pulvinulina concentrica Parker and Jones. Brady, 1864, p. 470, pl. 48, fig. 14; 1884, p. 686, pl. 105, figs. 1a–c; Cushman, 1915, p. 51, pl. 28, fig. 4; Cushman, 1921, p. 327, pl. 68, figs. 4a–c.

Discorbina vestita Seguenza, 1880, p. 148, pl. 13, fig. 39.

Eponides concentrica (Parker and Jones). Cushman, 1930, p. 8, pl. 9, figs. 4–5.

Stomatorbina concentrica (Parker and Jones). Phleger and Parker, 1951, p. 22, pl. 12, figs. 2a–b; McGowran, 1966, p. 482, 484, 486, pl. 4, figs. 1–7.

Mississippina concentrica (Parker and Jones). Uchio, 1952, p. 197–199, pl. 18, figs. 3–5; Hofker, 1968, p. 90, pl. 13, figs. 3–4; Hornibrook, 1968, p. 56, fig. 8.

Description: Test biconvex, with bluntly rounded at periphery, margin carinate; low

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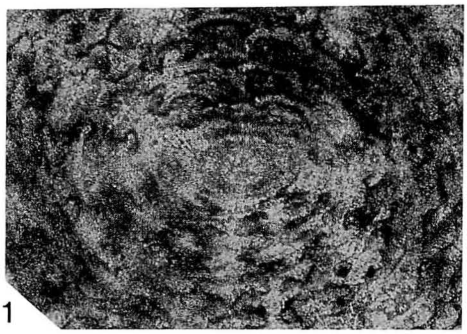
Explanation of Plate 78

Orbitogypsina globulus Matsumaru, n. gen., n. sp.

1–2. Axial sections. 1. Enlarged central part of Figure 3 in Plate 92 showing embryonic, and periembryonic chambers in planispiral coil, and dorsal and ventral chambers in overlapping coil. ×116. 2a–b. Axial sections of megalospheric form. 2a. ×116. 2b. ×43. 3–4. Equatorial sections. 3a. Central part of microspheric form showing coil and later overlapping coil. ×116, 3b. ×43. 4a–b. Equatorial sections of megalospheric form. 4a. ×43, 4b. ×116. Minamizaki Limestone; Localities: 1. 9704, 2–4. 9716 (Minami-Jima).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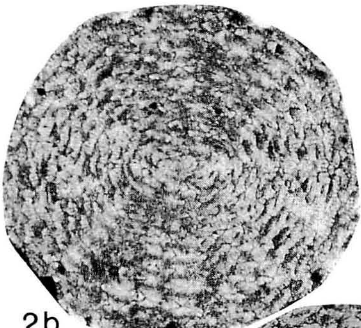
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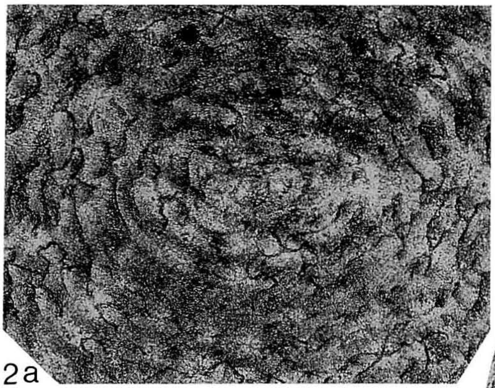
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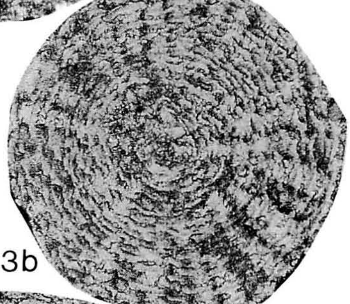
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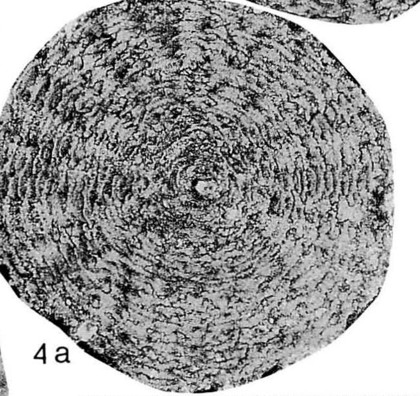
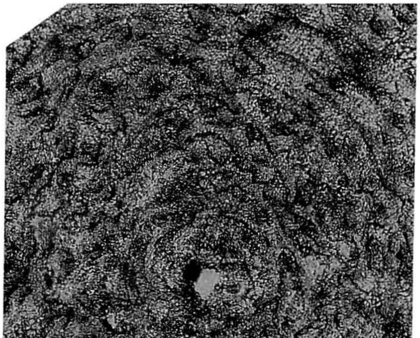

4a


3a


4b

trochoid in early stage to nearly planispiral coiling in adult; 0.36 to 0.87 mm in diameter, and 0.20 to 0.29 mm in thickness; form ratio of diameter to thickness; 1.9 to 3.0; spiral side umbonate, umbilical side evolute; sutures depressed on both sides; septa nearly radial, slightly curved in horizontal section; 7 chambers in the last coil; wall calcareous, lamellar; primary wall, monolamellar, and granular, but thick secondary accretions with radial texture; aperture interiomarginal on periphery, and extending from ventral side, across periphery to dorsal side.

Stratigraphic horizon: Sekimon and Minamizaki Limestones.

Remarks: The present specimens from Ogasawara are characterized by having a calcareous, granular monolamellar primary wall throughout with a darker and opaque band, and an interiomarginal slit aperture extending on the umbilical to the dorsal side. The present form was compared with *Mississippina concentrica* (Parker and Jones) by various authors, and is assigned to this species. Also the present form resembles *Mississippina monsouri* Howe, 1930, the type species of *Mississippina* Howe, 1930 from the Oligocene Byram Marl at Byram, Mississippi, U.S.A., but it differs in having a larger test with roundness of the periphery, and fewer chambers in the last whorl.

Suborder Lagenina Delage and Hérouard, 1896

Superfamily Nodosariacea Ehrenberg, 1838

Family Vaginulinidae Reuss, 1860

Subfamily Lenticulininae Chapman, Parr, and Collince, 1934

Genus *Lenticulina* Lamarck, 1804

Lenticulina sp.

Plate 59, figures 6–9.

Description: Test lenticular, planispiral, more or less involute, biumbonate, periphery keeled; 0.62 to 1.12 mm in diameter, and 0.27 to 0.50 mm in thickness; form ratio of diameter to thickness, 2.2 to 2.3. Proloculus small, spherical to subspherical; 44 × 44 μm in diameter in horizontal section, and 80 × 72, and 105 × 98 μm in diameter and height in vertical section. Chambers increase gradually in size; 312 μm in breadth, and 141 μm in height at chamber beyond final one; and number 9, and 10 comprising first and second

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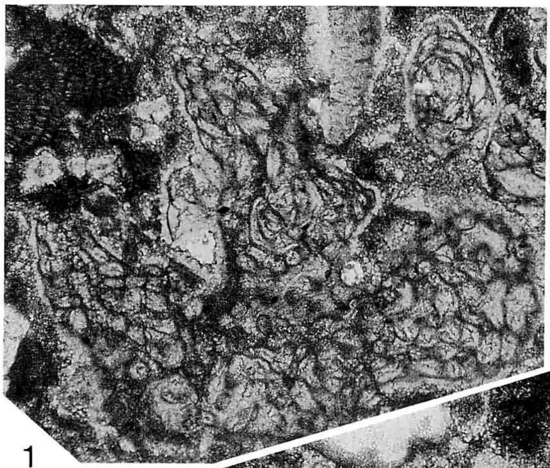
Explanation of Plate 79

Miniacina miniacea (Pallas)

1, 4. Oblique sections. 1. Microspheric form showing early chambers, and surrounding reniform to elongate chambers. ×43, 4. ×43, 2, 5. Vertical sections. 2a. Numerous chambers growing up from the flat attachment. ×43, 2b. Enlarged form of Figure 2a showing reniform to elongate chambers, and tubular chambers pierced by pillar-pores. 116, 3a–b. Horizontal sections of megalospheric form. 3a. ×43, 3b. Central part of Figure 3a showing proloculus, ovoidal chambers arranged with raspberry type, and tublar to reniform chambers. ×116. Minamizaki Limestone; Localities: 1, 1305 (Minamizaki Cape), 2–3, 5. 9709 (Minami-Jima), 4. 43 (801S Section).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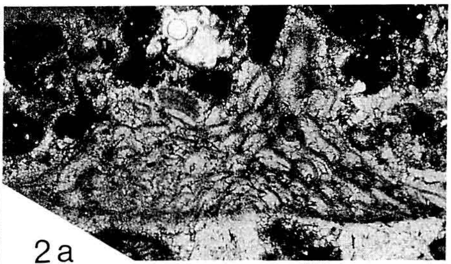
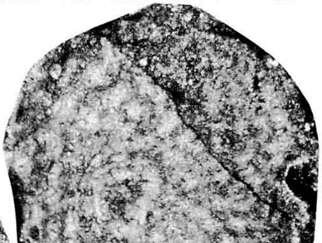
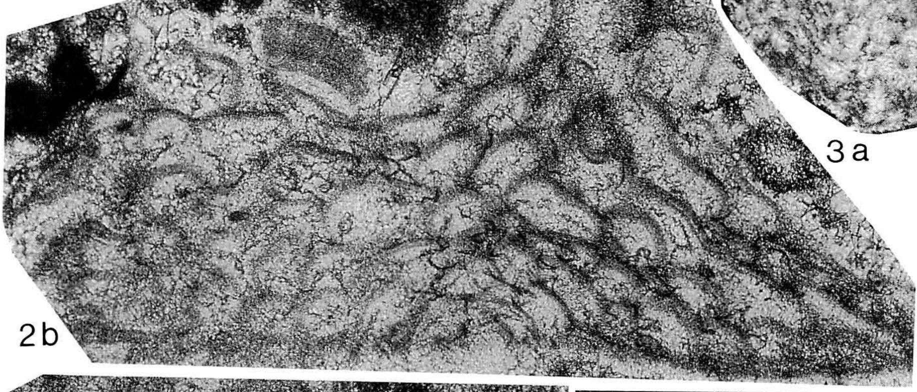
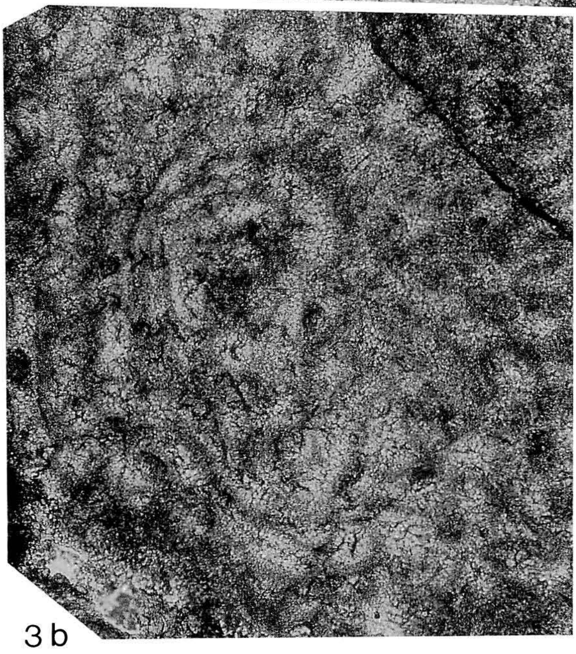
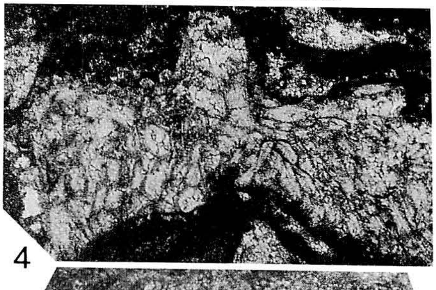

2a


3a


2b


3b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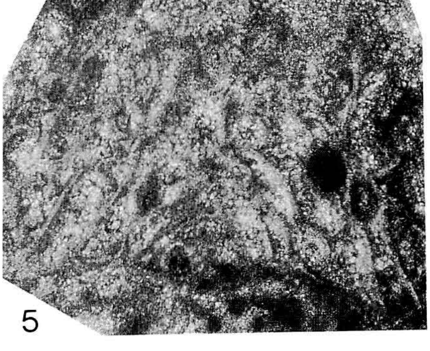
5

whorls, respectively; single septa oblique, straight, and curved at the polar plug (72 μm across); wall calcareous, optically radiate, perforate, secondarily lamellar with different in thickness of walls; aperture slitlike at periphery.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: Some specimens of *Lenticulina* Lamaeck, 1804 occur in scattered samples from the Minamizaki Limestone. The present form resembles *Lenticulina cultrata* (Montfort, 1808), but it does not show the same number of chambers in the last whorl.

Suborder Miliolina Delage and Hérouard, 1896

Superfamily Alveolinacea Ehrenberg, 1839

Family Alveolinidae Ehrenberg, 1839

Genus *Alveolina* d'Orbigny, 1826

Alveolina elliptica (Sowerby, 1840)

Plate 81, figures 1–4; Plate 82, figures 1–8; Fig. 34.

Fasciolites elliptica Sowerby, 1840, p. 329, pl. 24, fig. 17.
Alveolina javana Verbeek, 1892, p. 111–114, pl. 1, figs. 4–7; Verbeek and Fennema, 1896, p. 1137, pl. 2, figs. 27–36, pl. 3, figs. 37–38.
Alveolina wichimanni Rutten, 1914a, p. 45, pl. 9, figs. 1–2; Rutten, 1914b, p. 315–318, pl. 26, figs. 3–4, pl. 27, fig. 2.
Fasciolites javana (verbeek). Bakx, 1932, p. 231–234, pl. 4, figs. 21–25.
Fasciolites wichmanni (Rutten). Bakx, 1932, p. 234, pl. 4, figs. 26–28; Henrici, 1934, p. 42–43, pl. 3, fig. 6; Caudri, 1934, p. 132, pl. 4, figs. 7–8.
Alveolina javana Verbeek var. *boninensis* Hanzawa, 1950, p. 1–4, pl. 1, figs. 1–6.
Alveolina elliptica (Sowerby). Hottinger, 1960, p. 146, pl. 12, figs. 1–3.

Description: Test fusiform, in smaller size to elongated and elliptical to cylindrical, in larger size; 3.48 to 7.76 mm in axial diameter, and 1.1 to 3.3 mm in equatorial diameter; form ratio of axial diameter to equatorial diameter, 2.32 to 3.31. Megalospheric forms, spherical to subspherical proloculus; of diameter 60 × 52, 80 × 80, 88 × 100, 105 × 100, 112 × 112, 120 × 104, 125 × 114, 125 × 125, 136 × 120, 162 × 162, and 184 × 136 μm in 11 specimens; and 10 to 22 closely coiled whorls, of which earliest 4 to 6 whorls having, at times, basal thickning of wall (flosculinized wall); a radius of 312 to 324 μm in 5 whorls, 697 to 790 μm in 10 whorls, and 1317 to 1383 μm in 15 whorls. Septula alternating in position, in

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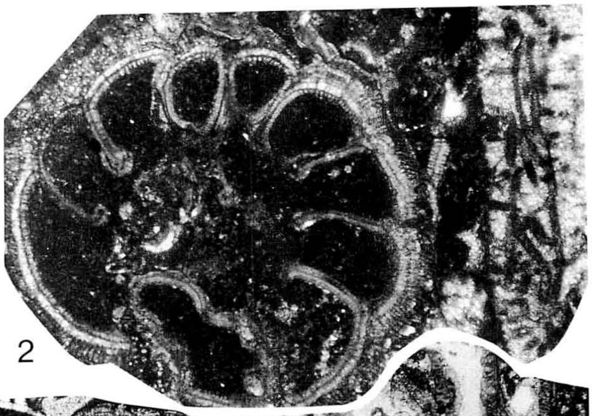
Explanation of Plate 80

Sporadotrema cylindricum (Carter)

1. Vertical section showing cylindrical through subconical to dendroid growing test, and chambers growing upward from attached early chambers. ×20, 2–3, 5. Horizontal sections. 2–3. ×20, 5. Showing early chambers to later chambers in spiral coil separated by nontubulous septa, thick wall with coarse pores, and imperforate pustules. ×43, 4a–b. Centered oblique sections of megalospheric form. 4a. ×20, 4b. Enlarged form of Figure 4a showing spherical protoconch, reniform deuteroconch, and early chambers in spiral. ×116. Minamizaki Limestone; Localities: 1. 44, 2. 46, 3. 12 (All belonging to 1304 Section), 4. 82703 (Minamizaki Cape), 5. 16 (1301 Section).

1



2

3

4a

4b

5

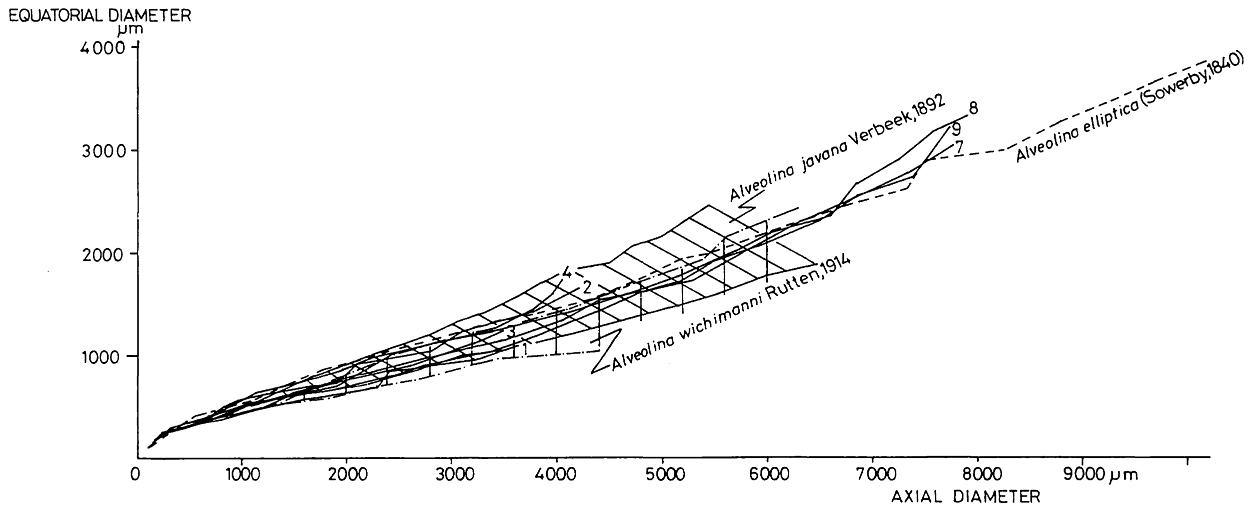
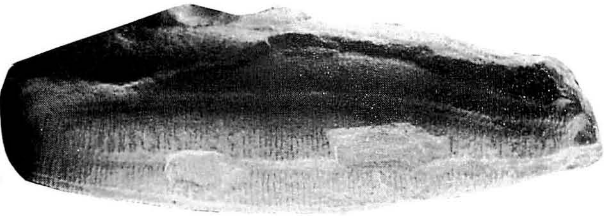


Fig. 34. Ontogenetic growth rates of *Alveolina elliptica* (Sowerby) from the Yusan and Okimura Formations, Haha-Jima, Ogasawara Islands. 1. NS72404–7 specimen; 2. NK81902–21 specimen; 3. NS72404–16 specimen; 4 NS72404-18 specimen; 7. NS82101–12 specimen; 8. SZ72305–5 specimen; 9. NH82202–27 specimen. 1, 3–4, 7, 9. Okimura Formations; 2, 8, Yusan Formation. Growth rates of *Alveolina elliptica* (Sowerby), *Alveolina javana* Verbeek, and *Alveolina wichimanni* Rutten, are respectively from topotype, Cutch (Kutch), India (Hottinger, 1960); from Verbeek (1882), Bakx (1932), Henrici (1934), Caudri (1934), and Hanzawa (1950); and from Rutten (1914b) and Caudri (1934). The diagonal and vertical lines represent the extent of ontogenetic growth rates of *Alveolina javana* Verbeek and *A. wichimanni* Rutten, respectively.

