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Late Oligocene larger foraminifera from the Komahashi-Daini Seamount, Kyushu-Palau Ridge and their tectonic significance

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Abstract. A larger foraminiferal assemblage consisting of *Miogypsinella ubaghsi* (Tan), *Spiroclypeus margaritatus* (Schlumberger) and other species is described from limestone blocks dredged at two sites on the Komahashi-Daini Seamount of the Kyushu-Palau Ridge. The fauna dates the limestone samples as Late Oligocene and is correlatable with the younger part of the Minamizaki Limestone on the Ogasawara (Bonin) Islands. These shallow-water benthic foraminifera give evidence for the shallow-water attitude of the Kyushu-Palau Ridge during the Oligocene, which has been rifted, submerged, and finally subsided to the present water depth.

Key words: Komahashi-Daini Seamount, Kyushu-Palau Ridge, larger foraminifera, Late Oligocene

Introduction

The Kyushu-Palau Ridge is an about 3,000 km long submarine ridge with a general N-S trend which divides the sea floor into the Nankai Trough on the east and the Ryukyu Trench on the west (Figure 1). On the Kyushu-Palau Ridge, a series of isolated seamounts were discovered during the 1970's (Shiki *et al.*, 1974; Shiki *et al.*, 1975). The Komahashi-Daini Seamount is located near the northern margin of this ridge. During the R/V Tansei-Maru KT94-10 Cruise, which operated July 5-12, 1994, we dredged limestone samples along with many intrusive, hypabyssal and volcanic rocks such as tonalite, andesite, tuff and pumice from the Komahashi-Daini Seamount. In this study, we describe the larger foraminifera in the limestone samples and discuss the age assignment based on the foraminiferal data and their tectonic significance.

Material

During the KT94-10 cruise, samples were dredged at two sites of the Komahashi-Daini Seamount. DG-04 site is located on the northeastern slope of the north peak, and DG-05 site on the eastern slope of the major peak (Table 1 and Figure 2). Among the rock samples, one limestone sample (DG-04-01) from the northern site and two (DG-05-01 and DG-05-02) from the southern site were studied.

The limestone samples are indurated packstone or packstone to wackstone. All these samples are moderately hard to compact, and white to creamy white in color. They contain abundant larger and smaller benthic foraminifera, together with coral biolithite, calcareous algae and mollusks.

All of the described larger foraminiferal specimens are kept in the Geological Survey of Japan, under catalogue numbers GSJF 15418 to GSJF 15427.

Results

Thirteen foraminiferal species were identified (Figures 3-8). Dominant species are *Spiroclypeus margaritatus, Nephrolepidina praejaponica, N. angulosa, N. marginata, Eulepidina ephippioides, Heterostegina borneensis, Miogypsinella ubaghsi* and *Austrotrillina howchini*. No distinct difference in species composition was found among the three samples. This assemblage was assigned an age of Te 1-4 (Tertiary e 1-4) according to the system of Far East Letter Stages, equivalent to Late Oligocene (Hashimoto *et al.*, 1980; Hashimoto and Matsumaru, 1984; Mohiuddin, 1997). Coexistence of *M. ubaghsi* and *S. margaritatus* along with *H. borneensis*, *Eulepidina*, *Miogypsinoides* and *Spiroclypeus* is indicative of a Late Oligocene age as seen in the Melinau Limestone of Sarawak, North Borneo (Adams, 1965). Moreover, Adams and Belford (1974) suggested that the association of *S. margaritatus, H. borneensis* and *E. ephippioides* is indicative of the Tertiary lower e, which is believed to be equivalent to the Upper Oligocene (Chattian) of Europe.

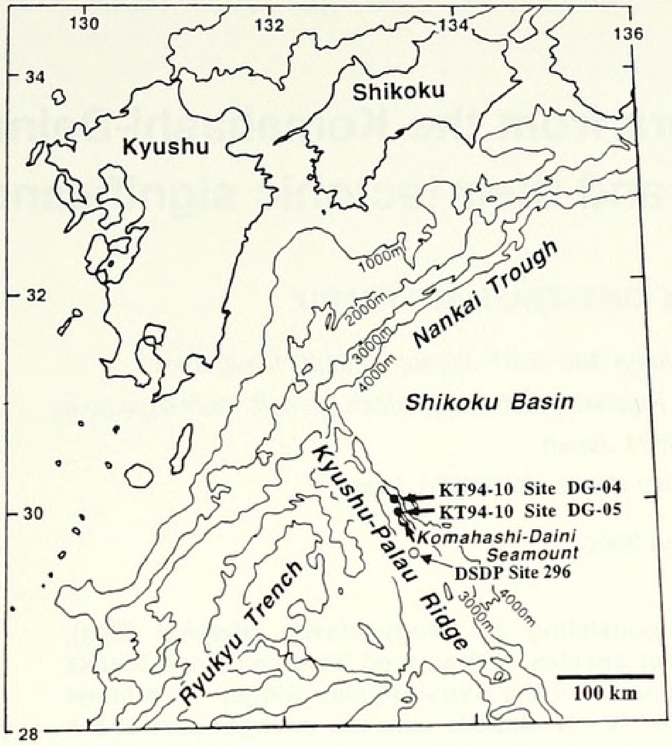


Figure 1. Index map of dredged samples used for this study.

