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A Standard Late Cenozoic Microbiostratigraphy in Southern Okinawa-jima, Japan
Part 1. Calcareous Nannoplankton Zones and their Correlation to the Planktonic Foraminferal Zones

By

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Abstract—The present investigation attempts to establish a standard biostratigraphic sequence by means of calcareous nannoplanktons and planktonic foraminifera for the Shimajiri Group and overlying Chinen Formation, which are well developed in the southern Okinawa-jima region, using 20 well-core samples and 52 surface samples. It results in the recognition of eight calcareous nannofossil datum planes from the CN9a through CN13a Zones in OKADA and BUKRY's (1980) scheme and of eight planktonic foraminiferal datum planes, aside from two coiling-change data of *Pulleniatina* species, from the N16 through N22 Zones in BLOW's (1960) shceme. Through this upper Miocene to lower Pleistocene sequence, the stratigraphic positions of both kinds of datum planes are agreably located from each other, particularly when their calibrated ages are considered.

It is also suggested that the geographic tracing of some planktonic foraminiferal datum planes is much useful for further study of geological structure of the Shimajiri Group. Standard microbiostratigraphic scale proposed here may offer us more reliable and detailed procedures for such an advanced geological investigation. On the basis of field observation and laboratory work, an unconformable relationship is conclusively estimated between the Shimajiri Group and the Chinen Formation of the Ryukyu Group. During the time gap between the two groups, a movement might have caused the tectonic feature of the present-day Ryukyu Arc System.

Introduction

Since the geology of the whole Ryukyu Islands was outlined by an exhaustive field work of HANZAWA (1935), the Shimajiri Group has been regarded as to represent a good sedimentary sequence of the late Cenozoic age. On the basis of the U. S. military geological survey by FLINT *et al.* (1959), MACNEIL (1960) and LEROY (1964) respectively studied molluscan fossils and benthic foraminifera from the Group developed in southern Okinawa-jima. Their biostratigraphical contributions, however, were rather limited. Just before the retrieval of Okinawa to Japan, the Geological Survey of Japan started the extensive survey of this region for natural gas prospecting and published the results in a summarized form (*e. g.*, FUKUTA *et al.*, 1970). NATORI

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(1976), a member of this research group, reported a considerably detailed result on the planktonic foraminiferal stratigraphy of the Shimajiri Group. Meanwhile, UJIIÉ and OKI (1974) established a similar zoning for the Group developed as the basement of Miyako-jima, about 200 km southwest of Okinawa-jima. Concerning the calcareous nannofossil stratigraphy, NISHIDA (1973) published a preliminary note. His report is so sketchy and re-examination of the result is almost impossible.

For past few years, our group has worked on the detailed geology of the Shimajiri Group in southern Okinawa-jima by applying microbiostratigraphic methods. Because majority of the Group exposed on surface are composed of massive mudstone without any useful lithostratigraphic key bed, only datum planes identified by microfossils can offer us any useful means to reveal the geological structure. A preliminary result for this subject is already published by MISHIMA and UJIIÉ (1983).

In the course of this continued work, we noticed that the zonal scheme of planktonic foraminifera proposed by NATORI (1976) needs some revision in viewpoint of the recently developed taxonomic and biostratigraphic concepts. The zonal scheme also needs refinement through more detailed field work and support through the other kinds of microfossils, particularly of calcareous nannofossils. The purpose of this paper is to establish a comprehensive microbiostratigraphic zonation that is useful for further study of the Shimajiri Group, which is developed in Okinawa-jima as well as under the bottom of the adjacent seas.

This paper also discusses the Pliocene-Pleistocene boundary for the uppermost part of the Group, and compare our result with previous works of IBARAKI and TSUCHI (1975) and NISHIDA (1980) who studied the planktonic foraminifera and calcareous nannofossils, respectively.

Details of the taxonomy and stratigraphic problem of planktonic foraminifera will be given in Part 2.

Summarized Geology of the Southern Okinawa-jima Region, especially on the Shimajiri Group

The southern area of Okinawa-jima is occupied with hilly region, which consists mainly of the uppermost Miocene to lowermost Pleistocene Shimajiri Group and the Pleistocene Ryukyu Group. The latter Group, reefal facies dominant, unconformably overlies on the Shimajiri Group and makes terraces in many places. The altitude of terraces varies from approximately 180 m above to approximately 30 m below the sea level owing to a block movement called as "Uruma movement" by KIZAKI and TAKAYASU (1976). The Shimajiri Group is composed of massive mudstone which is so susceptible to weathering and erosion that low hilly topography develops unless the mudstone is covered by the Ryukyu Group.

Shimajiri Group (HANZAWA, 1935)

By FUKUTA *et al.* (1970), this group was divided into three formations; namely, Tomigusuku, Yonabaru and Shinzato Formations, in ascending order.

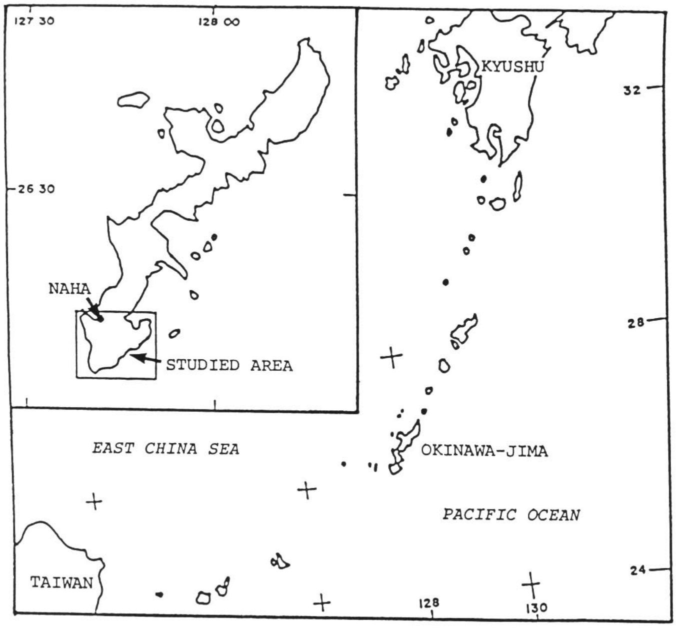

Fig. 1. Location map.

Tomigusuku Formation (Okinawa Natural Gas Prospecting Group, 1971 = Naha Formation of MAKINO and HIGUCHI, 1967)

The Tomigusuku Formation is not exposed on surface, except for the uppermost part which was called as the Oroku Sandstone Member by MAKINO and HIGUCHI (1967). Total thickness of this formation is about 940 m at Ryusei Well No. 2 (R2) which was drilled at Ônoyama of Naha City in 1969. The drilling penetrated down to the pre-Neogene Nago Formation which unconformably underlies the Tomigusuku Formation.

The cored sequence at this well indicates that the formation consists essentially of alternation of sandstone-rich unit and siltstone-rich unit. FUKUTA *et al.* (1970) discriminated these units as T1, T2, · · · T13, in descending order*; odd suffix represents sandstone-rich unit and even one does siltstone-rich unit. Electric logging record well reflects the alternative mode of these units at R2 well and makes it possible to correlate seven wells from one another; they were drilled in the southern Okinawa-jima region for natural gas prospecting (FUKUTA *et al.*, 1970; Okinawa Natural Gas Exploration Company, 1983, unpublished data).

The uppermost unit (T1) called as the Oroku Sandstone Member outcrops not only around Oroku but also in two areas northern outside of the studied region; *i. e.*,

* The stratigraphic assignment of these units shown by FUKUTA *et al.* (1970) and by NOHARA and KOMINE (1978) in the brief notes agrees well to our detailed re-examination (Fig. 3a-d) of the same core, except for the slight difference in thickness and in stratigraphic positions of T5, T7 or T9.

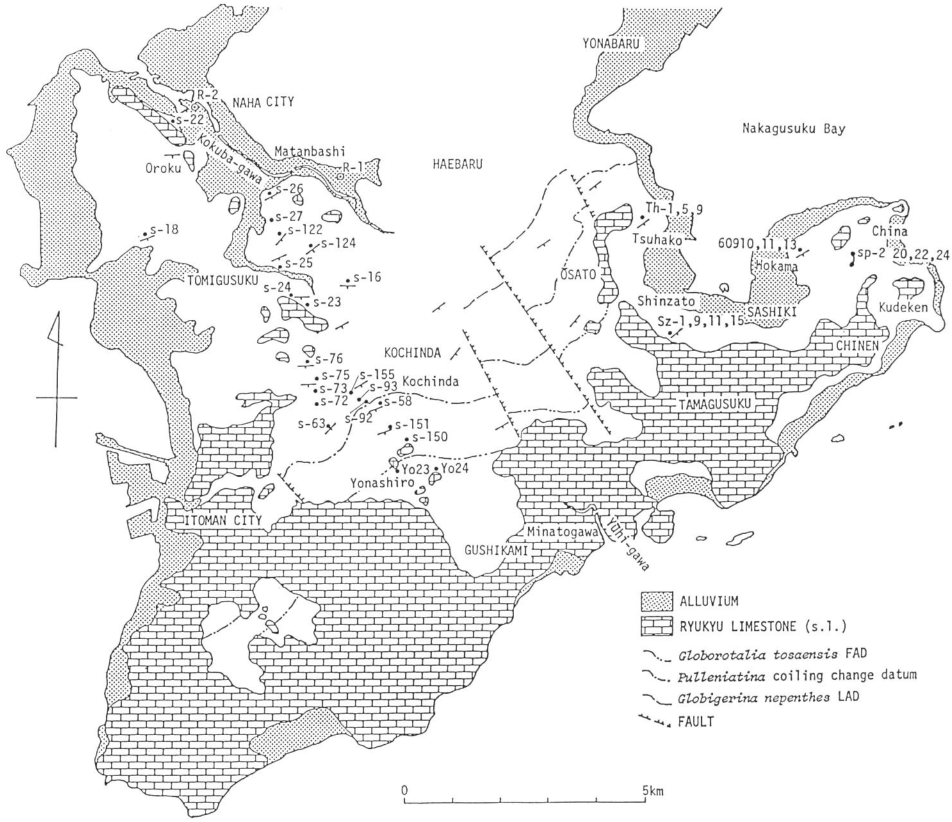

Fig. 2. Locality map of studied samples.
Majority of the white area consists of the Shimajiri Group. Tracing of three planktonic foraminifera datum planes are based on Y. SUZUKI (1984 MS).

around Maeda of Urasoe City and in the southern territory of Okinawa City. The sandstone, bluish in color (yellowish brown after weathering), is rather well sorted, and is medium- to fine-grained. This general character is common for the other sandstones of this formation excluding the bottom unit (T13) which is well indurated and is somewhere calcareous or conglomeratic.