Explanation of Plate 81

Alveolina elliptica (Sowerby)

1, 3. Exteriors of axial view showing apertural face in the last row, alternating septula in adjacent chambers, and septal furrow of final whorl. 1a–b. ×11, 1c, 3. ×16. 2, 4. External forms of equatorial view showing chamberlet, preseptal and postseptal passages, septum, and basal layer. ×16. Yusan Formation; Locality: MI81807 (Miyukihama Section).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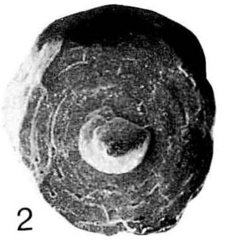
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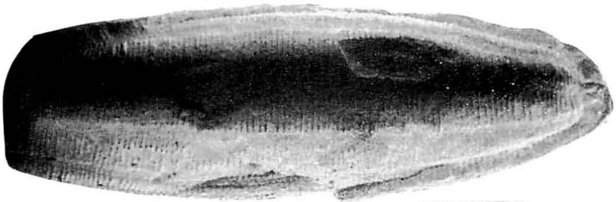
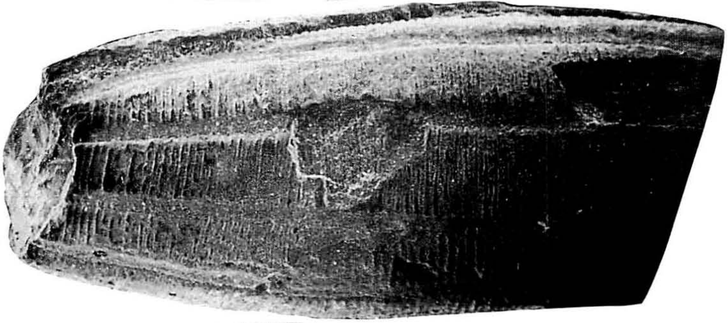
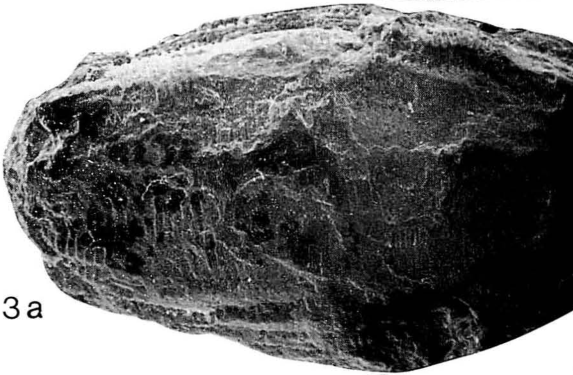
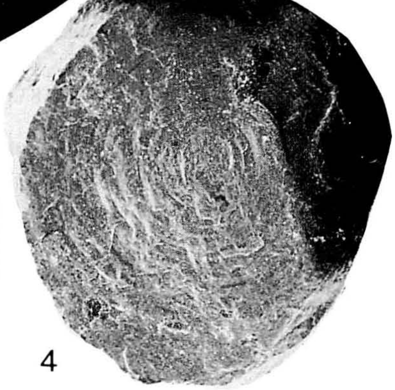

1b


1c


3a


4


3b

adjacent chambers; with preseptal and postseptal passages present; wall porcellaneous; aperture, two rows of openings near basal part of apertural face, alternating in position.

Stratigraphic horizon: Yusan and Okimura Formations.

Remarks: Hanzawa (1950) has referred *Alveolina* species from Shizukazawa, Haha-Jima, to a variety of *Alveolina javana* Verbeek, after comparison with Bakx's *Fasciolites javana*, in 1932. As shown in Fig. 34, the ontogenetic growth curves of axial diameter to equatorial diameter of the present form from Shizukazawa, Nishiura, and other localities in Haha-Jima, are however, in accord with those of the topotype specimens of *Alveolina elliptica* (Sowerby) by Hottinger (1960). As such, the present form from Haha-Jima is assigned to *Alveolina elliptica* (Sowerby). The ontogenetic growth curve of topotype of *Alveolina elliptica* is very similar to that of *Alveolina wichimanni* Rutten from the Eocene limestone of southwest New Guinea, and east Celebes, by Rutten (1914a, b), and from Soemba Island, Indonesia, by Caudri (1934). Moreover the growth curve of topotype *Alveolina elliptica* is similar to that of the topotype specimens of *Alveolina oblonga* d'Orbigny from the Ilerdian, by Hottinger (op. cit., figs. 76d and f).

According to Nuttall (1925), *Alveolina oblonga* occurs from the upper Ranikot Series to Laki Limestone, Pakistan, while *Alveolina elliptica* occurs from the Khirthar Series in Sind and Baluchistan, Pakistan. Rutten (1914a, b) described that *Alveolina wichimanni* was in association with *Nummulites* sp. cf. *bagelensis* Verbeek from the Eocene beds, east Celebes. According to Caudri (1934), *Alveolina wichimanni* has a range from Tertiary a2 Stage, based on the common presence of the genera *Assilina* and *Alveolina* to Tertiary b Stage, based on the association of *Nummulites*, *Pellatispira*, and *Discocyclina*. Judging from the ontogenetic growth curves of *Alveolina elliptica*, *A. javana*, *A. wichimanni*, and *A. oblonga*, they belong to a related species group. The former three species, which are well known in the Indo-Pacific Region from the middle to upper Eocene, would be related to *Alveolna elliptica* (Sowerby), and could have evolved from *Alveolina oblonga* d'Orbigny from the upper Paleocene to lower Eocene.

Genus *Borelis* de Montfort, 1808

Borelis boninensis Matsumaru, n. sp.

Plate 83, figures 1–2; Plate 85, figure 5.

Type material: Holotype, axial section, Saitama University coll. no. 8826 (Plate 83, fig. 1); Paratype, tangential section, Saitama University coll. no. 8827 (Plate 83, fig. 2).

Description: Test small, globular; 0.75 to 0.76 mm in axial length, 0.76 to 0.79 mm in

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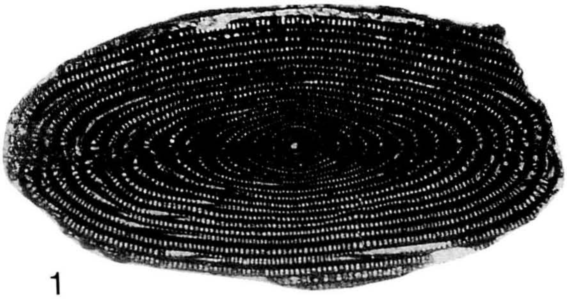
Explanation of Plate 82

Alveolina elliptica (Sowerby)

1, 3–4, 6–8. Axial sections. 1, 3–4, 6–7. Megalospheric forms, 8. Microspheric form. 1, 6, 8. ×10, 3–4. ×14, 7. ×21. 2, 5. Equatorial sections, 2. Microspheric form. ×25, 5. Megalospheric form. ×21. Yusan Formation; Localities: 1. SZ72305 (Shizukazawa Section), 2, 5–6. MI81806, 7. MI81805 (Miyukihama Section). Okimura Formation; Locality: 3–4. NS72402 (Nishiura Section).



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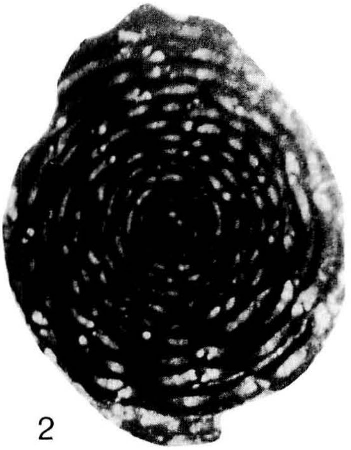

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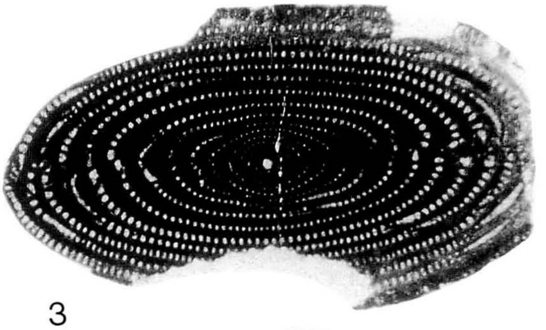

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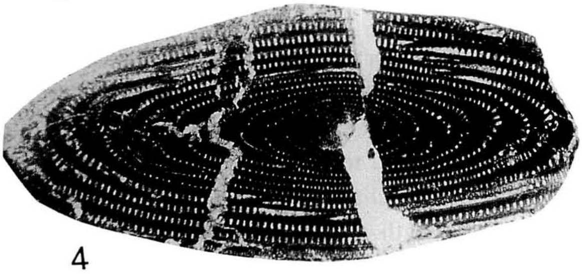

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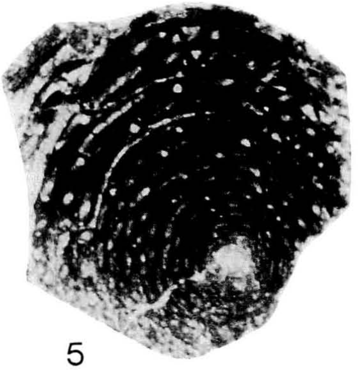

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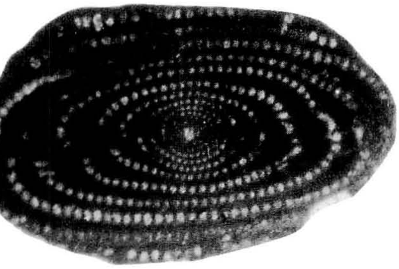
6



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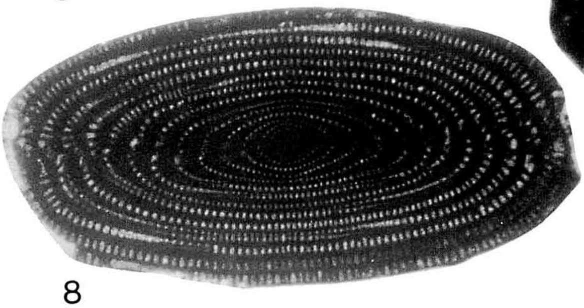

8

height; form ratio of length to height, 0.95 to 1.0; consisting of spherical proloculus 32 × 32 μm across; and total of 7 close whorls, from first irregularly coiled whorl to 6 planispiral whorls; septula and chamberlets, in alignment from chamber to chamber; chamberlets in the last whorl, 32 to 36 μm in tangential length, and 47 to 48 μm high; preseptal passage present; apertures in single row.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: The species is similar to *Borelis melo* (Fichtel and Moll), but differs in having fewer irregularly coiled, and planispiral whorls. This species resembles *Borelis parvulus* Hanzawa, 1957, from Saipan, but differs in having a globular test.

Borelis pygmaeus Hanzawa, 1930

Plate 83, figures 3–4.

Borelis sp. indet. Yabe and Hanzawa, 1929, p. 181, pl. 15, figs. 12–13, pl. 23, fig. 7.
Borelis (Fasciolites) pygmaea Hanzawa, 1930, p. 94–95, pl. 26, figs. 14–15.
Neoalveolina pygmaea (Hanzawa). Bakx, 1932, p. 237–238, pl. 3, figs. 18–20.
Fasciolites pygmaea (Hanzawa). Henrici, 1934, p. 44, pl. 2, fig. 18, pl. 3, figs. 1, 5.
Borelis pygmaeus Hanzawa. Hanzawa, 1947b, p. 9–11, pl. 5, figs. 1–4; Cole and Bridge, 1953, p. 27, pl. 12, fig. 16, pl. 13, figs. 4–7; Hanzawa, 1957, p. 55–56, pl. 34, figs. 8–9; Cole, 1957a, p. 336, pl. 102, fig. 1, pl. 110, figs. 5–7.

Description: Test small, fusiform; 0.63 to 0.96 mm in axial diameter, and 0.40 to 0.50 mm in height; form ratio of diameter to height, 1.58 to 1.96; nucleoconch and first two or three coils, not exposed, but later planispiral whorl, observed; involuted test, nearly subspherical until about third whorl; adult test elongated toward its poles, beginning from the 4th whorl; septula and chamberlets, in alignment from chamber to chamber; chamberlets in the 6th to 8th whorls, 24 to 36 μm in tangential length, and 32 to 40 μm high; preseptal passage present; and apertures in single row.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form is assigned to *Borelis pygmaeus* Hanzawa from Saipan, Timor, Java, Celebes, Nias Island, northeast Borneo, New Guinea, Cebu, and Luzon, in the Indo-Pacific Region. The present form from Chichi-Jima is the infant or early adult form of *Borelis pygmaeus* based on the small test, fewer whorls, and the low ratio of length

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Explanation of Plate 83

Borelis boninensis Matsumaru, n. sp.

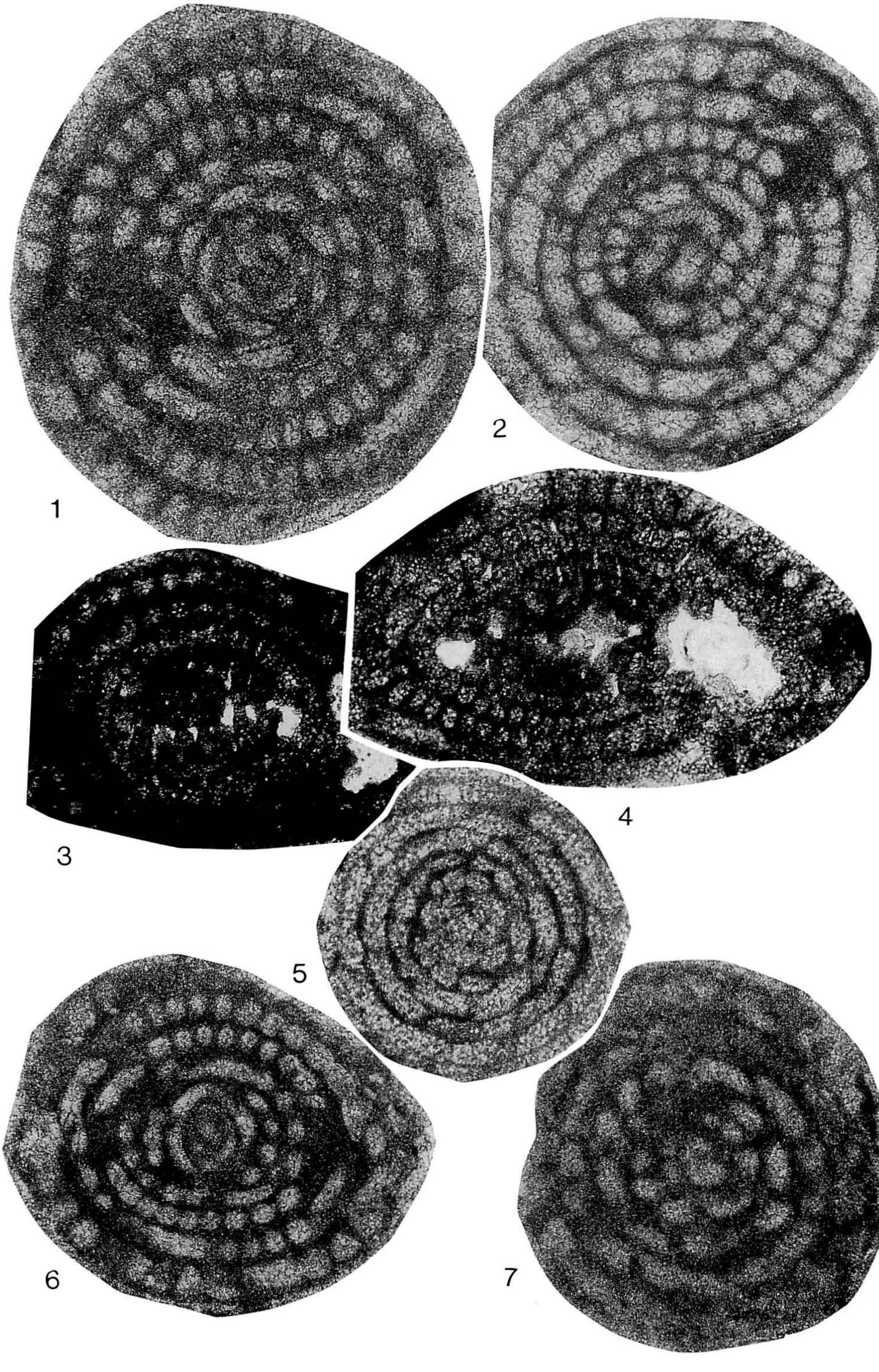
1. Axial section. Holotype, Saitama University coll. no. 8826. 2. Tangential section. Paratype, Saitama University coll. no. 8827. ×116. Minamizaki Limestone; Localities: 1. 53, 2. 57 (Both of 801N Section).

Borelis pygmaeus (Hanzawa)

3. Tangential section. 4. Axial section. ×100. Minamizaki Limestone; Localities: 3. 21.5 (1301 Section), 4. 49 (1304 Section).

Bullalveolina boninensis Matsumaru, n. sp.

5. Equatorial section. Paratype section, Saitama University coll. no. 8829. 6. Axial section. Holotype, Saitama University coll. no. 8828. 7. Tangential section. ×116. Minamizaki Limestone; Locality: 53 (801N Section).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2
3
4
5
6
7

to height.

Genus *Bullalveolina* Reichel, 1936

Bullalveolina boninensis Matsumaru, n. sp.

Plate 83, figures 5–7.

Type material: Holotype, axial section, Saitama University coll. no. 8828 (Plate 83, fig. 6); Paratype, equatorial section, Saitama University coll. no. 8829 (Plate 83, fig. 5).

