

日本古生物学会
報告・紀事

Transactions and Proceedings
of the
Palaeontological Society of Japan

New Series

No. 91



日本古生物学会

Palaeontological Society of Japan

September 20, 1973

Editor: Hiroshi UJIIÉ

Associate editors: Ikuwo OBATA, Yasuji SAITO, Kazuhiko UEMURA

Officers for 1973 – 1974

Honorary President: Teiichi KOBAYASHI

President: Tatsuro MATSUMOTO

Councillors (*Executive): Kazuo ASAMA,* Kiyoshi ASANO, Kiyotaka CHINZEI,* Takashi HAMADA,* Tetsuro HANAI,* Katora HATAI, Itaru HAYAMI, Kametoshi KANMERA,* Tamio KOTAKA, Tatsuro MATSUMOTO,* Tokio SHIKAMA, Tsugio SHUTO, Yokichi TAKAYANAGI,* Toshimasa TANAI, Hiroshi UJIIÉ*

Executive Committee:

General Affairs: Kiyotaka CHINZEI, Yasuhide IWASAKI

Membership: Kazuo ASAMA, Ienori FUJIYAMA

Finance: Takashi HAMADA, Naoaki AOKI

Planning: Tetsuro HANAI, Saburo KANNO

Publications

Transactions: Hiroshi UJIIÉ, Ikuwo OBATA, Yasuji SAITO, Kazuhiko UEMURA

Special Papers: Kametoshi KANMERA, Itaru HAYAMI, Tomowo OZAWA

“Fossils”: Yokichi TAKAYANAGI, Toshiaki TAKAYAMA

Fossil on the cover is *Bellerophon jonesianus* DE KONINCK
from the Late Permian Akasaka Series in Gifu Prefecture.

All communications relating to this journal should be addressed to the
PALAEOLOGICAL SOCIETY OF JAPAN
c/o Business Center for Academic Societies, Japan.
Yayoi 2-4-16, Bunkyo-ku, Tokyo 113, Japan
Sole agent: University of Tokyo Press, Hongo, Tokyo

620. PLANKTONIC FORAMINIFERA OF THE NISHIKUROSAWA
FORMATION, NORTHEAST HONSHU, JAPAN*

TSUNEMASA SAITO

Lamont-Doherty Geological Observatory of Columbia University,
Palisades, New York 10964

and

SEIJURO MAIYA

Japan Petroleum Exploration Company, Otemachi, Tokyo 100

西黒沢層産浮遊性有孔虫：秋田県男鹿半島南岸，台島部落の海岸に露出する西黒沢層から，*Globorotalia peripheroronda* BLOW and BANNER, *G. birnageae* BLOW, *G. densconnexa* SUBBOTINA, *Globigerina praebulloides pseudociperoensis* BLOW 等で特徴づけられる浮遊性有孔虫化石群を見出した。産出層準は女川層基底から約 40 m 下位の西黒沢層上部である。この化石群を構成する種のこれまでに記録された層位学的分布をもとにして西黒沢層の時代を考慮すると BLOW (1969) の Zone N. 8-N. 9 に対比出来る。Zone N. 8 と N. 9 の識別に重要な *Praeorbulina* 属の種が存在しないために，西黒沢層群集を二つの帯のどちらかに限定することは今のところ困難であるが，*G. peripheroronda* が群集の重要な構成要素である事実からすると，西黒沢層群集は N. 9 に対比するのが妥当と考えられる。*Globorotalia quinifalcata* および *Globigerinoides japonicus* の 2 浮遊性有孔虫種が新種として記載されている。齋藤常正・米谷盛壽郎

Introduction

Over most of the Japanese Islands the first major transgression occurred in early Miocene time. This transgression culminated in middle Miocene time submerging most of the Islands and depositing as much as 5,000 meters of sediment in some basins. The Neogene formations have been studied intensively not only because they are widely distributed but also because of their being reservoirs of important minerals such as petroleum,

copper and zinc. On the other hand, Paleogene sediments are locally distributed in the Japanese Islands, along the southwestern coast and on the northernmost island of Hokkaido.