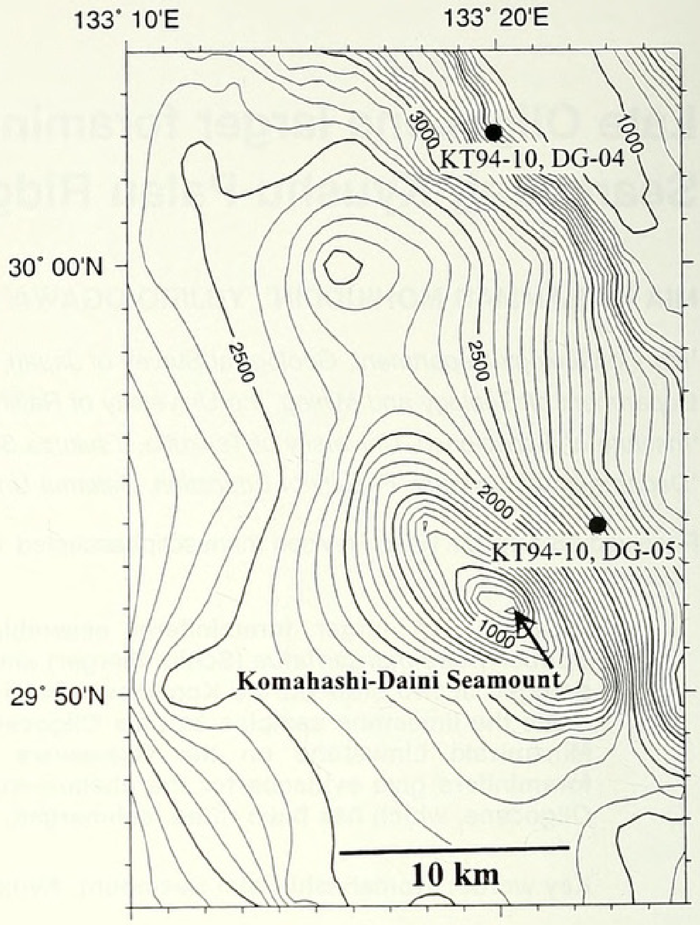


Figure 2. Location of dredge sites KT94-10 on Kyushu-Palau Ridge. Adopted from Ohara *et al.* (1999). Contours in meters.

The *M. ubaghsi -S. margaritatus* assemblage can be correlated with the fauna of the upper member of the Minamizaki Limestone in Chichi-Jima and Minami-Jima, Bonin Islands. *Miogypsinella boninensis* (Matsumaru, 1996) described from the Bonin Islands is thought to be a junior synonym of *Miogypsinella ubaghsi* (Tan, 1936). This assemblage may be correlated with the assemblage of Te Stage limestones from 1210 to 1599 feet depth in Enewetok Atoll Drill Hole and with those from 1597.5 to 1671 feet depth in Bikini Atoll Drill Hole. The *M. ubaghsi -S. margaritatus* assemblage is also correlated with the fauna of the Bubton Limestone, Mindoro, Philippines (Hashimoto and Matsumaru, 1984). The Te Stage is regarded as corresponding to Zone P. 21 of Blow's (1969, 1979) planktonic foraminiferal zonation.

Discussion

Konda (1975) reported larger foraminifera in limestone samples dredged from the eastern slope near a peak of the Komashashi-Daini Seamount, Kyushu-Palau Ridge and assigned to the samples an age younger than Middle Miocene based on the foraminiferal assemblage. The northern half of the Kyushu-Palau Ridge was dated around 48 Ma by Ar-Ar dating of volcaniclastic and granitic rocks (Ozima *et al.*, 1977). A similar age was also obtained from K-Ar age of augite-orthopyroxene andesite rocks in Haha-Jima of the Bonin Islands (Kaneoka *et al.*, 1970). These age data suggest that the Izu-Ogasawara arc was juxtaposed with the northern Kyushu-Palau Ridge before the initiation of back-arc spreading in the Shikoku Basin. Moreover, larger foraminiferal age data in this study gave a Late Oligocene age for the limestone blocks of the Komahashi-Daini

Table 1. Location of dredged samples on the Kyushu-Palau Ridge.

Sample No.	Location	Hit bottom Latitude	Hit bottom Longitude	Water depth (m)	Off bottom Latitude	Off bottom Longitude	Water depth (m)	Dredged materials
DG-04-01	KPR, Unnamed Seamount	30°02.983′N	133°19.880′E	3800	30°02.074′E	133°18.465′E	2632	tuff, pumice and limestone
DG-05-01 and DG-05-02	KPR, Komahashi-Diani Seamount	29°53.983′N	133°22.656′E	3334	29°53.160′N	133°20.992′E	2500	tonalite, andesite and limestone

Sample No.			Larger foraminiferal species
DG-04-01	DG-05-01	DG-05-02	
X	X	X	*Spiroclypeus margaritatus* (Schlumberger)
X	X		*Heterostegina borneensis* van der Vlerk
X	X		*Nephrolepidina praejaponica* Matsumaru
X	X		*Nephrolepidina angulosa* (Provale)
X	X		*Nephrolepidina marginata* (Michelotti)
X		X	*Miogypsinella ubaghsi* (Tan)
X		X	*Austrotrillina howchini* (Schlumberger)
X			*Eulepidina dilatata* (Michelotti)
	X	X	*Eulepidina ephippioides* (Jones and Chapman)
	X		*Amphistegina radiata* (Fichtel and Moll)
X			*Eulepidina* sp.
X			*Ammonia* sp.
X		X	*Heterostegina* sp.

Figure 3. Occurrence of larger foraminiferal species in dredged samples.

Seamount, which is consistent with the oldest age of the basement rocks in the Shikoku Basin (Watts and Weissel, 1975).

The association of Late Oligocene coral-bearing limestone with benthic foraminifera of shallow-sea nature and igneous rocks recognized at the Komahashi-Daini Seamount has also been reported at DSDP Site 296, south of the seamount, at a depth of 2,920m (Figure 1). This evidence suggests that volcanogenic-calcareous sedimentary sequences of Oligocene age are rather widely distributed in the northern part of the Kyushu-Palau Ridge, including the Komahashi-Daini Seamount.

In view of the paleoenvironmental nature of the larger foraminiferal assemblage consisting of *Miogypsinella, Spiroclypeus, Austrotillina, Eulepidina, Amphistegina* and *Heterostegina*, an environment of the shallow open ocean at the shelf edge was suggested for the deposition of limestone beds of the Komahashi-Daini Seamount, as in the case of the limestone beds of the Minamizaki Limestone, Chichi-Jima (Matsumaru, 1996). Moreover, the presence of several species of *Lepidocyclina* (*Eulepidina*) associated with pyroclastic sediments in cores 56 and 57 at DSDP Site 296 indicates a neritic environment (Ujiié, 1975).

In contrast to the cases of the Komahashi-Daini Seamount and of Chichi-Jima, where the Late Oligocene sediments are exposed near the seamount surface, a drill hole at DSDP Site 296 displays a considerably continuous sequence from in situ volcanic rocks through Late Oligocene shallow-water sediments. It includes larger foraminifera and pelagic calcareous ooze, suggesting a subsidence of the Kyushu-Palau Ridge (Ujiié, 1975).

It is noteworthy that the northern parts of the Kyushu-Palau Ridge and the Izu-Bonin Arc resemble each other in the timing of the cessation of volcanic activity and in the final paleoenvironment reaching a shallow-water depth. Since Uyeda and Ben-Avraham (1972) many authors have supposed that both ridges formed a single arc at the initial stage and then were divided into two arcs owing to the spreading of the Shikoku and Parce Vella Basins. This study offers a new line of supporting evidence for this hypothesis.