Yonabaru Formation (MAKINO and HIGUCHI, 1967)

The Yonabaru Formation conformably rests on the Oroku Sandstone Member. This formation is mostly composed of bluish gray massive siltstone throughout the total thickness of about 900 m. NAKAGAWA *et al.* (1982) studied the tephrochronology of this formation and the overlying Shinzato Formation. Both formations are intercalated with so numerous (more than hundreds), mineralogically similar, and generally thin (a few cm for many cases) tuff layers that the utilization of these layers for correlation purpose is found to be impossible. And light minerals and volcanic

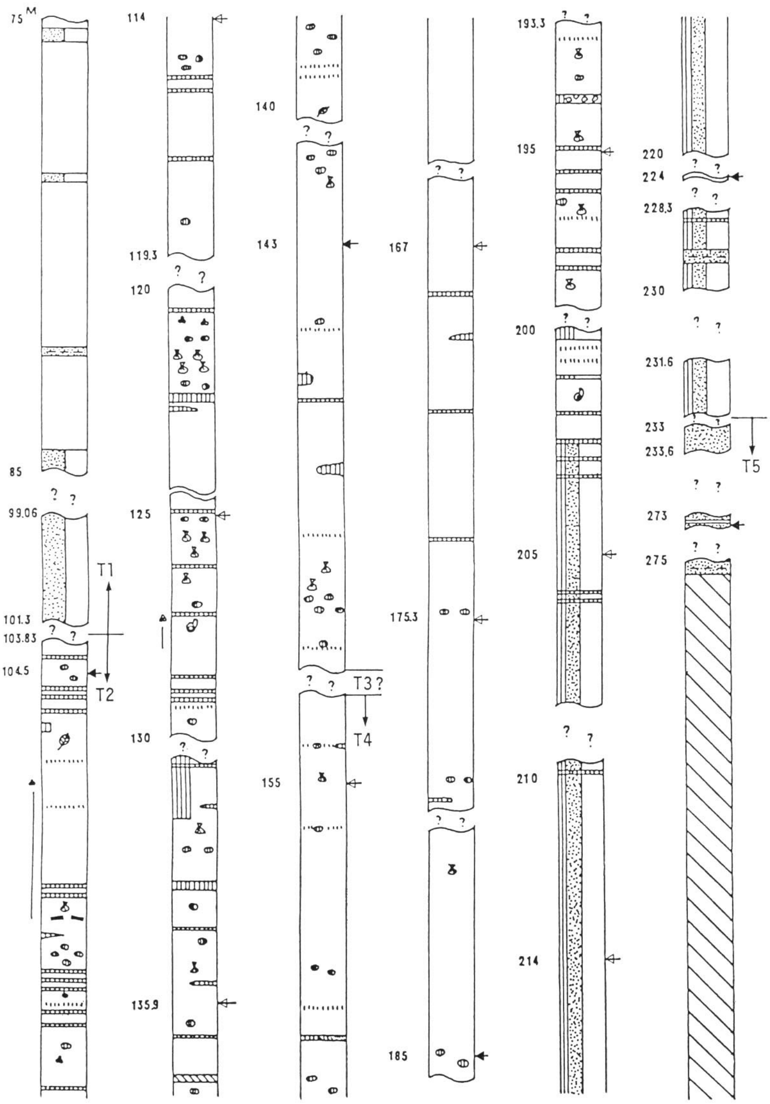

Fig. 3a

Fig. 3. Columnar sections of the Ryusei Well No. 2 drilled at Onoyama, Naha City (slightly modified from MISHIMA, 1983 MS).

glass shards in the tuffs were so much decomposed as to make discrimination of each layer impossible.

The intercalations of sandstone beds are not common except for the Nakagusuku Sandstone Member (TANAKA, 1982 MS; MISHIMA and UJIIÉ, 1983) that is situated at

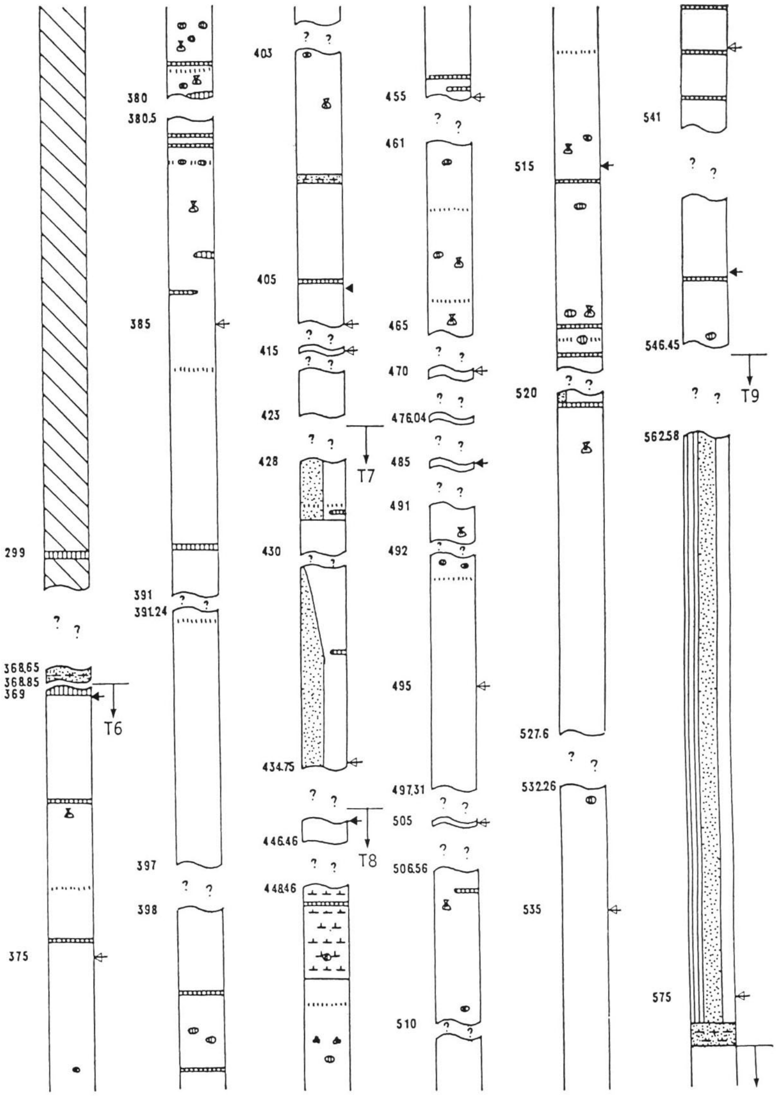

Fig. 3b

about 100 m above the base of this formation. This sandstone is fine- to medium-grained and, at many places, becomes coarser (even conglomeratic) toward the base, at which load cast structure commonly develops. Although its thickness varies from a few meters to about 8 m (in exceptional case reaches up to about 40 m), the distribution can be well traced in the region north of the studied area. In the studied area, however, the Nakagusuku Member has not yet been completely traced due to the restricted outcroping.

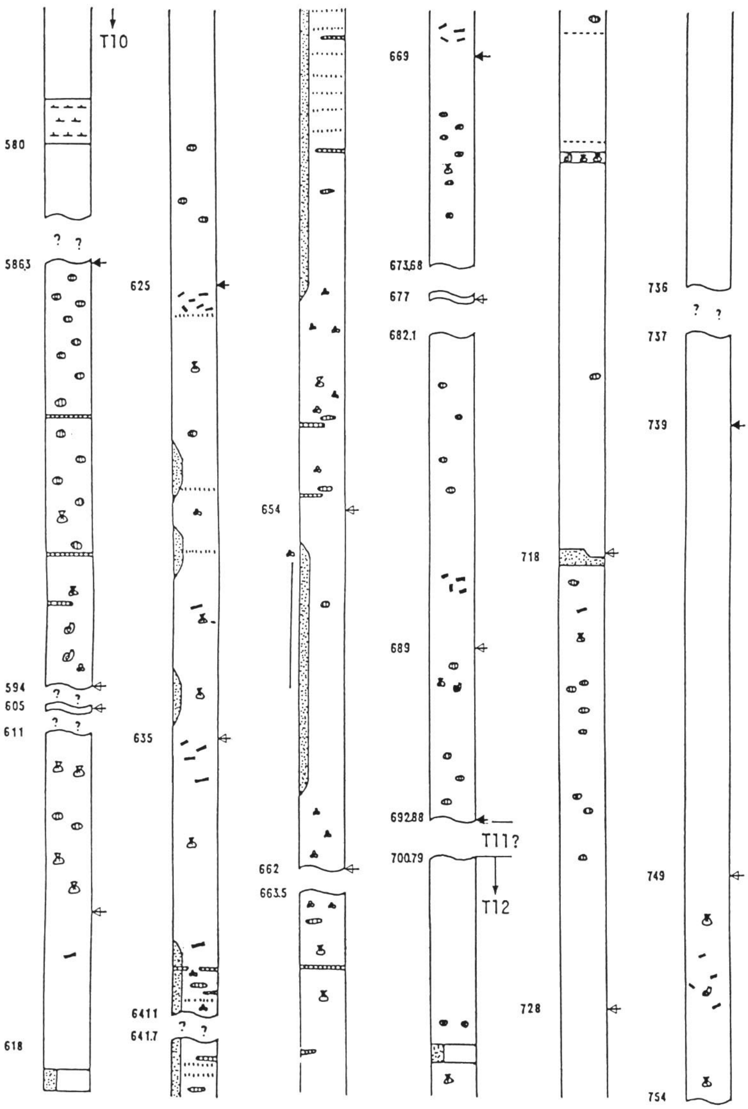

Fig. 3c

Shinzato Formation (= Shinzato Tuff of MAKINO and HIGUCHI, 1967)

The Shinzato Formation, the uppermost constituent of the Shimajiri Group, consists of essentially identical siltstone with that of the Yonabaru Formation. The Shinzato Formation is discriminated from the Yonabaru merely by an insertion of sandstone layer at its base. Different from somewhat exaggerated estimation of FUKUTA *et al.* (1970), we observed the lithology of the basal unit as about one meter thick coarse-grained sandstone bed containing subangular cobbles of mudstone at the basal

