報　文

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Eocene Larger Foraminifers from the Sea Floor near Oki-daito-shima Island (GH74-7-167)*

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Abstract

The larger foraminiferal fossils of *Nummulites boninensis* HANZAWA (forma S), *Asterocyclina penuria* COLE and *A.* sp. found from the dredge haul near Oki-daito Island are described. They suggest an extensive distribution of middle Eocene shallow marine deposits, the upper part of N formation, on the main topographic highs of the Daito Ridges, from the joint consideration of acoustic profiles and occurrences of similar nummulitic faunas in other parts of the highs. It was evidenced that the Daito Ridges area was under the same biogeographic province as the Ogasawara Islands in that time, as to a nummulitic fauna, and also that the first appearance of *Asterocyclina penuria* which has been regarded as the guide species of late Eocene goes back to middle Eocene.

Introduction

The research cruise GH74-7 by R/V Hakurei-maru, conducted by the senior author, revealed many significant new facts concerning the geology of the Daito Ridges area and the northern part of the Kyushu-Palau Ridge, both in northern sector of the Philippine Sea (MIZUNO, ed., in preparation; MIZUNO *et al.*, 1975). One of them was the discovery of the Eocene larger foraminiferal fossils from the sea floor near the Oki-daito-shima Island on the Oki-daito Ridge, which represents the southernmost arc in the Daito Ridges area. A larger part of the fossils was identified to *Nummulites boninensis* HANZAWA and *Asterocyclina penuria* COLE, both conspecific to those from the sea floor of the Amami Plateau, northerly about 390 km away from the Oki-daito Ridge, previously reported by KONDA (1975), KONDA *et al.* (1975) and KONDA *et al.* (1977).

In this paper, the authors will decribe the occurrence of the larger foraminiferal fossils from the Oki-daito Ridge and discuss some related problems. The detailed examination on the fossils was made by the junior author, particularly in comparison with those from the Amami Plateau.

The authors are deeply indebed to Dr. T. SHIKI and Mr. A. NISHIMURA for their kind permission for citing of their unpublished data. They are also obliged to the colleagues of the Marine Geology Department, Geological Survey of Japan, who participated the cruise GH74-7.

Occurrence of larger foraminifers

The fossils were collected by means of chain-bag and cylinder dredges from St. GH74-7-167, which is situated at 24°20.0′N, 131°42.2′E (water depth, 2,330 m)[1]—24°19.9′N, 131°41.5′E (water depth,

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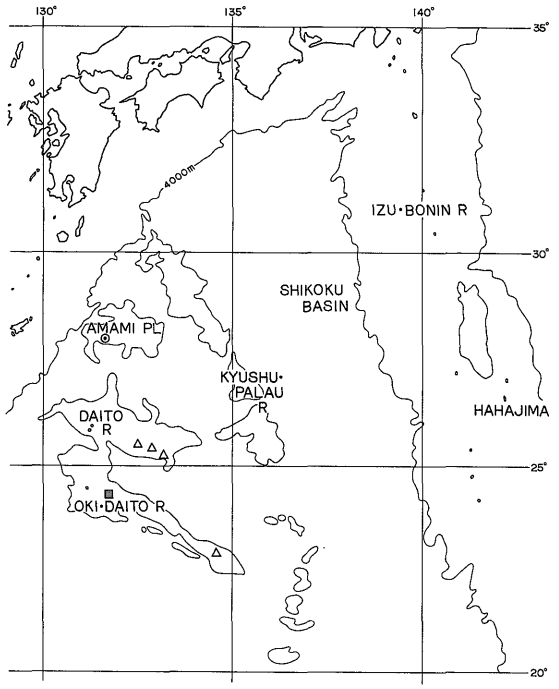
1) Position of hit-bottom of dredge.



■ GH74–7–167. ◎ GDP–11–9 (after KONDA, 1976).
△ GDP–15 cruise (after SHIKI *et al.*, 1975).

Fig. 1 Distribution of *Nummulites boninensis* HANZAWA in the topographic highs of Daito Ridges.

2,340 m)[2], about 55 km south-east-east of the Oki-daito-shima Island (Text-fig. 1). The materials dredged are as follows; 1) separated individual specimens of microspheric form of *Nummulites*, numbering more than five hundred, 2) separated individual specimens of pelecypod *Venericaria* and gastropods, 3) *Nummulites-Asterocyclina* limestone and sandstone, and 4) calcareous mudstone. The recovering of sediments within the cylinder dredge shows that these rocks are most likely covered with a very thin veneer of pale grayish yellow brown foraminiferal sandy silt.

