〔 Appendix Documents 〕

Appendix Document 1 Fossil Inspection of Limestone
Appendix Document 2 Fossil Inspection of Bottom Sediment
Appendix Document 3 Analysis Method of Manganese Oxides

[Appendix Document 1]　Fossil Inspection of Limestone

The sample used for the inspection is given in Table 1. Work was done along appropriate procedure and method.

Table 1　Inspected Sample

Sea Area	Sample no.	Depth(m)	Lithology
Kiribati	03SE01AD09 FR01	1,910	limestone

1. Petrologic Observation and Description

1-1. Analysis Method

(1) Eye Observation

Using field type magnifier, rock forming minerals, fossils, and textural characteristics were observed. Photograph of the sample is given in the last.

(2) Thin section Observation

The sample specimen was cut by a diamond cutter into 30×22×15mm piece specimen for the chip of thin section (primary cutting) and one side of the tip was polished by #180～#2500 abrasive powder (primary polishing), and cemented on the object glass. It was cut into 5mm thin chip (secondary cutting). The other side of the chip on the object glass was further grounded by the grinding machine using #180～#800 abrasive powder up to the thickness not thicker than 0.1mm. This was moved to the opal plate and the thickness was controlled to make uniform 0.03mm thickness using #2500 powder and cover glass was cemented on for the thin section observation. They were observed under non- and cross-polarized light.

1-2 Result of Observation

(1) Eye Observation

The specimen contains abundant calcareous fossil fragments, but rock or mineral fragments are not observed. The maximum size of fossil fragment is 15mm, and mostly large foraminifer fossils. Foraminifers are spindle to pancake shape in appearance, composed of white fragile carbonate minerals. Small foraminifers of the size smaller than 3mm are also abundant. Other than foraminifer fossils, corals, calcareous algae are included but very small in amount. Groundmass consists of fine micritic carbonate minerals. It shows pale brown color, and compact. Porous part of rock is mostly chamber part of foraminifer shell and it is not admitted in groundmass. The surface of the specimen is coated with black ～dark brown color, iron or manganese stain, and they are filtrated to groundmass. The thickness of disseminated depth is about 1～2cm.

(2) Thin Section Observation

Microscope observation was done under polarized and non-polarized light Photographs are shown in the last of the report.

Sample no. 03SE01 AD09 FR01
Rock: bioclastic packstone
Texture: clastic texture
Fragment

Fossil fragment: It is abundant to moderately included, maximum size is 11mm. Fossils are foraminifer, coral, calcareous algae. Large fossil pieces are often replaced to crystalline carbonate minerals.

Groundmass

Micrite: Commonly included. Maximum crystal size is 0.01mm, ahedral, irregular shaped microcrystalline groundmass. Mostly brown color cryptocrystalline groundmass.

Iron hydroxide: Contained small in amount. Maximum size is 0.01mm, soil to dendritic showing under microscope, shows brown mottled stain.

Pore: A little porous. Maximum cavity size is 0.7mm, develops chamber parts between cepta of foraminifer shell.

Note: Fossiliferous limestone, and its groundmass is composed of micrite. Main fossils are foraminifers and others are coral, and algae. No mineral grains. It is classified into packstone after Dunham (1962), since grains are making bundle of rock and groundmass is calcareous clay.

2. Microfossil Analysis

2-1 Analysis method

(1) Calcareous Nannoplankton

The method is followed basically after Takayama (1976) and the slide glass for inspection was prepared by the following procedure. About 1gram of sample is put into a beaker and added 20ml of water. Stir well to make suspension. The suspension is left about 30 second, and the upper part is sucked up by a sipper, and spilled onto the slide glass(18 x23mm) evenly and dried on a hot plate under about 40° C. After the sample is completely dried out, cover glass is put on and cemented by a light hardening adhesive agent and the slide glass is prepared. Microscopic inspection was made under the phase microscope with polarizing function under ×1500 time magnification.

Counting is aimed number of fossil individuals to reach about 100, except *Florisphaera profunda*, living species under the lower light transmitting zone, and whole sample was thoroughly inspected in order not to overlook bearing species. The reason of the exclusion of *Florisphaera* profunda is that this species normally appear very many numbers and when we evenly count numbers, it often occupies over 90% of counting standard. In that case, identification of other species such as time index fossils becomes difficult.

The identification has been made after Aubry (1985; 1986), Perch-Nielsen (1985) and Pujos (1987).

On the preservation and abundance of fossils in a sample of concerned, the following indicators were used (result is listed in the table).

For the preservation, G (good): Shells are not dissolved (destructed) or not receiving re-crystallization effect. M (moderate): Partly dissolved (destructed) or re-crystallized fossil individuals are admitted. P (poor): Almost all shells are dissolved (destructed) or have trace of re-crystallization. VP (very poor): All shells are dissolved or re-crystallized, and identification of fossil species is not easy. VVP (very, very poor) All shells are dissolved or re-crystallized and identification is difficult.

For the abundance,

A (abundant):	≧10 individuals in 0.1m ㎡
C (common):	≧1 individual in 0.1m ㎡
F (few):	≧1 individual in 0.2m ㎡
R(rare):	< 1 individual in 0.2m ㎡
VR (very rare):	≧1 individual in 4m ㎡
VVR(very, very rare)	< 1 individual in 4m ㎡

(2) Foraminifer Fossil

The rock sample of amount of 150gr were selected and prepared into mud by means of the sodium sulfate method and the naphtha method (Takayanagi ed. 1978). The sample was so compact, the sodium sulfate method was first attempted and after that, the naphtha method was repeatedly applied for three times.

After the mud processing, they were sieved through 0.063mm sieve and sand grains were separated using a simple separator. Extraction of about 200 benthic foraminifer fossil individuals was aimed under binocular microscope observation. Counting of number of individuals and identification of species are made on the extracted sample..

The inspection is made under microscope of magnification of × 20 ～× 60.

2-2 Analysis of Geologic Age

(1) Calcareous Nannoplankton Fossil

Microfossil chronological time scale by Berggren et al. (1995) is applied as the basis of the analysis. Other basic references are as follows. For nannoplankton fossil zones, the result by Okada and Burkry (1980) is applied. For fossil datum plane and geologic age of Paleogene and Neogene Tertiary is, by Berggren et al. (1995), For Late Neogene Tertiary to Quaternary is, by Takayama and Sato (1987), Takayama (1993), Sato, Kameo and Takayama (1991), Takayama and others (1995), Raffi and Flores (1995), and Okada (1999). The age estimation of Tertiary to Quaternary Time by means of calcareous nannoplankton fossils is, mainly done on the basis of the work by Sato et al (1998).

In the next, the summary of fossil zoning and datum plane by Okada and Burkry (1980) is briefly explained. They set 34 fossil zonings in Neogene Time and if the zoning is included sub-zone, total of 58 fossil zones are set. Code number is put on each zone, for example, Paleogene is coded from the bottom to upward, CP-1 to 19 and Neogene is CN-1 to 15. The boundary of each zone (sub zone) is not only correlated with paleo-magnetostratigraphy but also checked by absolute age data (Appendix Table 2).

The result of this survey is made based upon the datum plane of this fossil zone.

- On the geologic age of appearance and extinction of fossil zone boundary

Concerning geologic age, Table 2 is the one directly referred from Okada and Burkry (1980). But since 1990s, Energetic re-examination of paleo-magnetostratigraphy has being done and age determination of major boundary of datum plane had been done by means of Ar-Ar dating method (formerly by K-Ar dating method). As the result, some of the age of extinction of fossil species, appearance of new species, or boundary of time slices became necessary to be revised. Fossil zone of nannoplankton itself is not revised after the work of Okada and Burkry (1980), however, the boundary of datum plane should be replaced by the recent result. A summary paper of such revision works is the one reported by Bergrren et al. (1995). Other main reference papers on this subject are, Backman et al. (199), Gartner (1992), Olafsson (1991), Poore et al. (1984), Rio et al. (1990), Sato et al. (1998), Young 1998), Okada (1999), and so on.

Since after 1996, successive re-measurements on the determined age are being continued, and they are referred on the occasion of necessity.

(2) Foraminifer Fossil

For the analysis of data, the zonation proposed by Blow (1969) is taken in as the basis and for foraminifer fossil chronological scale, the proposal by Berggren et al. (1995) is applied. Other references are, Kennett & Srinivasan (1983), and Bolli & Saunders (1985). In case of Mesozoic time scale, the result proposed by Caron (1985) is generally accepted world-widely and thus his result is applied but Cretaceous time scale has been revised a little, this part is replaced by the work of Felix et al. (1995), and chronological stage boundary proposed by them is inserted into Caron's result Caron (1985) and used in this report.

For the analysis of sedimentary environment, the following papers are referred: Ecological research on Recent foraminifer around Japan] by Inoue (1980), [Bathymetric distribution of the Recent benthic foraminifers around Japan] by Akimoto & Hasegawa (1989), [Late Cenozoic paleobathymetric indeces based on benthic foraminifers in Japan] by Hasegawa and others (1989), and Murray (1991).

2-3 Result and Consideration

(1) Calcareous Nannoplankton Fossil

The result of analysis was shown in Appendix Table3. The production rate of fossil is low. Total of 62 individuals were counted from the 18mm ×24mm size slide glass where sediments were scattered evenly for counting purpose. In case of nannofossil inspection by same way, usually tens of thousands to hundreds of thousands individuals are observed in a slide glass, so that the number of individuals included in the sample is very small.

The preservation condition of individuals is in the state almost all of the shells are dissolved, and rims are lost and numbers of fossil individuals with perfect shell shape were small, for this, preservation of fossil is poor (C).

Nannofossils extracted from the sample are grouped into 14 taxa with 7 Genera with 9 species and 5 unknown species. There were 4 fossil individuals whose genus and species could not be determined. They include individuals whose shell has too big defect or too heavily dissolved to identify and individuals whose genus assumption could be made.