A sequence of Neogene strata exposed along the coast of the Oga Peninsula, Akita Prefecture, has been the focus of particular attention since this sequence is widely recognized as a standard for the correlation of Japanese Neogene formations. There the following eight "stages" have been established in order of decreasing age (HUZIOKA, 1956; MINATO *et al.*, 1965): Nishioga, Daijima, Nishikurosawa, Onnagawa, Funakawa, Kita-

* Received March 10, 1973; read January 17, 1973 at Sendai.

ura, Wakimoto and Shibikawa Stages. The Nishioga and Daijima Stages comprise largely terrestrial and deltaic facies deposited prior to the marine transgression. The other six stages include typical marine facies, representing sediments and faunas accumulated in the Neogene sea. Thus, the Nishikurosawa Stage represents an important period in the geologic development of the Japanese Islands marking the first stage of the extensive Neogene marine transgression.

The name Nishikurosawa was first introduced by OHASHI (MS) in 1918 (*vide* CHITANI, 1925) as the Nishikurosawa beds. Its type locality was chosen on the northern coast of the Oga Peninsula, at Nishikurosawa, Oga City, Akita Prefecture, where it unconformably overlies volcanic rocks of the Nishioga Stage and consists largely of bluish-grey calcareous sandstone. The type Nishikurosawa Formation contains abundant marine faunas such as the foraminifera *Amphistegina radiata* (FICHTEL and MOLL), *Miogypsina kotoi* HANZAWA and *Operculina complanata japonica* HANZAWA; the molluscs *Chlamys kaneharai* (YOKOYAMA) and *Anadara makiyamai* (YOKOYAMA); and the echinoids *Echinolampus yoshiwarai* LORIAL and *Astriclypeus manni ambigenus* NISHIYAMA, all indicative of a shallow marine environment. The Nishikurosawa Formation crops out in the western part of the Oga Peninsula, across a distance of about 15 km, along hill-sides, brook and stream banks, road cuts and sea coast, in a trend striking northwest-southeastward. It is only 20 m thick at the type locality but thickens considerably southward attaining a thickness of about 250 m on the southern coast of the Peninsula. The change in thickness is also accompanied by facies changes and, on the southern

coast, the formation is largely composed of a grey, thinly-bedded siltstone, underlain by a thin basal conglomerate bed (HUZIOKA, 1959). These two sections of the Nishikurosawa Formation have been regarded as the type section of the Nishikurosawa Stage, the northern section representing shallow-water facies and the southern section characterized by shallow to moderately deep water facies (see MINATO *et al.*, 1965).