Text-fig. 2 shows the continuous seismic reflection record passing near the sampling station in north-south direction. As shown in the figure, the station is situated on the southern slope probably originated by faulting near the crest of the Oki-daito Ridge. The materials of 1–3) and 4) cited above may have come from the densely stratified layer and overlying transparent layer, respectively, and the dredging may have been done on the just boundary part of both the layers, from a joint consideration of water depth, materials obtained and seismic profile.

The larger foraminifers collected are identified to *Nummulites boninensis*, *Asterocyclina penuria* and *A.* sp., and there are some species indeterminable in genus as yet. *Nummulites boninensis* occurs as a microspheric form individually separated and as a megalospheric form crowded in fragments of *Nummulites-Asterocyclina* rocks which contain also some microspheric specimens. Having maximum diameter of 32 mm and not so inflated test with diameter-thickness ratio of 3.9–6.5 (mostly represented by 5.0–6.0), the microspheric forms are quite safely identified to the forma S of the species from the Amami Plateau (KONDA, 1975; KONDA *et al.*, 1977), under visual and microscopic observation on the specimens

2) Position of off-bottom of dredge.

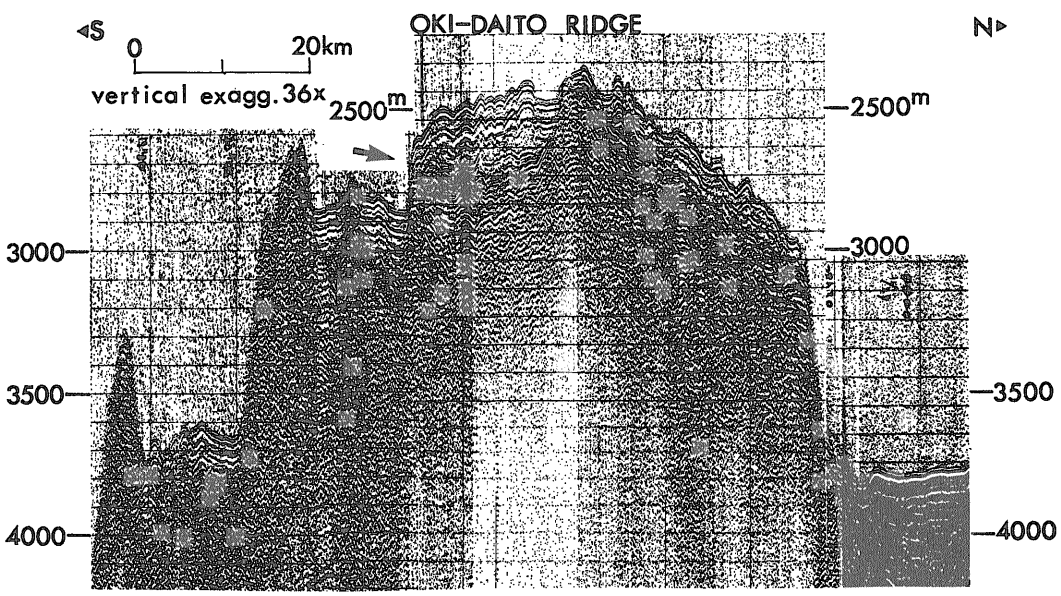


Fig. 2 Continuous seismic reflection profile near St. GH74–7–167 (after MIZUNO *et al.*, 1975).
The arrow shows the corresponding dredge site on this profile, which is more deeply situated than GH74–7–167.

including those of equatorial split artificially prepared. In the *Nummulites-Asterocyclina* limestone and sandstone, abundant fossils of two species of *Asterocyclina* are found under microscope, besides *Nummulites*.

Another fossils obtained are one specimen of large type *Venericardia*, namely "*Venericor*", which characterizes Eocene, and two small sized gastropods, but their details are unknown, owing to ill-preservation.

Morphology of larger foraminifers

Nummulites boninensis HANZAWA (Pl. 13, 14)

Megalospheric form: Test is moderately sized, usually with diameter of 3.0–3.5 mm (rarely more than 4.0 mm) and thickness of 1.3–2.5 mm. Test and proloculus are somewhat smaller than the syntype described by HANZAWA (1947, p. 256–259, figs. 1–9) from Hahajima Island of Ogasawara. Some statistics of test and internal structure are shown in Table 1. The other essential features of the present specimens such as septa, septal filaments and pillars are quite coincident to the syntype.