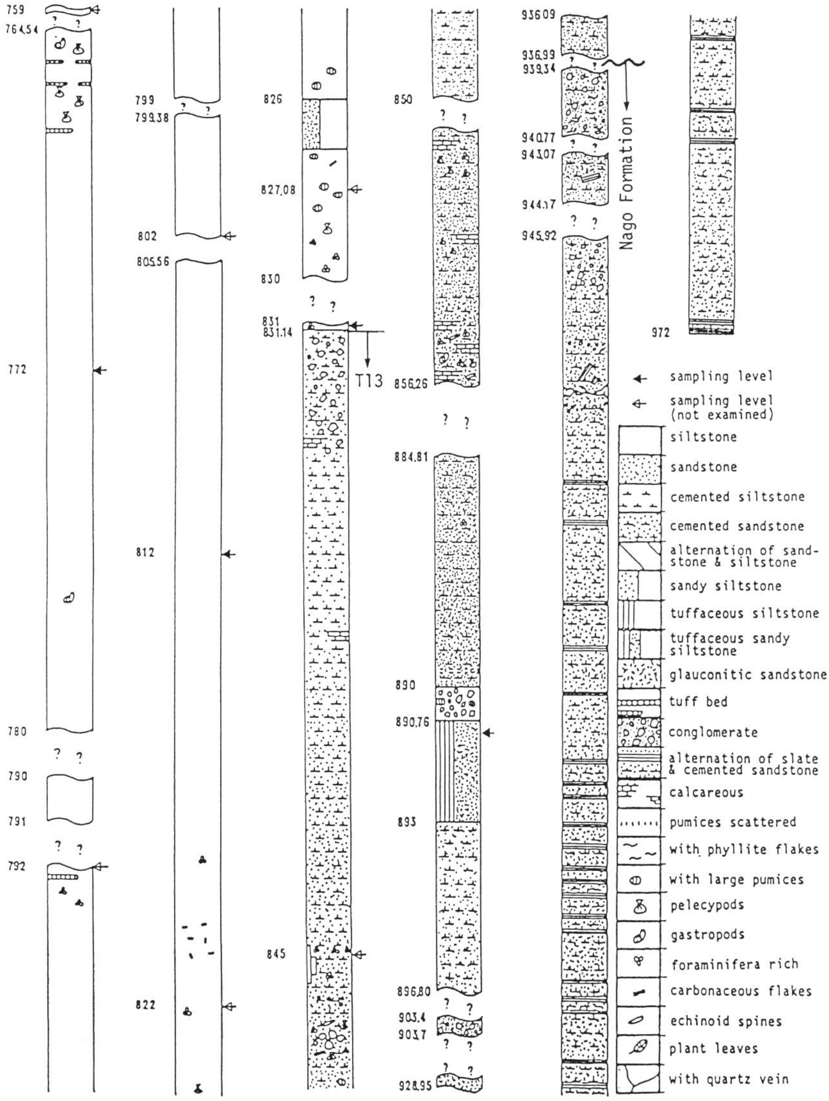

Fig. 3d

part at southwest of China, Chinen-son. The basal bed of the Shinzato Formation at the base of an about 30 m high cliff at Shinzato, Sashiki-chô, is represented by about 2.5 m thick pumiceous sandstone and it changes to about 7 m thick pumiceous tuff at another locality which is approximately 600 m away westwards. Around the Shinzato area, the siltstone of this formation contains charcoal fragments and more number of pumice patches than that in the China or Hokama areas. *Globigerinoides*

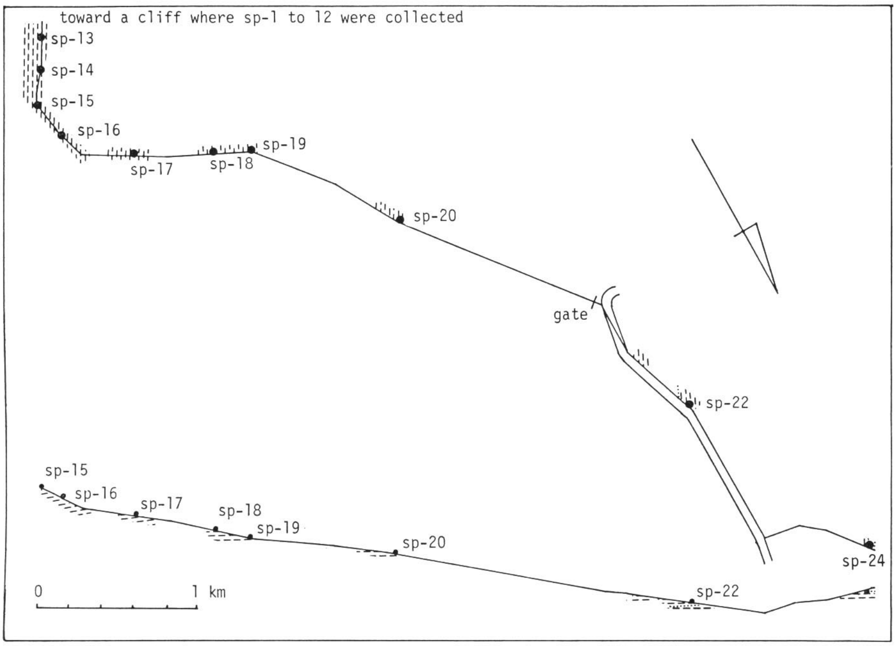

Fig. 4. A route map for the Shinzato Formation, southwest of China, Chinen-son, and its geological section perpendicular to the general strike (N 29°E) (modified from M. SUZUKI, 1981 MS).

fistulosus (SCHUBERT), a planktonic foraminifera, has its initial occurrence just below the sandstone bed at both localities of China and Shinzato.

The Shinzato Formation distributes almost exclusively in the environs of the Chinen Peninsula, and its maximum thickness attains to about 110 m along a sampling route southwest of China (Fig. 4).

Ryukyu Group (= Riukiu Limestone and Kunigami Gravel of HANZAWA, 1935)

Chinen Formation (MACNEIL, 1960)

MACNEIL (1960) assigned the calcareous sandstone in the basal part of his Naha Formation (main component of the Ryukyu Group) as the Chinen Sandstone Member [Formation] which unconformably overlies the Shimajiri Formation [Group]. Since then many authors have argued about the nature of the boundary between the two groups.

At a cliff in the golf links of the Shurei Country Club, southwest of China, the Chinen Formation contacts with the uppermost portion of the Shinzato Formation. A columnar section (Fig. 5) indicates that a calcareous sandstone, main lithofacies of the Chinen Formation, gradually changes to underlying sandy mudstone and then to siltstone, whose basal 15 cm is composed of compactly aggregated breccias of granule- to small pebble-sized siltstone. The base of this breccia bed cut a slightly inclined tuff

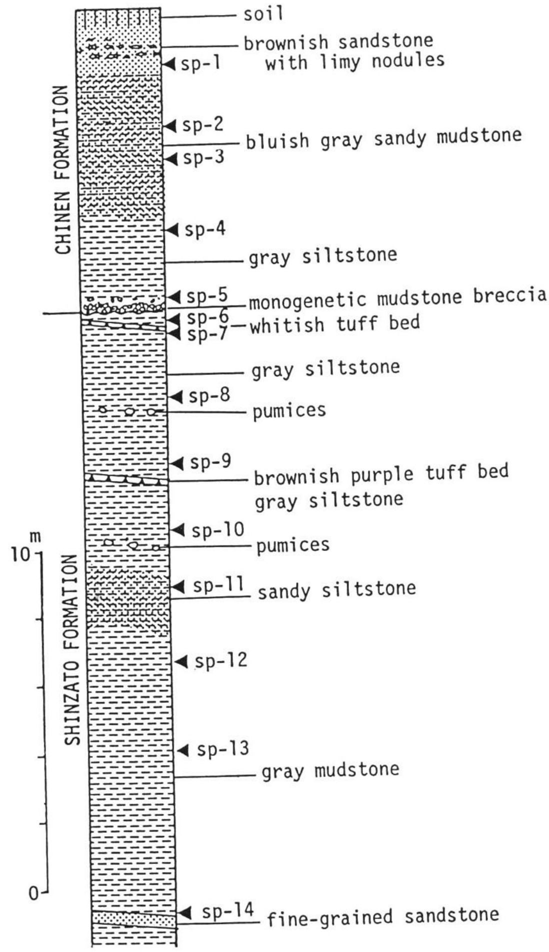

Fig. 5. A columnar section of the Shinazato Formation and the lower part of the Chinen Formation, based upon the route map shown in Fig. 4.

layer of some 10 cm thickness. Since the breccia bed seemed to have been overlooked and both the siltstones above and below the bed are quite similar each other, some authors may have considered the relationship between the Chinen and Shinzato Formations as to be conformable. According to preliminary study of benthic foraminifera by M. Suzuki (1981 MS), the estimated water depth for the portion above the boundary is comparatively shallower but is still under the open sea so that the unconformity presumed here may have been formed by submarine erosion. IBARAKI and TSUCHI (1975) and NISHIDA (1980), who worked on planktonic foraminifera and nannofossils of this section, respectively, appear to have regarded only the calcareous sandstone and probably sandy mudstone as the Chinen Formation.

Geological Structure

As a whole the Shimajiri Group gently dips toward the southeast so far as the southern Okinawa-jima region is concerned. The inclination of more than 10 degrees were measured at many localities as shown in the geologial map of FLINT *et al.* (1959) and MAKINO and HIGUCHI (1976) for examples. In general trend, however, the Group should have much less inclination, if we would consider the subsurface stratigraphy obtained by drillings of the Okinawa Natural Gas Exploration Company (1983, unpublished data), the result of FUKUTA (1978) who calculated its average inclination as 5°27′, and also the survey result of the Nakagusuku Sandstone Member (TANAKA, 1982 MS; MISHIMA and UJIIÉ, 1983).

Some steep or even reversed inclinations develop at where minor faults exist or as a part of large-scaled slumping structure whose majority is not exposed. The slumping structure in the Yonabaru Formation develops well at the horizons adjacent to the sandstone layers, particularly near the Oroku and Nakagusuku Sandstone Members.

The existence of some large-scaled and steeply inclined normal faults with northwest-southeast trend was presumed in the Shimajiri Group as a result of geographic tracing of the planktonic foraminiferal datum planes (MISHIMA and UJIIÉ, 1983; Y. SUZUKI, 1984 MS; see Fig. 2). The maximum vertical displacement is estimated as approximately 800 m. These faults appear to reflect the block movement of the basement judging from the distribution of gravity anomaly cited by FUKUTA *et al.* (1970) but do not affect the structure of the overlying Ryukyu Group. An unconformity between the Shimajiri and Ryukyu Groups must be re-considered from a viewpoint of their different geological structures.

Samples for Microbiostratigraphic Work

Subsurface samples of the Tomigusuku Formation were collected from the Ryusei Well No. 2, which was drilled near the river coast of the Kokuba-gawa at Ônoyama, Naha City, in 1969 and has been preserved at the College of Education, University of the Ryukyus, by the courtesy of Dr. Tomohide NOHARA. Figure 3 shows the detailed lithology and sampling points.

Majority of surface samples of the Yonabaru Formation were taken along a route which runs from Oroku to Yonashiro, Kochinda-chô (Fig. 2). This route is roughly parallel to general dip of strata, whose average inclination was estimated to 4.5° and was used for calculating stratigraphic distance from sample to sample. It was calibrated that the uppermost sample (Yo-24) along this route is located about 75 m above the first appearance datum plane of *Globorotalia tosaensis.* To fill out sampling blank between this sample and the base of the overlying Shinzato Formation, which may situated about 350 m above the datum plane, we chose two cliffs at Tsuhako (Th-1, -5, and -9) and Hokama (60910, 11, and 13), both faced to Nakagusuku Bay. Between this coastal area and the Oroku-Yonashiro route, three faults are presumed