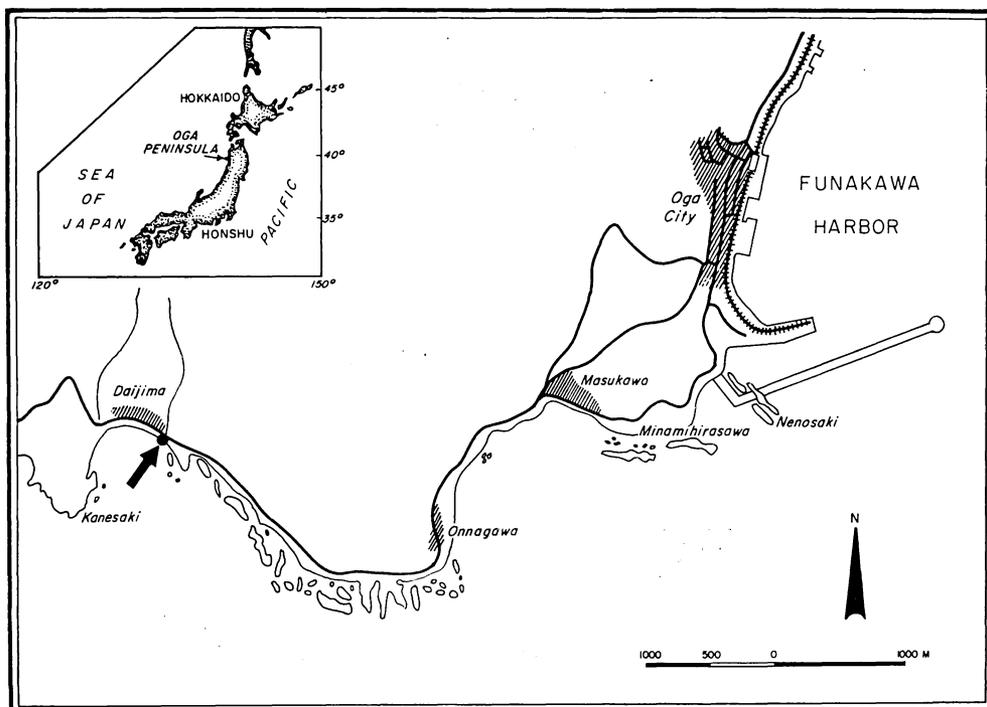
The faunas of the Nishikurosawa Formation have received considerable attention. Molluscan fossils have been described by HATAI (1938), NOMURA and HATAI (1938) and KOTAKA (1957). Larger benthonic foraminifera have been studied by YABE (1927, 1933), HANZAWA (1935, 1964), UJIIÉ (1966) and MATSUMARU (1971). Occurrences of benthonic smaller foraminifera have been listed by HUZIOKA (1959) and IKEBE (1962).

The age of the Nishikurosawa Formation has so far been discussed largely in the light of the two larger benthonic foraminifera *Miogypsina kotoi* HANZAWA and *Operculina complanata japonica* HANZAWA. YABE (1927), in recognizing a similarity of these two larger foraminifera with those from the Tertiary of Europe, assigned a Burdigalian (middle Miocene) age to the Nishikurosawa Formation. However, in proposing the existence of two separate stratigraphic horizons characterized by distinct larger benthonic foraminiferal assemblages in Japan, HANZAWA (1950) reassigned a Helvetian age to those strata containing *Miogypsina kotoi* and *Operculina complanata japonica* assemblage and a Burdigalian age to those strata having *Lepidocyclina* assemblage. However, no single stratigraphic sequence bearing the two faunas superposed one upon the other has been found in Japan.

Field and laboratory procedures

Although the type section of the Nishikurosawa Formation has been intensively searched for planktonic foraminifera, no planktonic species have so far been reported. The shallow marine facies of the type Nishikurosawa Formation (indicated by the occurrence of benthonic foraminifera *Operculina complanata japonica*, *Miogypsina kotoi*, *Florius kidoharensis* (FUKUDA), *Ammonia tochiensis* (UCHIO), *Elphidium* sp., and *Cibicides refulgens* MONTFORT) is likely to be the deciding factor for the absence

of planktonic foraminifera. A well preserved planktonic foraminiferal assemblage described here was recovered from an exposure of the Nishikurosawa Formation on the beach of Daijima at the confluence of a small stream with the sea near the eastern edge of Daijima Village, Oga City, Akita Prefecture, Japan (Text-fig. 1). This sample was taken approximately 40 m below a glauconitic sandstone bed of the basal Onnagawa Formation and lies within the upper part of the Nishikurosawa Formation, which has a total thickness of about 250 m in this area.



Text-fig. 1. Location of sample used in this study.

Most of the species recovered from this locality possess a fragile, thin, coarsely perforate wall, whereas the rock sample consisting of greenish-grey sandy siltstone was highly indurated.

Therefore, a special rock maceration technique was needed to extract foraminifera. Crushed rocks of nut-size were placed in a beaker and then oven-dried for two hours at a temperature of about

100°C. Then boiling water saturated with sodium sulphate (Na_2SO_4) was poured over the rocks until all rock-pieces were soaked with the liquid. After allowing about 30 minutes for the solution to completely saturate the rocks, the excess solution was drained off and the beaker was placed in a cool, dry place for about one week. By then the rock specimens were completely disintegrated due to the growth of sodium sulphate crystals inside the pore space. The disintegrated rocks were then boiled in water with the addition of 1-2% volume of sodium hexametaphosphate. The sample was finally wet-sieved with a standard 200 mesh sieve.