Conclusion

The oldest age of the Kyushu-Palau Ridge is Late Oligocene based on larger foraminifera. The benthic foraminiferal assemblage in the limestone samples is correlated with that from the upper part of the Minamizaki Limestone exposed on the Ogasawara (Bonin) Islands of the Izu-Bonin Arc. This fact suggests that the Kyushu-Palau Ridge and the Izu-Bonin Arc initially formed a single arc. Afterward the arc may have split by a spreading of the Shikoku and Parce Vella Basins.

Systematic descriptions

Family Lepidocyclinidae Scheffen, 1932

Genus ***Nephrolepidina*** Douvillé, 1911

Nephrolepidina praejaponica Matsumaru, 1989

Figures 6.1–6.4, 6.6, 6.7, 6.9, 6.10, 7.1, 7.6–7.9

Nephrolepidina praejaponica Matsumaru. In Matsumaru and Kimura, 1989, p. 265, 267, figs. 6.1–6.13; Matsumaru *et al.*, 1993, p. 8, figs. 2.4, 3.6–3.8.

Material.—Thirteen specimens (GSJF 15420–1—13) including one megalospheric specimen in a vertical section (GSJF 15420–1; Figure 6.1).

Description.—Tests of megalospheric specimens, GSJF

15420-1-8, are small lenticular with diameter of 3.5 to 5.5 mm and thickness of 1.5 to 2 mm. Conical pillars are from 80 μm to 100 μm in diameter, and distributed in the central part of the test surface. The embryonic chambers are of nephrolepidine type. The protoconch is subcircular wih a diameter of 240 μm. The second large chamber, the deuteroconch embraces the protoconch and has an internal diameter of 320 μm. The ratio of the inner diameter of the deuteroconch (II) to that of the protoconch (I) is 1.3. The outer wall of the embryonic chambers is more than 25 mm thick. The equatorial chambers of arcuate form near the periembryonic chambers change from ogival to short hexagonal near the periphery. The height of the equatorial layer near the center is about 200 μm and at the periphery less than 100 μm. The lateral chambers are rectangular in shape and are arranged in a tier of 10 to 12 layers over the center. Chambers over the central area of the test have a length of more than 160 to 200 μm, a height of 45 to 60 μm, and floors and roofs 20 to 25 μm thick.

Remarks.—The present specimen has the same features of small embryonic chambers and short hexagonal equatorial chambers in as *N. praejaponica* Matsumaru from the Lower Member of the Misaki Formation, Tosa Shimizu City, Kochi Prefecture, Shikoku (Matsumaru and Kimura, 1989) and the Early Miocene (Aquitanian) Shimizu Formation (Matsumaru *et al.*, 1993), Shikoku Island. *Nephrolepidina praejaponica* is similar to *N. japonica* (Yabe) in overall morphology, but differs from the latter in having a small test and small embryonic chambers, primitive form of the embryonic chambers, short hexagonal equatorial chambers, rectangular lateral chambers and wavy floors and roofs.

Nephrolepidina species have been reported from Zones N. 8 and N. 9 of Blow (1969) in the Japanese mainland (Yabe, 1906; Yabe and Hanzawa, 1922; Hanzawa, 1931a, b; 1964; Matsumaru, 1967, 1971a) except the Izu Peninsula and Shikoku Island (Matsumaru, 1971a; Matsumaru and Kimura, 1989).

Nephrolepidina angulosa (Provale, 1909)

Figure 6.5

Lepidocyclina tournoueri Lemoine and R. Douvillé var. *angulosa* Provale, 1909, p. 28, pl. 3, figs. 13-15.
Lepidocyclina angulosa Provale. Rutten, 1912, p. 21, figs. 1-4.
Lepidocyclina (*Nephrolepidina*) *angulosa* Provale. Hanzawa, 1957, p. 76, 77, pl. 20, figs. 1-9, pl. 21, fig. 5, pl. 22, figs. 4, 14.
Nephrolepidina angulosa (Provale). Matsumaru, 1992, p. 259, 260, figs. 1.6, 1.7.

Material.—One megalospheric specimen in a vertical section, GSJF 15421.

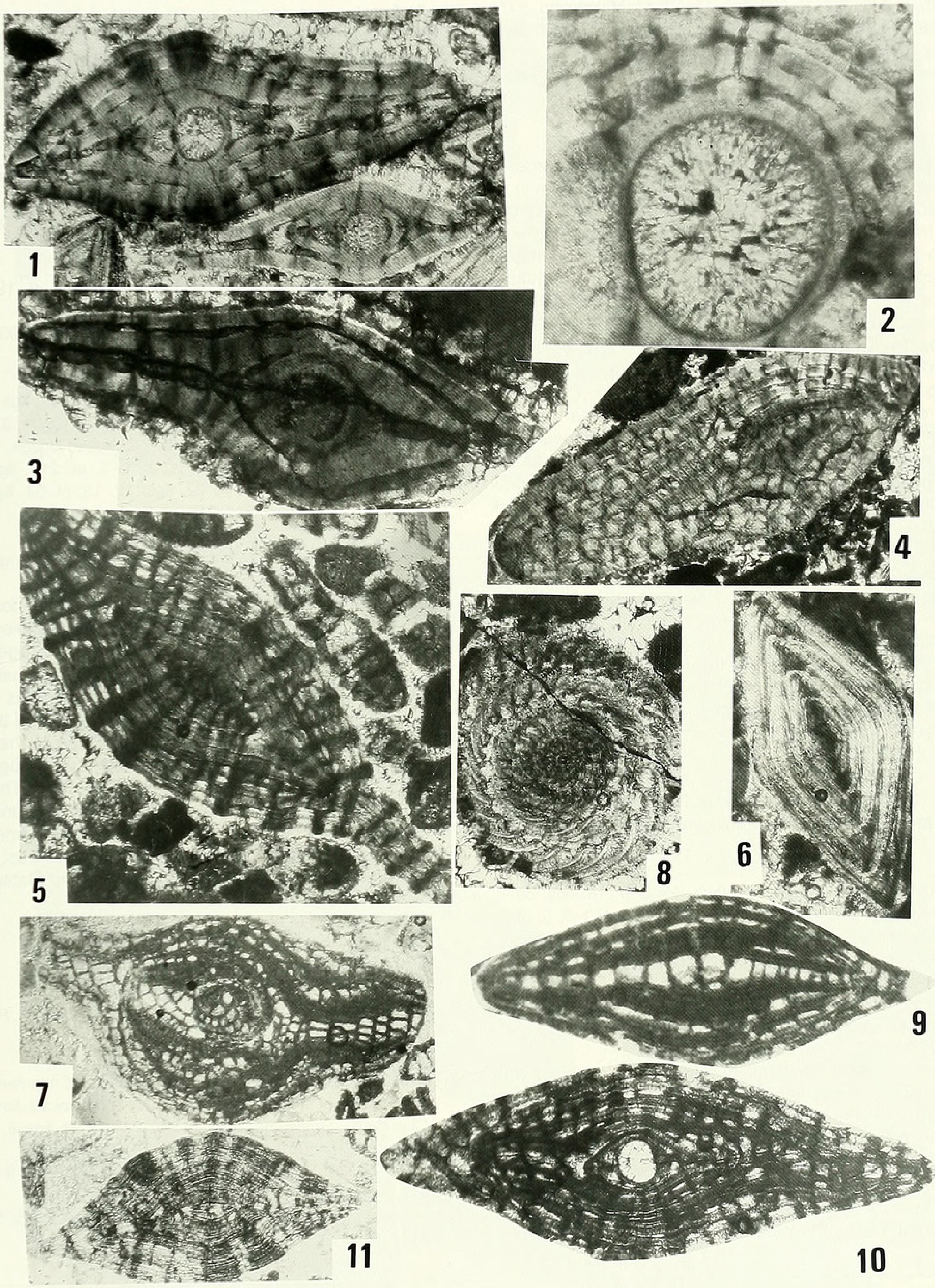
Remarks.—This species is characterized by having a flat-topped central boss with stout pillars; equatorial chambers in the mature stage are hexagonal in shape; the roof and floor of the lateral chambers are straight; and the chamber cavities are narrow and long. External appearance of the shell is similar to that of *Nephrolepidina praejaponica* Matsumaru, but it differs from the latter in possessing several conical pillars formed on the flat top of the central boss.