Table 1. Occurrence chart of calcareous nannofossils in the Shimajiri Group and

NN15	CN11	s-58								VR	VR	C	R	R	F	VR	R		F				F		R			VR			F		C	F		VR		VR		VR	C	R	R	VR	C			VR
		s-92								VR	VR	C	F	F	F	VR	R		F		VR		R		VR				R		F		C	F	VR	VR		VR	VR	VR	C	R	F	VR	C	VR		R
		s-93								VR	VR	C	F	R	F				F				F		F			R	VR		C		R	F		VR					C	R		R	F	VR		
		s-63								R	F	A	R	F	F	VR	R	VR	F		R		F		R			R		VR	C			F		VR				F	F	F	VR		C	VR		
		s-155							VR	VR	F	A	R	F	R	VR	F		R		VR		F		F			VR		VR	C			F		VR		VR				C	VR	VR	C			
		s-72								VR	VR	A	F	VR	VR	VR	VR		F		R		F		F			F			C			F		VR			VR	VR		F	VR	VR	F	VR		VR
		s-73								VR	R	A	F	R	F	VR	R		F		R		R		R			R			F			F					VR			F	VR	VR	C	VR		
		s-75								R	F	A	R	VR	VR	VR	VR	VR	R		VR		R	VR	VR			VR			C			F					VR	R		F		VR	C	VR		VR
		s-76								R	F	A	F	VR	F	VR			R		F		VR	VR	VR			F			F			F					VR	R		F	VR		F	R		R
		s-23					VR			VR	VR	A	F	VR	F	VR		VR	R		R		F		R		VR	R	VR		C			F				VR				C	VR		F	VR		VR
13/14	CN10c	s-24			R					VR	R	A	F	R	VR		VR		R				R	VR	F						C			F		VR			VR	VR		C	VR	VR	C			VR
NN12	CN10b	s-25				VR		VR			VR	A	R	VR	VR			VR	R		VR		VR		VR			R						C	VR	VR			VR	VR		C	VR		C			
		s-122	VR		VR			VR			R	A	R	R	VR	R			F		VR		R	VR	R			F			C			R					VR			C	VR		C		VR	
		s-127	VR	VR				VR			F	C	F	R	R	VR	VR	F	F		R		VR	R	R			F			F			F		VR			VR	R		C			C		VR	
NN11	CN10a	R1-5									F	A	R		VR		VR	VR	VR		VR		VR	VR	VR						F			R	VR				VR	VR		A	VR		C			
		s-26									F	A	R	R	VR			F	VR		VR		R	F	VR			VR			F			F					VR	VR		C	VR		C		C	
		s-18									R	A	VR	VR	VR			F	VR		VR		VR	R	VR			VR			F			F					VR	VR		C			C		R	
		s-22	VR	VR							F	A	F	F		R		F	R		F		VR	F	R			F			F			F								C			C		VR	
		R2-104									R	A	F	R		VR	F	VR	R		R	VR	R							VR	C			R		VR						C	VR		C		VR	R
		R2-143	VR								C	C	F		C	VR	F	R	F		F		R	R	R			C			F			F		VR				VR		C	F		C		VR	
		R2-185									F	A	VR	VR	F	VR		R	VR		F	VR	VR	F				F			VR			R								C		F	C		VR	VR
		R2-224	VR	VR							VR	A	VR	VR	VR			R	VR				R	R	VR			VR			R			R				VR					VR		C		R	VR
		R2-273	[Barren]																																													
	CN9b	R2-369	VR								VR	A	R	VR	VR			F	VR		VR		VR	F	VR			R			F			F				VR		VR		C			C		VR	
		R2-405		VR							R	A	R	F	VR			F	VR		VR		VR	F	VR			VR			F			F		VR				VR		C	VR		C		VR	VR
		R2-445		VR							R	A	R	F	VR	VR		F	F		R	VR		C	F			F			VR			F						VR		F	VR	VR	C		VR	
		R2-485	VR	VR							R	A		VR				F			VR		F	F	R			VR		VR	F			F								C	C		C		VR	VR
		R2-515	VR	VR							VR	A	R	R		VR		F	F		R		F	C	R			F			VR			R								C		VR	C		F	VR
	CN9a	R2-545									VR	A	R	F	VR			R	R		VR		R	C	R			F						F						VR		F			C		F	
		R2-586									F	A	VR	VR	F	VR.		C	R		R		VR	C	R			R			R			R				VR		VR		C			C		R	
		R2-625									R	A	VR	F	VR			F	R		R		VR	C				R	VR					R								C	VR		C	R	F	
		R2-669									C	A	R	R	C	VR		R	R		VR	VR		F	VR			VR			VR			R						R		C	VR		C		F	VR
		R2-693									F	A	R	F	R			F	F		VR	VR	VR	C	VR			VR	VR		F			R								C			C		R	
		R2-739									F	A	R	R	VR	VR		F	R		VR	VR	VR	C	VR			R			R			R								C	VR		C	VR	R	
		R2-772									C	C	VR	R	VR	R		C	F		VR	VR		C	R			R						VR								C	VR		C		F	
		R2-812									F	A	R	F	F	VR		F	VR		VR	VR		F				R			F			F						VR		C	VR		C		F	
		R2-831									F	A	R	F	R	VR		VR	F		VR			VR	VR									F						VR		C			C		F	
		R2-891									F	A	F	F	VR	VR		F	R	VR	F			F	R			R			R			R					VR	VR		C	VR		C		F	

r: possibly reworked, VR: less than 1%, R: 1 to 1.9%, F: 2 to 7.9%, C: 8 to 31.9%, A: more than 32%.

lower portion of the Chinen Formation, based upon the observation under optical microscope.

NN16 (CN12a, CN12b)														NN17 CN12c		NN18 CN12d							NN19 CN13a											Calcareous Nannofossil Zones (Okada & Bukry, 1980)
s-151	s-150	Yo-24	Th-1	Th-5	Th-9	60910	60911	60913	sp-22	Sz-15	sp-24	Sz-11	Sz-9	Sz-1	sp-20	sp-19	sp-18	sp-17	sp-16	sp-15	sp-14	sp-13	sp-12	sp-11	sp-10	sp-9	sp-8	sp-7	sp-6	sp-5	sp-4	sp-3	sp-2	Sample Nos.
																																		Amaurolithus delicatus
																																		A. primus
																																		A. tricorniculatus
								VR	R						VR	VR		VR	VR	VR	VR	VR	VR	R			VR	VR	VR	VR	VR	VR		*Anoplosolenia brasiliensis*
																					VR		VR	VR		VR								*Braarudosphaera bigelowi*
																																		Ceratolithus acutus
				VR	VR		VR									VR	VR	VR	VR								VR		VR					*C. cristatus*
		R	VR	R	VR				VR			VR		VR			VR				VR		VR		VR		VR			VR		VR		*C. rugosus*
	VR	F	VR	R	R	VR	R	R	VR				R	VR	R	F	R	F	VR	VR	R	R		VR	VR	R	VR	VR		F	VR	R	VR	*Coccolithus pelagicus*
C	F	C	A	A	A	A	C	C	C	A		C	C	A	C	C	F	C	C	C	C	C	C	C	C	C	C	C	F	C	C	C	A	*Crenalithus doronicoides*
R	F	F	F	F	VR	VR	VR	R	F	F	[Barren]	R	F	F	F	F	F	F	R	VR	F	R	R	F	F	F	R	R	F	R	R	F	F	*Cyclococcolithus leptopora*
VR	VR	F	F	F	VR	VR	VR	VR	VR	F		R	F	VR	VR	VR		R		VR	VR	VR		VR		VR		r						*C. macintyrei*
VR	R		VR	R	R	VR	R	R	R	R		VR	VR	VR	VR			VR		VR	VR		VR		VR						VR		VR	*Cyclolithella annula*
VR			VR				VR			VR																r								*Discoaster adamanteus*
VR	VR	R	VR	VR	VR	VR	R		VR	VR																			r		r	r	r	*D. asymmetricus*
					r																													*D. berggrenii*
F	VR	F	VR	R	R	R	R	R	VR	F		R	F	VR	R	F	F	F	F	F	R	R			r		r	r					r	*D. brouweri*
																																		D. braarudii
VR		R						VR	VR	VR																								*D. challengeri*
VR																																		*D. intercalaris*
	F	F	VR	R	VR	R	R	F	F	F		R	F	R	F		r								r		r	r	r				r	*D. pentaradiatus*
																																		D. quiqueramus
VR	VR	VR		R		F	VR	VR	R	R		F	VR																r				r	*D. surculus*
		VR	VR	VR			VR			R							r	r															r	*D. tamalis*
						VR						VR	VR																		r	r	r	*D. tani*
VR				VR		VR		VR	R								r				r					r						r	r	*D. variabilis*
VR	VR		VR				VR	VR	F			R				VR	VR	VR		VR	R	R	VR	VR		R	VR			F	VR	VR	VR	*Discolithina japonica*
																																		D. pacifica
F	C	C	F	F	C	F	C	F	C	F		F	C	F	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	F	C	C	F	*Florisphaera profunda*
																								VR	VR			VR		R		VR	VR	*Gephyrocapsa caribbeanica*
F	F		R	R	R	C	F	F	R	F		F	F	VR	VR	C	A	C	C	C	F	C	C	C	F	C	C	F	C	F	C	C		small *Gephyrocapsa*
R	C	F	R	F	R	VR	R	R	C	R		F	F	VR	F	R	F	F	F	F	F	F	F	F	F	F	F	F	F	F	R	R	R	*Helicosphaera carteri*
VR				VR		VR			VR			VR	VR		F				VR		VR	VR	VR	VR		VR	VR	F	VR	VR			VR	*H. sellii*
VR		R		VR			VR	VR				VR	VR	VR	VR		VR	VR			R	VR		VR				VR	VR				VR	*H. wallichii*
						VR						R											VR	R		VR	VR							*Hyaster perplexus*
		VR				VR	VR			VR											VR			VR										*Pontosphaera discopora*
			R	VR		VR		R	R	VR			VR		R			VR	VR	VR	F	R	VR	VR		VR	VR	VR	VR	VR	R	VR	VR	*P. japonica*
								VR	VR	R		R			R	VR	VR		VR		F	VR	R	R	VR	VR	VR	VR	VR			VR	VR	*P. multipora*
A	A	A	C	C	C	A	A	A	A	C		A	A	A	A	A	C	C	C	C	C	C	C	C	A	A	A	A	A	A	A	A	C	*Pseudoemiliania lacunosa*
										r												r												*Reticulofenestra pseudoumbilica*
VR	VR		VR	R	VR	VR			F	F		R			F		VR	VR	R	F	R	R	R	VR	R	F	VR	R	F	R			VR	*Rhabdosphaera clavigera*
	F	VR	R	R	F	VR	VR	R	F	F		F	R	VR	F	VR	VR	VR	F	R	F	F	R	F	F	F	R	R	F	F	r	VR	VR	*Scyracosphaera* spp.
										r			r		r	r	r		r			r				r			r	r	r	r	r	*Sphenolithus abies*
VR	VR	VR		VR	R				R			VR	R			R	VR			VR	VR						VR	VR	VR	R	VR	VR	VR	*Thoracosphaera* spp.
																															r			*Triquetrorhabdulus rugosus*
							VR			VR		VR		VR	VR		VR			R	R	VR	F	R	VR			F	R	VR	R	VR	R	*Umbellosphaera* spp.

by tracing three planktonic foraminiferal datum planes by Yoshifumi SUZUKI (1984 MS) who examined 128 samples taken from all over the region. Sampling route of NATORI (1976) for his planktonic foraminiferal work is unfortunately located across these faults.

For the Shinzato Formation and the lowermost portion of the Chinen Formation, we carried out more detailed sampling from a route indicated in Fig. 4. Somewhat detailed columnar section (Fig. 5) represents the uppermost portion of section obtained from this route, southwest of China, Chinen-son. The lower part of the Shinzato Formation was supplemented by a cliff at Shinzato, Sashiki-chô.

Calcareous Nannofossil Zonation

In this paper, the calcareous nannoplankton zonation was assigned in adopting the zones proposed by BUKRY (1973, 1975)* and their numerical equivalents shown by OKADA and BUKRY (1980). For geochronological representation of the boundaries, HAQ (1983) was employed instead of OKADA and BUKRY's.