Detected species are, *Biscutum spp., Chiasmolithus oamaruensis, Chiasmolithus aff. Solitus, Coccolithus eopelagicus, Coccolithus pelagicus, Cyclicargolithus floridanus, Markalius spp., Reticulfenestra aff. Dictyoda, Reticulofenestra hillae, Reticulofenestra umbilica, Sphenolithus moriformis.*

These living time and life range are as follows. Biscutum spp: This genus already appeared in Cretaceous and is known to have lived approximately up to Paleocene but not admitted since after Eocene. Chiasmolithus oamaruensis is known to have lived in CP12-17 zone of Okada and Burky (1980) (ReferAppendix Table 2). Chiasmolithus aff. Solitus has bad shell preservation condition and identification of certain individuals could not be made, but individuals resemble to *Chiasmolithus solitus* having characteristic "cross-bridge structure" were confirmed. The life range of this species is during CP10-14a subzone. *Coccolith eopelagicus* is the species admitted from late Eocene to Oligocene. The life range of *Cyclicargolithus floridanus* is known to have been late Eocene CP 14 zone to middle Miocene CN 5a subzone. *Markalius spp.* is same as *Biscutum spp.,* had clearly lived from late Cretaceous to Oligocene but the data are too few to assume the taxon of this species after Eocene. *Reticulofenestra aff. Dictyoda* is, as later described, taxonomically close to *Reticulofenestra hillae* and it is thought highly possible to be differentiated from this species. For this, characteristics of shell is close each other and also middle type individuals are admitted. In this survey, the individual put name to *aff. dictyoda* is this middle type. The life range of this species is CP11-14 zone. On the other hand, *Reticulofenestra hillae* is known to have lived during CP14-16 zone. Moreover, that of *Reticulofenestra umbilica* is CP14-16 zone. This species is the index fossil of late Eocene to Early Oligocene. *Sphenolithus moriformis* has comparatively long life range, during CP1—CN8b subzone.

From the occurrence of above groups, the assumed age of this limestone is certain to lie somewhere on the biostratigraphic time scale of CP14 –16 zone by Okada and Burkry(1980), because *Reticulofenestra umbilica and Reticulofenestra hillae* were confirmed. Taking into account the fact that fossil individuals taxonomically close species to have lived until CP14 zone (*Chiasmolithus aff. Solitus* and *Reticulofenestra aff. Dictyoda*) were confirmed, the age of this limestone is suggested to lie near CP14 zone.

(2) Foraminifer Fossil

Many benthic foraminifer mega fossils were admitted by naked eyes, but observation of details was difficult, and the following remarks are described on the basis of microscopic inspection.

Bedrock is mudstone and from microscope observation of thin section under polarized light, planktonic foraminifers, benthic foraminifers, echinoids, spine of echinoids, calcareous pebble, fragment of gastropods, coral algae were observed. Space among large grains, there occur many planktonic foraminifers and the gap is stuffed with micrite. In the shell of foraminifer, block of inter locking was observed.

There occur foraminifers among grains and the numbers of planktonic foraminifers are unanimous than that of benthic foraminifers, so that the depositional environment is assumed far off the shell calm depositional environment. Calcareous pebbles were found associated with planktonic foraminifers, the bed rock is suggested to be pelagic origin. Echinoid fossil observed in the thin section showed characteristics of syntaxial cement and thus influence of post depositional diagenesis is suggested. Inside of foraminifer with spiney, aragonitic shell surface, interlocking was observed and this fact also suggests diagenetic influnce. From these facts, the following assumption may be drawn out. After the bedrock had deposited under pelagic environment far off the shelf, it had been raised on the sea surface.

3. Summary

From the result of thin section inspection and microfossil analysis, the following is drawn.

1. The sample rock is fossiliferous limestone and groundmass is composed of micrite. Fossils are, mainly foraminifers. Corals, calcareous algae, echinoids, and so on are contained. According to the classification of limestone by Dunham (1962), the bedrock limestone is classified into packstone.
2. From the analysis of nannoplankton fossil, the age of limestone is plotted somewhere on the CP14-16 zone of biostratigraphic scale by Okada and Burkry (1980), and the time is assumed late Eocene to early Oligocene. However, the limestone has possibility of shallow sea product to have deposited after oceanic sediments had been uplifted, and possibility to occur fossil foraminifer assemblages of different geologic time. The above said geologic time means the age of the final formation of limestone.
3. From the analysis of foraminifer fossils, it is assumed that the limestone had been deposited under calm environment far off the shelf. From the fact that post depositional diagenetic influence is suggested, and occur shallow sea or coral benthic foraminifers, it is assumed that the bed rock had been deposited at oceanic environment far off the shelf, it had been uplifted above the sea surface.

Table2 Calcareous Nannofossil Zones (Okada & Bukry 1980)

Modified coccolith zones and subzones and corresponding code numbers

Age	Zone		Subzone		Martini (1971) Zone	Duration (m.y.)	Boundary (Ma)
Quaternary	CN15	Emiliania huxleyi			NN21	0.2	0.2
	CN14	Gephyrocapsa oceanica	CN14b	Ceratolithus cristatus	NN20	0.1	0.3
			CN14a	Emiliania ovata	NN19	0.6	0.9
	CN13	Crenalithus doronicoides	CN13b	Gephyrocapsa caribbeanica		0.7	1.6
			CN13a	Emiliania annula		0.2	1.8
Pliocene	CN12	Dicoaster brouweri	CN12d	Calcidiscus macintyrei	NN18	0.2	2.0
			CN12c	Discoaster pentaradiatus	NN17	0.1	2.1
			CN12b	Discoaster sulculus	NN16	0.4	2.5
			CN12a	Discoaster tamalis		0.5	3.0
	CN11	Reticulofenestra pseudoumbilica	CN11b	Discoaster asymmetricus	NN15	0.5	3.5
			CN11a	Sphenolithus neoabies		0.5	4.0
	CN10	Amaurolithus tricorniculatus	CN10c	Ceratolithus rugosus	13/14	0.4	4.4
			CN10b	Ceratolithus acutus	NN12	0.6	5.0
Miocene			CN10a	Triquetrorhabdulus rugosus		0.6	5.6
	CN9	Discoaster quinqueramus	CN9b	Amaurolithus primus	NN11	1.0	6.6
			CN9a	Discoaster berggrenii		0.4	7.0
	CN8	Discoaster neohamatus	CN8b	Discoaster neorectus	NN10	0.5	7.5
			CN8a	Discoaster bellus		3.5	11.0
	CN7	Discoaster hamatus	CN7b	Catinaster calyculus	NN9	1.0	12.0
			CN7a	Helicosphaera carteri		1.0	13.0
	CN6	Catinaster coalitus			NN8	0.2	13.2
	CN5	Discoaster exilis	CN5b	Discoaster kugleri	NN7	0.2	13.4
			CN5a	Coccolithus miopelagicus	NN6	0.6	14.0
	CN4	Sphenolithus heteromorphus			NN5 – NN2	1.0	15.0
	CN3	Helicosphaera ampliaperta				2.0	17.0
	CN2	Sphenolithus belemnos				1.0	18.0
	CN1	Triquetrorhabdulus carinatus	CN1c	Discoaster druggii		3.0	21.0
			CN1b	Discoaster deflandrei	NN1	2.0	23.0
Oligocene			CN1a	Cyclicargolithus abisectus	NP25	1.0	24.0
	CP19	Sphenolithus ciperoensis	CP19b	Dictyococcites bisectus		1.0	25.0
			CP19a	Cyclicargolithus floridanus	NP24	1.5	26.5
	CP18	Sphenolithus distentus			NP23	3.5	30.0
	CP17	Sphenolithus predistentus				4.0	34.0
	CP16	Helicosphaera reticulata	CP16c	Reticulofenestra hillae	NP22	0.5	34.5
			CP16b	Coccolithus formosus	NP21	2.5	37.0
			CP16a	Coccolithus subdistichus		1.0	38.0
Eocene	CP15	Discoaster barbadiensis	CP15b	Isthmolithus recurvus	19/20	3.0	41.0
			CP15a	Chiasmolithus oamaruensis	NP18	1.0	42.0
	CP14	Reticulofenstra umbilica	CP14b	Discoaster saipanensis	NP17	2.0	44.0
			CP14a	Discoaster bifax	NP16 – NP15	1.0	45.0
	CP13	Nannotetrina quadrata	CP13c	Coccolithus staurion		1.5	46.5
			CP13b	Chiasmolithus gigas		0.5	47.0
			CP13a	Discoaster strictus		1.0	48.0
	CP12	Discoaster sublodoensis	CP12b	Rhabdosphaera inflata	NP14	1.0	49.0
			CP12a	Discoasteroides kuepperi		0.5	49.5
	CP11	Discoaster lodoensis			12/13	0.5	50.0
	CP10	Tribrachiatus orthostylus				2.0	52.0
	CP9	Discoaster diastypus	CP9b	Discoaster binodosus	NP11	0.8	52.8
			CP9a	Tribrachiatus contortus	NP10	0.7	53.5
Paleocene	CP8	Discoaster multiradiatus	CP8b	Campylosphaere eodela	NP9	0.5	54.0
			CP8a	Chiasmolithus bidens		1.0	55.0
	CP7	Discoaster nobilis			7/8	0.5	55.5
	CP6	Discoaster mohleri				1.5	57.0
	CP5	Heliolithus kleinpellii			NP6	1.0	58.0
	CP4	Fasciculithus tympaniformis			NP5	2.0	60.0
	CP3	Ellipsolithus macellus			NP4		
	CP2	Chiasmolithus danicus			NP3		
	CP1	Zygodiscus sigmoides	CP1b	Cruciplacolithus tenuis	NP2		
			CP1a	Cruciplacolithus orimus	NP1		65.0

Table 3 Calcareous Nannofossils

Species	Range Age／CN Zone	Sample No.
Biscutum spp.	Creta.-Paleo.?	1
Chiasmolithus oamaruensis (Deflamdre)Hay et al.	E.Eo.-E.Oligo.(CP12-17)	3
Chiasmolithus aff. *solitus* (Bramlette and Sullivan)Locker	E.Eo.-L.Eo.(CP10-14a)	1
Coccolithus eopelagicus (Bramlette and Riedel)Bramlette and Sullivan	L.Eo.-Oligo.	1
Coccolithus pelagicus (Wallich) Schiller	long range≒Creta.→	3
Coccolithus spp.	-	1
Cyclicargolithus floridanus (Roth & Hay) Bukry	L.Eo.-M.M.(CP14-CN5a)	3
Cyclicargolithus aff. *floridanus* (Roth & Hay) Bukry	L.Eo.-M.M.(CP14-CN5a)	2
Markalius spp.	Creta.-Paleo.?	6
Reticulofenestra aff. *dictyoda* (Deflandre)Stradner and Edwards	E.Eo.-L.Eo.(CP11-14)	1
Reticulofenestra hillae Bukry and Percival	L.Eo.-E.Oligo.(CP14-16)	19
Reticulofenestra umbilica (Levin) Martini and Ritzkowski	L.Eo.-E.Oligo.(CP14-16)	1
Reticulofenestra spp.	Palaeogene form	5
Sphenolithus moriformis (Bron. & Strad.)Bramlette & Wilcoxon	Pal.-L.M(CP10-CN8b)	9
Sphenolithus spp.	Palaeogene form	3
unknown	-	4
Total namber of calcareons nannofossils		62
Abundance A:abundant, C:common, F:few, R:rare, VR:vary rare, VVR:vary vary rare, No:barren		VVR
Preservation G:good, M:moderate, P:poor, VP:vary poor		VP