Microspheric form: Test is 10–32 mm in diameter, flat and occasionally undulated, with thickness of 4.0–6.5 mm and diameter-thickness ratio of 3.9–6.5, having narrowly rounded or rather acute periphery. Surface is smooth, and numerous meandriform and complicatedly anastomosing septal filaments are observed just bellow it. The filaments number is two or three within 1 mm.

Examining numerous specimens from the sea bottom of the Amami Plateau, KONDA (1975) and KONDA *et al.*, **1977** clarified a remarkable intra-specific variation of *Nummulites boninensis*, and they discriminated two morphological types concerning to microspheric form, namely inflated type as forma M and less inflated type as forma S, particularly on the basis of external view and the internal

Table 1 Statistics of megalospheric specimens of *Nummulites boninensis* HANZAWA.

Specimen	a	b	c						d				
			I	II	III	IV	V	VI	I	II	III	IV	V
1	686	$3\frac{1}{4}$	7	13	22	5			0.95	1.52	1.90		
2	533	$3\frac{1}{8}$	7	13	25	4			0.88	1.45	1.75		
3	762	$2\frac{1}{3}$	7	13	8				1.04	1.72			
4	610	$5\frac{1}{2}$	8	14	21	22	24	13	0.85	1.30	1.75	2.10	2.32
5	533	$4\frac{1}{3}$	8	17	24	25	8		0.88	1.30	1.60	1.71	

a : diameter of proloculus in microns.
b : number of whorls.
c : number of chambers in whorls.
d : height of whorls in mm.
I, II, ····· : 1st whorl, second whorl, etc.

structure of test (especially mode of development of lamellae and chambers). The essential features of the present microspheric specimens are quite coincident with *N. boninensis* forma S.

Asterocyclina penuria COLE (Pl. 15, figs. 1–8)

The present species was found only in thin sections of *Nummulites-Asterocyclina* limestone.

Test of megalospheric form is relatively small, usually attaining 1.2–2.0 mm in diameter and 0.6–0.9 mm in thickness at the center. Its vertical section shows a lenticular shape, rarely inflated in central area. Embryonic apparatus, as stated in original description (COLE, 1957a), consists of two large embryonic chambers in which the large second chamber slightly embraces the initial chamber, and they are surrounded completely by large peri-embryonic chambers. The initial embryonic chamber is always bordered by two elongated peri-embryonic chambers. In the present specimens, there are

Table 2 Measurements of equatorial sections of *Asterocyclina penuria* COLE.

		Specimens		
		1	2	3
Diameter	(mm)	2.0	1.2	1.6
Embryonic chambers:				
Distance of initial chamber	(μ)	120×140	110×150	85×110
Distance of second chamber	(μ)	100×200	110×190	80×150
Distance across both chambers	(μ)	230	220	170
Thickness of outer wall	(μ)	10	10	10
Equatorial chambers:				
In rays:				
Radial diameter	(μ)	50–85	50–85	35–40
Tangential diameter	(μ)	20–25	20–30	20–30
In interrays:				
Radial diameter	(μ)	20–60	30–35	15–30
Tangential diameter	(μ)	25–35	20–30	15–30

Table 3 Mesurements of transverse section of *Asterocyclina penuria* Cole.

		Specimens		
		1	2	3
Diameter	(mm)	1.5	2.0	1.7
Thickness	(mm)	0.66	0.87	0.84
Embryonic chambers:				
Length	(μ)	220	140	120
Height	(μ)	120	110	90
Thickness of outer wall	(μ)	10	10	10
Equatorial layer*:				
Height at center	(μ)	30	20	15
Height of periphery	(μ)	20	40	20
Lateral chambers:				
Number		12	20	15
Length	(μ)	20–50	30–70	20–80
Height	(μ)	10–20	10–20	10–20
Thickness of floors and roofs	(μ)	10–20	10–20	10–20
Surface diameter of pillars	(μ)	30–60	30–110	30–130

* Includes thickness of floor and roof.

normally five rays in which the equatorial chambers are radially elongated. Results of measurements of equatorial sections are shown in Table 2. Lateral chambers are abundant, and arranged in regular tiers. The chambers are low, but open, with straight floor and roof. Distinct pillars are irregularly scattered throughout transverse sections, and the greatest concentration is rarely observed in the umbonal area. Measurements of transverse sections are shown in Table 3.

This species was first described as *Orthophragmina pentagonalis* by Deprat (1905) from New Caledonia. Caudri (1934) identified the specimens from Soemba to *Asterocyclina* aff. *pentagonalis* Deprat. Cole (1957a) proposed the specific name *Asterocyclina penuria* from the reason that the specific name *pentagonalis* has been used by Shaufhaült in 1863 for a different European species. Since that time, in the Indo-Pacific region, *A. penuria* has been successively reported from the drill holes on Eniwetok Atoll (Cole, 1957b), a seamount near Tuamotu Island (Cole, 1959), Guam Island (Cole, 1963), Ishigaki-jima Island (Cole, in Foster, 1965) and the Amami Plateau (Konda, 1975).