Family Nummulitidae de Blainville, 1827
Genus ***Spiroclypeus*** H. Douvillé, 1905
Spiroclypeus margaritatus (Schlumberger, 1902)

Figures 4.1, 4.2, 4.4, 4.5, 4.7, 4.9, 4.10, 5.1-5.13, 8.1

Heterostegerina margaritata Schlumberger, 1902, p. 152, 153, 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; Cole, 1957a, p. 332-333, pl. 95, figs. 6-12; Matsumaru, 1976a, 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. 1-4, 10, 13-15, 21-23, 28; Matsumaru, 1976a, p. 199, 200, pl. 1, figs. 4-7, 14, 15, 21, 23, 4.
Spiroclypeus yabei van der Vlerk, 1925, p. 16, pl. 2, fig. 19, pl. 5, figs. 40, 50; Tan, 1937, p. 183, pl. 1, figs. 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, 1976a, p. 200, pl. 1, figs. 3, 9, 12, 18-20, 22, pl. 6, fig. 15; Hashimoto, Matsumaru and Sugaya, 1981, p. 60, 61, pl. 13, figs. 9, 12.
Spiroclypeus margaritata (Schlumberger). Yabe and Hanzawa, 1925, p. 627-630, pl. 2, fig. 10, pl. 3, figs. 8, 9, pl. 4, figs. 3-8, text-figs. 1-4; 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, 1975, p. 122, pl. 13, figs. 11, 12; Hashimoto, Matsumaru and Sugaya, 1981, p. 59, 60, pl. 13, fig. 3; 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. Hanzawa, 1957, p. 45, pl. 5, figs. 1-6, 14; Cole, 1957a, p. 332, pl. 95, figs. 1-5, pl. 109, fig. 16; Cole,

➡ **Figure 4. 1, 2, 4, 5, 7, 9, 10.** *Spiroclypeus margaritatus* (Schlumberger), **1** (upper), **5, 9, 10**: vertical sections, x 30, (GSJF 15418-1—4) **4, 7**: oblique sections, x 30, (GSJF 15418-5—6), **2**: megalospheric protoconch x 200, (GSJF 15418-7). **3**. *Heterostegina* sp. vertical section, x 30. **6, 8**. *Amphistegina radiata* (Fichtel and Moll), **6**: vertical section, x 20, (GSJF 15427-1) **8**: median section, x 20, (GSJF 15427-2) **11**. *Heterostegina borneensis* van der Vlerk, vertical section, x 30, (GSJF 15419).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1957b, p. 763, 764, pl. 239, figs. 11, 12, 14; Matsumaru, 1974, p. 108, pl. 15, figs. 1, 5, 8, 12, 18, 19; Matsumaru, 1976a, p. 199, pl. 1, figs. 2, 11, 16, 17.

Spiroclypeus margaritatus (Schlumberger). Matsumaru, 1996, p. 104-108, pl. 32, figs. 1-8, pl. 33, figs. 1-9.

Material.—Twenty specimens, GSJF 15418-1—20.

Description.—Test small, inflated to lenticular, bordered by a rather thin flange, central area more than 3.5 mm in diameter and 1.5 mm in thickness. Low raised pustules distributed in umbonal portion of the test having a diameter of less than 100 μm. The megalospheric embryonic chambers consist of a spherical protoconch followed by a reniform deuteroconch. The inner diameters of protoconch (DI) and deuteroconch (DII) vary from 200 to 250 μm and 450 to 550 μm, respectively with a (DII/DI) ratio of 2.2.

Remarks.—Tan (1937) divided the species of *Spiroclypeus* into the pustulate and the reticulate group. The former group is characterized by prominent pillars on the umbonal portion of the test, the later one by the development of an external reticulation of the septa at the central part of the test. *Spiroclypeus margaritatus* belongs to the pustulate group and is characterized by large and heavy pillars, thick roofs and floors in lateral chambers, and moderate sized operculine chambers.

According to Matsumaru (1996), all the *Spiroclypeus* species reported from the West Pacific region are junior synonyms of *Spiroclypeus margaritatus* (Schlumberger). This species, known from Chichi-Jima, is restricted in occurrence to the Upper Member of the Minamizaki Limestone. It has a comparatively short stratigraphic range in Te, from the top of the *Heterostegina borneensis* Zone to the base of the *Miogypsinoides dehaartii* Zone, in the Eniwetok Atoll Drill Holes (Cole, 1957b).

Genus **Heterostegina** d'Orbigny, 1826
Heterostegina borneensis van der Vlerk, 1929

Figure 4.11

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. 95, pl. 26, figs. 11, 19; pl. 27, figs. 4-8; Matsumaru, 1976a, p. 199, pl. 3, figs. 17-19, 21-22; Matsumaru, 1996, p. 94-96, pl. 28, figs. 1-7.