Pleist.:Pleistocene
E.Pli.:Early Pliocene, L.Pli.:Late Pliocene,
E.M.:Early Miocene, M.M.:Middle Miocene, L.M.:Late Miocene,
Pal.:Paleocene, Eo.:Eoceme, Oli.:Oligocene,
Creta.:Cretaseous

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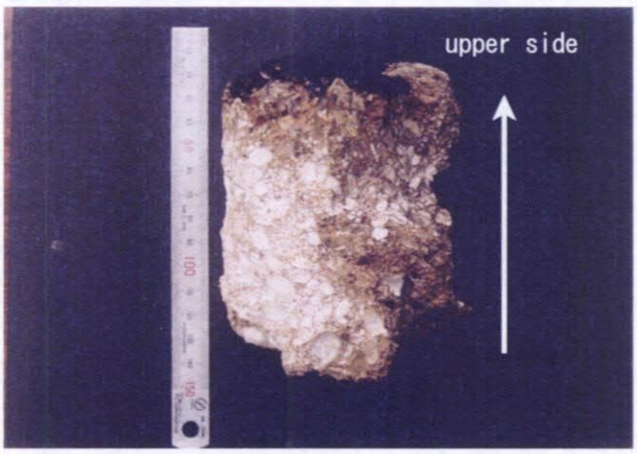
Upper side

Reverse side



Side face

Photo of AD sample

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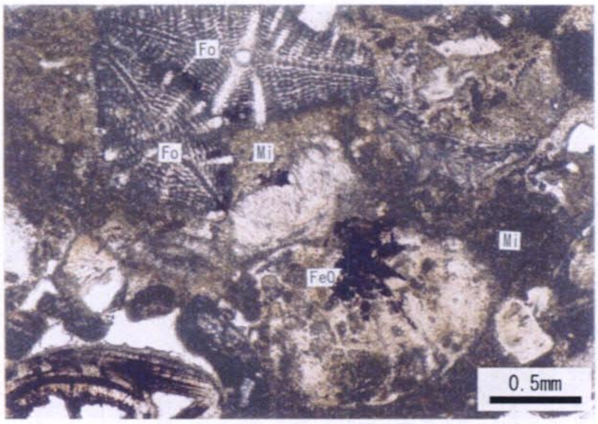
Open nicol



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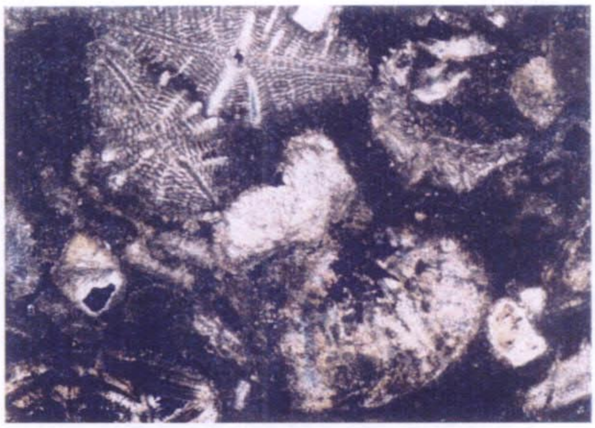

Fo:Foraminifera

Mi:Micrite

FeO:Iron hydroxide

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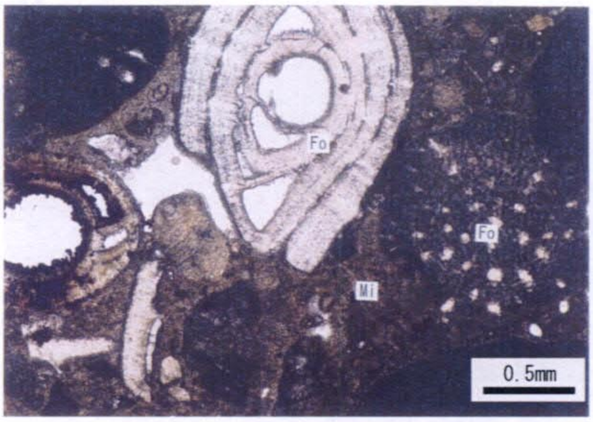
Open nicol



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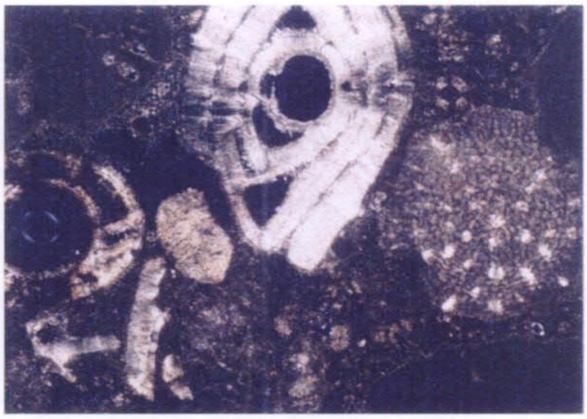

Fo:Foraminifera

Mi:Micrite

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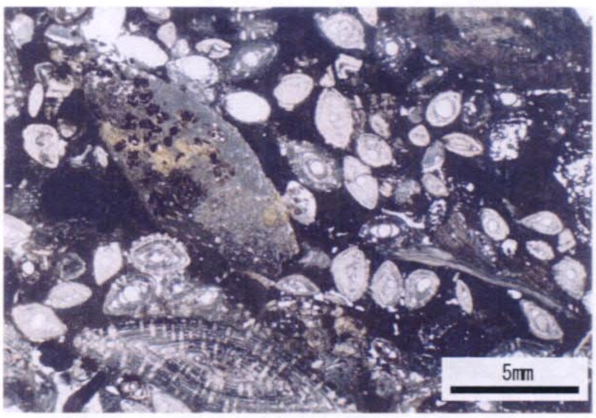
Open nicol



Large Individual:Benthonic Foraminfer

Micro Individual:Planktonic Foraminfer

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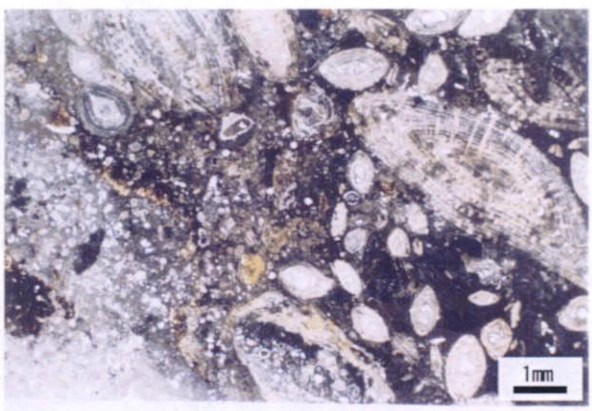
Open nicol



Photomicrographs(1)