Planktonic foraminifera

Since BERGGREN (1972) proposed a refined Cenozoic radiometric time-scale to which planktonic microfossil zonal schemes can be related, the planktonic foraminiferal assemblage of the Nishikurosawa Formation offers an excellent opportunity to document its precise position within the world-wide chronostratigraphic framework and to date the time of Neogene transgression over the Japanese Islands. Three species make up the majority of the fauna: *Globorotalia peripheroronda* BLOW and BANNER, *G. denseconnexa* SUBBOTINA and *Globigerina praebulloides praebulloides* BLOW. The other species identified are: *Globigerina woodi* JENKINS, *G. praebulloides pseudociperoensis* BLOW, *G. angustiumbilicata* BOLLI, *Globorotalia birnageae* BLOW, *G. quinifalcata* SAITO and MAIYA n. sp., *Globigerinita glutinata* (EGGER), *Globoquadrina obesa* AKERS and *Globigerinoides japonicus* SAITO and MAIYA n. sp. Text-fig. 2 shows the ranges of these species as presently understood in terms of the zonation of BLOW (1969).

Because the Nishikurosawa Formation was deposited in a rather shallow-water environment in a high northerly latitude (40°N), the fauna like those of European type sections, is characterized by a small number of species, precluding a full representation of those species living contemporaneously in deeper-tropical waters. Thus, species diversity is low, and the lack of certain species cannot positively be taken as evidence for a specific zonal assignment. Therefore, a correlation can best be achieved by those species that are present. On the presence of *G. birnageae*, *G. peripheroronda* and *Globoquadrina obesa*, the Nishikurosawa can be assigned to the interval encompassing zones N.8 and N.9 of BLOW (1969). *G. denseconnexa* has not been recorded previously from the Far East Neogene sequences but has been reported by PARKER (1964) from the Experimental Mohole section near Guadalupe Island, Mexico. SUBBOTINA *et al.* (1960) reported it as ranging from the Oligocene to the Helvetian-Tortonian.

Although this is the first report of planktonic foraminifera from the Nishikurosawa Formation, the planktonic foraminifera from other formations assignable to the Nishikurosawa Stage have been reported. These are the Higashinai Formation of the Noto Peninsula (ASANO, 1962; SAITO, 1963), Uyashinai Formation of Akita Prefecture (SAITO, 1963) and the Nanatani Formation of Niigata Prefecture (SHINBO and MAIYA, 1971), and represent marine facies deeper than that of the type Nishikurosawa Formation. In the upper part of these formations, the extinction point of *Globorotalia peripheroronda* was observed to occur near the first appearance of *G. praemenardii* CUSHMAN and STAINFORTH, both species thus ranging concurrently for a short stratigraphic interval. BLOW

Pl. 17, fig. 1a-c

Globigerina praebulloides BLOW, 1959, pp. 180, 181, pl. 8, fig. 47a-c; JENKINS, 1960, p. 352, pl. 2, fig. 1a-c; SAITO, 1963, p. 187; HUANG, 1969, pl. 2, figs. 48, 49; BANDY and INGLE, 1970, figs. 7, 18, 19.

Globigerina praebulloides praebulloides BLOW. BLOW, 1962, pp. 92, 93, pl. 9, figs. 1, 2.

Remarks:—This species is distinguished from *G. bulloides* by its elongate equatorial profile, the final chamber which increases rapidly in size, and a rather low-arched aperture with a lip. It has a smoother chamber wall than *G. woodi*. Maximum diameter of figured specimen: 0.46 mm.

Globigerina praebulloides
pseudociperoensis BLOW, 1969

Pl. 17, fig. 4a-c

Globigerina praebulloides pseudociperoensis BLOW, 1969, pp. 381-382, pl. 17, figs. 8, 9.