Description: Test minute, subglobular; 0.40 to 0.59 mm in diameter, and 0.47 to 0.56 mm in height; form ratio of diameter to height, 1.1 to 1.2; consisting of megalospheric spherical proloculus, 34 × 34 μm across; and 6 closely coiled whorls, of first irregular whorl, streptospirally enrolled, and later ones, planispiral; first whorl, with more than 3 to 4 chamberlets per chamber, and perpendicular in coiling axis, then later rapidly enlarging whorls along coiling axis; septula and chamberlets, alternate in position from chamber to chamber; large preseptal passage present; porcelaneous wall, relatively thin, 5 to 10 μm thick; aperture of three rows of small openings, of diameter 6 to 8 μm.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form resembles *Bullalveolina bulloides* (d'Orbigny) from the middle Oligocene (Stampian) beds, Gaas, Aquitanian, France (Reichel, 1937), but differs in having a peculiar arrangement of the first planispiral whorl for the coiling axis, and in having more planispiral whorls. The present form is identified as a new species.

Genus *Flosculinella* Schubert, 1910

Flosculinella reicheli Mohler, 1950

Plate 84, figures 1–2.

Flosculinella reicheli Mohler, 1950, p. 521–527, text-figs. 1–3.

Description: Test small, globular; 0.66 to 0.67 mm in axial diameter, and 0.60 to 0.68 mm in height; form ratio of diameter to height, 1.0 to 1.1; nucleoconch and early streptospiral coils, not exposed, but later planispiral whorls observed; every whorl divided by tangential septa into low outer and high inner series; both series in every whorl, divided into chambers of nearly same tangential length by meridional septa; and chambers, further

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Explanation of Plate 84

Flosculinella reicheli Mohler

1. Axial section. 2. Equatorial section. ×116. Minamizaki Limestone; Localities: 1. 53 (801N Section), 2. 9704 (Minami-Jima).

Austrotrillina howchini (Schlumberger)

3–4, 6. Transverse sections. 3a–b. Megalospheric forms. 4, 6. Microspheric forms. 3a. ×100, 3b, 4, 6. ×40. 5, 7. Longitudinal sections. ×100. Minamizaki Limestone; Localities: 3, 6. 9709 (Minami-Jima), 4, 5, 7. 49 (1304 Section).


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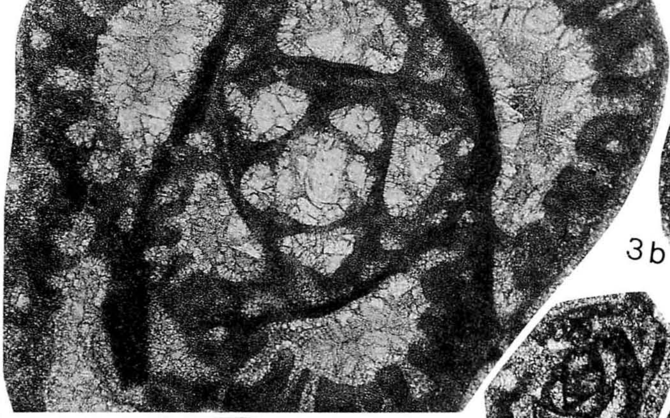
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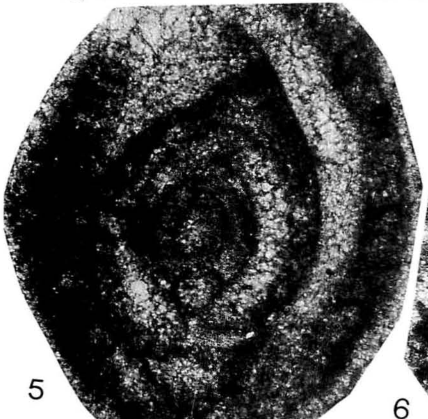
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subdivided into chamberlets by secondary septa in alternating alignment. Chamberlets in two series, outer series small, regular and inner series always large, regular. In last whorls, outer series 16 μm in length, and 12 μm in height; inner one 28 μm long, and 52 μm high; post-septal passage absent.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form is assigned to *Flosculinella reicheli* Mohler, 1950, based on small globular test and the number of planispiral whorls. *Flosculinella reicheli* resembles *F. globulosa* Rutten, 1917, but according to Mohler (1950), the former is exclusively spherical in form and the latter has a tendency to become spindle in form, such as *Flosculinella globulosa* Rutten-*F. bontangensis* (Rutten, 1912). The present form from Chichi-Jima always a small globular test, although it is of limited occurrence.

Superfamily Miliolacea Ehrenberg, 1839

Family Austrotrillinidae Loeblich and Tappan, 1986

Genus *Austrotrillina* Parr, 1942

Austrotrillina howchini (Schlumberger, 1893)

Plate 84, figures 3–7.

Trillina howchini Schlumberger, 1893, p. 119–120, text-figs. 1–2, pl. 3, fig. 6; Hanzawa, 1940, p. 791–793, pl. 42, figs. 1–2.

Austrotrillina howchini (Schlumberger). Parr, 1942, p. 361, text-figs. 1–3; Cole and Bridge, 1953, p. 20, pl. 14, fig. 12; Cole, 1954, p. 573, pl. 210, figs. 6–9; Hanzawa, 1957, p. 38, pl. 22, figs. 12–13, pl. 34, figs. 1–2; Chaproniere, 1984, p. 28–29, pl. 14, figs. 1–2.

Description: Test elongated, and ovate; 0.75 to 1.29 mm in length, and 0.56 to 1.19 mm in width at adult stage; form ratio of length to width, 1.3 to 1.5; subtriangular in transverse section, but with peripheral angles rounded; chambers arranged in triloculine or quinqueroculine; adult chambers, added layers against previous ones, as well as adult chamber wall. Megalospheric apparatus, biloculine; protoconch spherical to subspherical; of inner diameters 83 × 75, and 133 × 104 μm, and deuteroconch reniform; of inner diameter 62 × 42, and 80 × 32 μm; microspheric spherical proloculus; of inner diameter 36 × 36 μm. Wall calcareous, porcelaneous; adult outer portion thick, with alveolar structure, composed of compact thin

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Explanation of Plate 85

(All figures ×43)

Pyrgo sp.

1. Transverse section of microspheric form. Minamizaki Limestone; Locality: 49 (801N Section).

Quinqueloculina? boninensis Matsumaru, n. sp.

2–3 (left), 5 (left). Oblique sections. 2, 5 (left). Microspheric forms, 3 (left). Megalospheric form. Paratype, Saitama University coll. no. 8831. 3 (right), 4. Transverse sections. 3 (right). Holotype, Saitama University coll. no. 8830. 4. Microspheric form is associated with species of Sigmoilinitinae. 5 (right). Longitudinal section of microspheric form, which is associated with *Borelis boninensis*, n. sp. Paratype, Saitama University coll. no. 8832. Minamizaki Limestone; Localities: 2–4. 49, 5. 53 (Both of 801N Section).

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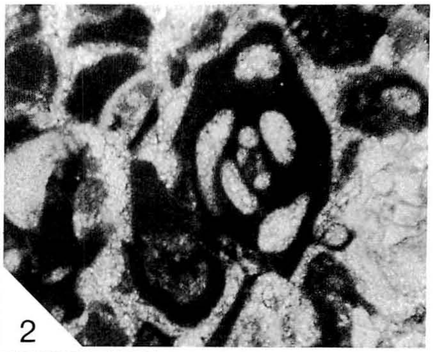

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outer layer; 8 to 24 μm thick, and inner layer of alveoli 40 to 96 μm thick; each alveolus 12 to 32 μm wide, and lamella of alveolar structure 12 to 36 μm thick, that against previous infant chambers, thin and solid in structure; aperture terminal, rather large, elongate or rounded.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present specimens show features ascribed to *Austrotrillina howchini* (Schlumberger), and the specific name *Austrotrillina howchini* is given. There may, however, be considerable similarity to the general shape of the elongated test of *Austrotrillina striata* Todd and Post, 1954, from Bikini Atoll, as viewed in random sections of the Minamizaki Limestones, but it is different to discriminate between *Austrotrillina howchini* (Schlumberger) and *Austrotrillina striata* Todd and Post with internal features, although there may be slightly different in the test surface.

Family Hauerinidae Schwager, 1876

Subfamily Miliolinellinae Vella, 1957

Genus *Pyrgo* Defrance, 1824

Pyrgo sp.

Plate 85, figure 1.

Description: Test ovate, periphery carinate; 360 to 496 μm in length, and 404 to 424 μm in breadth; megalospheric proloculus subspherical; of diameter 48 μm, and height 44 μm; chambers biloculine; final chamber of length 446 μm, and height 88 μm; and thickness of wall 22 μm; wall calcareous, imperforate, porcelaneous; aperture at end of final chamber.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form is similar to *Pyrgo fornasinii* Chapman and Parr (Barker, 1960, pl. 2, figs. 7a–b) in a general test shape, but is obscure in an apertural view. According to Barker (op. cit.), Cushman's (1921, p. 471) *Biloculina sarsi* (Schlumberger) is nothing but *Biloculina bradyi* Schlumberger, and the latter is assigned to *Pyrgo fornasinii* Chapman and Parr. The present form from the Minamizaki Limestone may be *Pyrgo fornasinii* Chapman and Parr.

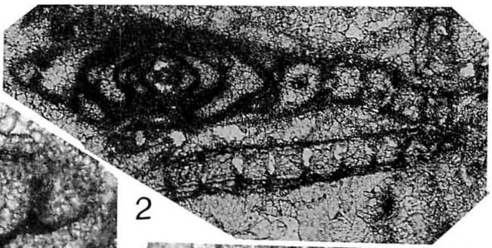
Explanation of Plate 86

Peneroplis planatus (Fichtel and Moll)

1–2. Axial sections of megalospheric form. 1. ×100, 2. ×40. 3, 5. Oblique sections. ×100, 4. Equatorial section. ×100. Yusan Formation; Localities: 1, 3–5. 49, 2. 56 (Both of 1304 Section).

Amphisorus hemprichii Ehrenberg

6. Axial section of megalospheric form. ×116, 7, 10. Oblique sections. ×40, 8–9. Tangential sections. ×40. Minamizaki Limestone; Locality: 49 (1304 Section).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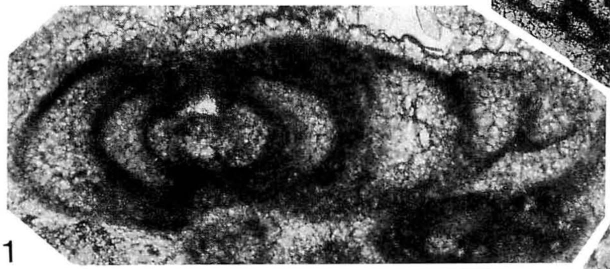
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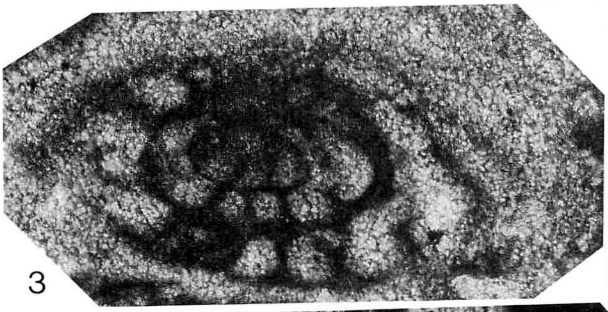
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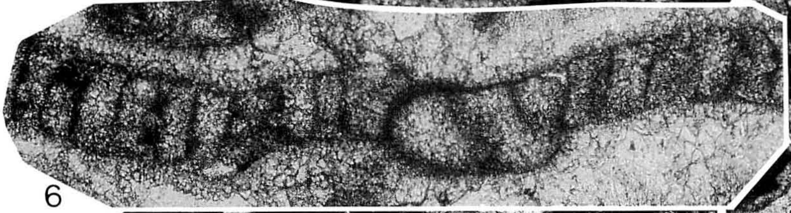
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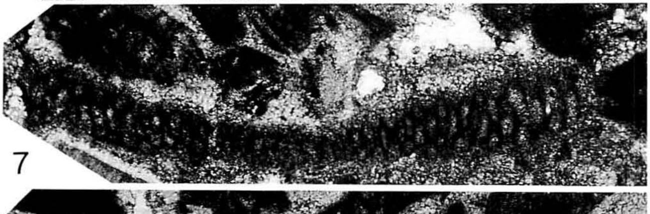
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Subfamily Haueringinae Schwager, 1876

Genus *Quinqueloculina* d'Orbigny, 1826

Quinqueloculina? boninensis Matsumaru, n. sp.

Plate 85, figures 2–5.

Type material: Holotype, transverse section of microspheric form, Saitama University coll. no. 8830 (Plate 85, fig. 3 (right)); Paratype, oblique section of megalespheric form, Saitama University coll. no. 8831 (Plate 85, fig. 3 (left)); Paratype, longitudinal section, Saitama University coll. no. 8832 (Plate 85, fig. 5 (right)).

Description: Test ovate in outline; 0.83 to 1.21 mm in length, and 0.48 to 0.54 mm in breadth in longitudinal section, and 0.68 × 0.51, 0.93 × 0.64, and 1.00 × 0.54 mm in diameter in transverse section; early chambers quinqueloculine or cryptoquinqueloculine in both megalospheric and microspheric generations. Megalospheric proloculus, spherical to subspherical; 40 × 40, 68 × 56, 92 × 92, and 110 × 108 μm in diameter in transverse section, and 40 × 37 μm in diameter in longitudinal section; microspheric proloculus spherical, 20 × 20 μm in diameter in transverse section. Chambers one-half coil in length; wall calcareous, imperforate, porcelaneous, 33 to 130 μm in thickness in last coil; aperture at end of final chamber, rounded.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: Although the present specimens are obscure about a tooth in the apertural part, they have quinqueloculine chamber arrangement, and the outer wall is usually thick, with a calcareous, imperforate, and porcelaneous layer. As such, the present form seems to be closely related to the genus *Quinqueloculina* d'Orbigny, 1826, but the present form shows a very thick wall, like *Scandonea* de Castro, 1971, and is assigned to *Quinqueloculina? boninensis*, n. sp. The present form resembles *Hauerina lyra* Serova, 1955, from the middle Miocene beds of Ukraine, the type species of *Podolia* Serova, 1961, but it does not show the pentagonal shape in the transverse section.

Explanation of Plate 87

Cyclorbiculina compressa (d'Orbigny)

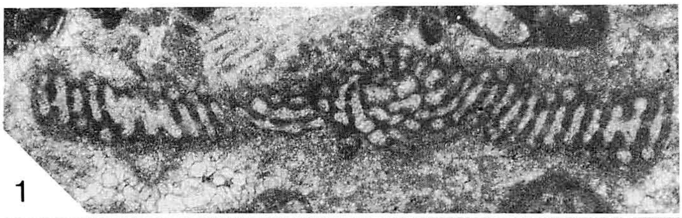
1–2. Oblique sections. ×43. Minamizaki Limestone; Locality: 56 (801N Section).

Praerhapydionina boninensis Matsumaru, n. sp.

3, 6–7, 10. Oblique sections. ×43. 4–5, 9. Axial sections. ×43. 4–5. Megalospheric forms. 4. Paratype, Saitama University coll. no. 8834. 9. Microspheric form. Paratype, Saitama University coll. no. 8835. ×43. 8. Equatorial section of megalospheric form. Holotype, Saitama University coll. no. 8833. ×43. Minamizaki Limestone; Localities: 3–5. 49, 6. 57, 7–8, 10. 58 (All belonging to 801N Section), 9. 9711 (Minami-Jima).

Sorites orbiculus (Forskal)

11. Tangential section. ×40. 12–13. Oblique sections. 12. Megalospheric form. ×100, 13. Microspheric form. ×40. Minamizaki Limestone; Localities: 11. 9709 (Minami-Jima), 12. 47 (801S Section), 13. 43 (1304 Section).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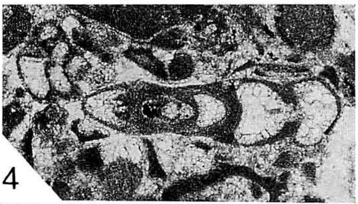
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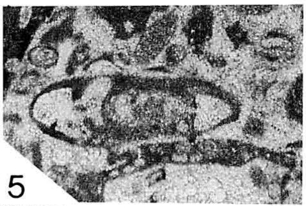
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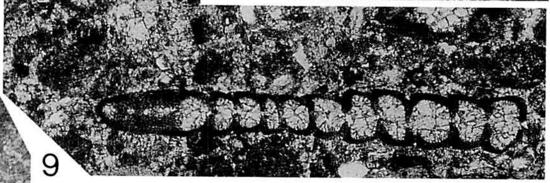
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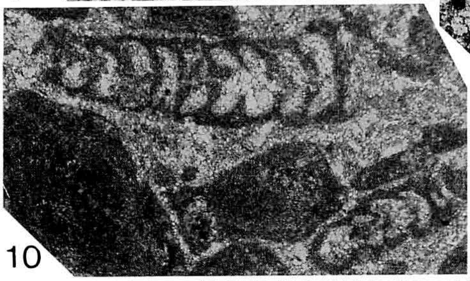
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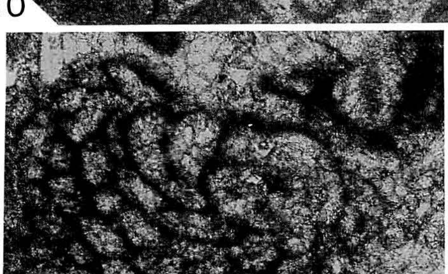
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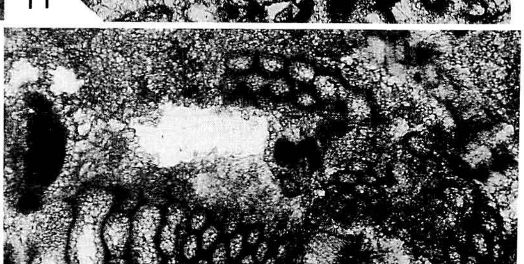
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Superfamily Soritacea Ehrenberg, 1839

Family Peneroplidae Schultze, 1854

Genus *Peneroplis* de Montfort, 1808

Peneroplis planatus (Fichtel and Moll, 1798)

Plate 86, figures 1–5.

Nautilus (Lituus) arietinus (part) Batsch, 1791, p. 4, p. 6, figs. 15a–b.
Nautilus planatus var. b, Fichtel and Moll, 1803, p. 91, pl. 16, figs. 1d, e–f.
Peneroplis planatus (Fichtel and Moll). d'Orbigny, 1826, p. 285.
Peneroplis pertusus (Fortskål) var. a, Brady, 1884, p. 204, pl. 13, fig. 15.
Peneroplis pertusus (Fortskål) var. *planatus* (Fichtel and Moll). Cushman, 1917, p. 87, pl. 37, fig. 3.
Peneroplis planatus (Fichtel and Moll.) Cushman, 1921, p. 481; Cushman, 1930, p. 39, pl. 14, figs. 6–7; Cole, 1965, p. 8–10, pl. 2, figs. 1–2, pl. 4, fig. 6.