Asterocyclina sp.

A slightly oblique equatorial specimen was found in a thin section, associated with the preceding species.

This specimen has the diameter of ca. 1.6 mm and fairly small, typical nephrolepidine and bilocular embryonic chambers of which dividing wall is folded in three. The second chamber slightly embraces the initial chamber which has the internal diameter of 85 by 110 microns. The second chamber has a diameter of 80 by 150 microns. The distance across both chambers is 170 microns. There are two large prominent peri-embryonic chambers situated on each side of the embryonic chambers at each end of the dividing wall between them. But the other peri-embryonic chambers can not be observed clearly in this section.

There are perhaps five rays, although three of them are not observed. The equatorial chambers are

small in general, and radially elongated in the rays. Radial and tangential diameters of them are 35–40 microns and 20–30 microns, respectively, in rays, while both diameters are 15–30 microns in the inter-ray areas. The shape of chambers is nearly square or tangentially rather elongated, but some of them have a hexagonal shape.

Owing to poorness of specimen, the specific name can not be determined as yet, and a further examination is necessary on more abundant specimens.

Discussion

Throughout the topographic highs and depressions of the Daito Ridges area, five acoustic stratigraphic units partly evidenced geologically are discriminated, as shown in Table 4 (Okuda *et al.*, 1976; Mizuno *et al.*, 1976). The densely stratified layer at GH74–7–167 from where *Nummulites* and *Asterocyclina* may have come represents a part of N formation, according to those authors.

On the continuous reflection seismic records obtained, N formation seems to be developed through the Oki-daito Ridge, and it also extends northwards over the wide areas of the topographic highs of Daito Ridge and Amami Plateau and also of the inter-ridge basins. According to the data by Okuda *et al.* (1976), *Nummulites boninensis*-bearing bed at the Amami Plateau which was estimated as his C formation by Misawa (1975) is identified to N formation. It has been reported that the bed also yields *Asterocyclina penuria* (Konda, 1975), as well as Oki-daito.

The recent work by GDP-15 cruise (Shiki *et al.*, 1976; Nishimura and Shiki's personal communications) evidenced the occurrence of the same species of *Nummulites* in the N formation at the eastern parts of both Daito and Oki-daito Ridges (Text-fig. 1). Also, an examination on stratigraphic horizon of each fossil occurrence leads the conclusion that those of larger foraminifers cited above are most likely confined to the upper part of N formation (Mizuno *et al.*, 1976). Thus, we have presently the information that *Nummulites boninensis* and some other larger foraminifers are widely distributed in the upper part of N formation at the main topographic highs of Daito Ridges area, ranging from 1,200 m to 2,300 m in depth.

Nummulites boninensis was first described from the Eocene bed of Hahajima Island in Ogasawara

Table 4 Stratigraphy of the Daito Ridges area (after Okuda *et al.*, 1976)

	Kitaamami Basin	Amami Plateau	Kitadaito Basin	Daito Ridge	Minamidaito Basin	Okidaito Ridge
Quaternary Pliocene Miocene	O	O	O	O	O	O
Oligocene	J_2	J_2	J_2	J_2	J_2	J_2
	J_1		J_1		J_1	
Eocene Paleocene (?)	N	N	N	N	N	N
Pre-Tertiary	?	Acoustic Basement*	?	Acoustic Basement**	Acoustic Basement	Acoustic Basement

* Including volcanic rocks and granitic rocks
** Including schists

(Hillsborough Island in Bonin) by Hanzawa (1947), and he concluded its geological age as Lutetian of middle Eocene from its larger form with complicated internal structure. Later, Saito (1962) considered the *Nummulites*-bearing bed as *Orbulinoides beckmanni* zone of late Lutetian from his study on planktonic foraminiferal fossils. These show that at least the upper part of N formation at Daito is correlated with middle Eocene. Unfortunately no evidence is available concerning its middle and lower parts, but their thick sequence suggests their earlier age possibly down to Paleocene, in together consideration with the occurrence of Paleocene foraminifers which could have been derived from the Oki-daito Ridge in the DSDP Holes 294/295 (Ujiié, 1975; Karig, 1975).