Remarks:—This subspecies is distinguished from the Oligocene *G. ciperoensis ciperoensis* BOLLI by the more rapidly opening and higher spire. Also in this subspecies, chambers increase in size more gradually than those of *G. ciperoensis*. It also differs from *Globigerina concinna* REUSS in its much smaller umbilicus and a low-arched aperture. Maximum diameter of figured specimen: 0.22 mm.

Globigerina woodi JENKINS, 1960

Pl. 17, figs. 2a, b, 3

Globigerina woodi JENKINS, 1960, p. 352, pl. 2, fig. 2a-c; TAKAYANAGI and SAITO, 1962, p. 91, pl. 25, fig. 6a-c; SAITO, 1963, p. 188; JENKINS, 1965b, p. 117, pl. 17; JENKINS and ORR, 1972, p. 1090, pl. 111, figs. 10-12.

Globigerina woodi woodi JENKINS. JENKINS, 1971, pp. 159, 160, pl. 18, figs. 548-550.

Remarks:—This species is characterized by having a coarsely perforate wall, a high-arched aperture with rim, and U-shaped sutures. Maximum diameter of figured specimens: 0.32 mm.

Globigerina angustiumbilitata BOLLI, 1957

Pl. 17, figs. 5, 6a, b

Globigerina ciperoensis angustiumbilitata BOLLI, 1957, p. 109, pl. 22, figs. 12, 13.

Globigerina angustiumbilitata BOLLI. BLOW, 1959, p. 172, pl. 7, figs. 2a-c; TAKAYANAGI and SAITO, 1962, pp. 82, 83, pl. 28, figs. 3-9; SAITO, 1963, p. 183.

Remarks:—This species has been regarded as the ancestor of *G. pachyderma* by SAITO (*op. cit.*) and of *G. quinqueloba* by ASANO *et al.* (1968). It is characterized by a very small interiomarginal aperture, which is often concealed underneath a distinct lip.

Family Globorotaliidae CUSHMAN, 1927

Genus *Globorotalia* CUSHMAN, 1927

Globorotalia birnageae BLOW, 1959

Pl. 18, figs. 1a, b, 2

Globorotalia birnageae BLOW, 1959, pp. 210, 211, pl. 17, fig. 108a-c; SAITO, 1963, p. 174, pl. 56, fig. 3a-c; BLOW, 1969, p. 346, pl. 34, figs. 7, 8.

Remarks:—This short-ranging species has been reported sporadically only from the Caribbean region and Japan. This species has five to six chambers in the last whorl, most of the Nishikurosawa specimens being five-chambered. It differs from *G. siakensis* in being consistently much smaller in size and in having an almost closed umbilicus. It is also distinguished from *G. peripheroronda* in having more circular outline and rather

tangentially elongated chambers as viewed from the spiral side. Maximum diameter of figured specimens: 0.20-0.24 mm.

Globorotalia peripheroronda BLOW
and BANNER, 1966

Pl. 17, figs. 7a, b, 8

Globorotalia barisanensis (sic) LEROY. STAINFORTH, 1948, p. 120, pl. 26, figs. 24-26.

Globorotalia fohsi barisanensis LEROY. BOLLI, 1957, p. 119, pl. 28, fig. 8a-c; CHANG, 1959 (part), pp. 68, 69, pl. 5, figs. 6, 7 (not figs. 8, 9); SAITO, 1963, p. 176, pl. 53, figs. 3, 4; HUANG, 1963 (part), p. 165, pl. 5, fig. 2a-c (not fig. 1a-c); JENKINS, 1972, pl. 29, figs. 9-11.

Globorotalia fohsi barisanensis (LEROY). BLOW, 1959, p. 212, pl. 17, figs. 110, 111a-c.

Globorotalia (*Turborotalia*) *peripheroronda* BLOW and BANNER, 1966, p. 294, pl. 1, fig. 1a-c, pl. 2, figs. 1-3.

Globorotalia fohsi peripheroronda BLOW and BANNER. OLSSON, 1972, pp. 170-172, figs. 4-6.

Not *Globorotalia barisanensis* LEROY, 1939.