Description: Test planispiral, compressed, with early stage involute; 478 to 936 μm in diameter, and 248 to 374 μm in thickness in vertical section; form ratio of diameter to thickness, 2.3 to 2.5; Megalospheric proloculus, subcircular 32 × 26, and 56 × 52 μm in inner diameter and height in vertical section; more than 10 chambers in last whorl in early stage in oblique section. Later chambers rapidly increasing in breadth, resulting in flared test; 1.6 to 1.7 mm in diameter of entire test. Periphery bluntly acute in early stage, lobulated in adult; interior of chambers, not subdivided with subepidermal partitions; wall calcareous, porcellaneous; aperture in early stage irregular, ellipsoidal opening bordered by slightly raised rim, slightly above base of apertural face, in adult obscured with secondary calcification.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form is composed with *Peneroplis planatus* (Fichtel and Moll), and is regarded as identical to the latter species. *Peneroplis planatus* (Fichtel and Moll) resembles *P. proteus* d'Orbigny, but differs in having a flared test, and no annular chambers after the initial involuted coil.

Family Soritidae Ehrenberg, 1839

Subfamily Soritinae Ehrenberg, 1839

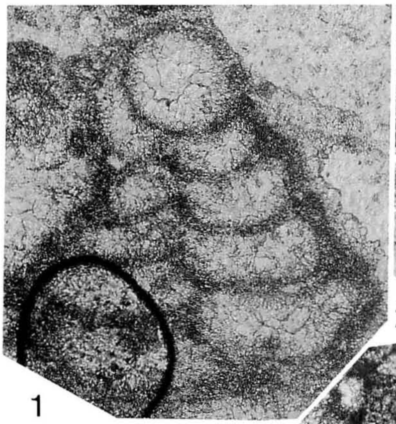
Genus *Amphisorus* Ehrenberg, 1839

Amphisorus hemprichii Ehrenberg, 1839

Explanation of Plate 88

Textularia sp.
1–3. Longitudinal sections. 1. Megalospheric form. ×116, 2–3. Microspheric forms. ×43. Minamizaki Limestone; Localities: 1. 9 (1302 Section), 2. 9704, 3. 9702 (Minami-Jima).

Valvulina sp.
4, 7–8. Transverse sections. ×43, 5–6. Longitudinal sections. ×43, 5. Megalospheric form, 6. Microspheric form. Minamizaki Limestone; Localities: 4. 9709, 6, 8. 9704 (Both of Minami-Jima), 5. 58, 7. 57 (Both of 801N Section).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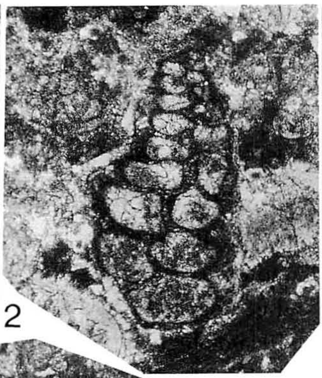
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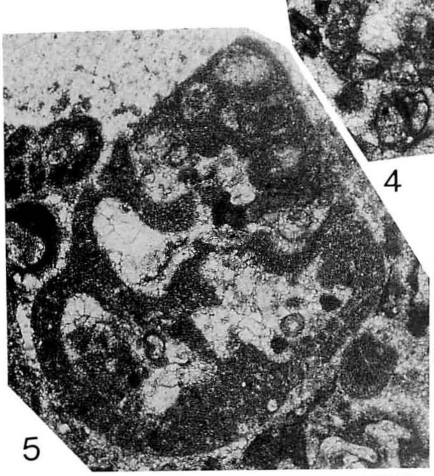
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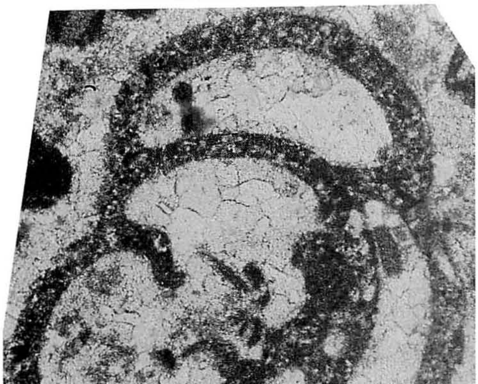
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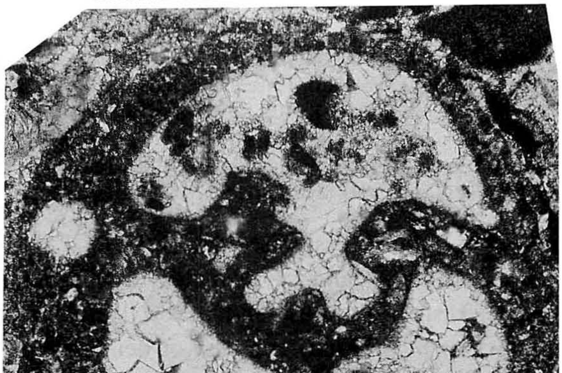
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Plate 86, figures 6–10.

Amphisorus hemprichii Ehrenberg, 1839, p. 130; Lehman, 1961, p. 649–650, text-figs. 39–40, pl. 10, figs. 6–9, pl. 11, figs. 1–5; Smout, 1963, p. 239; Hottinger, 1977, p. 99–100, figs. 10, 22B, 31, 32C, 33A.
Orbitolites duplex Carpenter, 1856a, p. 220, 224.
Bradyella duplex (Carpenter). Munier-Chalmas, 1902, p. 353.

Description: Test large, discoidal, biconcave, with thickened rim; 1.14 to 3.28 mm in diameter, and 0.08 to 0.13 mm in thickness in central portion, and 0.16 to 0.20 mm in periphery; form ratio of diameter to thickness in periphery, 7.2 to 16.0. Megalospheric embryonic apparatus, proloculus, and flexostyle tubular chamber, deuteroculus; embryonic apparatus 208 μm wide, and 104 μm high in vertical section; wall of embryonic apparatus 8 μm thick. Periembryonic chambers spiral; later median chambers, subdivided by septula, and with subepidermal partitions (6 to 28 μm thick), arcuate, ogival to hexagonal chambers disposed in cycles; 56 × 28, 56 × 40, 64 × 40, 64 × 48, 104 × 48, and 120 × 56 μm, in inner radial and tangential diameters. Septula alternating and forming lateral chamberlets; large median annular passages (8 to 48 μm in diameter) and crosswise oblique stolons connecting successive chambers and chamberlets; wall calcareous, porcelaneous; aperture of numerous pores on peripheral margin.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: Although there are no exact equatorial sections of specimens from the Minamizaki Limestone for study, the present form agrees well with Lehmann's description and illustration, and is of the same or nearly the same size in embryonic apparatus, measured from Lehmann's drawing (fig. 40), and plate (pl. 11, fig. 3). Then the present form is assigned to *Amphisorus hemprichii* Ehrenberg as a monotypic genus.

Genus *Sorites* Ehrenberg, 1839

Sorites orbiculus (Forskål, 1775)

Plate 87, figures 11–13.

Nautilus orbiculus Forskål, 1775, p. 125.
Sorites orbiculus (Forskål). Ehrenberg, 1839, p. 134, pl. 3, figs. 2a–d; Cole, 1965, p. 20–21, pl. 6, figs. 1–5, 7, 9, pl. 7, figs. 1–8, 10–12, pl. 8, figs. 7–9.
Sorites martini (Verbeek). Hanzawa, 1957, p. 55, pl. 6, figs. 3–4, 8–9, pl. 35, fig. 16.
Sorites orbiculus Ehrenberg. Lehmann, 1962, p. 641–643, text-fig. 36, pl. 8, figs. 1–8.
"Orbitolites" orbiculus (Forskål). Smout, 1963, p. 259, pl. 4, figs. 3–4.

Description: Test discoidal; 1.33 to 1.80 mm in diameter, and 0.11 to 0.15 mm in thickness; form ratio of diameter to thickness, 11.0 to 12.0. Megalospheric apparatus, subspherical proloculus, and flexostyle tubler chamber, deuteroculus; inner diameter of proloculus 80 × 52 μm, and that of deuteroculus 175 × 136 μm; followed by one undivided chamber through flexostyle canal; and 8 to 9 planispirally coiled peneroplid chambers present. Later chambers with annular series, subdivided into lateral chamberlets symmetric in respect to equatorial plane; of dimension 56 × 48, 64 × 56, 104 × 72, 104 × 80, 112 × 88, and 128 × 88 μm in inner radial and tangential diameters in equatorial section; all connected by crosswise oblique stolon system, reduced to one stolon layer of median annular passages (16 μm in diameter); wall calcareous, porcelaneous; aperture typically in single row of openings at periphery.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: The present form is assigned to *Sorites orbiculus* (Forskål, 1775) in every respect. *Sorites martini* (Verbeek, 1896) from the Tagpochau Limestone, Saipan, by Hanzawa (1957, pl. 35, fig. 16), is simply *Sorites orbiculus* in every respect, except that *Sorites martini* has a large test, whereas *Sorites orbiculus* does not. As such, it appears that *Sorites martini* (Verbeek) is a junior synonym of *Sorites orbiculus* (Forskål).

Subfamily Archaiasinae Cushman, 1927

Genus *Cyclorbiculina* A. Silvestri, 1937

Cyclorbiculina compressa (d'Orbigny, 1839)

Plate 87, figures 1–2.

Orbiculina compressa d'Orbigny, 1839, p. 66; Cushman, 1919, p. 70, pl. 7, fig. 6.
Archaias compressus (d'Orbigny). Cole, 1957a, p. 328, pl. 24, figs. 1–9.
Puteolina (Archaias) compressa (d'Orbigny). Hofker, 1971, p. 47–48, pl. 85, figs. 1–2, 4, pl. 86, figs. 1–7.
Cyclorbiculina compressa (d'Orbigny). Seiglie, Grove and Rivera, 1977, p. 863–864.

Description: Test discoidal, with central portion swollen; more than 2.0 mm in diameter, and 0.94 mm in diameter of swollen center, and 0.2 mm thick in final discoidal part. Proloculus subspherical, $84 \times 80\,\mu m$ in diameter, followed by flexostyle tublar chamber, and then by involuted planispiral early chambers in several whorls, and flared, reniform, annular chambers; those subdivided by two sets of radial septula or pilintradermal plates, projected inward from lateral facies of chambers toward rows of apertures; aperture, two or three rows of multiple pores in median groove on truncate apertural face; pillars present on median groove; wall calcareous, imperforate porcelaneous.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: Although there are no exact equatorial sections for study, the present form is easily identified as *Cyclorbiculina compressa* (d'Orbigny) in every respect: proloculus and flexostyle tublar chamber, followed by a planispiral, involuted early stage, and then followed by flared, reniform, annular chambers. The present form has chambers with pilintradermal partitions and pillars, but no other endoskeleton, and apertures confined to the central zone of chambers. Seiglie *et al.* (1977, p. 858–859) showed the evolution of genera of the subfamily Archaiasinae Cushman, 1927. According to them, *Cyclorbiculina* A. Silvestri, 1937 evolved from *Archaias* de Montfort, 1808 in Oligocene, and *Miosorites* Seiglie and Grove, 1977 evolved from *Cyclorbiculina*, with the disappearance of pillars and an involuted stage in late Oligocene. The presence of *Miosorites* is, however, not yet known from the Minamizaki Limestone, Chichi-Jima, Ogasawara Islands.

Subfamily Praerhapydionininae Hamaoui and Fourcade, 1973

Genus *Praerhapydionina* van Wessem, 1943

Praerhapydionina boninensis Matsumaru, n. sp.

Plate 87, figures 3–10.

Type material: Holotype, equatorial section of megalospheric form, Saitama University coll. no. 8833 (Plate 87, fig. 8); Paratype section of megalospheric form, Saitama University coll. no. 8834 (Plate 87, fig. 4); Paratype, axial section of microspheric form, Saitama University coll. no. 8835 (Plate 87, fig. 9).

Description: Test elongate, conical; 0.81 to 1.33 mm in longitudinal diameter, and 0.18 to 0.35 mm in transverse diameter at end of adult uniserial stage; megalospheric generation, involuted and planispiral in early stage; 0.66 to 0.81 mm in diameter; consisting subspherical proloculus, 56 μm in diameter, and 50 μm in height; followed by chambers in as many as two volutions in vertical section; microspheric generation, involuted and planispiral in early stage, 0.29 to 0.37 mm in diameter, followed by chambers more than two volutions. Uniserial stage added to planispiral early stage, from 4 to 10 chambers; uniserial chambers laterally compressed in longitudinal section, and circular in transverse section, subdivided by septa, 20 to 25 μm thick; terminal uniserial chambers, large; 154 to 320 μm in diameter, and 80 to 110 μm in height. Each septum, buttressed by radial wedge-shaped subepidermal partitions, tapering in transverse section; from 16 μm thick at the test wall to about 5 μm thick at interior ends; subepidermal partitions, triangular in vertical section, number about 10 per chamber in transverse section of adult test; partitions, aligned in successive uniserial chambers; wall microcrystalline calcite, porcelaneous; 5 to 24 μm thick; apertures in uniserial test, about 20 μm in diameter, surrounded by subsidiary cribrate apertures, 4 to 16 μm in diameter.

Stratigraphic horizon: Upper member of Minamizaki Limestone.

Remarks: The present specimen, which has chambers with subepidermal partition but no other endoskeleton, resembles *Praerhapydionina* (?) *vanwessemi* Frost and Langenheim, 1974, from the lower Eocene Lecheria Limestone, Chiapas, Mexico, but differs in having about 10 partitions. *Praerhapydionina boninensis*, n. sp. resembles *P. delicata* Henson from the Oligocene stage, Moratella, Spain (Hottinger, 1963), but differs in lacking secondary radial partitions between primary ones.

Suborder Textulariina Delage and Hérouard, 1896

Superfamily Textulariacea Ehrenberg, 1838

Family Textulariidae Ehrenberg, 1838

Subfamily Textulariinae Ehrenberg, 1838

Genus *Textularia* Defrance, 1824

Textularia sp.

Plate 88, figures 1–3.

Description: Test elongate, leaf-shaped, triangular in longitudinal section, compressed in transverse section; 304 to 853 μm in length, and 280 to 437 μm in breadth at frontal base; form ratio of length to breadth, 1.1 to 2.0. Megalospheric proloculus subspherical, 64 μm in diameter, and 56 μm in height in longitudinal section; wall of proloculus, 6 μm thick; chambers biserial, increasing gradually in size; 236 to 270 μm in breadth, and 92 to 139 μm in height at final one; floors and roofs, 21 to 24 μm thick; wall agglutinated, canaliculate; aperture interiomarginal.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: Some specimens of *Textularia* Defrance, 1824 occur in random thin sections from the Minamizaki Limestone. The present form does not show enough characteristics to enables species identification.

Family Valvulinidae Berthelin, 1880

Subfamily Valvulininae Berthelin, 1880

Genus *Valvulina* d'Orbigny, 1826

Valvulina sp.

Plate 88, figures 4–8.

Description: Test conical; 1.28 to 1.66 mm in length, and 0.36 to 1.64 mm in breadth at frontal base; form ratio of length to breadth, 1.0 to 1.3; early stages triseptal, and triangular in longitudinal section; later stages loose spiral of more than three chambers per whorl; proloculus spherical, $80 \times 80\,\mu$m in diameter in megalospheric generation, and $40 \times 40\,\mu$m in microspheric one; wall thick, agglutinated, canaliculate; 110 μm thick at base of final chamber; aperture interiomarginal with valvular tooth or flap.

Stratigraphic horizon: Minamizaki Limestone.

Remarks: The present form is similar to *Valvulina triangularis* d'Orbigny, 1826, type species of *Valvulina* d'Orbigny, 1826, but is obscure in the aperture at the base of the apertural face. According to Bourdon and Lys (1955), *Valvulina triangularis* d'Orbigny occur from the *Ostrea* Marl of Stampian, Bordeau, France. The present form resembles *Valvulina mixta* Parker and Jones, 1865, the type species of *Cribrobulimina* Cushman, 1927, in general shape, but differs in not having a double shell wall, consisting of an inner tubular layer and an outer arenaceous layer.

Place Names

Chichi-Jima 父島, Haha-Jima 母島, Minami-Jima 南島, Kinseki Beach 金石海岸, Minamizaki Cape 南崎, Same-Ike 鮫池, Ōgi-Ike 扇池, Okimura 沖村, Okiko 沖港, Chibusa dam 乳房ダム, Ōtani 大谷, Hyōgidaira 評議平, Miyukihama 御幸浜, Nankinhama 南京浜, Yusankaigan ユーサン海岸, Shizukazawa 静沢, Nishiura 西浦, Nenbutsu-Tōge 念仏峠, Sekimon 石門, Harinoiwa 針ノ岩, Old Ichinohashi Bridge 旧一ノ橋, Ninohashi Bridge 二ノ橋, Rōsuishi ロース石, Rōsudani ロース谷, Tsukigaoka Shrine 月ガ岡神社, Sonminkaikan 村民会館, Maehama Beach 前浜, Toeijūtaku 都営住宅,

References Cited

Adams, C. G.,. 1965: The foraminifera and stratigraphy of the Melinau Limestone, Sarawak, and its importance in Tertiary correlation. *Quart. Jour. Geol. Soc. London*, vol. 121, p. 283–338, pls. 21–30.

——— and Belford, D. J., 1974: Foraminiferal biostratigraphy of the Oligocene-Miocene limestones of Cristmas Island (Indian Ocean). *Palaeont.*, vol. 17, p. 475–506, pls. 71–74.

Alcantara, P. M., 1980: Tertiary larger foraminifera from the Argao-Dalaguete region, southern Cebu Island, Philippines. *In*, Igo, H. and Noda, H., eds., *Professor Saburo Kanno Memorial Volume, Ibaraki*, p. 221–232.

Archiac, E. J. A. d', and Haime, J., 1853: Description des animaux fossiles du groupe nummulitique de l'Inde. *Monographie des Nummulites*, p. 373 pp., 36 pls.

Asami, S., 1970: Topography and geology of Ogasawara Islands. *Research report of Landscape, Ogasawara Islands*, 1970, p. 85–116, 11 figs. (in Japanese).

Bakx, L. A. J., 1932: De genera *Fasciolites* en *Neoalveolina* in het Indo-Pacifische gebied. *Verh. Geol. Mijnb. Gen. Ned. Kol., Geol. ser.*, vol. 9, p. 205–266, 4 pls.

Barker, R. W., 1960: Taxonomic notes on the species figured by H. B. Brady in his report on the Foraminifera dredged by H. M. S. Challenger during the years 1873–1876. *Soc. Econ. Pal. Mineral. Spec. publ.* no. 9, 238 pp., 115 pls.

——— and Grimsdale, T. F., 1936: A contribution to the phylogeny of the orbitoidal foraminifera, with descriptions of new forms from the Eocene of Mexico. *Jour. Paleont.*, vol. 10, p. 231–247, pls. 30–38.

——— and ——— 1937: Studies of Mexican fossil foraminifera. *Ann. Mag. Nat. Hist.*, vol. 19, p. 161–178, pls. 5–9.

Barron, E. J., Harrison, C. G. A., Sloan, J. L. and Hay, W. W., 1981: Paleogeography, 180 million years ago to the present. *Eclog. Geol. Helv.*, vol. 74, p. 443–470.