In the westward and northwestward of the Daito Ridges area, it has been known that some fossil species of *Nummulites* are distributed in Eocene sequences. The Miyara formation in Ishigaki and Iriomote Islands yield *N. pengaroensis* and *N. saipanesis* respectively (Ujiié and Miyagi, 1973; Cole in Foster, 1965). In the former, *Asterocyclina penuria* coexists with some species of *Biplanispira* and *Pellatispira* and the fauna is regarded as late Eocene (Priabonian) in age. On the other hand, it is well known that the early Eocene (Ypresian) nummulitic fauna is yielded in the lowest marine facies of Paleogene sequence in Amakusa of Kyushu. It is characterized by small-sized *N. amakusensis* and some other species of the genus (Yabe and Hanzawa, 1925; Hanzawa and Urata, 1964). Small-sized nummulitic fossils have been also found in the folded beds in Amami-oshima and Okinawa Islands. But their poor preservation rejected their specific determination, and they are known as *N.* sp. (Konishi *et al.*, 1973; Ishida, 1969).

Thus,in the vicinity of western margin of the Philippine Sea, different species of the respective age of Eocene are known at present. It is noteworthy that *Nummulites boninensis* from Daito suggests the paleobiogeographical similarity between Daito and Ogasawara concerning nummulitic fauna, although there remain some problems that no middle Eocene fauna has been found as yet at the area other than Daito in the western margin of the Philippine Sea.

Another interesting problem is shown by the occurrence of *Asterocyclina penuria* associated with *N. boninensis* in one sample of limestone at the Daito Ridges area. In the other areas from where it has been reported, *A. penuria* is associated with other genera and species of larger foraminifers which characterize the upper Eocene, Tertiary b of the Indo-Pacific region of lower latitudes, and it has been regarded as one of the guide species of the horizon. In this respect, Konda *et al.* (1977) who first found the assemblage of *N. boninensis-A. penuria* in unconsolidated foraminiferal sand at the sea floor of Amami Plateau writes that it is uncertain if *A. penuria* was originally associated with the middle Eocene larger foraminifera, *N. boninensis*, in the Amami Plateau, because they are both the derived fossils. Thus, the present article is the first undoubted record of the assemblage of *N. boninensis-A. penuria* in middle Eocene horizon, and *A. penuria* would appear since the age.

N. boninensis is morphologically characterized by having two form types of microspheric generation, which were named forma M to inflated form and forma S to less inflated form (Konda, 1975; Konda *et al.*, 1977), based on the fossils obtained from Amami Plateau where two forms of the present species were abundantly found. While, as described previously, the species from Oki-daito is only represented by its forma S. This seems to suggest some differences of paleo-environmental conditions in the depositional time of N formation between Oki-daito and Amami, but their details remain to be unsolved.

Lastly, the distribution of N formation including shallow dwellers of the larger foraminifers reported

here raises the problem that the main topographic highs of the Daito Ridges area may have subsided in some time after late Eocene, as discussed by SHIKI *et al.* (1975). This problem will be discussed elsewhere.

Summary

The research cruise GH74–7 by the Geological Survey of Japan discovered Eocene larger foraminiferal fossils of *Nummulites boninensis* HANZAWA (forma S), *Asterocyclina penuria* COLE and *A.* sp., together with "*Venericor*" sp. and other some molluscs, in the dredge hauls near Oki-daito Island on Oki-daito Ridge. They evidences the extensive distribution of middle Eocene shallow marine deposits on the main topographic highs of Daito Ridges, from a joint consideration with the occurrences of nummulitic faunas previously reported from Amami Plateau and found recently from Daito Ridge and other parts of Oki-daito Ridge. Also, it is suggested as to a larger foraminiferal fauna that both the Daito Ridges area and Ogasawara Islands area were under a same biogeographic province during the age at least. It is noteworthy the co-existence of *Asterocyclina penuria* and middle Eocene *Nummulites boninensis* was first assured in the present dredge hauls. This shows the going back of the appearance of *A. penuria* to middle Eocene time, which has been regarded as the guide species of late Eocene. The wide distribution of the nummulitic fauna on the topographic highs of the Daito Ridges, ranging from 1,200 m to 2,300 m in depth, suggests the extensive subsidence at some time since late Eocene.