Calcareous nannofossil

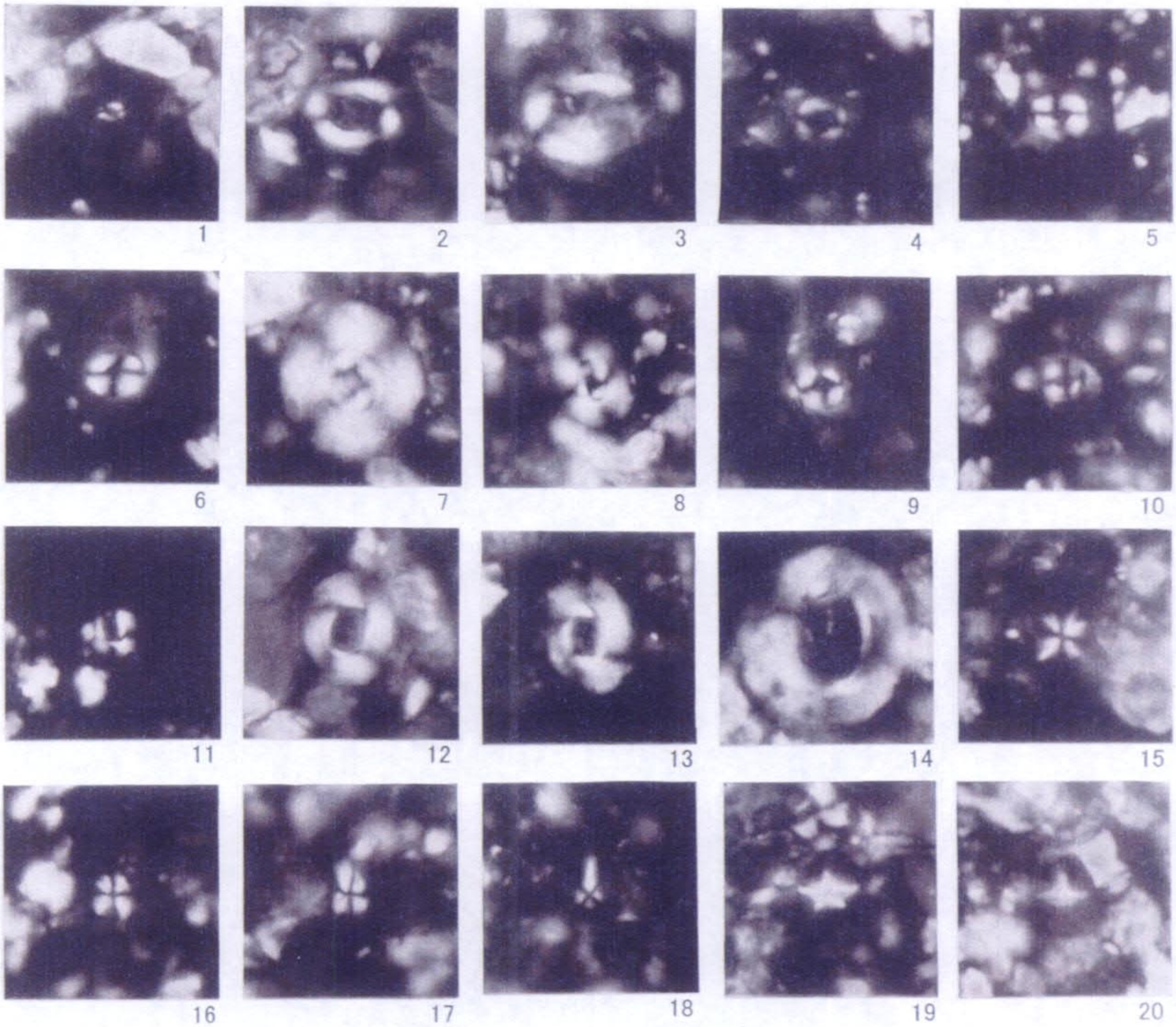
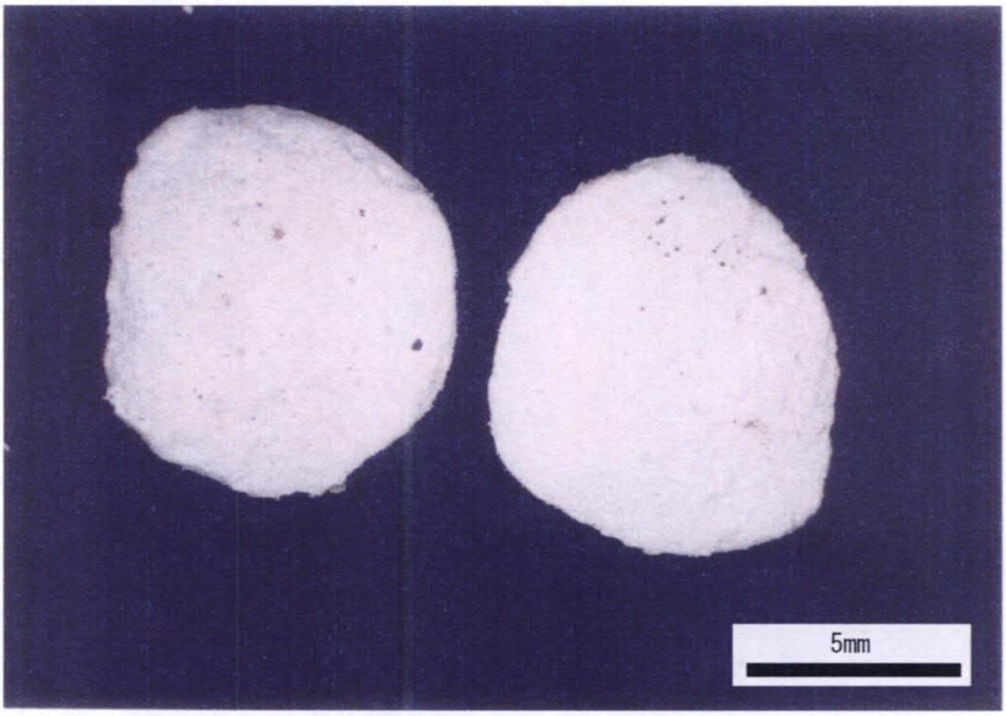


Photo No.	Species
1	*Biscutum* spp.
2	*Chiasmolithus oamaruensis*(Deflamdre)Hay et al.
3	*Chiasmolithus* aff. *solitus* (Bramlette and Sullivan)Locker
4	*Chiasmolithus* spp.
5	*Coccolithus pelagicus* (Wallich) Schiller
6	*Coccolithus* spp.
7	*Cyclicargolithus floridanus* (Roth & Hay) Bukry
8	*Cyclicargolithus floridanus* (Roth & Hay) Bukry
9	*Markalius* spp.
10	*Markalius* spp.
11	*Reticulofenestra* aff. *dictyoda* (Deflandre)Stradner and Edwards
12	*Reticulofenestra hillae* Bukry and Percival
13	*Reticulofenestra hillae* Bukry and Percival
14	*Reticulofenestra umbilica* (Levin) Martini and Ritzkowski
15	*Sphenolithus moriformis* (Bron. & Strad.)Bramlette & Wilcoxon
16	*Sphenolithus moriformis* (Bron. & Strad.)Bramlette & Wilcoxon
17	*Sphenolithus* spp.
18	*Sphenolithus* spp.
19	unknown
20	unknown

Photomicrographs(2)

Benthonic Foraminfer



Photomicrographs(3)

[Appendix Document 2] Fossil Inspection of Bottom Sediment

Samples and inspected fossils are listed in Appendix Table 1. Relevant sample processing and appropriate analysis method were determined for fossils and inspection was performed.

1. Analysis Method

Sample processing and analysis method of fossils are explained in the next.

- Foraminifers

Collected sample was water washed through 74μm sieve and dried under room temperature. Dried sample was dispersed onto a tray with mesh, and counting of fossil individuals and identification of genus and species were made under microscope. Concerning planktonic foraminifers, individuals larger than 150μm size were treated for fossil assemblage analysis. Other fossils and mineral grains were inspected as well but almost all of the sample grains are planktonic foraminifers and radiolarian fossils and volcanic materials or manganese crust grains, and other grains were seldom included.

- Nannofossils

Sample processing was done following the smear slide technique. Fresh part of sample specimen is powdered and mounted on the cover glass. The sample is immersed to a drop of water and fossil bearing sample grains are smeared evenly using toothpick and dried on the hot plate. "Light hardening agent" for permanent mounting is dropped on the sample slide glass and cover glass is carefully put on it. It is exposed under ultraviolet light in the ultraviolet box for 15 seconds and hardened and labeled.

For calcareous nannoplanktonic fossil inspection, polarizing microscope (Olympus BX-P- partly improved) was used. For identification of fossil species, individuals were inspected under × 1500 magnification, and identification excluding lower light-transmitting species *Florisphaera profunda*, individuals of nannoplankton fossils of numbers of 200 are picked up randomly. Other than that, occurrences of other fossils were inspected and the rate of appearance (frequency) was measured. At the same time, the occurrence rate of calcareous nannoplankton fossil (200 individuals) to *Florisphaera profunda* was measured.

Table 1 List of Samples for Microfossil Analysis

Sample No.		Water depth(m)	Sample depth(cm)	Sediment type	Foraminifer	Radiolarian	Nanno-plankton	Ichtyolith
03SE01MC01	FS01	4,351	0-2	Foraminiferal ooze	○		○	
	FS02	4,351	9-11	Foraminiferal ooze	○		○	
	FS03	4,351	19-21	Foraminiferal ooze	○		○	
	FS04	4,351	29-31	Foraminiferal ooze	○		○	
03SE01MC02	FS01	1,157	0-2	Foraminiferal sand	○		○	
	FS02	1,157	9-11	Foraminiferal sand	○		○	
	FS03	1,157	19-21	Foraminiferal sand	○		○	
03SE01MC03	FS01	2,184	0-2	Foraminiferal sand	○		○	
	FS02	2,184	9-11	Foraminiferal sand	○		○	
	FS03	2,184	19-21	Foraminiferal sand	○		○	
03SE01MC04	FS01	1,192	0-2	Foraminiferal sand	○		○	
	FS02	1,192	9-11	Foraminiferal sand	○		○	
	FS03	1,192	19-21	Foraminiferal sand	○		○	

2. Ocurrence

① Foraminifer

Foraminifer fossil occur all of the sample specimens . A part of the sample includes very few volcanic grains (pumice) and echinoid spines but other sediment grains are almost all plannktonic foraminifer fossils. Planktonic foraminifers included in three samples at the sampling point 03SE01MC01, are fragmented and thought receiving dissolution. On the other hand, occurrences of benthic foraminifers are small, rarely observed through all the sample specimens (Appendix Table 2). Photographs of main foraminifer fossil specimens are shown in the plate of the last of the report.

② Nannofossils

Well preserved nannofossils occurred from all of 13 samples. Species and numbers (%) are given in Appendix Table 3. Main calcareous nannoplankton specimens are given in the plate of the last of the report.

3. Geologic Age

① Foraminifer (fossil assemblages and geologic age)

In this survey, age determination was made after chronological time scale proposed by Berggren et al. (1995) (Appendix Figure 1). The datum planes shown in the Figure are applied to fossil assemblages of low latitudinal zone, and directly applicable to the survey area. Related fossil datum planes are two, 1) extinction (0.12 Ma) of pink color *Globigerinoides ruber* and 2) extinction of *Globoquadrina pseudofoliata* (0.22Ma). Important index fossil of Quaternary Time, *Globorotalia truncatulinoides* seldom occurs, but *Globigerina rubusense* (pink) and *Bolliella caldia* occur and thus all of the sample can be judged Quaternary occurrence.

a) Sample point no. 03SE01MC01 FS01 – 04 (Depth: 4,351m)

Assemblages: In the core samples, *Globigerina bulloides, Globigerinella aequilateralis, Globigerinita glutinata, Globigerinoides rubber, Globigerinoides sacculifer, Pulleniatina obliquiloculata* mainly occur. The uppermost sample FS01 has many numbers of following three species, *Globigerinita glutinata, Globigerinoides rubber, Globigerina bulloides,* but lower samples increase *Pulleniatina obliquiloculata,* and decrease *G. rubber.* As described before, core samples contain many fragmented specimens, and receive strong dissolution. The core collection depth is deep, 4,000m, and these assemblages are thought to have undertaken change of faunal assmblages by dissolution, and it is judged that the sample had many fossil assemblages weak to dissolution like genus *Globigerinoides*.

Geologic age: The lowermost of the sample FS03 (29-31cm) occur *Globoquadrina pseudofoliata* (Appendix Table 2), the geologic age is assumed earlier than 0.22Ma. The assemblages of the upper core samples, FS01 and FS02 should be younger than this age. In general, Late Pleistocene (<0.16 Ma) core samples obtained from the Equatorial Pacific Ocean occur individuals of pink color *Globigerinoides rubber* commonly. The analyzed samples do not occur *G. rubber* (pink), and it is thought to show younger age than 0.16 Ma (after Late Pleistocene).

b) Sample point no. 03SE01 MC02 FS01-04 (Depth: 1,157m)

Assemblages: On the assemblages of the core samples, five species, *Globigerina bulloides, Globigerinella aequilateralis, Globigerinita glutinata, Globigerinoides rubber, Globigerinoides sacculifer* mainly occur. Secondly, *Pulleniatina obliquiloculata* are many. Three samples (FS01 –FS03 from the bottom surface to 21 cm deep) have almost the same assemblages.