Batsch, A. I. G. C., 1791: Sechs Kupfertafeln mit Conchylien des Seesandes, gezeichnet und gestochen von A. J. G. K. Batsch, Jena, 6 pls.

Bellardi, L., 1852: Catalogue raisonne des fossiles nummulitique du Compte de Nice. *Mem. Soc. Geol. France*, vol. 4, p. 205–278.

Bemmelen, R. W. van., 1949: *The geology of Indonesia.* Martinus Nijhoff. The Hague. Vols. 1–2, 732 pp.

Berggren, W. A., Kent, D. V., Flyn, J. J. and van Couvering, J. A., 1985: Paleogene geochronology and chronostratigraphy. *In*, Snelling, N. J. *ed.*, *The Chronology of the Geological Record*, *Geol. Soc. Mem.*, vol. 10, p. 141–195.

Berthelin, G., 1880: Memoire sur les Foraminiferes fossils de l'Etage Albien de Moncley (Doubs). *Mem. Soc. Geol. France*, vol. 1, 84 pp., pls. 24–27.

Bieda, F., 1950: Sur quelques foraminiferes nouveaux ou peu connus du flysch des Karpates Polonaises. *Rocz. Pol. Tow. Geol.*, vol. 18, p. 167–179, pls. 3–4.

——— 1963: Duze Otwornice eocenu Tatrzanskiego. *Inst. Geol. Prace*, vol. 37, p. 157–215, 26 pls.

Blainville, H. M. D. de, 1826: *Dictionaire des Sciences Naturelle, pin-plo*. Paris: F. G. Levrault, vol. 41, p. 17.

——— 1827: *Manuel de malacologie et de conchyliologie* (1825). Paris: F. G. Levrault, 664 pp., 87 pls.

Blondeau, A., 1972: *Le Nummulites*. Paris: Vuibert, 254 pp., 38 pls.

Blow, W. H., 1969: Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *Proc. 1st Intern. Conf. Planktonic Microfossils, Geneva*, p. 199–421. 54 pls.

——— 1979: *The Cainozoic Globigerinida*, 3 vols., 1413 pp., 264 pls. E. J. Brill.

——— and Banner, F. T., 1962: The mid-Tertiary (Upper Eocene to Aquitanian) Globigerinaceae. *In*, Eames, F. E., Banner, F. T., Blow, W. H. and Clarke, W. J. *eds.*, *Fundamentals of Mid-Tertiary Stratigraphical Correlation*, p. 61–151, pls. 8–17. Cambridge Univ. press.

Bolli, H. M., 1957: Planktonic foraminifera from the Eocene Navet and San Fernando formations of Trinidad, B. W. I. *U. S. Nat. Mus., Bull.* vol. 215, p. 155–172, pls. 35–39.

——— and Saunders, J. B., 1985: Oligocene to Holocene low latitude planktonic foraminifera. *In*, Bolli, H. M., Saunders, J. B. and Perch-Nielsen, K. *eds.*, *Planktonic stratigraphy*, p. 155–264, 46 figs. Cambridge Univ. press.

Boubée, N., 1832: Presentaion de deux nouvelles especes de *Nummulites*. *Bull. Soc. Geol. France*, vol. 2, p. 444–445, pl. 15.

Boukhary, M., Blondeau, A. and Ambroise, D., 1982: Etude sur les *Nummulites* de la region de Minia-Samalut, vallee du Nil, Egypste. *Cahiers Micropal.*, vol. 1, p. 65–78, pl. 1.

Bourcart, J. and David, E., 1933: Etude stratigraphic et paleontologique des Gres a foraminiferes d'Ouezzan au Maroc (Olig. et Mioc. inferieur). *Mem. Soc. Nat. Maroc, Rabat*, no. 37, 62 pp., 7 pls.

Bourdon, M. and Lys, M., 1955: Foraminiferes du Stampien de la carriere de la Souys-Floirac (Gironde). Compte Rendu Seanc. *Soc. Geol. France* 1955, p. 336–338.

Boussac, J., 1906: Developpement et morphologie de quelques foraminiferes de Priabona. *Bull. Soc. Geol. France*, vol. 6, p. 88–100, pls. 1–3.

——— 1911: Etudes stratigraphiques et paleontologiques sur le Nummulitique de Biarritz. *An. Hebert., Ann. stratigr. paleont. Lab. geol. Paris*, 95 pp., 22 pls.

Brady, H. B., 1864: Contributions to the knowledge of foraminifera. On the rhizopodal fauna of the Shetlands. *Trans. Linn. Soc. London*, vol. 24, p. 463–476, pl. 48.

——— 1875: Fossil foraminifera of Sumatra. *Geol. Mag.*, vol. 2, p. 532–539, pls. 13–14.

——— 1884: Report on the Foraminifera dredged by HMS Challenger, during the years 1873–1876. *Rept. Sci. Res. Expl. Voyage HMS Challenger, Zoology*, vol. 9, 814 pp., 115 pls.

Brönnimann, P., 1940: Uber die tertiaren Orbitoididen und die Miogypsiniden von Nordwest-Marokko. *Schw. Pal. Gesel., Abh.*, vol. 63, 113 pp., 11 pls.

——— 1951: A model of the internal structure of *Discocyclina* s. s. *Jour. Pal.*, vol. 25, p. 208–211, 1 fig.

Brun, L., Butterlin, J. and Monteil, L., 1982: Découverte de lépidocyclines (Foraminiféres) d'age éocène dans le Golfe de Guinée. Implications paléobiogéographiques. *Cah. Micropal.*, vol. 2, p. 91–109.

Bursch, J. G., 1947: Micropaleontologische untersuchungen des Tertiar von Gross Kei (Molluken). *Schw. Pal. Gesel., Abh.*, vol. 65, 69 pp., 5 pls.

Butterlin, J., 1987: Origine et évolution des Lépidocyclines de la région des Carïbes. Comparisons et relations avec les Lépidocyclines des autres régions du monde. *Rev. Micropaléont.*, vol. 29, p. 203–219, 7 figs., 2 pls.

——— 1991: Reflexions sur l'origine et l'evolution des Lepidocyclines du Bassin Mediterraneen. *Ibid.*, vol. 34, p. 175–183.

Carpenter, W. B., 1856a: Researches on the foraminifera. Monography of the genus *Orbitolites*. *Philos. Trans. Roy. Soc. London*, vol. 146, p. 181–224.

——— 1856b: Researches on the foraminifera. Pt. 2. On the genera *Orbicula*, *Alveolina*, *Cycloclypeus* and *Heterostegina*. *Ibid.*, p. 547–569, pls. 28–31.

——— 1859: Researches on the foraminifera. *Ibid.*, vol. 149, p. 32–35, pls. 5–6.

——— Parker, W. K. and Jones, T. R., 1862: *Introduction to the study of the foraminifera*. London: Royal Society, 319 pp., 22 pls.

Carter, H. J., 1877: On a Melobesian form of foraminifera (*Gypsina melobesioides*, mihi); and further observations on *Carpenteria monticularis*. *Ann. Mag. Nat. Hist.*, vol. 20, p. 172–176.

——— 1880: Report on specimens dredged up from the Gulf of Manaar, and presented to the Liverpool Free Museum by Capt. W. H. Cawne Warren. *Ann. Mag. Nat. Hist.*, vol. 5, p. 437–457.

Caudri, C. M. B., 1932: De foraminiferenfauna van eeinige *Cycloclypeus* houdende gesteenten van Java. *Geol.-Mijnb. Genoot. Nederl.-Kol., Verh., Geol.*, vol. 9, p. 171–204. 3 pls.

——— 1934: *Tertiary deposits of Soemba*. H. J. Paris/Amsterdam-MCMXXXIV, 223 pp., 5 pls.

Caus, E., Hottinger, L. and Tambareau, Y., 1980: Plissement du "septal flap" et systeme de canaux chez *Daviesina*, foraminiferes paleocenes. *Eclog. Geol. Helv.*, vol. 73, p. 1045–1060, 4 pls.

Chapman, F., 1895: On some foraminifera obtained by the Royal Indian Marine Survey's S. S. "Investigator", from the Arabian Sea, near the Laccadive Islands. *Proc. Zoolog. Soc. London*, 1895, p. 4–55, pl. 1.

——— 1902: *The foraminifera. An introduction to the study of Protozoa*. London: Longmans, Green and Co., 354 pp., 13 pls.

——— 1921: Report of an examination of material obtained from a bore at Torquay. *Victoria Geol. Survey, Records*, vol. 4, p. 315–324, pl. 51.

——— and Crespin, I., 1930: Rare foraminifera from deep borings in the Victorian Tertiaries-*Victoriella*, gen. nov., *Cycloclypeus communis* Martin and *Lepidocyclina borneensis* Provale. *Proc. Royal. Soc. Victoria, N. S.* no. 42, p. 110–115, pls. 7–8.

——— and Parr, W. J., 1938: Australian and New Zealand species of the foraminiferal genera *Operculina* and *Operculinella*. *Royal Soc. Victoria, Proc.*, vol. 50, p. 279–299, pls. 16–17.

——— ——— and Collins, A. C., 1934: Tertiary foraminifera of Victoria, Australia. The Balcombian deposits of port Philip. Pt. 3. *Linnean Soc., Jour., Zool.*, vol. 38, p. 553–577, pls. 8–11.

Chaproniere, G. C. H., 1975: Paleoecology of Oligo-Miocene larger Foraminiferida, Australia. *Alcheringa*, no. 1, p. 37–58.

——— 1983: Tertiary foraminiferids from the northwestern margin of the Queensland Plateau, Australia. *BMR Bull.*, no. 217, p. 31–57, pls. 1–6.

——— 1984: Oligocene and Miocene larger foraminiferida from Australia and New Zealand. *Ibid.*, no. 188, 98 pp., 26 pls.

Checchia-Rispoli, G., 1909: La serie nummulitica dei dintorni di Termini-Imerese. I. II Vallone Tre Pietre. *Giorn. Sci. Nat. Econ.*, vol. 27, p. 53–137, 7 pls. Palermo.

——— 1911: Sull'Oligocece dei dintorni di Campofiorito in provincia di Palermo. *Ibid.*, vol. 28, p. 281–303, pl. 1.

Cizancourt, M. de, 1951: Grands foraminifères du paléocène, de l'Èocène inférieur et de l'Éocène moyen du Venezuela. *Mém. Soc. Géol. France*, vol. 64, p. 5–68, pls. 1–6.

Cloud, P. E. Jr., Schmit, R. G. and Burke, H. W., 1956: Geology of Saipan, Mariana Islands. Pt. 1. General Geology. *U. S. Geol. Surv., Prof. Paper*, 280-A, 126 pp. (1957).

Cole, W. S., 1939: Larger foraminifera from Guam. *Jour. Pal.*, vol. 13, p. 183–189, pls. 23–24.

——— 1944: Stratigraphic and paleontologic studies of wells in Florida. No. 3. *Florida Geol. Survey*, vol. 26, 168 pp., 29 pls.

——— 1945: Larger foraminifera. *In*, Ladd, H. S. and Hoffmeister, A. E. *eds.*, *Geology of Lau, Fiji. Bernice P. Bishop Mus., Bull.*, no. 181, p. 272–297, pls. 12–30.

——— 1954: Larger foraminifera and smaller diagnostic foraminifera from Bikini Drill Holes. *U. S. Geol. Surv., Prof. Paper*, 260-O, p. 569–608, pls. 204–222.

——— 1957a: Larger foraminifera (of Saipan). *Ibid.*, 280-I, p. 321–360, pls. 94–118.

——— 1957b: Larger foraminifera from Eniwetok Atoll. *Ibid.*, 260;V, p. 743–784, pls. 231–249.

——— 1959a: Names of and variation in certain Indo-Pacific Camerinids. *Bull. Amer. Pal.*, vol. 39, p. 349–371, pls. 28–31.

——— 1959b: *Asterocyclina* from a Pacific seamount. *Contr. Cushman Found. Foram. Res.*, vol. 10, p. 10–14, pls. 1–3.

——— 1960: Upper Eocene and Oligocene larger foraminifera from Viti Levu, Fiji. *U. S. Geol. Surv. Prof. Paper*, 374-A, p. 1–7, pls. 1–3.

——— 1961a: Names of and variation in certain Indo-Pacific Camerinids-No. 2. A Reply. *Bull. Amer. Pal.*, vol. 43, p. 111–128, pls. 14–16.

——— 1961b: An analysis of certain taxonomic problems in the larger foraminifera.*Ibid.*, p. 373–394, pls. 28–39.

——— 1963a: Tertiary larger foraminifera from Guam. *U. S. Geol. Surv., Prof. Paper*, 403-E, p. 1–28, 11 pls.

——— 1963b: Illustrations of conflicting interpretations of the biology and classification of certain larger foraminifera. *Bull. Amer. Pal.*, vol. 46, p. 5–50, 14 pls.

——— 1965: Structure and classification of some recent and fossil Peneroplids. *Ibid.*, vol. 49, p. 1–26, 9 pls.

——— and Bermúdez, P. J., 1936: New genera and species of Foraminifera from the Eocene of Cuba. *Contr. Cushman Lab. Foram. Res.*, vol. 12, p. 27–38, pls. 5–6.

——— and ——— 1944: New foraminifera genera from the Cuban middle Eocene. *Bull. Amer. Pal.*, vol. 28, p. 1–21, pls. 1–3.

——— and ——— 1947: Eocene Discocyclinidae and other foraminifera from Cuba. *Ibid.*, vol. 31, p. 3–36, pl. 5.

——— and Bridge, J., 1953: Geology and larger foraminifera of Saipan Island. *U. S. Geol. Surv., Prof. Paper*, 253, 45 pp., pls. 2–15.

Coleman, P. J., 1963: Tertiary larger foraminifera of the British Solomon Islands, southwest Pacific. *Micropaleont.*, vol. 9, p. 1–38, pls. 4–5.

Corby, G. W. et al., 1951: Geology and oil possibilities of the Philippines. *Depart. Agr. and Nat. Res., Tech. Bull., Manila*, no. 21, 363 pp., 48 pls.

Crespin, I., 1938: The occurrence of *Lacasina* and *Biplanispira* in the mandated territory of New Guinea and a lower Miocene limestone from the OK Ti river, Papua. *Pal. Bull.*, no. 3, p. 1–12, 3 pls.

——— 1952: Two new species of *Lepidocyclina* from Cape Range, northwestern Australia. *Cushman Found. Foram. Res., Contr.*, vol. 3, p. 28–32, pls. 6–7.

Cushman, J. A., 1915: A monograph of the foraminifera of the North Pacific Ocean. Pt. 5. Rotaliidae. *U. S. Nat. Mus., Bull.*, vol. 71, 81 pp., 28 pls.

——— 1917: A monograph of the foraminifera of the North Pacific Ocean. Pt. 6. Miliolidae. *Ibid.*, 108 pp., 39 pls.

——— 1919: Fossil foraminifera from the West Indies. *Carnegie Inst., Publ.*, no. 291, p. 23–71, 15 pls.

——— 1921: Foraminifera of the Philippines and adjacent sea. *Smith. Inst., U. S. Nat. Mus., Bull.*, vol. 4, 608 pp., 100 pls.

——— 1924: Samoan foraminifera. *Carnegie Inst., Publ. Washington*, no. 342, Dep. Marine Bio. paper, vol. 21, 75 pp.

——— 1927: An outline of a reclassification of the foraminifera. *Cushman Lab. Foram. Res., Contr.*, vol. 3, 105 pp., 25 pls.

——— 1930: The foraminifera of the Atlantic Ocean. Pt. 7. Nonionidae, Camerinidae, Peneroplidae and Alveolinellidae. *U. S. Nat. Mus., Bull.*, vol. 104, 79 pp., 17 pls.

——— 1931: The foraminifera of the Atlantic Ocean. Pt. 8. Rotaliidae, Amphisteginidae, Calcarinidae, Cymbaloporettidae, Globorotaliidae, Anomalinidae, Planorbulinidae, Rupertidae and Homotremidae. *U. S. Nat. Mus., Bull.*, vol. 104, 179 pp., 26 pls.

——— 1940: *Foraminifera; their classification and economic use*. 3rd ed. Cambridge, Mas.: Harbard Univ. Press., 535 pp., 48 pls.

——— and Bermúdez, P. J., 1936: Additional new species of foraminifera and a new genus from the Eocene of Cuba. *Contr. Cushman Lab. Foram. Res.*, vol. 12, p. 55–63, pls. 10–11.

——— Todd, R. and Post. R. J., 1954: Recent foraminifera of the Marshall Islands, Bikini and nearby atolls. Pt. 2 Oceanogr. (Biologic). *U. S. Geol. Surv. Prof. Paper*, 260-H, p. 319–384, pls. 82–93.

Cuvillier, J., 1930: Revision du Nummulitique egyptien. *Mem. Inst. Egypte*, vol. 16, 371 pp., 25 pls.

Davies, L. M., 1925: Notes on the geology of Kohat, with reference to the homotaxial position of the Salt Marlat Bahadur Khal. Asiatic Soc. Bengal. *Jour. Proc., N. S.*, vol. 20, p. 207–224.

——— 1940: The upper Khirthar beds of northwest India. *Quart. Jour., Geol. Soc. London*, vol. 96, 219 pp.

De Castro, P., 1971: Osservazioni su *Raadshoovenia* van den Bold, e i suoi rapporti col nuovo genere *Scandonea* (Foraminiferida, Miliolacea). *Boll. Soc. Nat. Napoli*, vol. 80, p. 161–235, 17 pls.

Deecke, W., 1914: Palaeontologische Betrachtungen. VI. Uber Foraminiferen. *N. Jb. Min. Geol. Pal.*, vol. 11, p. 21–43.

Defrance, J. L. M., 1822: *Dictionnaire des Sciences Naturelles*. Paris: F. G. Levrault, vol. 25, 485 pp.

——— 1824: *Dictionnaire des Sciences Naturelles*. Ibid., vol. 32, 567 pp.

Delage, Y. and Hérouard, E., 1896: *Treite de Zoologie Concrete*. Vol. 1. *La Cellude et les Protozoaires*. Paris: Schleicher Freres, 584 pp., 868 figs.

Deloffre, R. and Hamaoui, M., 1973: Revision des Chapmaninidae et Cymbaloporidae, *Angotia et Fabiania* (Foraminiferes). *Bull. Centre., Rech. Pan-SNPA*, vol. 7, p. 291–335.

Deprat, J., 1905: Les depots Eocene neocaledonieus. *Bull. Soc. Geol. France*, vol. 5, p. 485–516, pls. 16–19.

Deshayes, G. P., 1838: Description des coquilles fossiles recueillies en Crimee par M. de Verneuil. *In*, de Verneuil, E. *ed.*, *Memoire geologique sur la Crimee. Mem. Soc. Geol. France*, vol. 3, p. 37–69, pls. 1–6.

Doornink, H. W., 1932: Tertiary Nummulitidae from Java. *Verh. Geol. Mign. Genoot. Ned. Kolon. Geol.*, vol. 9, p. 267–315, pls. 1–10.