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地 質 調 査 所 月 報 （第 28 巻 第 10 号）

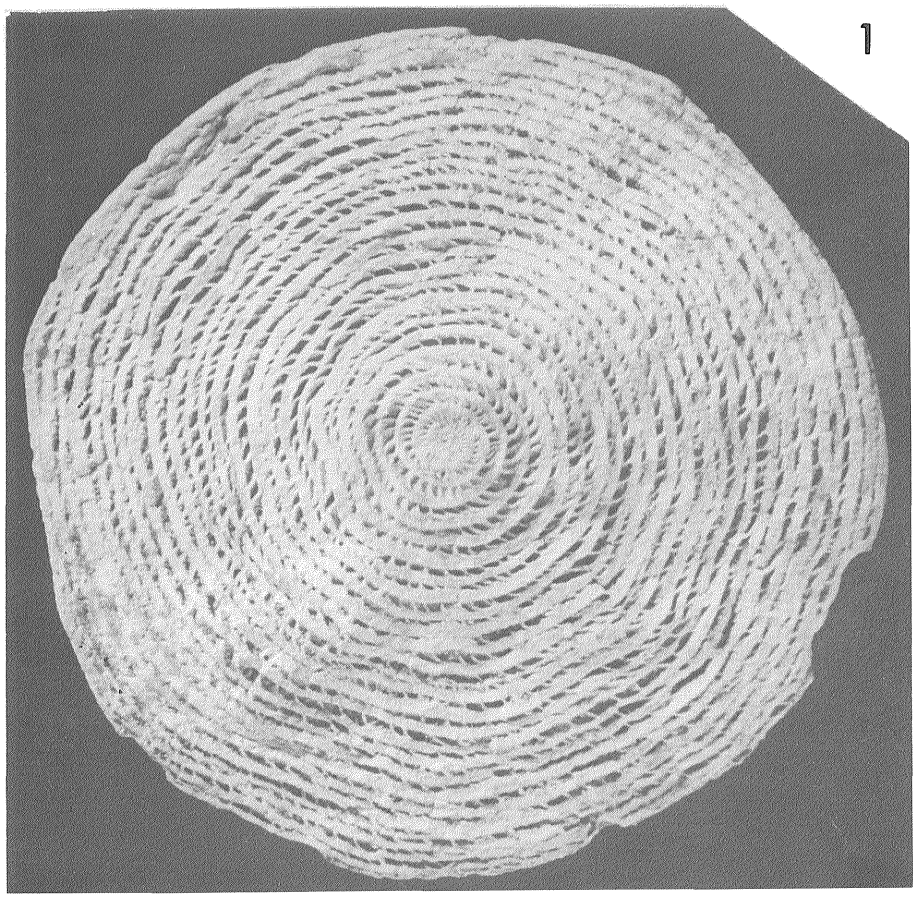
沖大東島付近の海底（GH74-7-167）から発見された始新世大型有孔虫化石について

水野篤行・紺田 功

要 旨

沖大東島付近の海底からドレッジにより得られた大型有孔虫化石，*Nummulites boninensis* HANZAWA (forma S)，*Asterocyclina penuria* COLE，*A*. sp. を記載し，その意義について検討した．エアガンの記録，大東海嶺群の主海嶺域の他の場所から得られている同様なヌムリテス動物群をあわせ考えると，これらは主海嶺域に始新世中期の浅海成層が広範に分布することを示している．同時期には，ヌムリテス動物群に関し，大東海嶺群域と小笠原諸島域が同一の古生物地理区に属していたことが明らかである．*Asterocyclina penuria* は従来始新世後期の示準化石とみなされているが，*Nummulites boninensis* との共存は，その最初の出現が始新世中期にさかのぼることを示している．