Remarks:—This is probably one of the most widely recorded Miocene planktonic foraminifera (JENKINS, 1965a, p. 266). It is characterized by a generally lobate equatorial periphery, fairly deeply incised sutures on the spiral side, and a particularly distinct sinuous suture between the last and penultimate chambers on the spiral side. Maximum diameter of figured specimens: 0.27-0.31 mm.

Globorotalia denseconnexa
SUBBOTINA, 1960

Pl. 18, figs. 3, 4a, b

Globorotalia denseconnexa SUBBOTINA, 1960, pp. 67-69, pl. 13, figs. 4-6; PARKER, 1964, p. 631, pl. 102, figs. 10-12.

Remarks:—As PARKER (*op. cit.*), the Nishikurosawa forms were unable to be compared with topotypes or plesiotypes of SUBBOTINA's species. Our specimens are closely comparable with those described from the Experimental Mohole cores by PARKER in that they are coarsely perforate for their size and have five to six chambers which are bound by short, gently-curving sutures on the spiral side. Maximum diameter of figured specimens: 0.24-0.26 mm.

Globorotalia quinifalcata SAITO
and MAIYA, n. sp.

Pl. 18, figs. 5a-c, 6a-c

Globorotalia scitula (BRADY) subsp. *praescitula* BLOW. JENKINS, 1960, p. 366, pl. 5, fig. 62a-c.

Globorotalia scitula praescitula BLOW. SAITO, 1963, p. 181, pl. 53, fig. 6a-c.

Description:—Test low trochospiral, umbilico-convex, spiral side slightly convex, umbilical side vaulted; spire opening fairly rapidly, with four to five chambers in the last whorl; equatorial periphery weakly lobulate, uniformly perforate, without carina or pseudo-carina; axial periphery rounded; sutures of the spiral side depressed and strongly curved; sutures of the umbilical side depressed, slightly sinuous to radial; chambers almost crescent-shaped as seen from the spiral side; aperture interior-marginal, umbilical-extraumbilical, a low arch with a distinct lip; wall calcareous, perforate. Maximum diameter of holotype 0.24 mm; paratype (fig. 6a-c) 0.25 mm.

Remarks:—This species differs from *G. peripheroronda* in having chambers more tangentially elongate, a more strongly vaulted umbilical side, and gently curving sutures on the spiral

side. This form has frequently been misidentified as *G. praescitula* BLOW by previous authors. Our examination of BLOW's holotype indicates that *G. praescitula* is a rather unique form having four strongly lobulate chambers in the last whorl (pl. 18, fig. 7a-c). It differs from *G. quinifalcata*, n. sp. in having more strongly lobulate chambers on the spiral side, a distinctly lobate equatorial periphery and more strongly curved sutures on the spiral side, and a much deeper umbilicus. The specimen described as *G. scitula praescitula* by PARKER (1964) from the Experimental Mohole core is, in our opinion, not *G. praescitula* BLOW but synonymous with *G. quinifalcata* because of its distinctly umbilico-convex test and the last whorl consisting of five, rather than four, less lobulate chambers. This new species is widely distributed over the Japanese Islands and occurs commonly in association with *G. peripheroronda* BLOW and BANNER. *G. quinifalcata* closely resembles *Globorotalia canariensis* (D'ORBIGNY) var. *minima* AKERS, the holotype of which is here re-illustrated (pl. 18, fig. 8a-c). However, *G. minima* can be distinguished by having a distinctly compressed periphery, and a pseudocarina

in the earlier chambers of the last whorl. Since the specimens of this species are poorly preserved in the Nishikurosawa Formation, the types of *G. quinifalcata* are chosen from the Hojuji Formation of the Noto Peninsula, Japan. The foraminiferal assemblage of the Hojuji Formation is closely comparable with the present Nishikurosawa fauna in species composition.

The specific name is from the Latin *quini*, five and *falcata*, sickle-shaped, referring to the five tangentially elongate chambers of the last whorl as seen from the spiral side.