Geologic Age: The core sample does not occur effective fossil assemblages to determine geologic age. From the fact that it does not occur *Globigerinoides rubber* (pink) individual but individuals of *Globigerina rubuscens* (pink) and *Bolliella cadlida* abundantly occur, the samples seem possibly to show Late Pleistocene assemblages. Perhaps core samples are younger geologic age than 0.16 Ma (after Late Pleistocene).

c) Sample point no. 03SE01MC03 FS01-04 (Depth: 2,184m)

Assemblages: Assemblages of the core samples are, mainly *Globigerina bulloides, Globigerinella aequilateralis, Globigerinita glutinata, Globigerinoides rubber, Globigerinoides sacculifer, Globoquadrina conglomerate, Globorotalia menardii, Globorotalia tumda, Neogloboquadrina dutertrei, Pulleniatina obliquiloculata*. Of them, genus *Globigerinoides* (*G. rubber, G. sacculifer* 2 species) is the most abundant and occupies 30～40% of occurrence. *P. obliquiloculata* is second, 16～29%. Comparing upper 2 samples (FS01 and FS02) with FS03 sample, it seems to increase occurrence of *G. bulloides* and *N. dutertrei*.

Geologic Age: The core samples do not occur effective time index assemblages. But same as 03SE01MC02, *Globigerinoides rubber* (pink) individuals do not occur. It occurs *Globigerina rubuscens* (pink) and *Bolliella calida*, it has possibility of Late Pleistocene assemblage. Accordingly, the core samples of this sampling point seem younger geologic age than 0.16 Ma (after Late Pleistocene).

d) Sample point no. 03SE01MC04 FS01-04 (Depth: 1,192m)

Assemblages: Assemblages of the core samples are mainly *Globigerina bulloides, Grobigerinella aequilateralis, Globigerinita glutinata, Globigerinoides rubber, Globigerinoides sacculifer, Pulleniatina obliquiloculata*. Of them, the most abundant species is, *G. rubber*, occupies 30～40%. *G. glutinata* is the second, 15～19%. This sampling point also has tendency that *G. bulloides and N. dutertrei* of FS03 sample increases the occurrence compared to the upper core samples (FS01 and FS02).

Geologic Age: *G. bulloides* occurs in FS02, so that two samples FS02 and FS03 sample are older than 0.22 Ma, and FS01 is thought younger than 0.22 Ma. Any of three samples do not occur *Globigerinoides rubber* (pink), but occur *Globigerina rubuscens* (pink) and *Bolliella caldia* (except FS03), they are faunal assemblages of Late Pleistocene. Perhaps, core samples of this sampling point may be younger than 0.16 Ma (after Late Pleistocene).

② Nannoplankton Fossil

Calcareous nannofossils are in total 18 genera 27 species (including sp.) Late Quaternary fossils are abundant and the assemblages are characteristic. Details of the assemblages are, the occurrence of index fossil of Quaternary, *Gephyrocapsa oceanica, G. Parallela* appeared in Middle Quaternary, just upper datum plane of Jaramillo event (0.95 Ma), occurrence of small (<4 μ m) species, *Gephyrocapsa*. So that Genera *Gephyrocapsadae* are characteristically abundant. Also *Emiliania huxley*, appeared in Late Quaternary (0.25 Ma), occur from all the samples, particularly, the samples, 03SE01MC02 FS02, 03SE01MC03 FS01, 03SE01MC03 FS03, 03SE01MC04 FS01, FS02, FS03 contain more than 15%. *Helicosphaera inversa* known to appear 0.51 Ma and extinct 0.250 Ma, are barely admitted in the MC01 FS 02 sample.

All of calcareous nannofossil assemblages are characterized by Late Quaternary assemblages, but only one sample 03SE 01 MC03 FS03 occurs limited species, *Reticulofenestra pseudoumbilicus and Sphenolithus abies*, which had appeared earlier than lower Pliocene.

4. Rate of Deposition

The stratigraphic sequences of core samples are sporadic and accurate assumption is difficult.

5. Depositional Environment (Paleogeographic Province)

① Foraminifers

Paleogeography: Nine samples from 03SE01MC02 to 03SE01MC0, show high percentage on the appearance of genus *Globigerinoides*, 30 to 50%. Genus *Globorotalia*, such as *G. menardii*, *G. tumida* are typical tropical to sub-tropical assemblages. From these, thus fossils obtained by this survey are without doubt they had lived in tropical to subtropical geographic province. That is, the sediment of the samples had been deposited under similar latitude as we see today.

However, as already described, four samples of the 03SE01MC01 sampling point are collected from the depth of water of over 4,000m and such species weak to dissolution as *Globigerinoides* decreases and species strong to dissolution, *Pulleniatina*, comparatively increases the occurrence. However, compositional characteristics of fossil assemblages are not so different from other core samples, and fossil assemblages of that core samples are thought to have similar, tropical to subtropical assemblages.

Sedimentary Environment: Almost all analyzed samples occur planktonic foraminifers and seldom occur benthic foraminifers, less than 1%. *Globocassidulina subglobosa, Oridorsalis umbonatus, Epistominella exigua* occurred at the deepest sample point, 03SE01MC01(4,351m). Of them, the living depth of *Oridorsalis umbonatus* is thought to show lower middle Bathyal (800-2,500m) (Inoue, 1989; Akimoto& Hasegawa, 1989), but the core samples are deeper than this, and fossil assemblages have possibility to have transported from other place.

Other samples sporadically occur *Pullenia quinqueloba, Cassidulina carinata, C. norvangi, Pyrgo spp., Fissulina spp.*, but the assumption of living depth or paleoenvironment is difficult. But the occurrences of benthic foraminifers are very rare, and this suggests that the flux of materials from the surface to deep position had been small. The survey area is the sea area to show low saline concentration at present and the paleodepositional environment seems not so different as we see today.

6. Correlation Datum Planes and Consideration of Geologic Age of Samples

Takayama and Sato (1987) performed nannoplankton fossil zonation work on the occasion of DSDP-IPOD Leg 49 conducted at the Northwest Pacific Ocean, and they defined 12 calcareous nannoplannkton datum planes in Pleistocene formation. Successively, Sato et al. (1991) set 21 calcareous nannoplankton fossil datum planes from Middle Pliocene to Quaternary sediments on the basis of newly obtained data. At the above stated DSDP drilling site, magetostratigraphy is established, and biostratigraphic chronology of these datum planes are established correlating magnetostratigraphic data Recently, magnetostratigraphic chronology was revised by

Cande & Kent (1995) and thus biostratigraphic data are also revised (Appendix Figure 2; Sato et al., 1999). On the other hand, concerning biostratigraphic time scale in Neogene Tertiary, datum planes put code number NN by Martini (1971) are widely applied for fossil zonation. Fossil assemblages analyzed by this survey are correlated with these two reports, that is, calcareous nannoplankton fossils were correlated with datum planes of Sato et al (1999), and other fossil zonation by Martini (1971) (NN in Appendix Figure 3). The next is the correlated result.

All of 13 samples occur index fossil of Pleistocene, *Gephyrocapsa oceanica* and *G. caribbeanica. G. parallera* which defines datum plane 6 of Sato et al. (1999) occurs from all of 13 samples, but *Reticulofenestra asanoi* which defines datum plane 7 does not occur, from this, all of 13 samples are correlated to Late Quaternary. More over, *Emiliania huxleyi* is admitted all of 13 samples and the lowermost limit of this species defines the datum plane 2. From these facts, all the 13 samples are correlated to Late Quaternary age younger than 0.25 Ma.

On the other hand, 13 samples occur genus *Helicosphaera*, but the occurrence is poor and thus biostratigraphic discussion related to the extinction of *Helicosphaera inversa* (datum plane 1: 0.16 Ma) cannot be made. *H. inversa* was obtained only from the 03SE01MC01 FS02 sample. This fact suggest that the sample and the lower sediments are lie between datum plane 1 and 2, or in other words, they are possibly be correlated to the age from 0.16～0.25Ma. Concerning biostratigraphic correlation of collected 13 samples with fossil zone proposed by Martini (1971), they are correlated to NN21 of his fossil zone coding because all of the samples occur *Emilliani huxleyi* (Appendix Table 3). NN21 is Late Quaternary fossil zone.

The sample specimen 03SE01MC03 FS03 occurred small numbers of *Reticulofenestra pseudoumbilicus* and *Sphenolithus abies* individuals, whose occurrences are defined limited to older than lower Pliocene, but judging from the above examination result, these individuals are thought reworked individuals.

Table 2 List of Foraminifera Fossils

A.Planctonic foraminifera(P.f.)