（受付：1976年10月 7 日；受理：1976年12月 4 日）



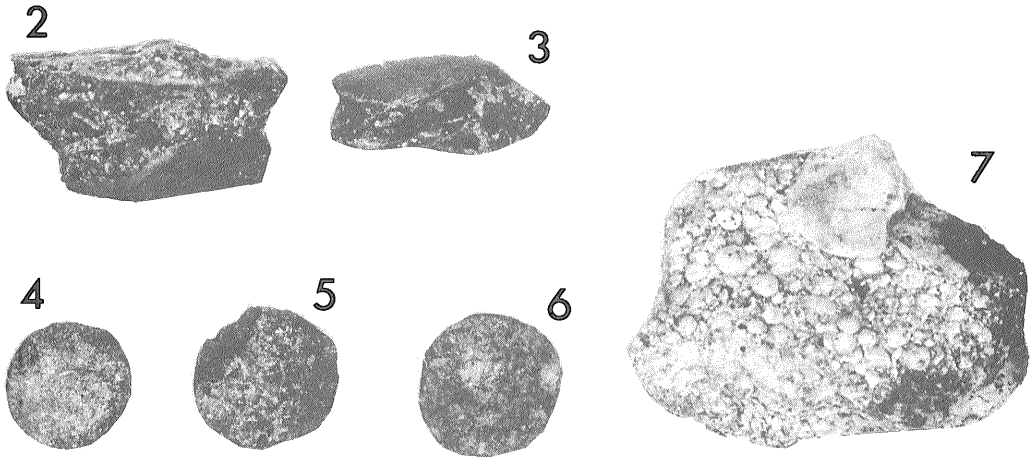


Plate 13 *Nummulites boninensis* HANZAWA forma S

1. Internal structure of microspheric form, artificially split along equatorial plane of test. ×3.7.
2, 3. Peripheral view of microspheric form in sandstone. ×0.9.
4–6. Lateral view of microspheric form, individually separated. ×0.6.
7. Nummulites-Asterocyclina limestone, in which megalospheric specimens of *N. boninensis* and *A. penuria* are crowded, together with some microspheric specimens of *Nummulites*. ×1.3.

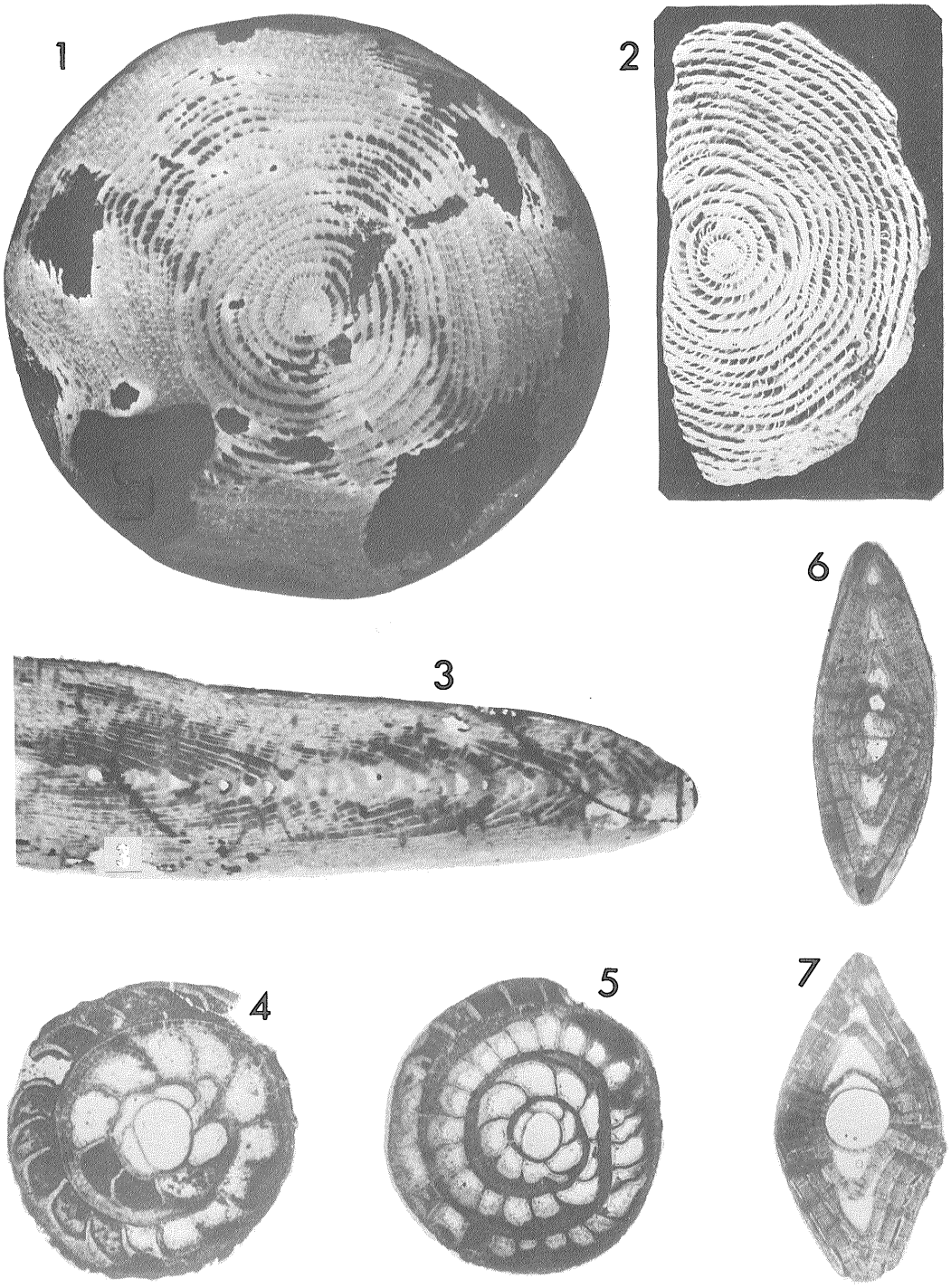
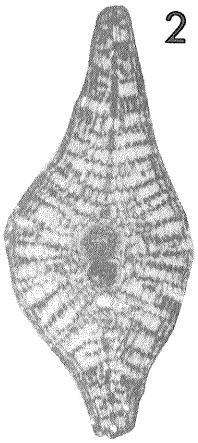
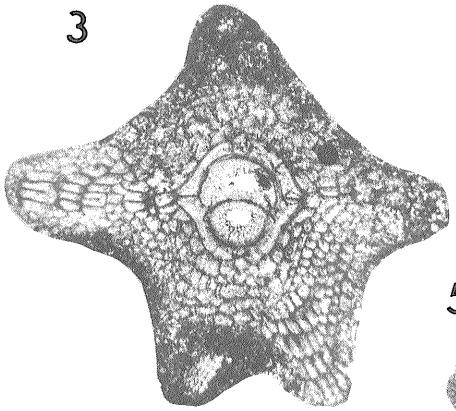
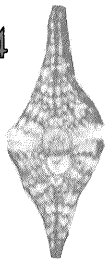