Douglass, R. and Woodruff, F., 1981: Deep-sea benthic foraminifera. *In*, Emiliani, C., *ed.*, *The sea*. Vol. 7, p. 1233–1328. New York: Wiley-Interscience.

Douvillé, H., 1905: Les foraminiferes dans le Tertiaire de Borneo. *Bull. Soc. Geol. France*, vol. 5, p. 435–464, pl. 14.

——— 1911: Les foraminiferes dans le Tertiaire des Philippines. *Philippine Jour. Sci., Manila*, vol. 6, p. 53–80, pls. A-D.

———1917: Les Orbitoïdes de l'ile de la Trinité. *Acad. Sci. Comptes Rendus, Paris*, vol. 164, p. 841–847, tfs. 1–4.

——— 1922: Loc. cit. Deuxieme partie-orbitoides du Danien et l'Eocene. *Bull. Soc. Geol. France*, vol. 22 p. 55–100, pls. 4–5.

——— 1925: Revision des Lepidocyclines. *Mem. Soc. Geol. France*, vol. 2, p. 51–123, pls. 3–7.

Douvillé, R., 1908: Observations sur les faunes a Foraminiferes du sommet du Nummulitique Italien. *Bull. Soc. Geol. France*, vol. 8, p. 88–95.

Drooger, C. W., 1952: *Study of American Miogypsinidae*. Utrecht Univ., Thesis, 80 pp., 18 figs.

Dunham, R. J., 1962: Classification of carbonate rocks according to depositional texture. *In*, Ham, W. E., *ed.*, *Classification of carbonate rocks*, p. 108–121, Amer. Assoc. Petrol. Geol.

Eames, F. E., 1952: A contribution to the study of the Eocene in western Pakistan and western India: The geology of the standard sections in the western Punjab and in the Kohat district. *Quart. Jour. Soc. London*, vol. 107, p. 159–171.

——— Banner, F. T., Blow, W. H. and Clark, W. J., 1962: *Fundamentals of Mid-Tertiary stratigraphical correlation*. Cambridge Univ. press, 163 pp., 17 pls.

Ehrenberg, C. G., 1838: Uber dem blossem Auge unsichtbar kalkthierchen als Haupt bestandtheil der Kreide gebirge. *Bericht, Koningl. Preuss. Akad. Wiss. Berlin* 1838, vol. 3, p. 192–200.

——— 1839: Uber die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen. *Physik. Abhandl. Kon. Akad. Wiss. Berlin* 1838, p. 59–147, 4 pls.

Eichwald, E. E. von, 1830: *Zoologia specialis*, vol. 2. Vilnae: D. E. Eichwaldus, 323 pp.

Fichtel, L. von, and Moll, J. P. C. von, 1798: *Testacea microscopica, aliaque minuta ex generibus Argonanta et Nautilus, ad naturam picta et descripta (Microscopische und andere klein Schalthiere aus den geschlechtern Argonaute und Schiffer)*. Vienna: Camesina, 123 +pp., 24 pls. (Reprinted, 1803).

Flandrin, J., 1938: Contribution a l'etude paleontologique du Nummulitique algerien. *Mat. p. la Carte Geol. l'Algerie. Ser.* 1. *Paleont.*, no. 8, 158 pp., 15 pls.

Fleury, J., Bignot, G., Blondeau, A. and Poignant, A., 1985: Biogéographie de Foraminifères benthiques téthysiens du Sénonien à l'Éocéne supérieur. *Soc. Géol. France, Bull.*, vol. 8, p. 757–770.

Forskål, P., 1775: *Descriptions animalium, quae in itinere orientali osservavit Petrus Forskål*. Haumiae (Copenhague).

Foster, H., 1965: Geology of Ishigaki-shima, Ryukyu-retto. *U. S. Geol. Surv., Prof. Paper*, 399-A, 119 pp.

Freudenthal, T., 1969: Stratigraphy of Neogene deposits in the Khania Province, Creta, with special reference to foraminifera of the Family Planorbulinidae and the genus *Heterostegina*. *Utrecht Micropal. Bull.*, no. 1, 208 pp., 15 pls.

——— 1972: On some larger Orbitoidal Foraminifera in the Tertiary of Senegal and Portuguese Guinea. *Proc. 4th African Micropaleont.*, Coll. Abidjan 1970), p. 144–162.

Fritch, K., 1875: Einige eozane foraminiferen von Borneo. *Paleontogr.*, vol. 1, p. 139–146, pls. 18–19.

Frost, S. H., and Langenheim, R. L., 1974: Tertiary larger Foraminifera and scleractinian corals from Mexico. *In, Cenozoic reef biofacies*. 388 pp., 123 pls. Northern Illinois Univ. Press, Dekalb.

Furrer, M., 1949: Der Subalpine Flysh nordlich der Schrattenfluh, Entlebuch (Kt. Luzern). *Eclog. Geol. Helv.*, vol. 42, p. 111–154, pl. 7.

Galloway, J. J., 1928: A revision of the family Orbitoididae. *Jour. Pal.*, vol. 2, p. 45–69, 4 figs.

——— 1933: *Amanual of foraminifera*. Bloomington: Principia press, 483 pp, 42 pls.

Geyn, W. A. E. van de, and Vlerk, I. M. van der, 1935: A monograph on the Orbitoididae occurring in the Tertiary of America. *Leid. Geol. Med.*, vol. 7, p. 221–272, 41 pls.

Ghose, B. K., 1972: The morphology of *Pellatispira glabra* with comments on the taxonomy, distribution and evolution of the genus. *Rev. Micropaléont.*, vol. 15, p. 149–162.

Glaessner, M. F., and Wade, M., 1959: Revision of the foraminiferal family Victoriellidae. *Micropaleont.*, vol. 5, p. 193–212, pls. 1–3.

Gray, J. E., 1858: On *Carpenteria* and *Dujardinia*, two genera of a new form of Protozoa with attached multilocular shells filled with sponge, apparently intermediate between Rhizopoda and Porifera. *Zool. Soc. London, Proc.*, vol. 26, p. 266–271, 4 figs.

Grimsdale, T. F., 1952: Cretaceous and Tertiary foraminifera from the Middle East. *British Mus. (Nat. Hist.), Bull., Geol.*, vol. 1, p. 221–248, pls. 20–25.

——— 1959: Evolution in the American Lepidocyclinidae (Cainozoic foraminifera); An interim review-1 and 2. *K. Ned. Akad. Weten., Proc.*, vol. 62, p. 8–33.

Gronovius, L. T., 1781: *Zoophylaqcii gronoviani*. vol. 3, Leiden: Theodorus Haak et Soc., p. 241–380.

Gümbel, C. W., 1861: *Geognostische beschreibung des bayerischen Alpengebirges und seines Vorlandes*, vol. 1, 950 pp., 42 pls., T. Perthas (Gotha).

——— 1870: Beitrage zur foraminiferenfauna der nordalpinen Eocangebilde. *Kon. Bayer. akad. Wiss. Abh., Cl.* II, vol. 10, 152 pp., pls. 1–4.

Hamaoui, M., and Fourcade, E., 1973: Revision des Rhapydionininae (Alveolinidae, Foraminiferes). Reclassification of the Rhapydionininae (Alveolinidae, Foraminifera). *Bull. Centr. Res. Pan-SNPA*, vol. 7, p. 361–435.

Hantken, M. von, 1875: A *Clavulina szaboi* retegek faunaja. I. Foraminiferak. *Foldt. Int. Evk.*, vol. 4, 82 pp., 16 pls.

Hanzawa, S., 1930: Notes on foraminifera found in the *Lepidocyclina*-limestone from Pabeasan, Java. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 14, p. 85–96, pls. 26–28.

——— 1931a: Note on Tertiary foraminiferous rocks from the Kwanto Mountainland, Japan. *Ibid.*, vol. 12, p. 141–157, pls. 24–26.

——— 1931b: On some Miocene rocks with *Lepidocyclina* from the Izu and Boso Peninsulas. *Ibid.*, p. 159–170, pls. 27–28.

——— 1935: Some fossil *Operculina* and *Miogypsina* from Japan, and their stratigraphical significance. *Ibid.*, vol. 18, p. 1–29, pls. 1–3.

——— 1937: Notes on some interesting Cretaceous and Tertiary foraminifera from the west Indies. *Jour. Pal.*, vol. 11, p. 110–117, pls. 20–21.

——— 1939: On the occurrence of *Lepidocyclina* (s. s.) in Taiwan (Formosa). *Im. Acad., Tokyo, Proc.*, vol. 15, p. 182–185, 4 figs.

——— 1940: Micropaleontological studies of drill cores from a deep well in Kita-Daito-Zima (North Borodino Island). *Jubil. Publ. H. Yabe's 60th birthday*, p. 755–802, pls. 39–42.

——— 1947a: Eocene foraminifera from Haha-Jima (Hillsborough Island). *Jour. Pal.*, vol. 21, p. 254–259, pls. 39–40.

——— 1947b: Note on *Borelis pygmaeus* (Hanzawa) from the Mariana Island. *Jap. Jour. Geol. Geogr.*, vol. 20, p. 9–11, pl. 5.

——— 1950: Eocene foraminifera from Haha-Jima (Hillsborough Island) (2). *Short Papers IGPS*, no. 1, p. 1–4, pl. 1.

——— 1957: Cenozoic foraminifera of Micronesia. *Geol. Soc. Amer., Mem.* no. 66, 163 pp., 41 pls.

——— 1959: The foraminifera species *Fabiania cassis* (Oppenheim), in Japan. *Contr. Cushman Found. Foram. Res.*, vol. 10, p. 119–122, pl. 9.

——— 1962: Upper Cretaceous and Tertiary three-layered larger Foraminifera and their allied forms. *Micropaleont.*, vol. 8, p. 129–186, pls. 1–8.

——— 1964: the phylomorphogenesis of the Tertiary foraminiferal families, Lepidocyclinidae and Miogypsinidae. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 35, p. 295–313.

——— 1965: The ontogeny and the evolution of larger foraminifera. *Ibid.*, vol. 36, p. 239–256, pls. 30–40.

——— 1967: *Nummulites* from Iran. *Trans. Proc. Palaeont. Soc. Japan, Tokyo*, no. 68, p. 174–176, pl. 16.

Harpe, de la, 1877: Note sur les *Nummulites* des environs de Nice et de Menton. *Bull. Soc. Geol. France*, vol. 5, p. 817–835, pl. 17.

——— 1883: Monographie der in Agypten und der Libyschen Wuste vorkommenden Nummuliten. *Paleontogr.*, vol. 30, p. 155–216, pls. 30–35.

Hartono, H. M. S., 1969: *Globigerina* marls and their planktonic foraminifera from the Eocene of Nanggulan, Central Java. *Cushman Found. Foram. Res. Contr.*, vol. 20, p. 152–159, pls. 20–21.

Hashimoto, W., Kitamura, N., Balce, G. R., Matsumaru, K., Kurihara, K., and Aliate, E. Z., 1979: Larger foraminifera from the Philippines. Pt. 10. Stratigraphic and faunal breaks between the Maybangain and Kinabuan Formations in the Tanay region, Rizal, Philippines. *Geol. Palaeont. SE Asia*, vol. 20, p. 143–157, pls. 30–35.

——— and Matsumaru, K., 1973: *Nephrolepidina parva* Oppenoorth from the Dahor Area, Tandjung, Kalimantan Selatan, Indonesia. *Ibid.*, vol. 11, p. 129–136, pl. 18.

——— and ——— 1975a: On the *Lepidocyclina*-bearing Limestone exposed at the Southern Cross Mountain Highway, Taiwan. *Ibid.*, vol. 16, p. 103–116, pl. 11.

——— and ——— 1975b: Larger foraminifera from the Philippines. Pt. 3. Limestone from eastern coastal ranges of north and central Luzon. *Ibid.*, p. 117–125, pl. 13.

——— and ——— 1978: Larger foraminifera from the Philippines. Pt. 8. Larger foraminifera from Central Samar. *Ibid.*, vol. 19, p. 81–88, pl. 1.

——— and ——— 1984: Mesozoic and Cenozoic larger foraminifera of the Philippines and a reference to those found from Borneo by the APRSA's paleontological reconnaissance. *Ibid.*, vol. 25, p. 147–166.

——— ——— and Alcantara, P. M., 1982: Larger foraminifera from the Philippines. Pt. 13. Larger foraminifera from the Trankalan Limestone and the Escalante (Toboso) Formation, west of Lanao River Valley, NE Occidental Negros. *Ibid.*, vol. 23, p. 31–38, pls. 10–11.

——— ——— and Kurihara, K., 1977: Larger foraminifera from the Philippines. Pt. 5. Larger foraminifera from Cenozoic Limestones in the Mansalay Vicinity, Oriental Mindoro, with an appendix "An Orbitoid-bearing Limestone from Barahid, Bongabong". *Ibid.*, vol. 18, p. 59–76, pls. 8–9.

——— ——— and Sugaya, M., 1981: Larger foraminifera from the Philippines. Pt. 11. On the Coal Harbor Limestone, Cagraray Island, Batan Island Group, Albay Province. *Ibid.*, vol. 22, p. 55–62, pl. 13.

Henrich, H., 1934: Foraminiferen aus dem Eocan und Altmiocan von Timor. *In*, Boehm, G., and Wanner, J. *eds.*, *Beitrage zur Geologie Niederlandisch-Indie. Paleontogr., Suppl.*, vol. 4, 55 pp., pls. 1–5.

Heron-Allen, E., and Earland, A., 1908: On *Cycloloculina*, a new generic type of the foraminifera, with a preliminary study of the foraminiferous deposits and shore-sands of Selsey Bill. *Jour. Roy. Microsc. Soc. London* 1908, p. 529–543, pl. 12.

——— and ——— 1918: The genus *Halkyardia*. *In*, Halkyard, E., 1919: *The fossil Foraminifera of the Blue Marl of the Cote des Basques, Biarritz. Mem. Proc. Manchester Lit. Philos. Soc.*, 1918, vol. 62, 145 pp., 9 pls.

Hickson, S. J., 1911: On *Polytrema* and some allied genera, a study of some sedentary foraminifera based mainly on a collection made by Prof. Stanley Gardiner in the Indian Ocean. *Linn. Soc. London, Trans. Zool.*, vol. 14, p. 445–462, pls. 30–32.

Ho Yen, Zhang Ping-Kao, Hu Lan-Ying and Sheng Jing-Chang., 1976: Mesozoic and Cenozoic foraminifera from the Mount Jolmo Lungma region. *Nanking Inst. Geol. Palaeont. Academia Sinica*, vol. 2

(Paleontology), 76 pp., 36 pls.

Hofker, J., 1927: Families Tinoporidae, Rotaliidae, Nummulitidae, Amphisteginidae. Siboga Exp., Pt. 1. *Monogr. 4 uitkom. Zool. Bot. Oceanogr. Geol. Geb. Ned. Oost.-Ind. 1800–1900, Foram.*, 78 pp., 37 pls.

——— 1968: Studies of foraminifera. Pt. 1. General problems. *Publ. Nat. Genootsch. Limburg*, vol. 18, 135 pp., 24 pls.

——— 1970: Studies of foraminifera. Pt. 2. Systematic problems. *Ibid.*, vol. 20, 98 pp., 53 pls.

——— 1971: Studies of foraminifera. Pt. 3. Systematic problems. *Ibid.*, vol. 21, 202 pp., pls. 5–109.

Hornibrook, N. de B., 1968: A handbook of New Zealand Microfossils (Foraminifera and Ostracoda). *N. Z. Dep. Sci. ind. Res. Inf. ser.* no. 62, 136 pp., 29 figs.

Hottinger, L., 1960: Recherches sur les Alveolines du Paleocene et l'Eocene. *Mem. Suiss. Paleont.*, vol. 75/76, 243 pp., 18 pls.

——— 1963: Quelques foraminiferes porcelanes Oligocenes dans la serie sedimentaire de Moratalla (Espagne medionale). *Eclog. Geol. Helv.*, vol. 56, p. 963–972, pls. 1–4.

——— 1977: Foraminiferes operculiniformes. *Mem. Mus. Nat. D'Hist.*, vol. 40, 159 pp., 66 pls.

——— 1983: Process determining the distribution of larger foraminifera in space and time. *In*, Meulenkamp, J. E. *ed.*, *Reconstruction of marine paleoenvironments. Utrecht Micropal. Bull.*, no. 30, p. 239–253.

Howe, H. V., 1930: Distinctive new species of foraminifera from the Oligocene of Mississippi. *Jour. Pal.*, vol. 4, p. 327–331, pl. 27.

Iwasaki, Y., 1975: On two fossil molluscan species from the Eocene of the Bonin Islands. *Trans. Proc. Palaeont. Soc. Japan, N. S.* no. 99, p. 143–155, pl. 13.

——— and Aoshima, M., 1970: Report on geology of the Bonin Islands. *In*, *The nature of the Bonin and volcano Islands.*, p. 205–220, Ministry of Education and agency for Cultural Affairs, Japan. (in Japanese).

Joly, N., and Leymerie, A., 1848: Memoire sur les *Nummulites* considerees zoologiquement et geologiquement. *Mem. Acad. Sci. Toulouse* (3), vol. 4, 70 pp., pls. 1–2.

Jones, T. R., and Chapman, F., 1900: On the foraminifera of the orbitoidal limestones and reef rocks of Christmas Island in a monograph of Christmas Island. *In*, Andrews, C. W. *ed.*, *A monograph of Christmas Island (Indian Ocean). British Mus. (Nat. Hist.), Monogr., London*, p. 226–264, pls. 20–21.

Kaneoka, I., Issiki, N., and Zashu, S., 1970: K-Ar ages of the Izu-Bonin Islands. *Geochemical Jour.*, vol. 4, p. 53–60.

Konda, I., and Okuda, S., 1977: *Asterocyclina* (larger foraminifera) from Haha-Jima (Hillsborough Island), Ogasawara (Bonin) Islands. *Jour. Geol. Soc. Japan*, vol. 83, p. 363–365.

Kapellos, C., and Schaub, H., 1973: Zur korrelation von Biozonierungen mit Grossforaminiferen und Nannoplankton im Palaozen der Pyrenaen. *Ecog. Geol. Helv.*, vol. 66, p. 687–734, 13 pls.

Krijnen, W. F., 1931: Het genus *Spiroclypeus* in het Indo-Pacifische gebied. *Geol. Mijnb. Genoot. Ned. Kol. Verh., Geol. ser.*, vol. 9, p. 77–111, pls. 1–3.

Kudo, R. R., 1931: *Handbook of Protozoology*. 451 pp., 175 figs., C. C. Thomas (Baltimore).

Kuroda, N., and Shiraki, K., 1975: Boninite and related rocks of Chichi-Jima, Bonin Islands, Japan. *Rep. Fac. sci. Shizuoka Univ.*, vol. 10, p. 145–155.

Laghi, G. F., and Sirotti, A., 1982: *Orbitoclypeus* Silvestri, 1907, revision of the type specimens. *Boll. Soc. Paleont. Ital.*, vol. 21, p. 1–4.

Lamarck, J. B., 1801: *Systeme des animaux sans vertebres*. Paris: The author, 432 pp.