Type locality:—Sample N-H-13, middle part of the Hojuji Formation, from a small road-side cliff in the village of Go, on the north side of the road, about 3 km west of the Ukai railroad station, Ukai City, Kanazawa Prefecture, Japan; in a dark grey diatomaceous mudstone.

Genus *Globigerinita* BRONNIMANN, 1951

Globigerinita glutinata (EGGER), 1893

Pl. 19, fig. 1a-c

Globigerina glutinata EGGER, 1893, p. 371, pl. 13, figs. 19-21; TAKAYANAGI and SAITO, 1962, pp. 86-88, pl. 27, figs. 13-17; SAITO,

Explanation of Plate 17

Fig. 1a-c. *Globigerina praebulloides praebulloides* BLOW.

1a, Spiral view of hypotype (NSMT 660). 1b, Side view. 1c, Umbilical view. ×102.

Figs. 2a-c, 3. *Globigerina woodi* JENKINS.

2a, Spiral view of hypotype (NSMT 662). 2b, Side view. 2c, 3, Umbilical view of hypotype (NSMT 663). ×128.

Fig 4a-c. *Globigerina praebulloides pseudociperoensis* BLOW.

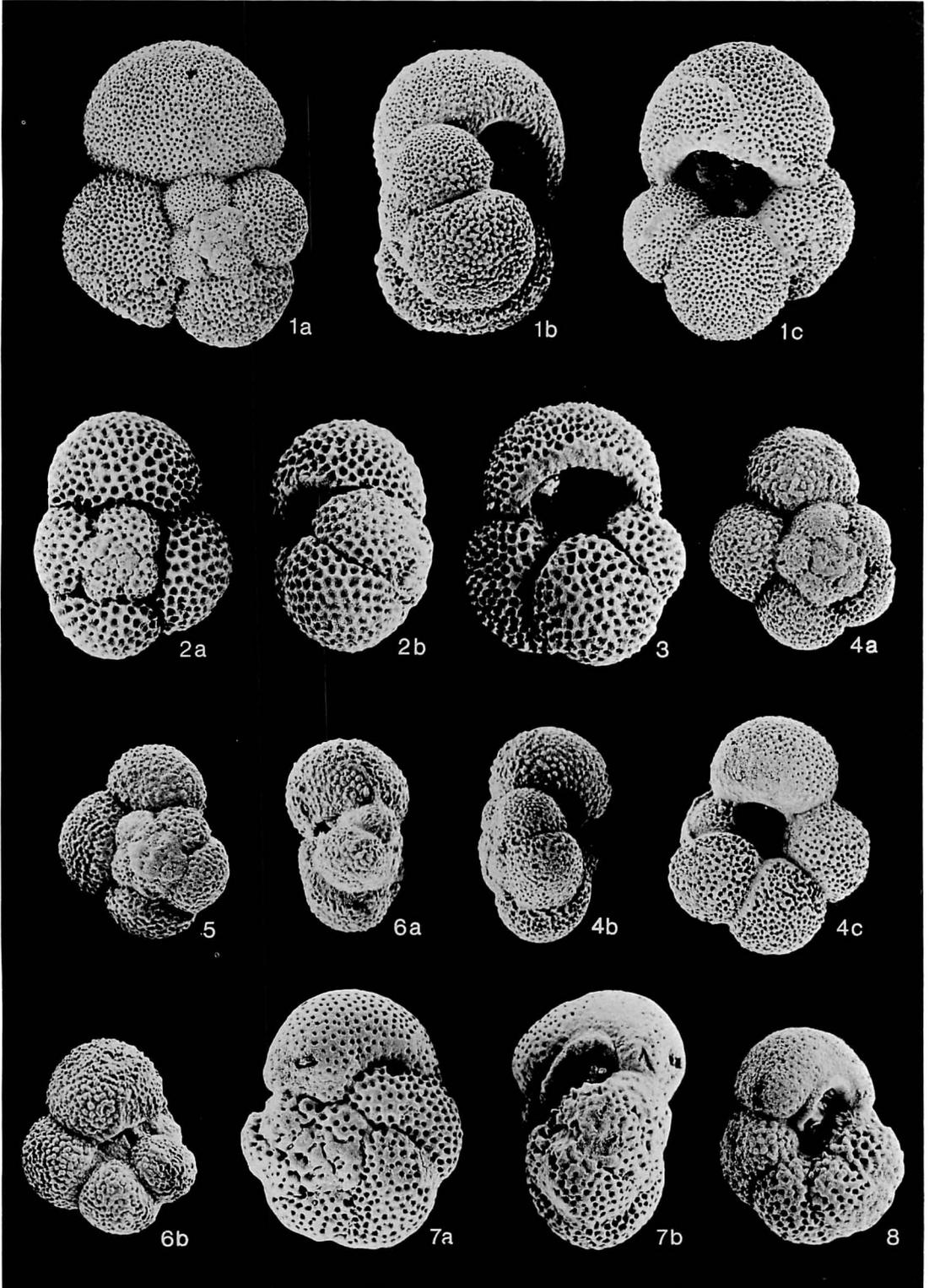
4a, Spiral view of hypotype (NSMT 661). 4b, Side view. 4c, Umbilical view. ×145.