Area	Sample No.		Depth (m)	Sampling Depth (cm)	Abvndance of p.f.	Preservation of p.f.	Geological time	*Beella digitata*	*Bolliella calida calida*	*Candeina nitida*	*Globigerina bulloides*	*Globigerina decoraperta*	*Globigerina falconensis*	*Globigerina quinqueloba*	*Globigerina rubescens*	*Globigerina rubescens (pink)*	*Globigerinella aequilateralis*	*Globigerinita glutinata*	*Globigerinoides conglobatus*	*Globigerinoides obliquus*	*Globigerinoides ruber*	*Globigerinoides sacculifer*	*Globigerinoides tenellus*	*Globoquadrina conglomerata*	*Globoquadrina pseudofoliata*	*Globorotalia crassaformis*	*Globorotalia ungulata*	*Globorotalia menardii*	*Globorotalia ronda*	*Globorotalia scitula*	*Globorotalia truncatulinoides*	*Globorotalia tumida*	*Globorotalia viola*	*Globorotaloides hexagona*	*Hastigerina pelagica*	*Neogloboquadrina dutertrei*	*Orbulina universa*	*Pulleniatina obliquiloculata (*	*Pulleniatina praecursor (D)*	*Pulleniatina primalis (D)*	*Sphaeroidinella dehiscens*	*Turborotalita humilis*		Total	Species Number
Kiribati	03SE01MC01	FS01	4,351	0-2	A	M	Late Pleistocene	3	3		72			5			17	178		1	100	13	8				1	1	1	1		X		4		9	X	18		4	X	1		433	16
		FS02		.9-11	A	M	Late Pleistocene				15						23	69	3		36	16						2				2		3		6		105			2			282	12
		FS03		19-21	A	M	Late Pleistocene				17	1				3	37	117	2		65	38	2	1			1	4				3		6		6		51		2				356	17
		FS04		29-31	A	M	Late Pleistocene				25					1	13	81			33	11		7	1	1		12	2	2	1	10				20		43	1	1	1			266	19
	03SE01MC02	FS01	1,157	0-2	A	G	Late Pleistocene		1		29				7	6	32	80	1		110	30		3				1				4			1	6	1	27		3		1		341	16
		FS02		.9-11	A	G	Late Pleistocene		7		34	5			1	14	28	49	3		142	36	7	2		1		5				1		2		13		16		18	1	1		378	19
		FS03		19-21	A	G	Late Pleistocene		3	2	40		4		1	12	26	82	3		111	19	4									1				6		12		4				327	15
	03SE01MC03	FS01	2,184	0-2	A	G	Late Pleistocene		3		11						23	32	6		57	60		26				22			1	14	1	1		11	2	112		7	2			388	17
		FS02		.9-11	A	G	Late Pleistocene		1		8						38	7	8		54	67		7				9				9				9		58		7		1		281	12
		FS03		19-21	A	G	Late Pleistocene		2		28					3	12	23	3		69	41		8		5		13		1		3	1			20		44		2		1		276	16
	03SE01MC04	FS01	1,192	0-2	A	G	Late Pleistocene		2		85	1			4	22	34	108	1		203	42	15					3		1				2		6	1	26		2		1		556	17
		FS02		.9-11	A	G	Late Pleistocene		3		13				2	7	29	53			136	51	3	7	1	1	X	3				X				4		44		5	1			360	16
		FS03		19-21	A	G	Late Pleistocene				62		1		8	2	11	60			139	17	2	4				3	2			1		1		15	X	15		7	X			350	17

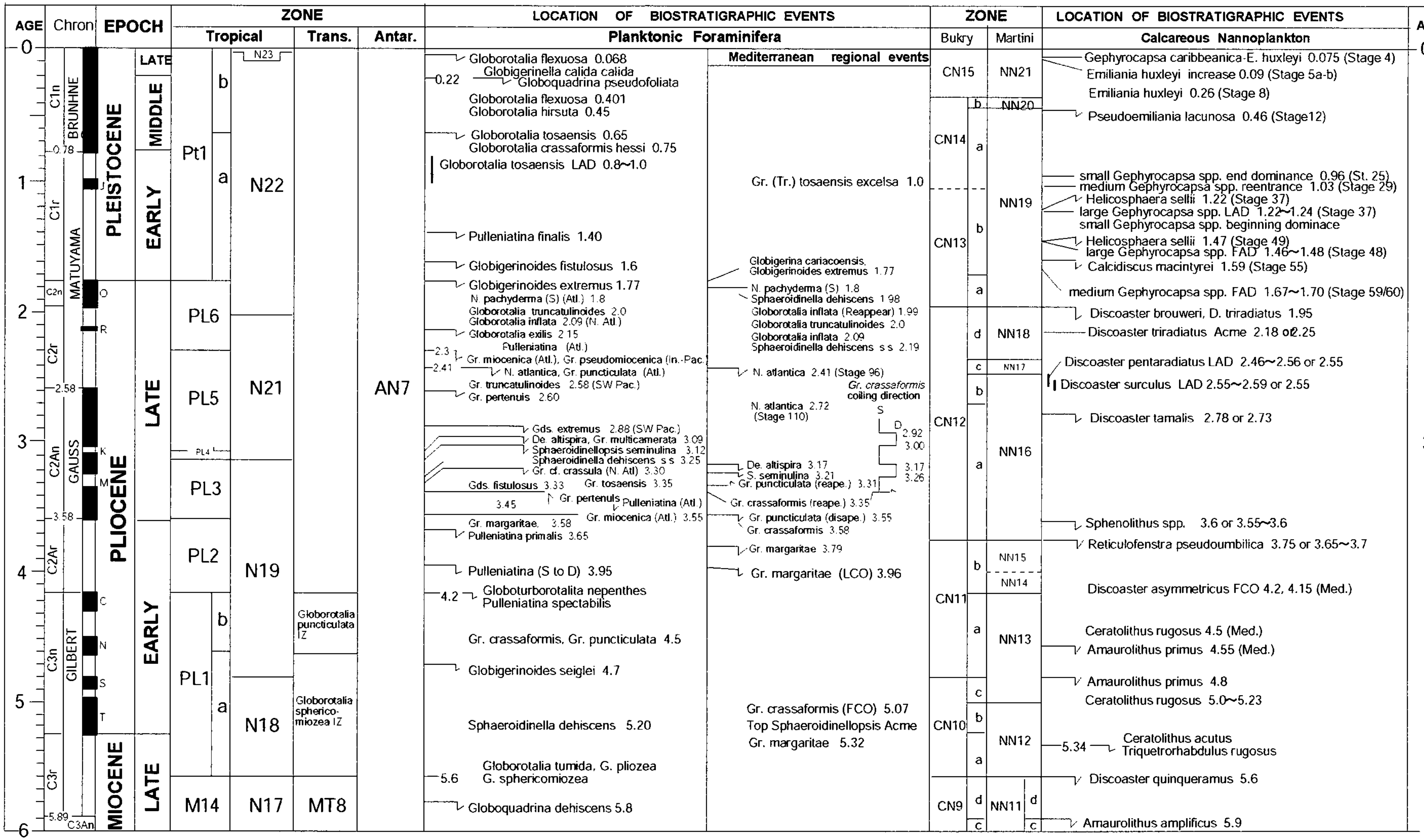
B. Benthic foraminifera(B.f.)

Area	Sample No.		Depth (m)	Sampling Depth (cm)	Abvndance of B.f.	Preservation of B.f.	Geological time	*Agglutinated species*	*Cassidulina carinata*	*Cassidulina norvangi*	*Cibicides spp.*	*Epistominella exigua*	*Fissurina sp.*	*Globocassidulina subglobo*	*Oridorsalis umbonatus*	*Pullenia quinqueloba*	*Pullenia okinawaensis*	*Siphouvigerina ampullace*	*Pyrgo spp.*	*Uvigerina aculeata*
Kiribati	03SE01MC01	FS01	4,351	0-2	R	G	Late Pleistocene					X		X	X					
		FS02		.9-11	R	G	Late Pleistocene												X	
		FS03		19-21	R	G	Late Pleistocene					X	X						X	
		FS04		29-31	R	G	Late Pleistocene				X	X	X				X			
	03SE01MC02	FS01	1,157	0-2	R	G	Late Pleistocene												X	
		FS02		.9-11	R	G	Late Pleistocene		X							X				
		FS03		19-21	R	G	Late Pleistocene	X		X			X						X	
	03SE01MC03	FS01	2,184	0-2	R	G	Late Pleistocene													
		FS02		.9-11	R	G	Late Pleistocene											X		
		FS03		19-21	R	G	Late Pleistocene													X
	03SE01MC04	FS01	1,192	0-2	R	G	Late Pleistocene	X												
		FS02		.9-11	R	G	Late Pleistocene												X	
		FS03		19-21	R	G	Late Pleistocene													

Table 3 List of Calcareons Nannofossils

Nannofossil Zone (Martini, 1971)	NN 21												
sample	03SE01MC01FS01	03SE01MC01FS02	03SE01MC01FS03	03SE01MC01FS04	03SE01MC02FS01	03SE01MC02FS02	03SE01MC02FS03	03SE01MC03FS01	03SE01MC03FS02	03SE01MC03FS03	03SE01MC04FS01	03SE01MC04FS02	03SE01MC04FS03
Calcidiscus leptoporus	8	4	2	10	9	4	12	6	3	5	4	10	7
Ceratolithus cristatus	1		+	+		+	+			1	+		
Coccolithus pelagicus				+									
Cricosphaera quadrilaminata					+								
Cyclolithella annula	+	+	+	+									
Discolithina japonica							1						
Discolithina spp.						+						1	+
Discosphaera tubifera												+	
Emiliania huxleyi	2	3	5	+	9	20	7	15	10	15	19	18	27
Gephyrocapsa caribbeanica								1					
Gephyrocapsa oceanica	18	11	14	21	9	15	24	3	11	11	8	3	7
Gephyrocapsa parallela	12	15	35	31	13	25	26	13	25	33	18	16	32
Gephyrocapsa spp. (small)	54	53	35	34	36	10	18	44	28	22	29	34	13
Helicosphaera carteri		1	+	+	1	2	1	+	1	+	1	1	+
Helicosphaera hyalina						+		+					+
Helicosphaera inversa		+											
Helicosphaera wallichii	1	1	+	+	2	1		1	+			+	
Oolithotus antillarum								1					
Reticulofenestra pseudoumbilicus										r			
Reticulofenestra spp. (small)										2			
Rhabdosphaera clavigera			+	+		+	+	1	+				+
Rhabdosphaera stylifera					+					+			+
Scapholithus fossilis			+	1	1	1	1	1	3	1	3	3	1
Sphenolithus abies										r			
Syracosphaera pulchra	+		+	1	1	3	+	+	+	+	+	1	
Umbellosphaera irregularis					1	2	1	+	1		+		1
Umbilicosphaera sibogae	4	12	9	2	18	17	9	14	18	10	18	13	12
Total number (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
No. of Florisphaera profunda to 200 coccolith	112	232	352	208	136	140	214	176	144	148	286	258	124

+: present (not counted), r: reworked



FOC, first common occurrence; Gr., Globorotalia; Gds., Globigerinoides; De., Dentoglobigerina; N., Neogloboquadrina; S., Sphaeroidinellopsis.
J, Jaramillo; O, Olduvai; R, Reunion; K, Kaena; M, Mammoth; C, Cochiti; N, Nunivak; S, Sidufjall; T, Thvera

(Berggren et al., 1995)

Fig. 1 Biostratigraphy basis of calcareous microfossil and geologic time in low latitude