——— 1804: Suite des memoires sur les fossiles des environs de Paris. *Mus. Nat. Hist. Nat. Paris, Ann.*, vol. 5, p. 179–188, pl. 62.

——— 1816: *Histoire naturelle des animaux sans vertebres*. vol. 2, Paris: Verdiere, 568 pp.

——— 1836: *Histoire naturelle des animaux sans vertebres*. vol. 20, Ibid., 684 pp..

Lange, H., 1968: Die evolution von *Nephrolepidina* und *Eulepidina* in Oligozan und Miozan der inser Ithaka (Westgriechenland). *Inaugural-Dissertation, Ludwig. -Max.-Univ.*, 78 pp., pls. 1–3.

Le Calvez, Y., 1949: Révision des foraminifères Lutétiens du Bassin de Paris. II. Rotaliidae et familles affines. *Mem. Serv. Carte Geol. Dep. France*, 54 pp., 6 pls.

Lehmann, R., 1961: Structuranalyse einiger gattungen der Subfamilie Orbitolitinae. *Eclog. Geol. Helv.*, vol. 54, p. 597–667, 14 pls.

Lemoine, P., and Douvillé, R., 1904: Sur le genre *Lepidocyclina* Gümbel. *Mem. Geol. Soc. France, Pal.*, vol. 12, 41 pp., pls. 1–3.

Less, G., 1987: Paleontology and stratigraphy of the European Orthophragminae. *Geol. Hungarica*, vol. 51, 373 pp., 45 pls.

Leupold, W., and Vlerk, I. M. van der., 1931: The Tertiary. *Leid. Geol. Meded.*, vol. 5, p. 611–648.

Liebus, A., 1911: Die foraminiferenfauna der mitteleocanen mergel von Nordalmatien. *Kaiserl. Akad. Wien. Sitzengsber.*, vol. 120, 92 pp., pls. 1–3.

Llueca, F. G., 1927: Algunas formas nuevas de Nummulitidos encontradas en Espana. *Bol. Soc. Esp. Hist. Nat.*, vol. 27, p. 420–426, pls. 29, 32, 34.

——— 1929: Los Nummulitidos de Espana. *Com. Invest. Pal. y prehist., ser. Pal.*, no. 36, 400 pp., 34 pls.

Loeblich, A. R. Jr., and Tappan, H., 1964: Sarcodina chiefly "Thecamoebians" and Foraminiferida. *In*, Moore, R. C. *ed.*, *Treatise on Invertebrate Paleontology*, *Part C. Protista 2*. Lawrence: Geol. Soc. America and Univ. Kansas Press. 900 pp., 653 figs.

——— and ——— 1986: Some new and redefined genera and families of Textulariina, Fusuliniina, Involutinina, and Miliolina (Foraminiferida). *Jour. Foram. Res.*, vol. 16, p. 334–346.

——— and ——— 1988: *Foraminiferal genera and their classification*. Van Nordstrand Reinhold Co., New York, 970 pp., 847 pls.

Marks, P., 1957: Stratigraphic Lexicon of Indonesia. *Djawatan Geologi Bandung, Publ. Keilmuan* no. 31, 233 pp., 4 tabs., 2 maps.

Martin, K., 1880: *Die Tertarschchten auf Java nach den Entdeckungen von Fr. Junghuhen*. Leiden 1879/1880. p. 150–164, pls. 25–28.

Matsumaru, K., 1971a: Studies on the genus *Nephrolepidina* in Japan. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 42, p. 97–185, pls. 9–26.

——— 1971b: The genera *Nephrolepidina* and *Eulepidina* from New Zealand. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 84, p. 179–189, pls. 22–23.

——— 1974: Larger foraminifera from east Mindanao, the Philippines. *Geol. Palaeont. SE Asia*, vol. 14, p. 101–115, pls. 14–19.

——— 1976a: Preliminary report on the Tertiary larger foraminiferal biostratigraphy in Chichi-Jima (Peel Island) and Haja-Jima (Hillsborough Island), Ogasawara Islands, Japan. *Jour. Saitama Univ. (Math., Nat. Sci.)*, vol. 24 (1975), p. 11–14. (in Japanese)

——— 1976b: Larger foraminifera from the islands of Saipan and Guam, Micronesia. *In*, Takayanagi, Y., and Saito, T., *eds.*, *Progress in Micropaleontology. Micropal. Press. Spec. Publ. New York: American Mus. Nat. Hist.*, p. 190–213, pls. 1–6.

——— 1976c: Larger foraminifera from the Ryukyu Group, Nansei Shoto Islands, Japan. *1st. Int. Symp. on Benthonic Foraminifera of continental Margins. Pt. B. Maritime Sed. Spec. Publ. 1*, p. 401–424, pls. 1–5.

——— 1978: Biostratigraphy and paleoecological transition of larger foraminifera from the Minamizaki Limestone, Chichi-Jima, Japan. *Proc. 2nd work. gr. meet. Biostr. Daum. Pacific Neogene IGCP Proj. 114, Bandung 1977*, p. 63–88, pls. 1–4.

——— 1984: Larger foraminiferal associations useful for the correlation of the Eocene and Oligocene sediments in the Ogasawara Islands, Japan, and an examination of *Nummulites boninensis* Hanzawa. *In*, SNEAP, Pau, *ed.*, *Benthos '83; 2nd Int. Symp. Benthic Foraminifera (Pau, April 1983)*, p. 415–422, 8 figs.

——— 1991: On the evolutionary classification of the Family Lepidocyclinidae (Foraminiferida). *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 164, p. 883–909, 20 figs.

——— 1992: Some Miocene *Nephrolepidina* (Family Lepidocyclinidae) from the Shimoshiroiwa Formation, Izu Peninsula, Japan. *In*, Ishizaki, K., and Saito, T. *eds.*, *Centenary of Japanese Micropaleontology*, p. 257–265, figs. 1–2, Terrapub., Tokyo.

——— 1994: A megalospheric schizont of *Nummulites perforatus* (Montfort) from upper Lutetian of the Yusan Formation, Haha-Jima (Hillsborough Island), Ogasawara Islands, Japan. *Rev. Micropaléont.*, vol. 37, p. 161–165, pl. 1.

——— and Kimura, K., 1989: Larger foraminifera from the Eocene Shimizu and Miocene Misaki Formations in Tosa Shimizu City, Kochi Prefecture, Shikoku, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 156, p. 255–269, 6 figs.

——— Myint Thein, and Ogawa, Y., 1993: Early Miocene (Aquitanian) larger foraminifera from the Shimizu Formation, Ashizuri Cape, Kochi Prefecture, Shikoku, Japan. *Ibid.*, no. 169, p. 1–14, 4 figs.

Matteucci, R., and Schiavinotto, F., 1977: Studio biometrico di *Nephrolepidina*, *Eulepidina* e *Cycloclypeus* in due Campioni dell'Oligocene di Monte Rocca, L'Aquila (Italia Centrale). *Geol. Romana*, vol. 16, p. 141–171, pls. 1–3.

McGowran, B., 1966: Bilamellar walls and septal flaps in the Robertinacea. *Micropaleont.*, vol. 13, p. 477–488, pls. 1–4.

Michelotti, G., 1841: Saggio storico dei Rizopodi caratteristi dei terreni sopracretacei. *Mem. Soc. Ital., Sci. Res.*, vol. 22, p. 253–302.

——— 1861: Etudes sur le Miocene inferieur de l'Italie septentrionale. *Nat. Verh. Holl. Maatsch. Wet., Haarlem.*, vol. 15, 183 pp., 16 pls.

Möbius, K. A., 1880: Foraminifera von Mauritius. *In*, Möbius, K., Richter, F., and Martens, E. von, *eds.*, *Beitrage zur Meeresfauna derInsel Mauritius und der Seychellen.* p. 65–112, 14 pls., Gutman (Berlin).

Mohler, W. A., 1950: *Flosculinella reicheli* n. sp. aus dem Tertiar e5 von Borneo. *Eclog. Geol. Helv.*, vol. 42, p. 521–527, 5 figs.

Montfort, D. P. de, 1808: *Conchyliologie systematique et classification methodique des coquilles*, vol. 1, Paris: F. Schoell, 409 pp.

Morton, S. G., 1833: Supplement to the "Synopsis of the organic remains of the ferruginous sand formation of the United States", contained in vols. XVII and XVIII of this journal. *Amer. Jour. Sci. Arts.*, vol. 23, p. 288–294, pls. 5, fig. 9.

Mulder, E. F. I. de, 1975: Microfauna and sedimentary tectonic history of the Oligo-Miocene of the Jonian Islands and western Epirus (Greece). *Utrecht Micropal. Bull.*, no. 13, 140 pp., 47 figs.

Munier-Chalmas, M., 1891: *Etude du Tithonique du Cretace et du tertiaire du Vicentin.* These de doctorat; Paris 1891: p. 71–77.

——— 1902: Sur les foraminiferes rapportes au groupe des Orbitolites. *Bull. Soc. Geol. France*, vol. 2, p. 353.

Nagappa, Y., 1959: Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India-Pakistan-Burma region. *Micropaleont.*, vol. 5, p. 145–192, 11 pls.

Nemkov, G. L., 1967: Nummulitides of the Soviet Union and their biostratigraphic significance. *Proc. Stud. Geol. Struct. USSR, Moscou*, vol. 16, 312 pp., 44 pls.

Neumann, M., 1958: Révision des orbitoïdés du Crétacé et de l'Éocène en Aquitaine occidentale. *Mem. Soc. Geol. France, N. S.*, vol. 37, 174 pp., 37 pls.

——— Ly, A., and Butterlin, J., 1986: Présence d'*Helicolepidina* et de lépidocyclines primitives dans l'Éocène du Sénégal (Casamance). *Rev. Micropaléont.*, vol. 29, p. 120–136, pls. 1–2.

Newton, R. B., and Holland, R., 1902: On some fossils from the Islands of Formosa and Riu-Kiu (= Loo Choo). *Jour. Coll. Sci. Imp. Univ. Tokyo*, vol. 17, p. 1–23, pls. 1–4.

Nishiyama, S., 1937: A new species of Sismondia from the Oligocene of Titizima. *Proc. Imp. Acad.*, vol. 8, p. 41–45.

Nuttall, W. L. F., 1925: The stratigraphy of the Laki Series (Lower Eocene) of parts of Sindo and Balchistan (India); with a description of larger Foraminifera contained in those beds. *Quart. Jour., Geol. Soc. London*, vol. 81, p. 417–453, pls. 23–27.

——— 1926a: The zonal distribution of the larger foraminifera of Middle and lower Kirthar Series (Middle Eocene) of parts of western India. *Rec. Geol. Surv. India*, vol. 59, p. 115–164, pl. 8.

——— 1926b: A revision of the Orbitoides of Christmas Island. *Quart. Jour. Geol. Soc. London*, vol. 82, p. 22–42, pls. 4–5.

——— 1928: Notes on the Tertiary foraminifera of southern Mexico. *Jour. Pal.*, vol. 2, p. 372–376.

——— 1932: Lower Oligocene foraminifera from Mexico. *Ibid.*, vol. 6, p. 175–177, pl. 24.

Ohde, M., and Elderfield, H., 1992: Strontium isotope stratigraphy of Kita-Daito-Jima Atoll, north Philippines Sea; implications for Neogene sea-level change and tectonic history. *Earth and Planet. Sci. Letters*, no. 113, p. 473–486.

O'Herne, L., 1974: A reconsideration of *Amphistegina lessoni. Scripta Geol.*, vol. 26, 53 pp., 20 pls.

Oppenheim, P. von, 1896: Das alttertiar der Colli Berici in Venetien, die Stellung der Schichten von Priabona, und die Oligocene transgression in alpinen Europa. *Zeit. Deutsch. Geol. Gesell*, vol. 48, p. 27–152, pls. 2–5.

Oppenoorth, W. F., 1918: Foraminiferen van de Noordkust van Atjeh. *Geol. Mijnb. Gen. Ned. Kol. Verh., Geol. ser.*, vol. 2, p. 249–258, pls. 8–9.

——— and Gerth, H., 1929: The upper Eocene Nanggoelan Beds near Djogjakarta. *Excursion guide D1. 4th Pacific Sci. Congr., Java.* p. 1–12.

Orbigny, A. d', 1826: Tableau methodique de la classe des Cephalopodes. *Ann. Sci. Nat.*, vol. 7, p. 245–314, pls. 10–17.

——— 1839: *Foraminiferes, in Kamon de la Sagra, Histoire physiqu, politique et naturelle de l'ile de Cuba.* Paris: Arthus Bertrand, 244 pp., 12 pls.

Ozima, M., Kaneoka, I., and Ujiié, H., 1977: ^{40}Ar-^{39}Ar age of rocks, and the development mode of the Philippines Sea. *Nature*, vol. 267, p. 816–817.

Pallas, P. S., 1766: *Elenchus Zoophytorum sistens generum adumbrationes generaliores et specierum cognitarum succinctas descriptiones cum selectis auctorum synonymis.* 451 pp., P. van Cleef (Hagae).

Papp, A., and Küpper, K., 1954: The genus *Heterostegina* in the upper Tertiary of Europe. *Cushman Found.*

Foram. Res., Contr., vol. 5, p. 108–120, pls. 20–23.

Parker, W. K., and Jones, T. R., 1860: On the nomenclature of the foraminifera. 4. *Ann. Mag. Nat. Hist.*, vol. 6, p. 29–40.

——— and ——— 1865: On some foraminifera from the north Atlantic and Arctic Oceans, including Davies Straits and Baffin's Bay. *Philos. Trans. Royal Soc.*, vol. 155, p. 325–441, pls. 12–19.

——— ——— and Brady, H. B., 1865: On the nomenclature of the foraminifera. Pt. 12. The species enumerated by d'Orbigny in the "Annales des Sciences Naturelles", vol. 7, 1826. *Ann. Nat. Hist., ser.* 3, vol. 16, p. 15–41, pls. 1–3.

Parr, W. J., 1942: New genera of Foraminifera from the Tertiary of Victoria. *Mining Geol. Jour.*, vol. 2, p. 361–363, 5 figs.

Phleger, F. B., and Parker, F. L., 1951: Ecology of foraminifera, northwest Gulf of Mexico. Pt. 2. Foraminifera species. *Mem. Geol. Soc. America*, vol. 46, 64 pp., 20 pls.

Pokorný, V., 1958: *Grundzuge der Zoologischer Mikropaleontologie*. vol. 1, Berlin: VEB Deutscher Verlag der Wissenschaften, 582 pp., 549 figs.

Premoli Silva, I., and Brusa, C., 1981: Shallow-water skeletal debris and larger foraminifers from Deep Sea Drilling Project site 462, Nauru Basin, western equatorial Pacific. *Initial Rep. Deep Sea Drilling Proj.*, vol. 61, p. 439–473, U. S. Gov. Printing Office, Washington, D. C.

Prever, P. L., 1912: La fauna a Nummuliti e ad Orbitoidi dei terreni terziarii dell'alta valle dell'Anieni. *Mem. Serv. Desc. carta. Geol. Ital.*, vol. 5, p. 139–141, pl. 1.

Provale, I., 1908: Di alcune Nummulitine e Orbitoidine dell'Isola di Borneo. *Riv. Ital. Paleont.*, vol. 14, p. 64–71, pls. 4–5.

Raadshooven, B. van, 1951: Some Paleocene and Eocene larger foraminifera of western Venezuela. *Third World Petr. Congr. Secc. 1*, E. J. Brill, La Haye, p. 476–489.

Rahaghi, A., 1983: Stratigraphy and faunal assemblage of Paleocene-lower Eocene in Iran. *Nat. Iran. oil Company Publ.*, no. 10, 73 pp., 49 pls.

——— and Schaub, H., 1976: *Nummulites* et Assilines du NE du L'Iran. *Eclog. Geol. Helv.*, vol. 69, p. 765–782, 9 pls.

Rao, S. R. N., 1940: On *Orbitosiphon*, a new genus of Orbitoidal foraminifera from the Ranikot beds of the Punjab Salt Range (N. W. India). *Current Sci., Bangalore*, vol. 9, p. 414–415.

Reichel, M., 1936: Bemerkungen uber einige von O. Renz im zentralen Apennin gesammelte foraminiferen. *Eclog. Geol. Helv.*, vol. 29, p. 136–142, pls. 12, 15.

——— 1937: Etude sur les Alveolines. I. *Schweiz Palaont. Abh.* (1937), vol. 59, p. 95–147, pls. 10–11.

Reiss, Z., 1963: Reclassification of perforate foraminifera. *Bull. Geol. Surv. Islarel*, no. 35, 111 pp., 8 pls.

——— and Hottinger, L., 1984: *The Gulf of Aqaba*. Springer-Verlag-Berlin, Heidelberg, New York, Tokyo, Ecological Studies, vol. 50, 354 pp.

Renz, O., 1936: Stratigraphische und mikropaleontologische untersuchung der Scaglia (Obere Kreide-Tertiar) im zentralen Apennin. *Eclog. Geol. Helv.*, vol. 29, 149 pp., 15 pls.

Reuss, A. E., 1848: Die fossilen Polyparien des Wiener Tertiarbeckens. *Nat. Wiss. Abh., Wien*, vol. 2, 109 pp., 11 pls.

——— 1860: Die foraminiferen der Westphalischen Kreide formation. *Kon. Akad. Wiss. Wien, Math.-Nat. Cl., Sitz.*, vol. 40, p. 147–238, 13 pls.

Reyes, M. V., and Ordoñez, E. P., 1970: Philippine Cretaceous smaller foraminifera. *Jour. Geol. Soc. Philippines*, vol. 24, 67 pp.

Rutten, L. M. R., 1912: Studien uber Foraminiferen aus Ost-Asien. *Samm. Geol. Reichmus. Leiden*, vol. 9, p. 202–224, pls. 2, 13.

——— 1914a: Foraminiferen fuhrende Gestein von Niederlandisch Neuw-Guinea. *Uitk. Ned. Niuw-Guinea Exped. 1903, Geol.*, vol. 6, p. 21–51, pls. 6–9.

——— 1914b: Studien uber foraminiferen aus Ost-Asien. *Samm. Geol. Reichsmus. Leiden*, vol. 9, p. 281–325, pls. 21–27.

——— 1917: Rhizopoda in K. Martin's die Altmiocane fauna des West Progogebirges auf Java. *Ibid., (N.S.)*, vol. 2, p. 276–277, figs. 140–142.

——— 1923: Over de foraminiferenfauna en den ouderdom van kalksteenen uit Zuid-Celebes, afkomstig uit de groep der vischresten-bevattende gesteenten. *Jaar. Mijnwezen Ned. Oost-Ind.*, p. 175–183, pl. 1.

——— 1928: On Tertiary rocks and foraminifera from north;western Peru. *Kon. Akad. Wetensch. Amsterdam, Proc.*, vol. 31, p. 1–16, pls. 1–2.

Saido, R., 1951: Restudy of the "races" of *Nummulites gizehensis. Contr. Cushman Found. Foram. Res.*, vol. 2, p. 119–130, 7 pls.

Saidova, Kh. M., 1981: *(On an up-to-date system of supraspecific taxonomy of Cenozoic benthonic foraminifera)*.