An occurrence chart (Table 1) was made from the observation of smear slides under an optical microscope at magnification of × 1,500. Some materials were further examined by using an electron microscope, Hitachi S-430. Figure 6 shows ranges of occurrences of 17 selected taxa.

1) *Discoaster quinqueramus* Zone (CN9). This zone was first proposed by MARTINI (1971), who gave a numerical term of NN11, as an interval zone between the first appearance datum (FAD) and the last appearance datum (LAD) of *Discoaster quinqueramus* GARTNER, 1969. This species occurs already in Sample R2-891 m, near the base of the Tomigusuku Formation. Both *Discoaster berggrenii* BUKRY, 1971 and *Discoaster surculus* MARTINI and BRAMLETTE, 1963 that are designated as marker species of CN9 by BUKRY (1972, 1973) were also observed in this lowest sample. The uppermost occurrence of *D. quinqueramus* is recorded till Sample s-75 of the early Pliocene, *i. e.*, within the CN11 Zone. It was impossible to determine whether this delayed occurrence is due to reworking or not, because this species occurs not commonly throughout. In this instance, therefore, the upper limit of the *D. quinqueramus* Zone can not be determined. HAQ and BERGGREN (1978) also reported a similarly delayed occurrence of this species in the MARTINI's (1971) NN15 Zone (early Pliocene) of a piston core CH115-67 from the Rio Grande Rise of the North Atlantic Ocean.

The base of the *Amaurolithus primus* Subzone (CN9b), upper one of two subdivisions of the *D. quinqeuramus* Zone, is defined by FAD of *Amaurolithus primus* (BUKRY and PERCIVAL, 1971) GARTNER and BUKRY, 1975, which is recognized in Sample R2-515 m. This datum can be supported by an almost simultaneous FAD of *Amaurolithus delicatus* GARTNER and BUKRY, 1975. Contemporaly appearance of this species has

* Another zonal scheme proposed by MARTINI (1971) will also be referred, in paying attention to priority, when there is recognized coincidence for naming and definition between the zones of MARTINI and BUKRY.

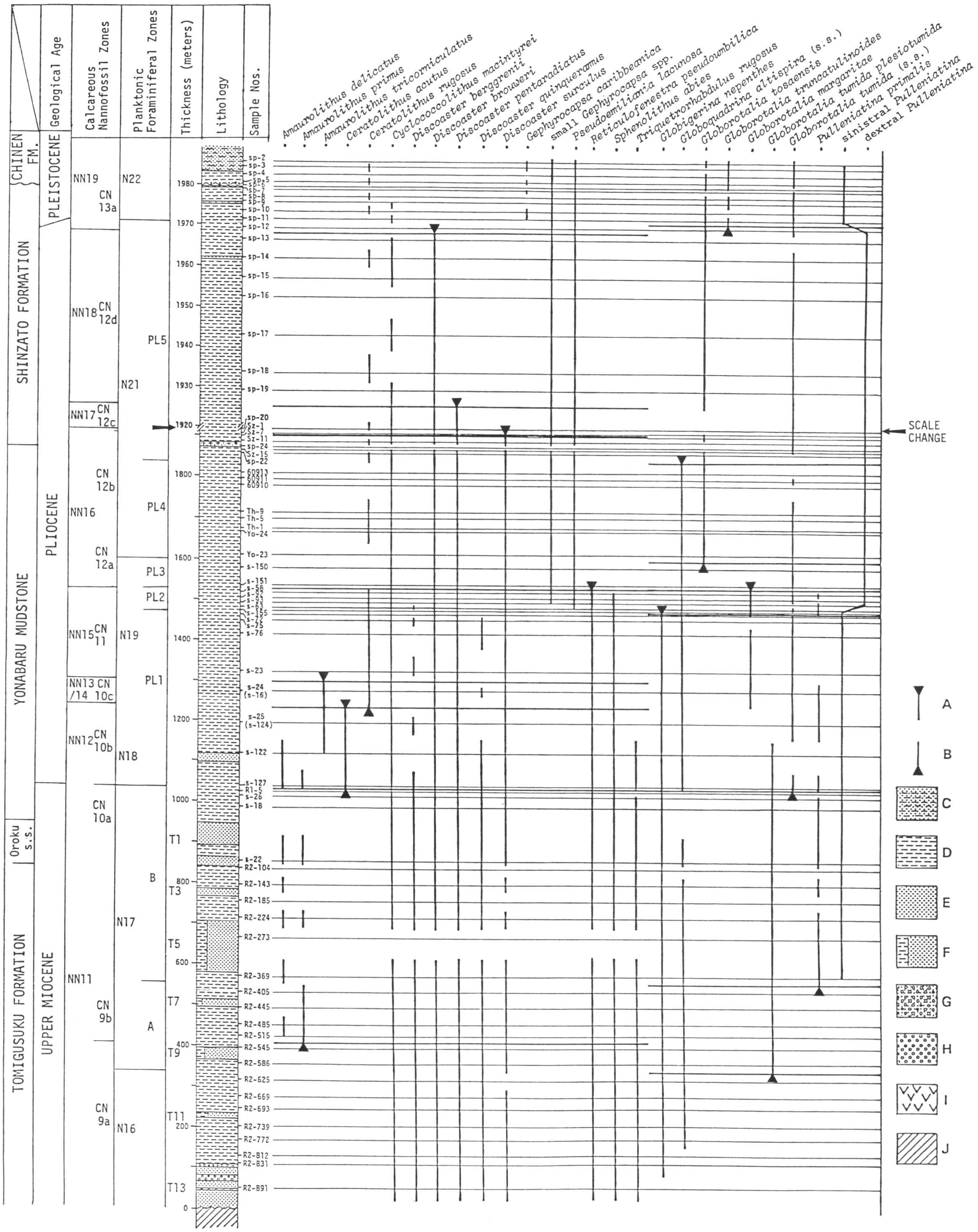

Fig. 6. Range chart of selected calcareous nannofossil and planktonic foraminiferal taxa, recognized in the Shimajiri Group and lower portion of the Chinen Formation.

A: Last appearance datum effective for the zonation, B: Effective first appearance datum, C: Sandstone with limy nodules, D: Massive siltstone, partly sandy, E: Sandstone, F: Sandstone rich alternation, G: Conglomeratic sandstone, H: Conglomerate, I: Tuff, J: Nago Formation. These legends express general lithofacies, except for C, G and I which are applied to the Shinzato and Chinen Formations.

been reported by some authors (*e. g.*, HAQ and BERGGREN, 1978; HAQ and TAKAYAMA, 1984; BUKRY, 1972, 1975).

2) *Amaurolithus tricorniculatus* Zone (CN10). This zone is divided into three subzones; *Triquetrorhabdulus rugosus* (CN10a), *Ceratolithus acutus* (CN10b) and *Ceratolithus rugosus* (CN10c) Subzones, in ascending order. The base of the CN10b Subzone is defined by FAD of *Ceratolithus acutus* GARTNER and BUKRY, 1974, and also by LAD of *Triquetrorhabdulus rugosus* BRAMLETTE and WILCOXON, 1967. The former, more reliable, datum can be set between Samples R1-5 m and s-127, although the other key species, *T. rugosus*, occurs scarcely above this horizon. The base of the CN10c is defined here between Samples s-25 and s-24 by the double criteria, *i. e.*, FAD of *Ceratolithus rugosus* BUKRY and BRAMLETTE, 1968, and LAD of *C. acutus*.

3) *Reticulofenestra pseudoumbilica* Zone (CN11), equivalent to the same name zone (NN15) of MARTINI (1971). This zone was defined by MARTINI as an interval between LAD of *Amaurolithus tricorniculatus* (GARTNER, 1967) GARTNER and BUKRY, 1975, and LAD of *Reticulofenestra pseudoumbilica* (GARTNER, 1967) GARTNER, 1969. The lower boundary is presumably set between Samples s-24 and s–23, while the upper boundary is easily determined between Samples s-58 and s-151. LAD of *Sphenolithus abies* DEFLANDRE (in DEFLANDRE and FERT), 1954, which is the criterion used by BUKRY (1973) is also observed at the upper boundary. It may be noticed that FAD of small *Gephyrocapsa* species and *Pseudoemiliania lacunosa* (KAMPTNER, 1963) GARTNER, 1969, are respectively located in Samples s-93 and s-53 (both slightly below LAD of *R. pseudoumbilica*).

Although BUKRY (1973) recognized an acme zone of *Discoaster asymmetricus* GARTNER, 1969, as the upper subdivision of the *R. pseudoumbilica* Zone, we could not disciminate this *D. asymmetricus* Subzone (CN11b) in the Shimajiri Group because of rather rare occurrence of the species throughout the sequence.

4) *Discoaster brouweri* Zone (CN12) of BUKRY (1975), not the same name zone (NN18) of MARTINI (1971). This zone is subdivided into four subzones; namely, *Discoaster tamalis* (CN12a), *Discoaster surculus* (CN12b), *Discoaster pentaradiatus* (CN12c), and *Cyclococcolithus macintyrei* (CN12d) Subzones, in ascending order. Since *Discoaster tamalis* KAMPTNER, 1967, always shows sporadic and rare yielding in the Shimajiri Group, we cannot set the boundary between the CN12a and CN12b Subzones, which is marked by LAD of this species. The top of the *D. surculus* Subzone (CN12b) that is designated by LAD of *Discoaster surculus* MARTINI and BRAMLETTE, 1963, is observed in Sample Sz-9. LAD of *Discoaster pentaradiatus* TAN SIN HOK, 1927, which defines the top of *D. pentaradiatus* Subzone, was observed in Sample sp-20.

5) *Crenalithus doronicoides** Zone (CN13) of OKADA and BUKRY (1980) = *Gephyrocapsa doronicoides* Zone of BUKRY (1973). This zone is separated from the underlying *Cyclococcolithus macintyrei* Subzone by LAD of *Discoaster brouweri* TAN SIN HOK,

* ROTH (1973) placed *Coccolithus doronicoides* BLACK and BARNES, 1961, under the genus *Crenalithus*.

1927. This last appearance datum is located between Sampes sp-12 and sp-13 within the upper Shinzato Formation. *Cyclococcolithus macintyrei* BUKRY and BRAMLETTE, 1969*, has been regarded to disappear at or shortly after LAD of *D. brouweri* by authors (*e. g.*, GARTNER, 1973, 1977). We find its disappearance at above Sample sp-9.

The *C. doronicoides* Zone is divided into two subzones, *i. e.*, *Emiliania annula* (CN13a) and *Gephyrocapsa caribbeanica* (CN13b) Subzones, which are separated by FAD of *Gephyrocapsa caribbeanica* BOUDREAUX and HAY, 1967. The first occurrence of *G. caribbeanica* is observed in Sample sp-12, which is located only two meters above Sample sp-13; the base of the CN13a Subzone is estimated between these two samples as stated above. If the age-calibration of nannofossil datum planes by HAQ (1983) is applied, then this 2 m thickness will represents about 0.2 Ma duration and the calculated sedimentation rate becomes incredibly slow (0.01 m per 1,000 years; see Table 2). Because such a contemporaneity between LAD of *D. brouweri* and FAD of *G. caribbeanica* has been reported from various places of the northwestern Pacific region (TAKAYAMA, 1973; ELLIS, 1975; OKADA, 1980), we hesitated to discriminate the two subzones here.