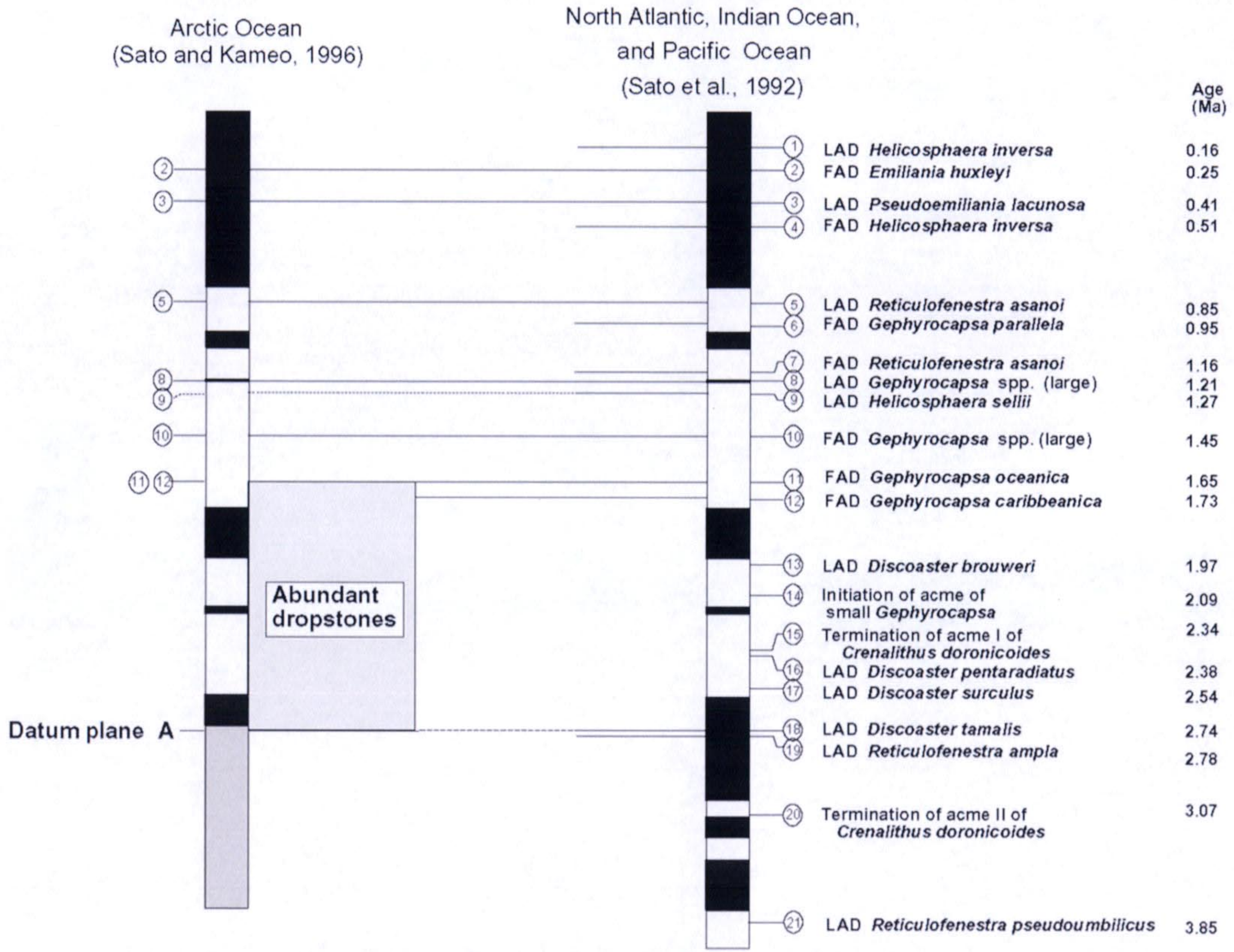


Fig. 2 Correlation of calcareous nannofossil and paleomagnetic in pliocene-quaternary (sato et al., 1999)

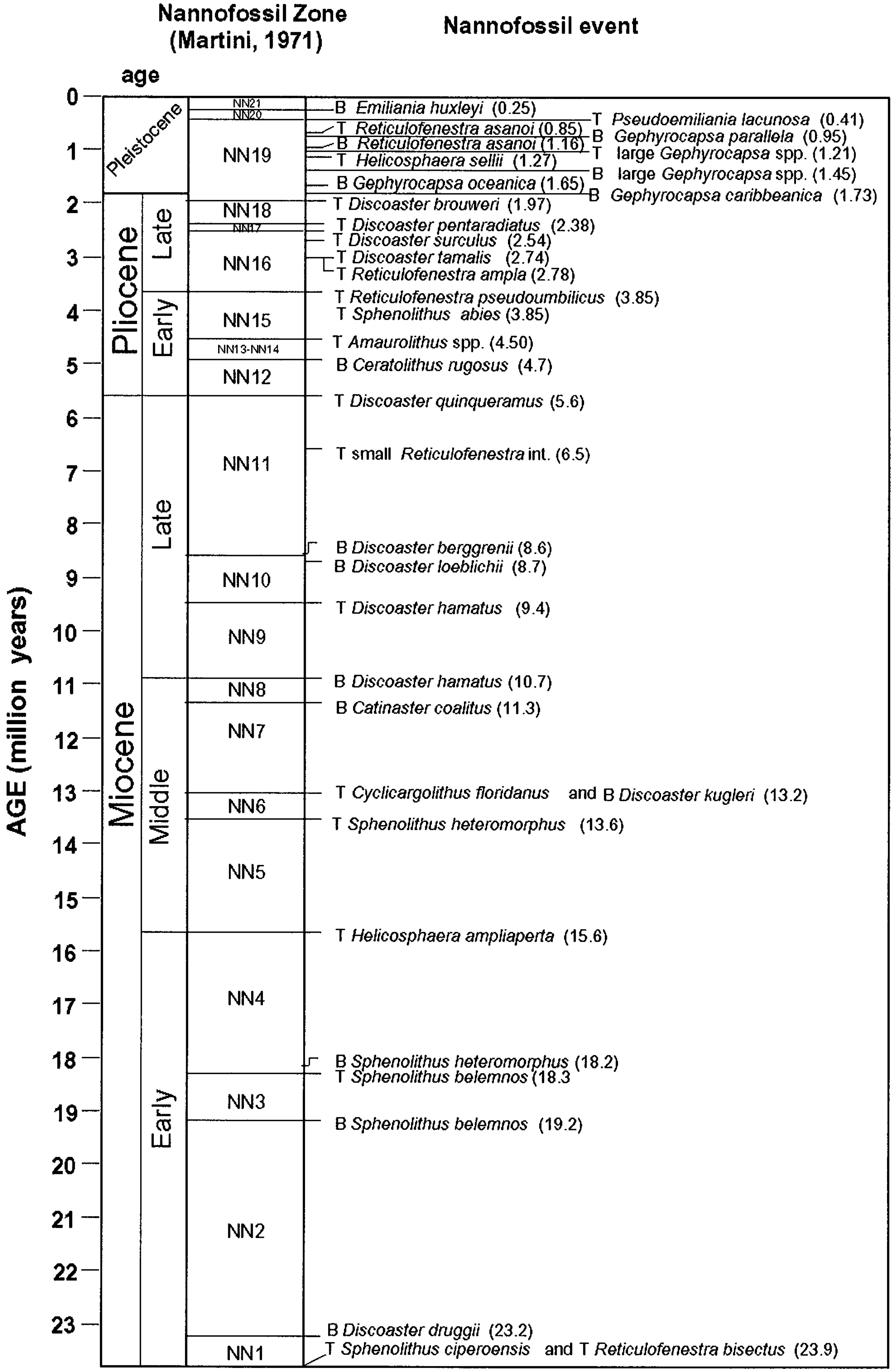
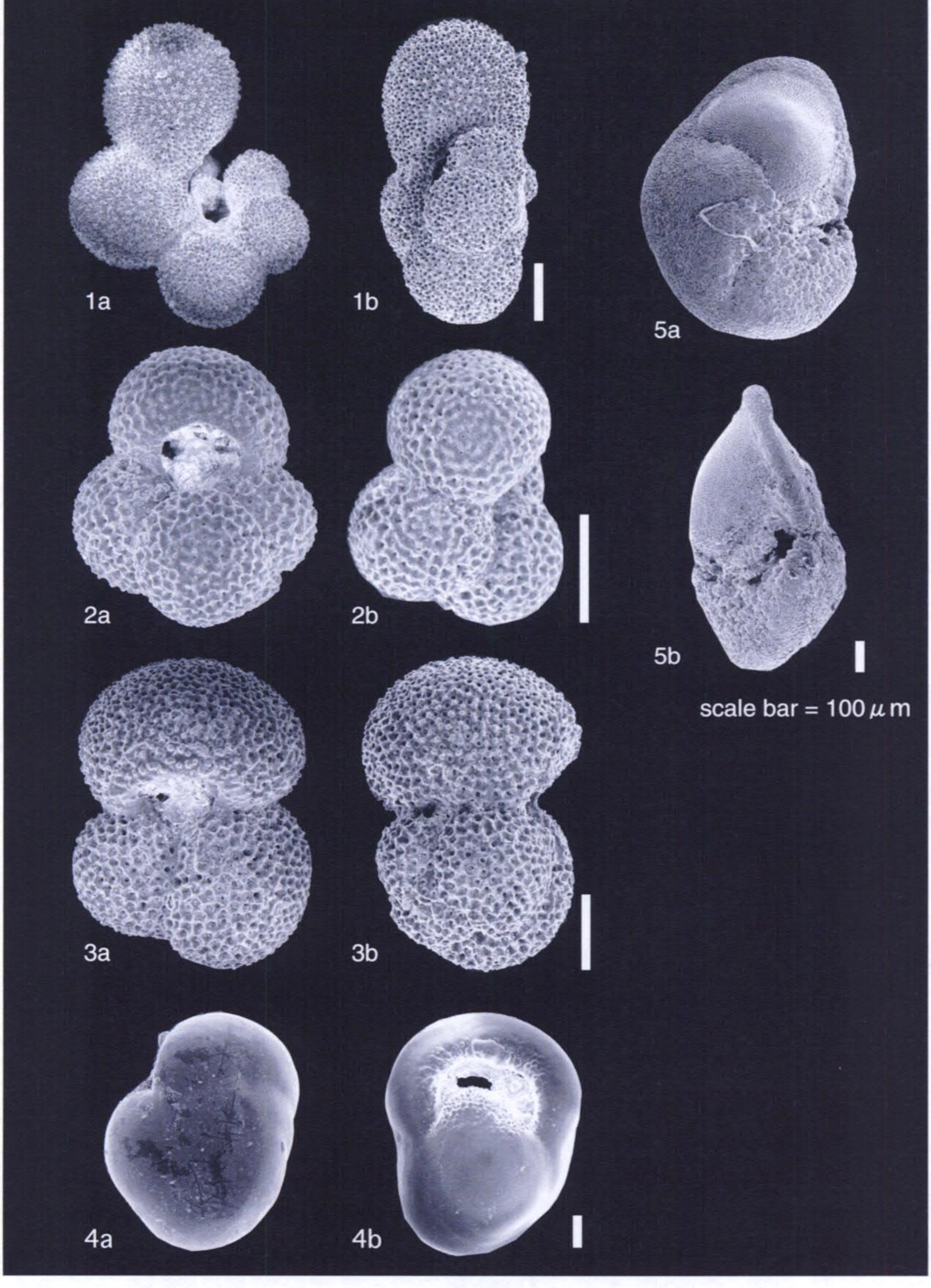