Material.—One microspheric specimen in a vertical section, GSJF 15419.

Description.—Test small, initial part evenly lenticular with a moderately wide, thin flange on distal part. Test diameter ranges from 2.2 mm to 2.7 mm; test thickness ranges from 1.0 to 1.2 mm; thickness of pillars varies from 120 μm at umbo to 100 μm at tip of flange. In vertical section, embryonic apparatus biloculine; initial protoconch subcircular; its diameter less than 100 μm. Prominent pillars are present on the central boss of the test. Pillars penetrating to outer wall of embryonic apparatus and equatorial layer.

Remarks.—*Heterostegina borneensis* and *Spiroclypeus margaritatus* co-occur in the Lower and Upper members of the Minaminizaki Limestone. In the Komahashi-Daini Seamount Limestone, *H. borneensis* is associated with *Spiroclypeus margaritatus*, the latter species being the more abundant one. *H. borneensis* has also been recognized as a marker species to distinguish Te1-4 from Te5 (Cole, 1957a; Adams, 1965; Matsumaru, 1974, 1978), since van der Vlerk (1925) regarded it to be a useful species for delimiting Te1-4.

Family Austrotrillinidae Loeblich and Tappan, 1986
Genus ***Austrotrillina*** Parr, 1942
Austrotrillina howchini (Schlumberger, 1893)

Figure 8.11

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). 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; Matsumaru, 1996, p. 214-216, pl. 84, figs. 3-7.

Material.—One microspheric specimen in a longitudinal section, GSJF 15424.

Remarks.—*Austrotrillina howchini* originally described from Saipan is also found in the Bikini Atoll Drill Holes associated with *Spiroclypeus* and *Eulepidina* in Te Stage (Cole, 1954). The stratigraphic range of this species has been given as Te through Tf1-2 (Glaessner, 1943) and as Te and Tf1 (van der Vlerk, 1948). Hanzawa (1940) stated that this species is found only in the Aquitanian stage in the Western Pacific. Hashimoto and Matsumaru (1984) suggested that *A. howchini* ranged from Te4 to Te5-Tf1. This species occurs in association with *Miogypsinella boninensis* and *Spiroclypeus margaritatus* in the Minamizaki Limestone, Chichi-Jima, assigned to Te 1-4 of the Far East Letter Stages (Hashimoto *et al.*, 1980; Hashimoto and Matsumaru, 1984).

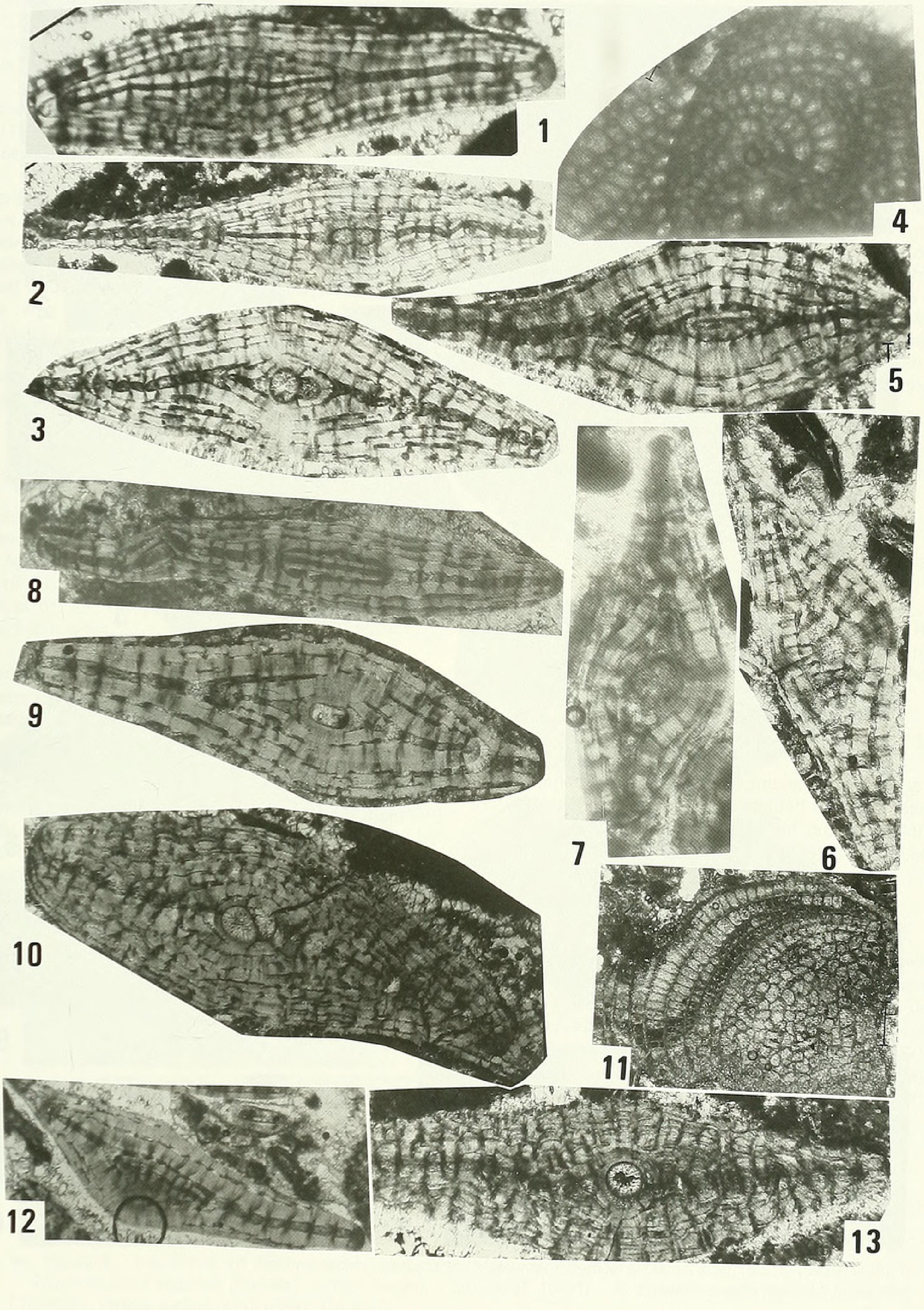
Family Lepidocyclinidae Scheffen, 1932
Subfamily Eulepidininae Matsumaru, 1991
Genus ***Eulepidina*** H. Douvillé, 1911
Eulepidina ephippioides (Jones and Chapman, 1900)

Figures 6.8, 7.3, 7.4

Orbitoides (*Lepidocyclina*) *ephippioides* Jones and Chapman, 1900, p. 251, 252, pl. 20, fig. 9. *Lepidocyclina ephippioides* Jones and Chapman. Grimsdale, 1952, p. 240-244, pl. 23, figs. 8, 17, 18. *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger. Cole, 1954, p. 594-597, pl. 216, figs. 1-16; pl. 217, figs. 9-11, pl. 218, figs. 1, 3, 4.