Summary of Planktonic Foraminiferal Zonation

In the previous report, MISHIMA and UJIIÉ (1983) preliminarily revised the late Cenozoic planktonic foraminiferal stratigraphy in the southern Okinawa-jima region proposed by NATORI (1976). Their revision was based upon the investigation of the same cores which were obtained from the Ryusei Well No. 2 for the Tomigusuku Formation and of materials collected in more closely spaced intervals from the surface for the remnant part of the Shimajiri Group and for the lower part of Chinen Formation. The results of MISHIMA and UJIIÉ (1983) were here re-examined by using more materials and by employing more improved taxonomy.

Followings are brief notes on the datum planes which can thus be recognized in these strata, adopting the numerical zonation scheme of BLOW (1969), BERGGREN (1983; for the Pliocene subdivisions) and KENNETT and SRINIVASAN (1983; for the subdivisions of N17). Further documentation and discussion will be given in Part 2 of this article. (see Fig. 6).

1) First appearance datum (FAD) of *Globorotalia* (*s.s.*) *plesiotumida* BLOW and BANNER, which defines the base of N17, is recognized in Sample R2-586 m, within T10 unit. NATORI (1976) also assigned the datum plane within this unit.

2) FAD of *Pulleniatina primalis* BANNER and BLOW defines the boundary between N17A and B of KENNETT and SRINIVASAN (1983) and is observed in T6 unit (R2-369 m), almost identical to the result of the previous works.

3) The base of N18 marked by FAD of *Globorotalia* (*s.s.*) *tumida* (BRADY) (*s.s.*)

* This species has been placed under various generic names such as *Cyclococcolithus*, *Calcidiscus*, and so on, by authors.

is found in Sample s-127, which is located about 80 m above the top of the Oroku Sandstone Member that is the top member of the Tomigusuku Formation. NATORI (1976) observed this datum plane approximately at the same horizon and MISHIMA and UJIIÉ (1983) suggested that the plane is traceable throughout the southern Okinawa-jima region as a horizon situating below the Nakagusuku Sandstone Member.

4) Specimens assignable to *Sphaeroidinella dehiscens immatura* (CUSHMAN) without any doubt could not be found in the lower Yonabaru Formation differently from NATORI (1976). The boundary between N18 and N19, therefore, can not be defined here as was stated by MISHIMA and UJIIÉ (1983).

5) The upper limit of PL1 of BERGGREN is recognized by a distinct disappearance of *Globigerina nepenthes* TODD between Samples s-72 and s-155. Further divisions of PL1 proposed by BERGGREN (1984) in the Atlantic and Meditteranean regions are not recognizable, since the FAD of *Globorotalia* (*Turborotalia*) *puncticulata* (DESHAYES) and of *Globorotalia* (*Turborotalia*) *crassaformis* (GALLOWAY and WISSLER) are found at the horizons much higher than expected, namely, in the upper part of the Yonabaru Formation.

The last appearance datum (LAD) of *Globigerina nepenthes* is immediately followed by a change of coiling for *Pulleniatina* complex from sinistral to dextral between Samples s-63 and s-93. This successional events have been emphasized as common phenomenon in the Pacific region (*e. g.*, TSUCHI, 1984) since HAYS *et al.* (1969).

6) LAD of *Globorotalia* (*s.s.*) *margaritae* BOLLI and BERMÚDEZ, which marks the the upper boundary of PL2, is clear at Sample s-58, although its occurrence range seems to be considerably shorter than that estimated by BERGGREN (1984).

Within N19 and N20, NATORI (1976) proposed two datum planes, namely, FAD of *Globorotalia* (*s.s.*) *ungulata* BERMÚDEZ and of *Globorotalia* (*Turborotalia*) *humerosa* TAKAYANAGI and SAITO. As will be discussed further in Part 2, these datum planes have not yet been recognized from the other regions and we obtained different occurrence ranges here, partly because of different taxonomic concepts.

7) FAD of *Globorotalia* (*Turborotalia*) *tosaensis* TAKAYANAGI and SAITO is observed in Sample Yo-23 and the base of N21 is thus defined. The stratigraphic position of this datum plane seems to be much lower than that shown by NATORI (1976). This discrepancy may be due to what a geologic columnar section shown by NATORI seems to depend upon probably incomplete field survey.

8) LAD of *Globoquadrina altispira* (CUSHMAN and JARVIS) (*s.s.*), which assignes the top of PL4, is recognized in Sample 60913 at slightly below the base of the Shinzato Formation.

9) FAD of *Globorotalia* (*s.s.*) *truncatulinoides* (D'ORBIGNY) is assigned as the basal datum of N22 by BLOW (1969) and has long been regarded as an indicator of the base of the Pleistocene till HAQ *et al.* (1977). We found the initial appearance in Sample sp-11 coinciding with repeated appearance of sinistral *Pulleniatina* species. Sample sp-12, which was taken from two meters below sp-11, contains dextral *Pulleniatina*. IBARAKI and TSUCHI (1975) studied planktonic foraminifera from the same section as

we did here. They noticed this coiling change but failed to recognize the real FAD of *G. truncatulinoides* and the true boundary between the Shizato and Chinen Formations.

A similar coiling change of *Pulleniatina* was reported from the Kakegawa region, central Japan, by IBARAKI and TSUCHI (1974). They also recognized FAD of *G. truncatulinoides* at the slightly higher horizon as pointed out by ODA (1977). On the Boso Peninsula, central Japan, ODA (1977) reported FAD of *G. truncatulinoides* at the base of the Olduvai Event and the coiling change evidently below the Olduvai base. TSUCHI (1984) assigned the age of the coiling change datum as 2 Ma and emphasized its stratigraphic significance, even though SAITO (1976) figured out somewhat more fluctuated mode of *Pulleniatina* coiling change through the latest Cenozoic, particularly for the period of the Matuyama Reversal Epoch, based upon piston cores from the tropical oceans.

Correlation between the Calcareous Nannofossil and Planktonic Foraminiferal Zones

As summarized in Fig. 6, we obtained the zoning results by means of calcareous nannoplanktons and planktonic foraminifera for the whole Shimajiri Group and the lower portion of the Chinen Formation developed in the southern Okinawa-jima region. The correlation between these zones for the horizons below the CN10b or N18 zones coincides with the framework standarized by BERGGREN (1984). Concerning the Pliocene portion, however, almost every nannofossil datum planes are situated silightly below foraminiferal ones, compared with BERGGREN's (1984) framework. Our results seems to be reasonable when we compare it with the correlation proposed in Taiwan (HUANG and HUANG, 1984) and in the mainland of Japan (TSUCHI, 1984), although these previous results were not based upon the multidisciplinary study of the the same materials.

We, therefore, examined the biostratigraphic results based upon the studies of the same samples from the northwestern Pacific region such as the Deep Sea Drilling Project Sites 292, 296 (ELLIS *vs.* UJIIÉ, 1975), 445 (OKADA *vs.* ECHOLS, 1980) in the Philippine Sea, and the Panay Islands, the Philippines (TAKAYANAGI *et al.*, 1977). Their results, in general, seem to agree with ours except for Site 296. At the site, the bases of N21 and N22 are correlated to the middle of CN11b and to the base of CN12d, respectively. As a case compatible with our correlation in the other ocean, we can refer to the results of the Deep Sea Drilling Project, Leg 73, in the South Atlantic Ocean (HSÜ *et al.*, 1984). At present, however, we need further reference works to answer the question whether the discrepancies between our correlation and BERGGREN's (1984) are caused by provincialism of these planktonic organisms, heterogeneity of the datum planes, or unknown reasons.

Apart from the above discussion, it can be demonstrated that there are considerable coincidences between the two kinds of datum planes studied in the Shimajiri

Group, if we adopt the age calibrations made by HAQ (1983) for the calcareous nannofossil datum planes and by TSUCHI (1984) for the planktonic foraminiferal ones.

On the basis of these age assignments, sedimentation rates between the adjacent datum planes were calculated as shown in Table 2. In general, the rates calculated for the short-durated (less than 0.4 Ma) zones tend to be much smaller or sometimes larger compared with the average of 33 cm per 1000 yrs. This discrepancy might be due to the limited accuracy of the age-assignment of planktonic microfossil datum plane and/or due to the limited resolution power by means of microbiostratigraphy.

On the Pliocene and Pleistocene Boundary

Before HAQ *et al.* (1977) argued this boundary problem, FAD of *Globorotalia* (*s.s.*) *truncatulinoides* and LAD of *Discoaster brouweri* have been regarded as the Pleistocene base markers; in this paper, these long-experienced datum planes were tentatively applied. In the Meditteranean region, the first appearance of the former taxon is located below the Olduvai Event and also within the upper part of the Piacenzian, *i. e.* stratotype of the Late Pliocene, whereas the disappearance datum of the latter taxon is placed within the Olduvai Event. Most recently, RIO *et al.* (1984) regarded FAD of *Gephyrocapsa oceanica* (*s.l.*) as to indicate the Pleistocene base.

Concerning the Shinzato-Chinen section, however, "true *G. oceanica*" was not recognized and reveresed occurrences between FAD of *G. truncatulinoides* and LAD of *D. brouweri* were observed. HSÜ *et al.* (1984) also reported the same reversed occurrences with more time gap at the Deep Sea Drilling Project Site 519 on the Mid-Atlantic Ridge of the South Atlantic Ocean. Before going into further discussion,

Table 2. Comparison between the calibrated ages of calcareous nannofossil datum planes (after HAQ, 1983) and of planktonic foraminiferal ones (after TSUCHI, 1984) and the sedimentation rates between the adjacent datum planes.

Calc. Nannofossil Datum	Age Ma	Sedimentation Rate cm/1000yrs			Age Ma	Planktonic Foram. Datum
					1.9	- FAD of *Gr. truncatulinoides*
LAD of *D. brouweri*	1.88					
		13.3		33.0		
LAD of *D. pentaradiatus*	2.2					
		14.7				
LAD of *D. surculus*	2.4					
					3.0	- FAD of *Gr. tosaensis*
		35.2		17.2		
					3.4	- LAD of *Gr. margaritae*
LAD of *R. pseudoumbilica*	3.5		32.8	16.6		
		32.1	33.0		3.8	- LAD of *G. nepenthes*
LAD of *A. tricorniculatus*	4.2					
		18.8		26.4		
FAD of *C. rugosus*	4.6					
		38.0				
FAD of *C. acutus*	5.0				5.4	- FAD of *Gr. tumida*
		39.1		115.6		
					5.8	- FAD of *P. primalis*
FAD of *A. primus*	6.7			21.9		
					6.8	- FAD of *Gr. plesiotumida*

D. Discoaster, *R. Reticulofenestra*, *A. Amaurolithus*, *C. Ceratolithus*

Gr. Globorotalia, *G. Globigerina*, *P. Pulleniatina* it is necessary to restudy the Shinzato-Chinen section by conducting more detailed sampling, together with magnetostratigraphic investigation.