Fig. 3 Classification calcareous nannofossil zone (Martini,1971) and geologic time in Neogene - quaternary (sato,2000)

Electron Microscope Photograph of Planktonic Forafeminifera

1. Bolliella calida calida (Parker). a Umbilical view, b. Side view. Sample from 03SE01MC02-FS02.
2. Globigerina rubescens Hofker. a. Umbilical view, b. Side View. Sample from 03SE01MC02-FS02.
3. Globigerinoides ruber (d'Orbigny). a. Umbilical view, b. Side View. Sample from 03SE01MC02-FS02.
4. Pulleniatina obliquiloculata (Parker and Jones). a. Umbilical view, b. Side View. Sample from 03SE01MC02-FS02.
5. Globorotalia tumida (Brady). a. Umbilical view, b. Side View. Sample from 03SE01MC02-FS02.


1a
1b
5a
2a
2b
5b
scale bar = 100 μm
3a
3b
4a
4b

Microscopic Phographs of Nannofossils

1. Emiliania huxleyi (Lohman) Hay and Mohler,
   sample 03SE01MC02FS02

2,3.Gephyrocapsa parallela Hay and Beaudry, sample 03SE01MC03FS03

4,5. Gephyrocapsa oceanica Kamptner, sample 03SE01MC02FS02

6.Gephyrocapsa caribbeanica Boudreaux and Hay,
   sample 03SE01MC03FS01

7.Calcidiscus leptoporus (Murray & Blackman) Loeblich & Tappan
   sample 03SE01MC02FS02

8. Umbilicosphaera sibogae (Weber-van Bosse) Gaarder
   sample 03SE01MC02FS02

9. Helicosphaera wallichii (Lohmann) Boudreaux and Hay,
   sample 03SE01MC02FS02

10. Helicosphaera carteri (Wallich) Kamptner
    sample 03SE01MC02FS02

11. Helicosphaera hyaline Gaarder, sample 03SE01MC02FS02

12. Discolithina sp. Sample 03SE01MC02FS02

13. Syracosphaera pulchra Lohmann, sample 03SE01MC02FS02

14. Scapholithus fossilisDeflandre, sample 03SE01MC02FS02

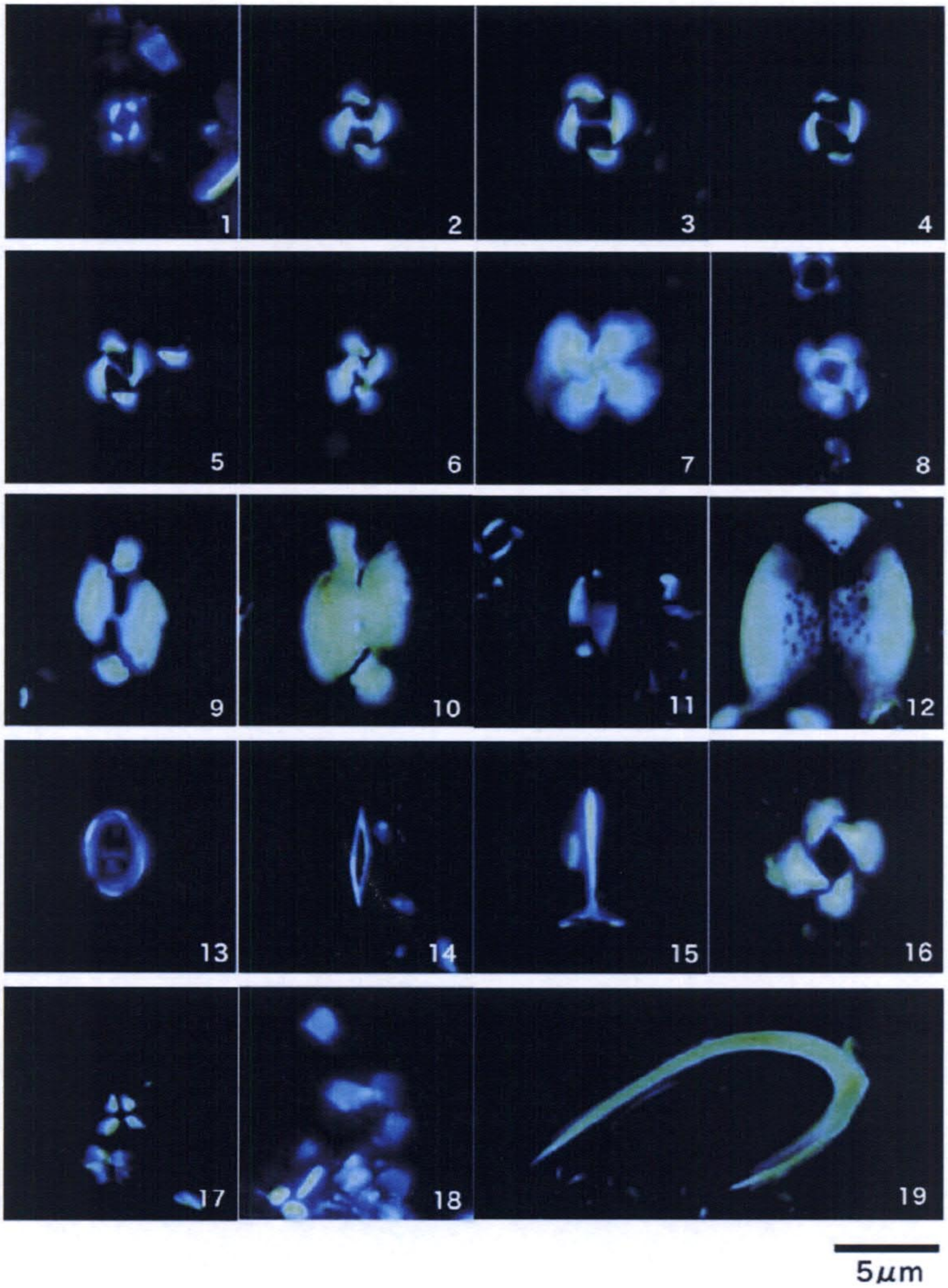
15. Rhabdosphaera clavigera Murray & Blackman
    sample 03SE01MC02FS02

16. Reticulofenestra pseudoumbilicus (Gartner) Gartner,
    sample 03SE01MC03FS03

17. Sphenolithus abies Deflandre, sample 03SE01MC03FS03

18. Florisphaera profunda Okada and Honjo, sample 03SE01MC03FS03

19. Ceratolithus cristatus Kamptner, sample 03SE01MC03FS03



Nannofossil Plate

[Appendix Document 3]　Analysis Method of Manganese Oxides

Chemical analyses of 22 samples of manganese oxides (manganese nodules, crust) were conducted at the Odate Technical Center Corp.

Eight elements (8) were analyzed for the samples including manganese nodule nuclei such as, Co, Ni, Cu, Mn, Fe, LOI, H_2O^+, H_2O^-, and thirty six(36) elements were analyzed for manganese nodules without nuclei and crust samples such as, Co, Ni, Cu, Mn, Fe, Pb, Zn, Ti, Mo, V, Si, Al, Ca, Na, K, P, Ba, Sr, Pt, LOI, H_2O^+, H_2O, REE (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). The analytical method and the detection limit are shown in Appendix Table 1.

Table 1　Analysis Method and Detection Limit

Element	Co	Ni	Cu	Mn	Fe	Pb
Method	ICP-emiss.	ICP-emiss .	ICP-emiss.	ICP-emiss.	ICP-emiss.	ICP-MS
Detection Limit	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Element	Zn	Ti	Mo	V	Si	Al
Method	ICP-MS	ICP- emiss.	ICP-MS	ICP-MS	ICP-emiss.	ICP-emiss.
Detection Limit	0.01%	0.01%	0.01%	1ppm	0.01%	0.01%
Element	Ca	Na	K	P	Ba	Sr
Method	ICP- emiss.	ICP- emiss.	ICP-emiss.	ICP-emiss.	ICP-MS	ICP-MS
Detection Limit	0.01%	0.01%	0.01%	0.01%	10ppm	1ppm
Element	Pt	Ig-loss	H_2O^+	H_2O^-	La	Ce
Method	Fire-Assey-ICP				ICP-MS	ICP-MS
Detection Limit	0.1ppm	0.01%	0.01%	0.01%	0.5ppm	0.5ppm
Element	Pr	Nd	Sm	Eu	Gd	Tb
Method	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS
Detection Limit	0.1ppm	0.5ppm	0.1ppm	0.1ppm	0.1ppm	0.1ppm
Element	Dy	Ho	Er	Tm	Yb	Lu
Method	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS
Detection Limit	0.1ppm	0.1ppm	0.1ppm	0.1ppm	0.1ppm	0.1ppm

For rare earth elements, obtained values are normalized on the basis of the value of chondrite and North American Shale Standard as below.

Table 2 REE Value used for Normalization

	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)
Chondrite	0.340	0.910	0.121	0.640	0.195	0.073	0.260
North American Shale Standars	32.00	70.00	7.900	33.00	5.700	1.240	5.200

	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)
Chondrite	0.047	0.300	0.080	0.200	0.032	0.220	0.034
North American Shale Standars	0.850		1.040	3.400	0.500	3.100	0.480

Chondrite value: after Wakita *et al.* (1971)

North American Shale Standard : after Haskin *et al.* (1968)