Lepidocyclina (*Eulepidina*) *gibbosa* Yabe. Cole, 1954, p. 597, pl. 217, figs. 9-11.

➡ **Figure 5.** **1-13**. *Spiroclypeus margaritatus* (Schlumberger). **1-3, 5-10, 12, 13**: vertical sections, x 30, (GSJF 15418-8—18), **4, 11**: oblique sections, x 30, (GSJF 15418-19—20).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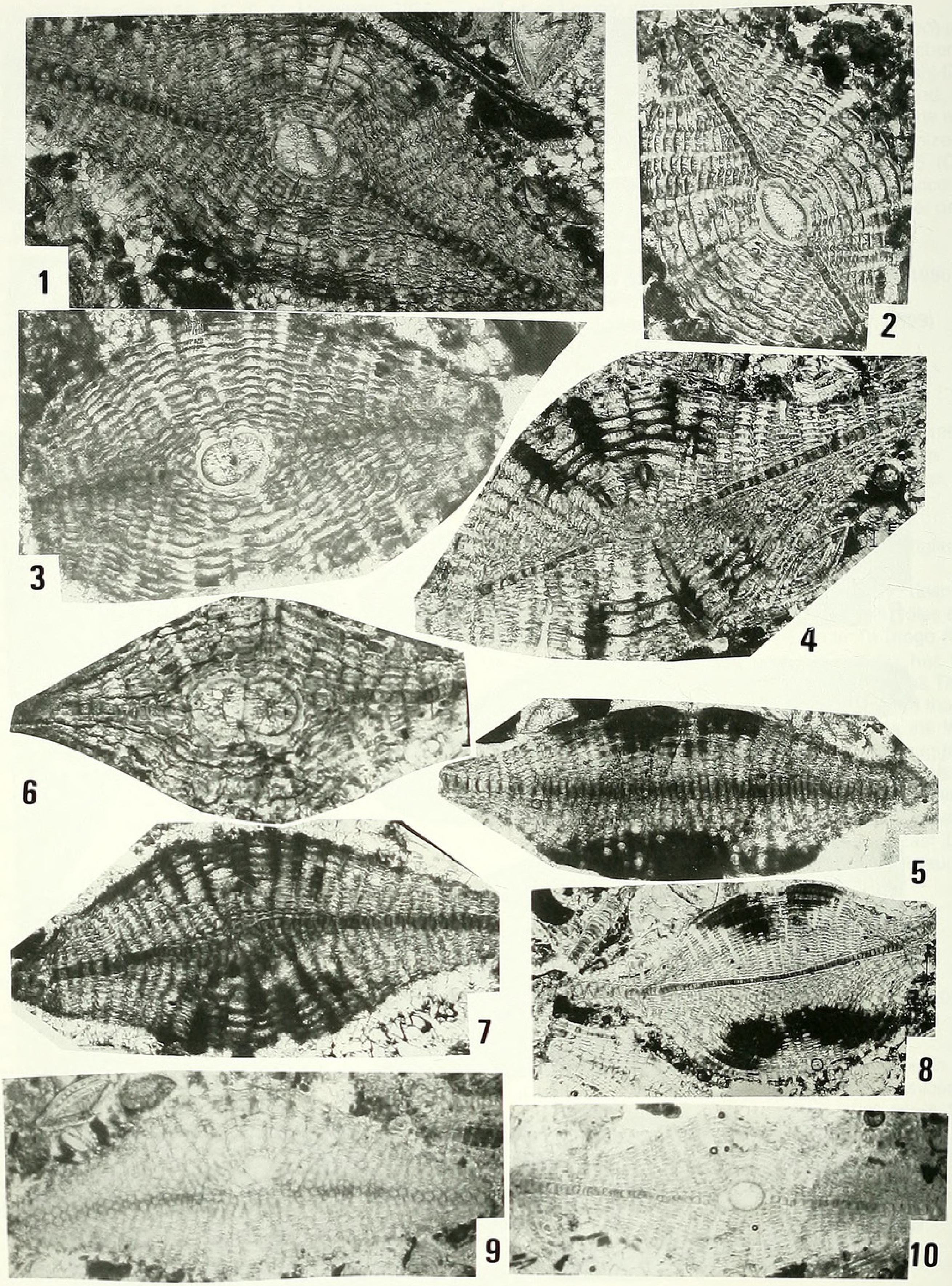
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Lepidocyclina (*Eulepidina*) *planata* Oppenoorth. Cole, 1954, p. 597, 598, pl. 217, figs. 7, 8; pl. 218, figs. 5, 6.
Lepidocyclina (*Eulepidina*) *ephilppioides* Jones and Chapman. Cole, 1957b, p. 346-337, pl. 108, figs. 4-13; pl. 109, figs. 11-15.
Eulepidina ephilppioides (Jones and Chapman). Matsumaru, 1996, p. 178-181, pl. 65, figs. 1-6, pl. 66, figs. 1-3; pl. 67, figs. 1-6; pl. 68, figs. 1-3; pl. 69, figs. 1-4; pl. 70, figs. 1-5, text-fig. 20-5.

Material. — Three megalospheric specimens (GSJF 15426-1—3).

Remarks.— *Eulepidina ephippioides* is characterized by the possession of a small nucleoconch and hexagonal or spatulate equatorial chambers. The earliest name of this species was thought to be *Orbitoides* (*Lepidocyclina*) *ephippioides* Jones and Chapman. According to Grimsdale (1952), the American Oligocene species *L.* (*E.*) *favosa* Cushman should be a synonym of *L. ephippioides* (Jones and Chapman).

Eulepidina dilatata (Michelotti, 1861)

Figure 8.1 (lower)

Orbitoides dilatata Michelotti, 1861, p. 17, pl. 1, figs. 1-2.
Eulepidina dilatata (Michelotti). Matsumaru, 1971b, p. 184, 185, pl. 22, figs. 28-38; Hashimoto and Matsumaru, 1975, p. 114, 115, pl. 12, figs. 10, 11; Matsumaru, 1996, p. 162-178, pl. 60, figs. 1-6; pl. 61, figs, 1-6; pl. 62, figs. 1-7; pl. 63, figs. 1-6; pl. 64, figs. 1-2, text-figs. 20-2, 4, text-fig. 30.