Moscow: Inst. Okeanolog. P. P. Shirshova, Akad. Nauk SSSR.

Saito, T., 1962: Eocene planktonic foraminifera from Haha-Jima (Hillsborough Island). *Trans. Proc. Palaeont. Soc. Japan. N. S.*, no. 45, p. 209–225, pls. 32–34.

Samanta, B. K., 1963: A new species of *Discocylina* from Eocene rocks of Garo Hills, Assam. *Sci. Culture*, no 29, p. 39–40, 4 figs.

——— 1964: The occurrence of Indo-Pacific *Discocyclina* in eastern India. *Micropaleont.*, vol. 10, p. 339–353, pls. 1–3.

——— 1965: *Discocyclina* from the upper Eocene of Assam, India. *Ibid.*, vol. 11, p. 415–430, pls. 1–4.

Schafhautl, K. E., 1863: *Sud-Bayerns Lethaea geognostica.* 104 pp., L. Voss, Leipzig.

Schaub, H., 1962: Uber einige stratigraphische wichtige Nummuliten-arten. *Eclog. Geol. Helv.*, vol. 55, p. 529–551, 8 pls.

——— 1963: Uber einige entwicklungsreihen von *Nummulites* und *Assilina* und ihre stratigraphische Bedeutung. *In*, Konigswald, G. H. R. von et al. *eds.*, *Evolutionary trends in foraminifera*, Elsevier Publ. Co., p. 282–297.

——— 1981: *Nummulites* et Assilines de la Tethys Paleogene. Taxinomie, phylogenese et biostratigraphie. *Mem. Suiss. Paleont.*, vols. 104–105, 238 pp., 97 pls.

Scheffen, W., 1932: Zur morphologie und morphogenese der "Lepidocyclinen". *Palaont. Zeitschr.*, vol. 14, p. 233–256, pls. 9–10.

Schiavinotto, F., 1978: *Nephrolepidina* nella Valle del Maso (Borgo Valsugana, Italia settentrionale). *Riv. Ital. Paleont.*, vol. 84, p. 729–750, pl. 75.

Schlanger, S. O., 1964: Petrology of the Limestones of Guam. *U. S. Geol. Surv. Prof. Paper*, 403-D, 52 pp.

Schlumberger, C., 1893: Note sur les genres *Trillina* et *Linderina*. *Bull. Soc. Geol. France*, vol. 21, p. 118–123, pl. 3.

——— 1900: Note sur le genre *Miogypsina*. *Ibid.*, vol. 28, p. 327–333, pl. 2, figs. 13–16, p. 209, pl. 3, figs. 18–21.

——— 1902: Note sur un *Lepidocyclina* nouveaude de Borneo. *Samm. Geol. Reichsmus. Leiden*, vol. 6, p. 250–253, pl. 7.

——— 1903: Troisieme note sur les orbitoides. *Bull. Geol. Soc. France*, vol. 3, p. 273–290, pls. 8–12.

——— 1904: Quatrieme note sur les orbitoides. *Ibid.*, vol. 4, p. 119–135, pls. 3–6.

Schmarda, L. K., 1871: *Zoologie*: x + 372 pp., 269 figs. Wien: Wilhelm Braumuller.

Schubert, R. J., 1910: *Alveolina (Flosculinella)* Schubert, in Richarz, P. S., 1910, Der geologische bau von Kaiser Wilhelm-Land nach dem heutigen stand unseres Wissens. *Neues Jahrb. Mineral., Geol. Paleont., Beil.*, vol. 29, p. 406–536, pls. 13–14.

——— 1911: Die fossilen Foraminiferes des Bismarckarchipels und einiger angrenzender Inseln. *Oster. Geol. Reichsanst., Verh.*, vol. 20, 130 pp., pls. 1–6.

Schultze, M. S., 1854: *Uber den Organismus der Polythalamien (Foraminiferen), nebst Bermerkungen uber die Rhizopoden im Allgemeinen.* 68 pp., 7 pls. Leipzig: Wilhelm Engelmann.

Schwager, C., 1876: Saggio di una classificazione dei foraminiferi avuto riguardo alle loro famiglie naturali. *Boll. R. Comit. Geol. d'Italia*, vol. 7, p. 475–485.

——— 1877: Quadro del proposto sistema di classificazione dei foraminiferi con guscio. *Ibid.*, vol. 8, p. 18–27, pl. 1.

——— 1883: Die Foraminiferen aus den Eocaenablagerungen der Libyschen Wuste und Aegyptens. *Paleontogr.*, vol. 30, p. 79–153, pls. 1–6.

Schweighauser, J., 1953: Micropaleontologische und stratigraphische untersuchungen im Paleocaen und Eocaen des Vicentin (Nord Italien). *Schweig. Pal. Abh.*, vol. 70, p. 3–97, 13 pls.

Seguenza, G., 1880: Le formazioni terziarie nella provincia di Reggio (Calabria): *R. Accad. Lincei, Cl. Sci. Fis. Mat. Nat., Mem.*, vol. 6, p. 3–446, 17 pls.

Seiglie, G. A., Grove, K., and Rivera, J. A., 1977: Revision of some Caribbean Archaiasinae, new genera, species and subspecies. *Eclog. Geol. Helv.*, vol. 70, p. 855–883.

Serova, M. Ya., 1955: (Stratigraphy and foraminiferal fauna of Miocene strata of the Pre-Carpathians). *In*, *Materialy po Biostratigrafii Zapadnykh Oblastey Ukrainskoy SSR. Moscow:* Minist. Geol. I Okhrany Nedr, p. 261–391, 29 pls.

——— 1961: (New late Tortonian genus *Podolina* (Miliolidae) of western Ukraine). *Paleont. Zhurnal 1961*, vol. 1, p. 56–60, pl. 4.

Serra-Kiel, J., 1984: Estudi dels *Nummulites* del grup de *N. perforatus* (Montfort). *Trebalis Inst. Catalana d'Hist. Nat.*, no. 11, 244 pp., 28 pls.

Siebold, C. T. E. von, and Stannius, H., 1845: *Lehrbuch der vergleichende Anatomie*: Pt. 1. *Wirbellose Thiere*, no. 1, 679 pp.

Silvestri, A., 1907: Fossil dordoniani nei dintornidi Termini Imerse (Palermo). *Accad. Pont. Romana Nuovi Lincei, Att.*, vol. 60, p. 105–110.

——— 1910: Lepidocycline sannoisiane di anatomia in Calabria. *Accad. Pont. Romana Lincei, Mem.*, vol. 28, p. 103–164, pl. 1.

——— 1924a: Revisione di fossil della Venezia e Venezia Giulia. *Atti dell'Accad. Sci. Veneto-Trent.-Ist., Padova*, vol. 14, p. 7–12.

——— 1924b: Fauna paleogenica di Vasciana presso Todi, Pt. 1, *Boll. Soc. Geol. Ital.*, vol. 42, p. 7–29, pl. 1.

——— 1926: Sulla *Patella cassis* Oppenheim. *Riv. Italiana Pal.*, vol. 32, p. 15–22, pl. 1.

——— 1928: Di alcune facies Litho-Paleontologiche del Terziario di Derna, nella Cirenaica. *Bull. Soc. Geol. Ital.*, vol. 37, p. 109–113, pl. 6.

——— 1937: Foraminiferi dell'Oligocene e del Miocene della Somalia. *Paleont. Italica*, vol. 32, p. 45–264, pls. 4–22.

Sirotti, A., 1978: Discocyclinidae from the Priabonian type section (Lessini Mountains, Vicenza, Northern Italy). *Boll. Soc. Paleont. Ital.*, vol. 17, p. 49–67, pls. 1–4.

Smith, W. D., 1906: Orbitoides from the Binangonan limestone. *Phil. Jour. Sci.*, vol. 1, p. 205, pl. 1.

Smout, A. H., 1954: Lower Tertiary foraminifera of Qatar Peninsula. *British Mus. (Nat. Hist.)*, p. 66–84, pls. 4–12.

——— 1963: The genus *Pseudedomia* and its phyletic relationships, with remarks on *Orbitolites* and other complex foraminifera. *In*, Konigswald, G. H. R. von, et al. *eds.*, *Evolutionary trends in foraminifera*, Elsevier Publ co., p. 224–281, pls. 1–4.

Sowerby, J. de C., 1840: Systematic list of organic remains. Appendix to Grant C. W.: Memoir to illustrate a geological map of Cutch. *Trans. Geol. Soc. London*, vol. 5, p. 327–329, pls. 21–26.

Srinivasan, M. S., 1966: Descriptions of new species and notes on taxonomy of foraminifera from the upper Eocene and lower Oligocene of New Zealand. *Trans. Royal Soc. New Zealand, Geol.*, vol. 3, p. 231–256.

Tambareau, Y., 1967: Sur une nouvelle espece d'Operculine, *Operculina tenuis* n. sp. *Bull. Soc. Hist. Nat. Toulouse*, vol. 103, p. 425–430, pl. 1.

——— 1972: Thanetien superieux et Ilerdien inferieur des Petites Pyrenees, du Plantourel et des Chainons audois These 502. *Sci. Nat. Univ. Pau Sabatien, Toulouse*, 377 pp., 20 pls.

Tan Sin Hok, 1932: On the genus *Cycloclypeus* Carpenter and an appendix on the Heterostegines of Tjimanggoe, S. Bantam, Java. *Weten. Meded. Dienst. Mijnb. Ned.-Ind.*, no. 19, 194 pp., 24 pls.

——— 1935: Die peri-embryonalen Äquatorial-kammern bei einigen Orbitoiden. *Ing. Ned.-Ind., Bandung, Java, Jaarg. 2, Afd. 4 (Mijnb. Geol.)*, p. 113–126, 2 figs.

——— 1936a: *Lepidocyclina zeijlmansi* nov. sp., eine Polylepidine Orbitoidide von Zentral-Borneo, nebst Bemerkungen uber die verschiedenen Einteilungesweisen der Lepidocyclinen. *Ing. Ned.-Ind., 4 Mijnb. Geol. 3rd Jaarg.*, no. 1, p. 7–14, pl. 1.

——— 1936b: Zur Kenntnis der Miogypsiniden. *Ibid.*, no. 3, p. 45–61, pls. 1–2.

——— 1937: On the genus *Spiroclypeus* H. Douvillé with a description of the Eocene *Spiroclypeus vermicularis* nov. sp. from Koetai in the East Borneo. *Ibid.*, Jaarg., 4, no. 10, p. 177–193, pls. 1–4.

Tobler, A., 1927: Verkalkung der Lateralkammern bei *Miogypsina*. *Eclog. Geol. Helv.*, vol. 20, p. 323–330, 5 figs.

Todd, R., 1957: Smaller foraminifera (of Saipan). *U. S. Geol. Surv. Prof. Paper*, 280-H, p. 265–320, pls. 64–93.

——— 1966: Smaller foraminifera from Guam. *Ibid.*, 403-I, p. 1–41, 19 pls.

——— and Post, R., 1954: Smaller foraminifera from Bikini Drill Holes. *Ibid.*, 260-N, p. 547–568, pls. 198–203.

Toumarkine, M., and Luterbacher, H., 1985: Paleocene and Eocene planktonic foraminifera. *In*, Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. *eds.*, *Planktonic Stratigraphy*, p. 87–154, 42 figs. Cambridge Univ. Press.

Tsunakawa, H., 1983: K-Ar dating on volcanic rocks in the Bonin Islands and its tectonic implication. *Tectonophysics*, vol. 95, p. 221–232.

Uchio, T., 1952: An interesting relation between *Stomatorbina* Doreen, 1948, and *Mississippina* How, 1930, of foraminifera. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 7, p. 195–200, pl. 18.

Ujiié, H., and Matsumaru, K., 1977: Stratigraphic outline of Haha-Jima (Hillsborough Island), Bonin Islands. *Mem. Nat. Sci. Mus., Tokyo*, no. 10, p. 5–18, pls. 1–4. (in Japanese)

Umbgrove, J. H. F., 1928: Het genus *Pellatispira* in het Indo-Pacifische gebied. *Wet. Med. Dienst. Mijnb. Ned.-Ind.*, no. 10, p. 43–71, 80 figs.

——— 1936: *Heterospira*, a new foraminiferal genus from the Tertiary of Borneo. *Leidse Geol. Med.*, vol. 8, Pt. 1, p. 155–159, pl. 1.

——— 1937: A new name for the foraminiferal genus *Heterospira*. *Ibid.*, vol. 8, p. 309.

——— 1938: A second species of *Biplanispira* from the Eocene of Borneo. *Ibid.*, vol. 10, Pt. 1, p. 82–89, 17 figs.

Van Wessem, A., 1943: Geology and paleontology of Central Camaguey, Cuba. *Thesis, Utrecht Univ.*, 91 pp., pls. 1–3.

Vaughan, T. W., 1924: American and European Tertiary larger foraminifera. *Geol. Soc. America, Bull.*, vol. 35, p. 785–822, pls. 30–36.

——— 1928: Subfamily Miogypsinidae Vaughan. *In*, Cushman, J. A., 1928, *Foraminifera their classification and economic use, Spec. Publ. Cushman Lab. Foram. Res.*, vol. 1, 401 pp.

——— 1933: Subfamily Lepidorbitoidinae Vaughan. *In*, Cushman, J. A., 1933, *Foraminifera their classification and economic use, Spec. Publ. Cushman Lab. Foram. Res.*, vol. 4, 349 pp.

——— and Cole, W. S., 1941: Preliminary report on the Cretaceous and Tertiary larger foraminifera of Trinidad British West Indies. *Geol. Soc. Amer., Spec. Paper*, vol. 30, 137 pp., 46 pls.

Vella, P., 1957: Studies in New Zeland foraminifera. *Paleont. Bull., Welington*, vol. 28, 64 pp., 9 pls.

Verbeek, R. D. M., 1871: Die Nummuliten des Borneo-Kalk-steines. *Neues Jahr. Min.*, p. 1–14, pls. 1–3.

——— 1891/1892: Voorloopig bericht over Nummulieten, Orbitoiden en Alveolinen van Java, en over den ouderdom der gesteenten waarin zij optreden. *Natuurk. Tijdsch. Ned.-Ind.*, vol. 12, p. 101–139, pl. 1.

——— and Fennema, R., 1896: *Geologische beschrijving van Java en Madoera*, Tome II. Amsterdam 1–2, p. 1141–1183, 11 pls.

Vervloet, C. C., 1966: Stratigraphical and micropaleontological data of the Tertiary of southern Piemont (northern Italy). *Schotanus, Jens Utrecht N. V.; Utrecht*, 64 pp., 12 pls.

Vlerk, I. M. van der, 1924: *Miogypsina dehaarti* nov. spec., de Larat (Moluques). *Eclog. Geol. Helv.*, vol. 18, p. 429–432, tfs. 1–3.

——— 1925: A study of Tertiary foraminifera from the Tidoengsche Landen (E. Borneo). *Wet. Med. Dienst. Mijnb. Ned.-Ind.*, no. 3, p. 13–32, pls. 1–6.

——— 1928: The genus *Lepidocyclina* in the Far East. *Eclog. Geol. Helv.*, vol. 21, p. 182–211, pls. 6–23.

——— 1929: Groote foraminiferen van N. O. Borneo. *Ibid.*, no. 9, p. 5–30, 51 pls.

——— 1963: Biometric research on *Lepidocyclina. Micropaleont.*, vol. 9, p. 425–426, 2 figs.

——— 1968: Two methods of worldwide correlation. *Ibid.*, vol. 14, p. 334–338.

——— 1974: Nomenclatural and Numerical Taxonomy (Name and Number). *Verhandl. Naturf. Ges. Basel*, vol. 84, p. 245–255, pl. 1.

——— and Postuma, J. A., 1967: Oligo-Miocene lepidocyclinas and planktonic foraminifera from East Java and Madura, Indonesia. *Mijnb. Geol.*, vol. 70, p. 392–399, pl. 1.

Weijden, W. J. M., van der, 1940: Het genus *Discocyclina* in Europa. *Thesis Univ. Leiden*, 116 pp., 12 pls. N. V. de Leidsche Cour., Leiden.

Whipple, G. L., 1934: Larger foraminifera from Vitilevu, Fiji. *In*, Ladd's Geology of Vitilevu, Fiji. *Bernice P. Bishop Mus., Bull.*, no. 119, p. 141–153, pls. 19–23.

Yabe, H., 1911: Ueber das Vorkommen von *Orthophragmina* auf den Bonin-Inseln. *Centralbl. Min. Geol. Paleont.*, 1921, p. 298–300.

——— 1918: Notes on *Operculina*-rocks from Japan, with remarks on "*Nummulites*" *cumingi* Carpenter. *Sci. Rep. Tohoku Univ. 2nd ser. (Geol.)*, vol. 4, p. 105–126, pl. 17.

——— 1919: Notes on *Lepidocyclina*-limestone from Cebu. *Ibid.*, vol. 5, p. 37–51, pls. 6–7.

——— 1920: Tertiary higher foraminiferal rocks from Japan. *Jour. Geol. Soc. Tokyo*, vol. 27, no. 322, p. 293–300. (in Japanese)

——— 1921: Notes on some Eocene foraminifera. *Sci. Rep., Tohoku Univ. 2nd ser. (Geol.)*, vol. 5, p. 97–100, pl. 14.

——— and Hanzawa, S., 1922: *Uhligina*, a new type of foraminifera in the Eocene of Japan and west Galicia. Japan. *Jour. Geol. Geogr.*, vol. 1, p. 71–75, pl. 12.

——— and ——— 1925a: A *Lepidocyclina*-Limestone from Klias Peninsula, B. N. Borneo. *Gedenkboek Verbeek, Verhdl. Geol.-Mijnb. Genoot. Nederl. en. Kol. Geol. Ser.*, vol. 8, p. 617–632, pls. 1–4.

——— and ——— 1925b: Nummulitic rocks of the islands of Amakusa (Kyushu, Japan). *Sci. Rep. Tohoku Univ. 2nd ser. (Geol.)*, vol. 7, p. 73–82, pls. 18–22.

——— and ——— 1925c: Notes on some Tertiary foraminiferous rocks from the Philippines. *Ibid.*, vol. 7, p. 97–109, pl. 25–27.

——— and ——— 1928: Tertiary foraminiferous of Taiwan. *Proc. Imp. Acad. Tokyo*, vol. 4, p. 222–225.

——— and ——— 1929: Tertiary foraminiferous rocks of the Philippines. *Ibid.*, vol. 11, p. 137–190, pls. 19–27.

——— and Hatai, K., 1939: On an interesting Gastropoda from Hahajiima, Ogasawara Islands, Japan. *Japan. Jour. Geol. Geogr.*, vol. 16, p. 209–212, pl. 12.

——— and Sugiyama, T., 1935: A new species of the genus *Ranina (Lophoranina)* from Hahajima, Ogasawara Group (Bonin Island), Japan. *Ibid.*, vol. 12, p. 1–4, pl. 1.

Yoshiwara, S., 1902: Geological age of Ogasawara Group (Bonin Islands) as indicated by the occurrence of *Nummulites. Geol. Mag., London*, vol. 9, p. 296–303.

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