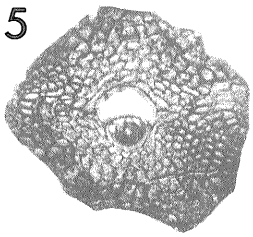
Plate 14 *Nummulites boninensis* HANZAWA forma S

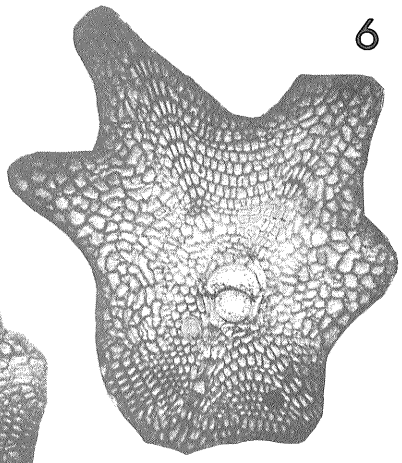
1. Equatorial section of microspheric form. ×3.
2. Internal structure of microspheric form. ×3.
3. Transverse section of microspheric form. ×6.
4, 5. Equatorial sections of megalospheric form. ×12.
6, 7. Transverse sections of megalospheric form. ×12.

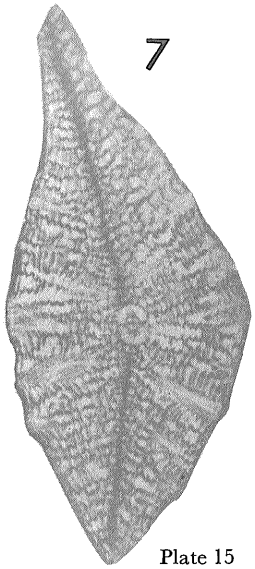


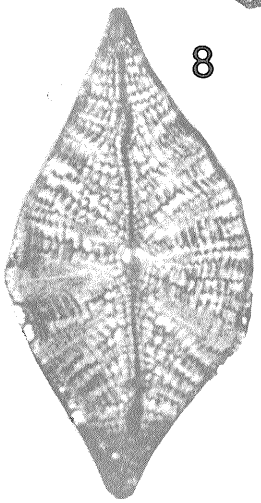












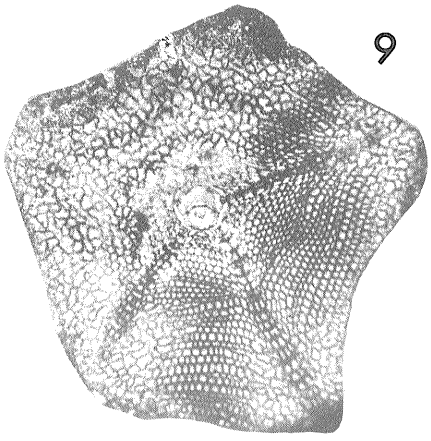


Plate 15

1. Thin section of *Nummulites-Asterocyclina* limestone, with megalospheric specimens of *Nummulites*. ×5.5.
2, 4, 7, 8. Transverse sections of *Asterocyclina penuria* COLE. ×38.
3, 5, 6. Equatorial sections of *A. penuria* COLE. 3, ×50. 5, 6, ×32.
9. Equatorial section of *Asterocyclina* sp. ×32.