Material. — One obliquely sectioned megalospheric specimen, GSJF 15425.

Remarks.—The present species is characterized by having a lenticular shape, polygonal outline, large nucleoconch, hexagonal equatorial chambers, low and long lateral chambers and thin roofs and floors. It differs in general shell shape from *Eulepidina ephippioides* (Jones and Chapman). Recently, Matsumaru (1996) investigated the size of the embryonic chambers of *E. dilatata* and *E. ephippioides* from the Minamizaki Limestone, Chichi-Jima and concluded that microspheric *E. dilatata* slightly differs in chamber budding formation from microspheric *E. ephippioides.*

Family Miogypsinidae Vaughan, 1928
Genus ***Miogypsinella*** Hanzawa, 1940
Miogypsinella ubaghsi (Tan, 1936)

Figures 7.2, 8.2, 8.3

Miogypsinoides ubaghsi Tan, 1936, p. 47, 48, pl. 1, figs. 1-7; Cole, 1954, p. 603, 604, pl. 221, figs. 5, 9-18; pl. 222, figs. 13, 15.
Miogypsinella ubaghsi (Tan). Hanzawa, 1940, p. 767, 768, text-fig. 4.

Material. —Three melalospheric specimens; one in an equatorial section, GSJF 15423-3 (Figure 8.3), one in an axial section, GSJF 15423-1 (Figure 8.2), and one in a vertical section, GSJF 15423-2 (Figure 8.2).

Description. —Test small, slightly wider than long, fan-shaped; 1.5 to 1.8 mm in diameter and 0.65 to 0.75 mm in thickness. Surface ornamentation consists of large pustules over the initial portion and finer, closer-spaced pustules over the distal portion. Embryonic chambers are bilocular, first chamber is nearly spherical and second chamber is reniform. Initial chambers are followed by subquadrate periembryonic chambers arranged so that they form virtually two coils. Periembryonic chambers gradually increase in length as they as added for about 1.5 volution at which point they decrease gradually in length to the end of the coil.

Remarks. —The present species differs from *Miogypsinella borodinensis* Matsumaru, 1996, described from Minamizaki Limestone, Chichi-Jima, in having fewer equatorial and embryonic chambers and a small apical angle.

Family Amphisteginidae Cushman, 1927
Genus ***Amphistegina*** d'Orbigny, 1826
Amphistegina radiata (Fichtel and Moll, 1798)

Figures 4.6, 4.8, 8.1

Nautilus radiatus Fichtel and Moll, 1798, p. 58, pl. 8, figs. 8a-d.
Amphistegina lessoni d'Orbigny. Yabe and Hanzawa, 1925, p. 48, 49, pl. 8, figs. 9, 10; Hanzawa, 1931b, p. 156, pl. 24, fig. 7; pl. 25, figs. 5-8; pl. 10, fig. 4.
Amphistegina radiata (Fichtel and Moll). Yabe and Hanzawa, 1929, p. 179, 180, pl. 18, fig. 6; Matsumaru, 1976b, p. 408, pl. 1, figs. 1-3, 5-13, 17, 23, 26-27, text-figs. 6-8. Matsumaru, 1996, p. 188, pl. 74, figs. 1-5.

Material.—Three microspheric specimens (GSJF 15427-1—3)

Remarks.—The present specimens show a close similarity with those of *A. radiata* described from the Minamizaki Limestones (Matsumaru, 1996) and are characterized by many chambers in the last whorl, curvature of the spiral suture and septa and a large protoconch.