Concluding Remarks

As stated at the begining of this paper, a major purpose of our study was to establish a standard microfossil zonation for the late Cenozoic Shimajiri Group. The investigation resulted in the recognition of eight calcareous nannofossil datum planes and ten planktonic foraminiferal ones, between which there is geochronologically compatible correlationship.

On the basis of this standard scale, we will be able to perform detailed geological survey of the Shimajiri Group, whose major lithofacies exposed on surface has no regional key bed or horizon. Preliminary studies utilizing these datum planes (MISHIMA, 1983 MS; Y. SUZUKI, 1984 MS) have already suggested a characteristic difference between the geological structures of the Shimajiri Group and the overlying Ryukyu Group. In the other words, it is suggested that the geological development of the present-day Ryukyu Island Arc sytsem might have been originated from a regional movement after the deposition of the Shimajiri Group and before that of the Ryukyu Group as anticipated by UJIIÉ (1980; 1983).

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Explanation of Plates

Plate 1

(All figures × 2500)

Fig. 1. *Amaurolithus primus* (BUKRY and PERCIVAL) GARTNER and BUKRY. Sample R2-515. Bright field.
Fig. 2. *Amaurolithus delicatus* GARTNER and BUKRY. Sample s-63. Bright field.
Figs. 3, 4. *Amaurolithus tricorniculatus* (GARTNER) GARTNER and BUKRY. Sample s-24. 3 Bright field. 4, Cross-polarized light.
Figs. 5, 6. *Ceratolithus cristatus* KAMPTNER. Sample s-93. 5, Bright field. 4, Cross-polarized light.
Figs. 7, 8. *Ceratolithus acutus* GARTNER and BUKRY. Sample s-127. 7, Bright field. 8, Cross-polarized light.
Fig. 9. *Ceratolithus cristatus* KAMPTNER. Sample sp-19. Cross-polarized light.
Fig. 10. *Ceratolithus rugosus* BUKRY and BRAMLETTE. Sample s-58. Cross-polarized light.
Fig. 11. *Discoaster intercalaris* BUKRY. Sample R2-515. Bright field.
Fig. 12. *Discoaster asymmetricus* GARTNER. Sample Yo-24. Bright field.
Fig. 13. *Discoaster berggrenii* BUKRY. Sample R2-772. Bright field.
Fig. 14. *Discoaster brouweri* TAN SIN HOK. Sample s-72. Bright field.
Fig. 15. *Discoaster challengeri* BRAMLETTE and RIEDEL. Sample s-63. Bright field.
Fig. 16. *Discoaster quinqueramus* GARTNER. Sample R2-585 Bright field.
Fig. 17. *Discoaster tamalis* KAMPTNER. Sample Yo-24. Bright field.
Fig. 18. *Discoaster variabilis* MARTINI and BRAMLETTE. Sampe s-63. Bright field.
Figs. 19, 20. *Sphenolithus abies* DEFLANDRE [in DEFLANDRE and FERT]. Sample s-76. 19, Bright field. 20, Cross-polarized light.

Plate 2

(All figures × 2500)

Fig. 1. *Discoaster challengeri* BRAMLETTE and RIEDEL. Sample s-72. Bright field.
Fig. 2. *Discoaster surculus* MARTINI and BRAMLETTE. Sample R2-772. Bright field.
Fig. 3. *Discoaster variabilis* MARTINI and BRAMLETTE. Sample s-150.
Figs. 4, 5. *Ceratolithus* cf. *telesmus* NORRIS. Sample sp-6. 4, Bright field. 5, Cross-polarized light.
Fig. 6. *Schyphosphaera* cf. *intermedia* DEFLANDER. Sample s-76. Cross-plarized light.
Figs. 7, 8, 9. *Triquetrorhabdulus rugosus* BRAMLETTE and WILCOXON. 7, 8, Sample R2-625, bright field. 9, Sample R2-245, Cross-polarized light.

Plate 3

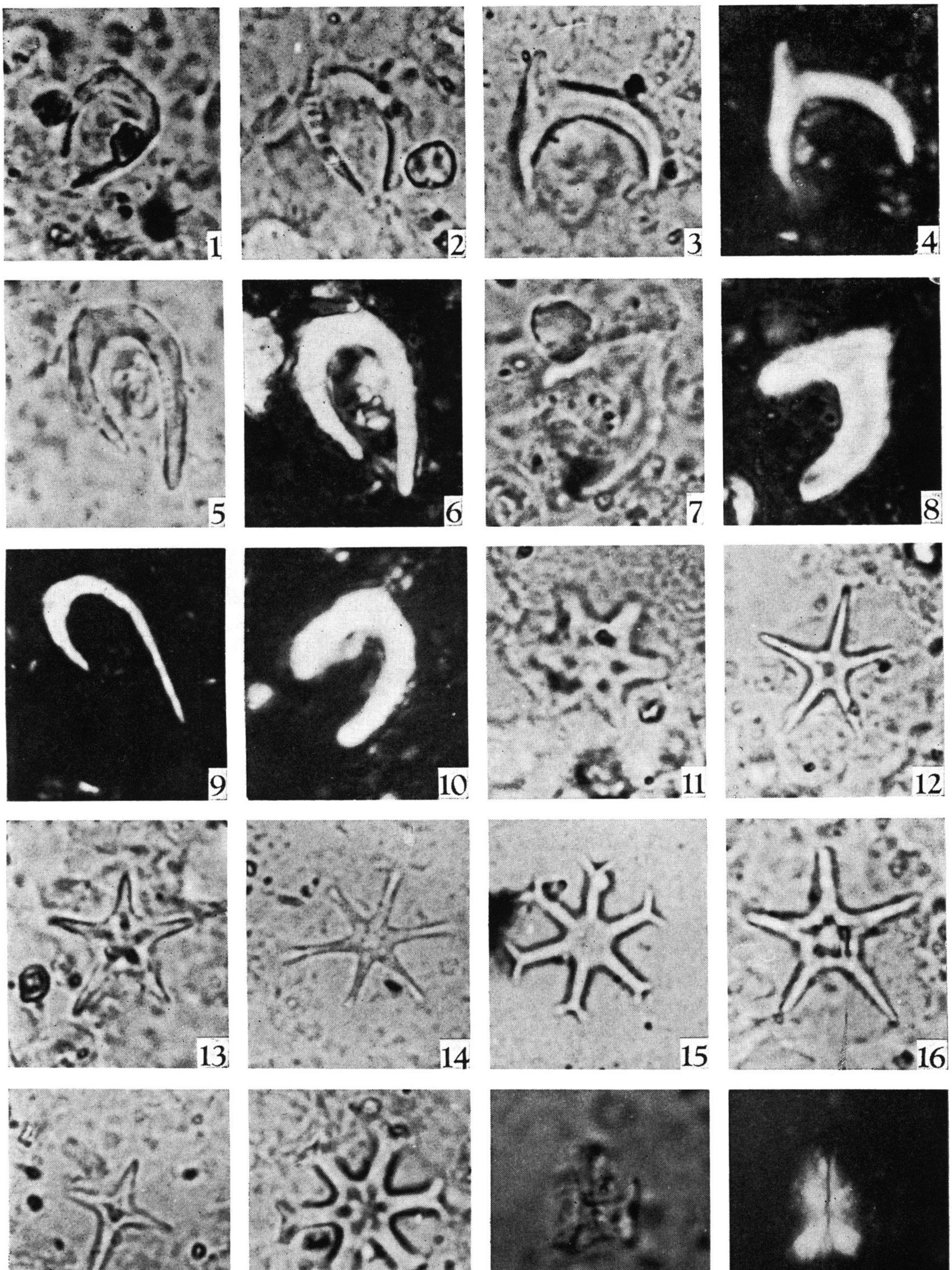
(All figures × 2500)

Figs. 1, 2. *Gephyrocapsa caribbeanica* BOUDREAUX and WILCOXON. 1, Sample sp-9. 2, Sample sp-5. Cross-polarized light.
Figs. 3, 4. *Gephyrocapsa* sp. 3, Sample sp-18, 4, Sample s-58. Cross-polarized light.
Figs. 5, 6. *Pseudoemiliania lacunosa* (KAMPTNER) GARTNER. 5, Sample sp-18, 6, Sample s-150.
Fig. 7. *Reticulofenestra pseudoumbilica* (GARTNER) GARTNER. Sample s-127. Cross-ploarized light.
Fig. 8. *Crenalithus doronicoides* (BLACK and BARNES) ROTH. Sample s-93. Cross-polarized light.

Fig. 9. *Coccolithus pelagicus* (WALLICH) SCHILLER. Samlpe s-58. Corss-polarized light.
Fig. 10. *Florisphaera profunda* OKADA and HONJO. Sample sp-8. Cross-polarized light.
Figs. 11, 12. *Cyclococcolithus macintyrei* BUKRY and BRAMLETTE. Sample sp-19. 11, Bright field. 12, Cross-polarized light.
Fig. 13. *Cyclolithella annula* (COHEN) McINTYRE and BÉ. Sample s-93. Bright field.
Fig. 14. *Discolithina japonica* TAKAYAMA. Sample sp-58. Cross-polarized light.
Figs. 15, 16. *Helicosphaera carteri* (WALLICH) KAMPTNER. Sample sp-7, 15, Bright field. 16, Cross-polarized light.
Figs. 17, 18. *Pontosphaera multipora* (KAMPTNER) ROTH. Sample sp-58. 17, Brigh field. 18, Cross-polarized light.
Fig. 19. *Rhabdosphaera clavigera* MURRAY and BLACKMAN. Sample sp-18. Bright field.
Fig. 20. *Syracosphaera* sp. Sample s-58. Cross-poralized light.