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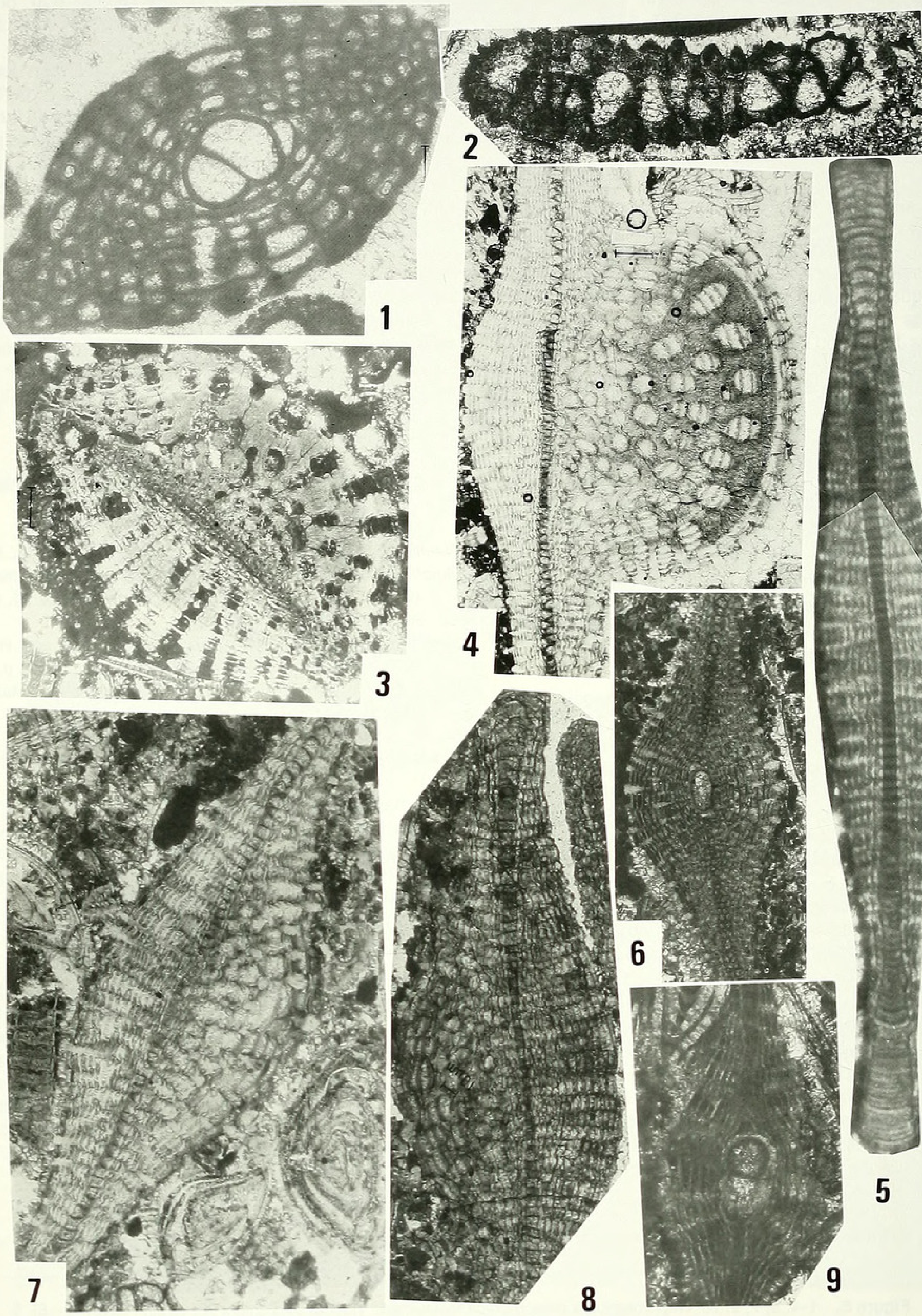
← **Figure 6.** **1-4, 6, 7, 9, 10**. *Nephrolepidina praejaponica* Matsumaru. vertical sections, x 30, (GSJF 15420-1—8). **5** *Nephrolepidina angulosa* (Provale), vertical section, x 30, (GSJF 15421). **8**. *Eulepidina ephippioides* (Jones and Chapman), vertical section, x 20, (GSJF 15426-1).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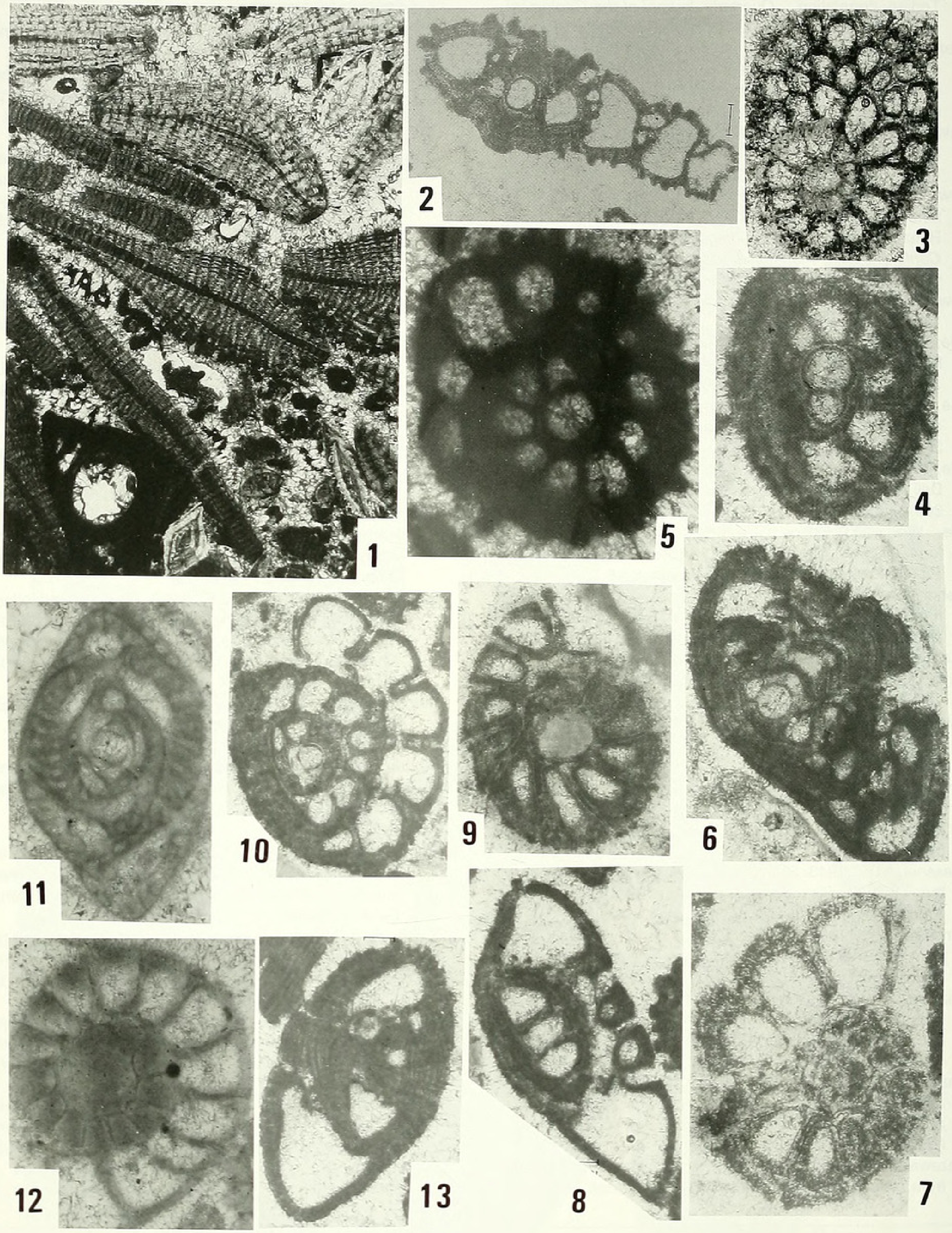
← **Figure 7. 1, 6-9**. *Nephrolepidina praejaponica* Matsumaru, **1:** oblique section, x 20, **6-9**: vertical sections, x 30, (GSJF 15420-9—13). **2.** *Miogypsinella ubaghsi* (Tan), vertical section, x 80, (GSJF 15423-1). **3, 4**. *Eulepidina ephippioides* (Jones and Chapman), vertical sections, x 20, (GSJF 15426-2—3). **5**. *Eulepidina* sp., vertical section, x 10.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← **Figure 8.** **1**. Bioclastic packstone containing diagnostic species such as *Spiroclypeus margaritatus* (Schlumberger) (GSJF 15418-20), *Nephrolepidina marginata* (Michelotti) (GSJF 15422), *Eulepidina dilatata* (Michelotti) (GSJF 15425) and *Amphistegina radiata* (Fichtel and Moll) (GSJF 15427-3) x 20. **2, 3**. *Miogypsinella ubaghsi* (Tan). **2**: axial section, x 20, GSJF 15423-2, **3**: equatorial section, x 20, (GSJF 15423-3). **4-10, 12, 13**. *Ammonia* sp., **4, 7, 9, 10, 12**: oblique sections, x 20, **5**: equatorial section, x 20, **6, 8, 13**: axial sections, x 20. **11**. *Austrotrillina howchini* (Schlumberger), longitudinal section, x 20, (GSJF 15424).

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