Plate 4

Fig. 1. *Reticulofeneastra pseudoumbilica* (GARTNER) GARTNER. Sample s-26. × 12,000.
Fig. 2. *Crenalithus doronicoides* (BLACK and BARNES) ROTH. Sample sp-19. × 8,200.
Fig. 3. *Gephyrocapsa* cf. *caribbeanica* BOUDREAUX and HAY. Sample sp-10. × 18,000.
Figs. 4, 5. *Pesudoemiliania lacunosa* (KAMPTNER) GARTNER. 4, Sample s-58. 5, Sample sp-22. 4, × 9,160. 5, × 12,400.
Fig. 6. *Cyclolithella annula* (COHEN) McINTYRE and BÉ. Sample s-150. × 10,400.
Fig. 7. *Discoaster quinqueramus* GARTNER. Sample R2-445. × 4,300.
Fig. 8. *Cyclococcolithus macintyrei* BUKRY and BRAMLETTE. Sample s-26. × 7,100.
Fig. 9. *Pontosphaera multipora* (KAMPTNER) ROTH. Sample s-63. × 6,800.
Fig. 10. *Crenalithus doronicoides* (BLACK and BARNES) ROTH. Sample s-26. × 5,700.
Fig. 11. *Sphenolithus abies* DEFLANDRE [in DEFLANDRE and FERT]. Sample s-93. × 10,000.
Fig. 12. *Anoplosolenia* sp. Sample sp-11. × 15,000.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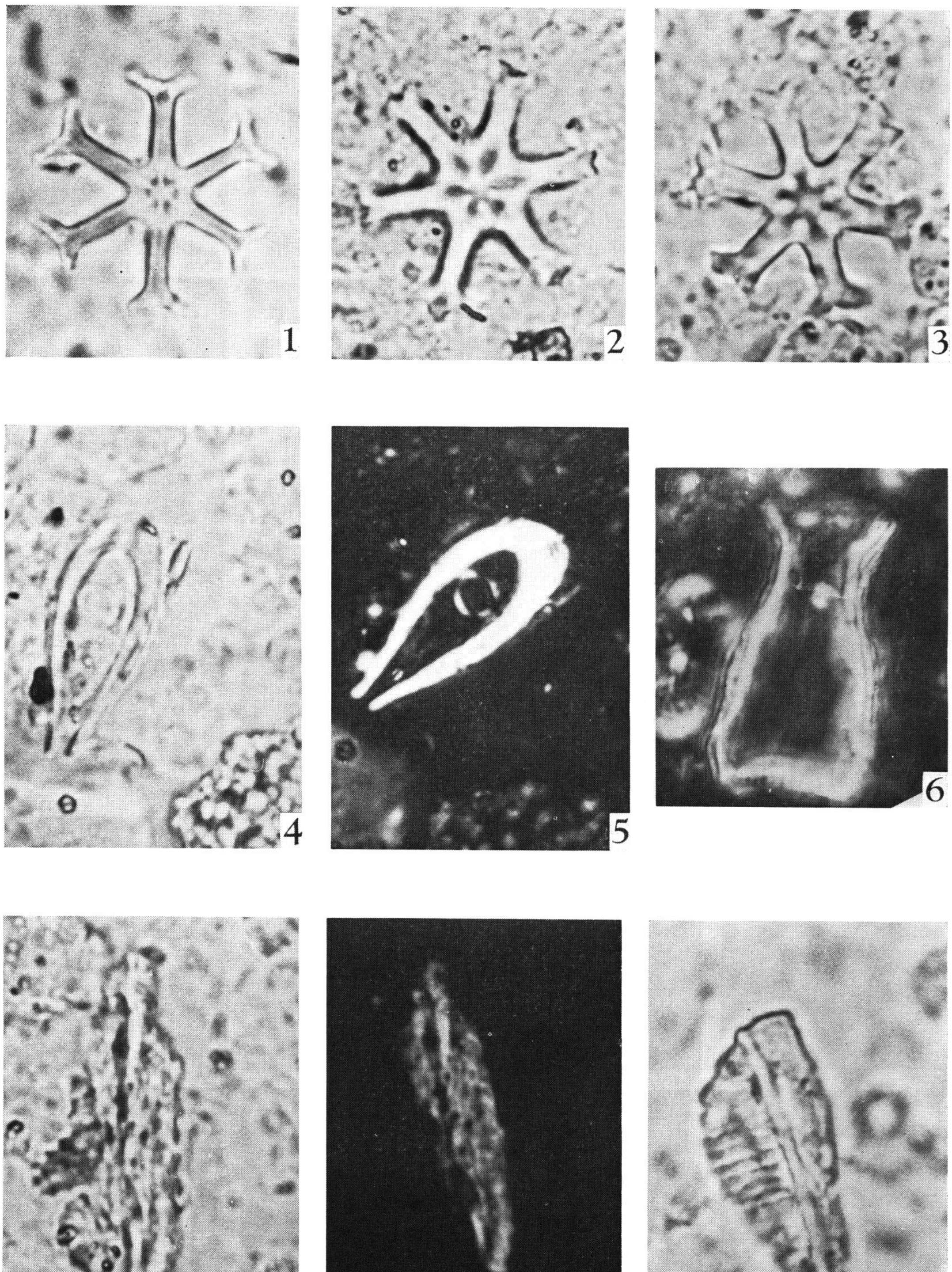
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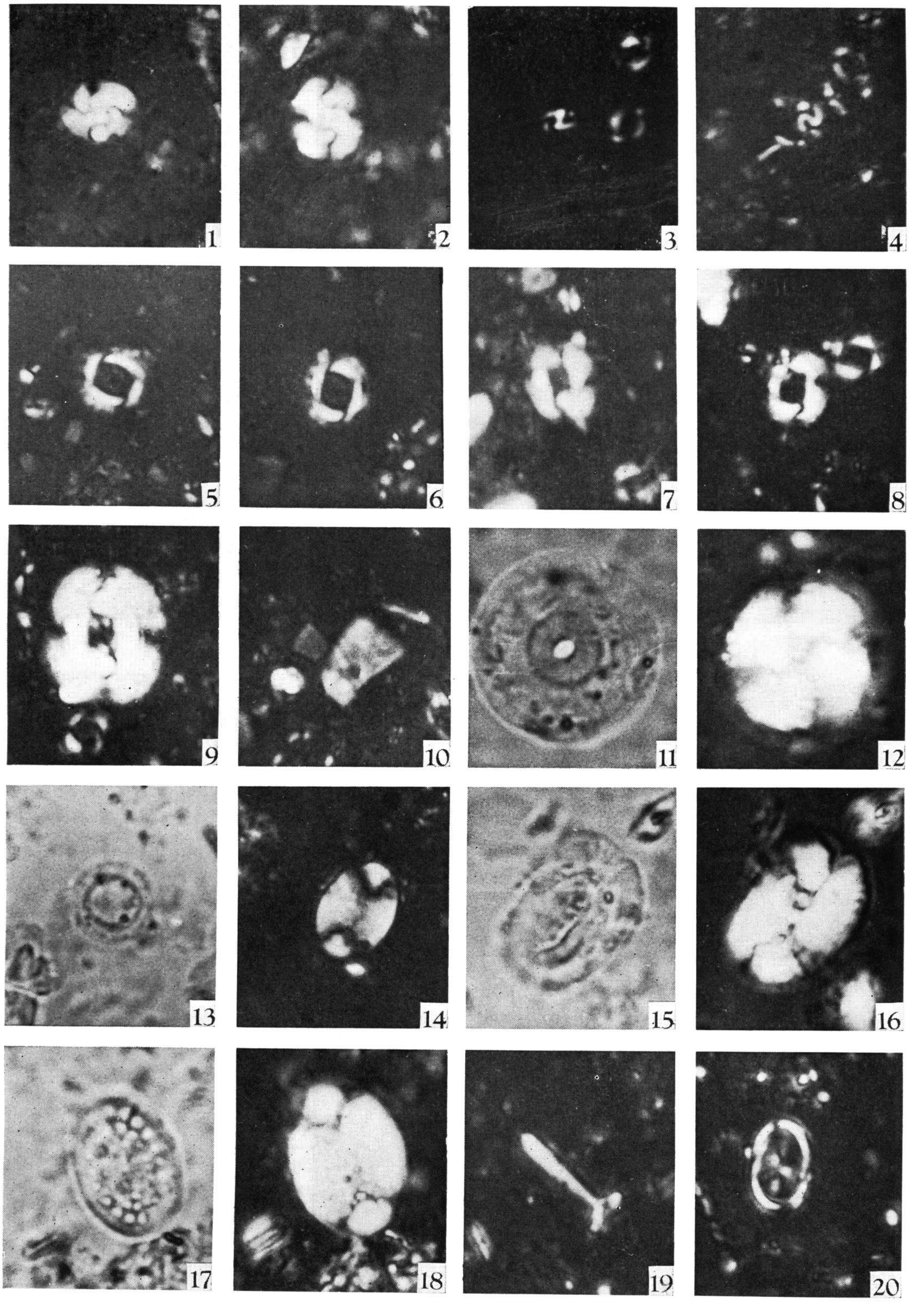
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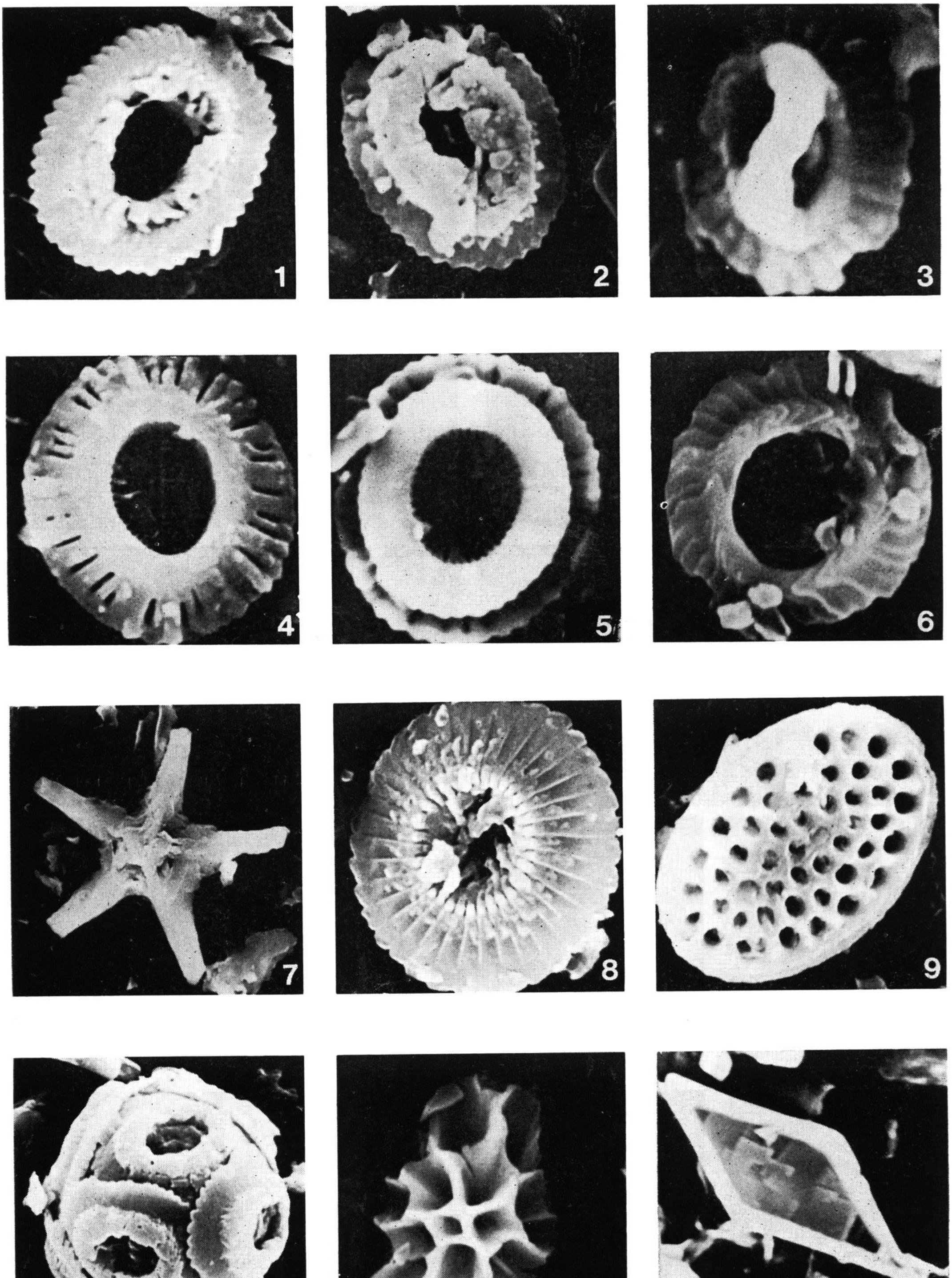
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