Figs. 5, 6a-b. *Globigerina angustiumbilitata* BOLLI.

5, Spiral view of hypotype (NSMT 664). 6a, Side view of hypotype (NSMT 665). 6b, Umbilical view. ×145.

Figs. 7a-b, 8. *Globorotalia peripheroronda* BANNER and BLOW.

7a, Spiral view of hypotype (NSMT 668). 7b, Side view. 8, Umbilical view of hypotype (NSMT 669). ×145.



1963, p. 185, pl. 56, fig. 4.

Globigerinita glutinata (EGGER). PARKER, 1962, pp. 246-249, pl. 9, figs. 1-16; HUANG, 1967, p. 187, pl. 16, fig. 6a, b.

Remarks:—This species usually has three and a half inflated chambers in the last whorl, a small umbilicus, a low-arched elongate umbilical aperture with a thin lip, and an irregular-shaped umbilical bulla with numerous infralaminar apertures. It also has a thin but very finely perforated wall. The umbilical bulla of the figured specimen broke off during the sample preparation process, and only a fraction of it can now be seen as a faint raised ring on the apertural face. The maximum diameter of figured specimen: 0.28 mm.

Genus *Globoquadrina* FINLAY, 1947

Globoquadrina obesa AKERS, 1955

Pl. 19, figs. 2a-c, 3a-c

Globoquadrina obesa AKERS, 1955, p. 661, pl. 65, fig. 5a-c.

Not *Globoquadrina larmeyi obesa* AKERS. BLOW, 1969, p. 342, pl. 28, figs. 7, 9.

Remarks:—The holotype of *Globoquadrina obesa* AKERS (USNM P 4758) in the collections of the U. S. National Museum of Natural History, Washington, D. C. has been examined. The type figure of AKERS (*op. cit.*) is a fairly good representation of the specimen, portraying three inflated chambers in the last whorl. In the umbilical view, this species closely resembles *Globigerina tripartita* KOCH of BANNER and BLOW (1962, pl. 10, figs. D-F), but differs in having a broader apertural face which slopes more gently towards the umbilicus. The specimen identified by BLOW (1969, *op. cit.*) as *G. larmeyi obesa* AKERS is considered to be different from *G. obesa* AKERS because

of its final whorl consisting of four, rather than three, distinct chambers. The Nishikurosawa specimens are closely comparable with the holotype in that all have three inflated chambers in the final whorl and a distinct apertural face of the last chamber on the umbilical side. Maximum diameter of figured specimens: 0.31-0.42 mm.

Genus *Globigerinoides* CUSHMAN, 1927

Globigerinoides japonicus SAITO

and MAIYA, n. sp.

Pl. 19, figs. 4a-b, 5a-b, 6a-b

Description:—Test free, medium in size for the genus, moderately high trochospire, equatorial profile ovoid, equatorial periphery slightly lobulate; axial profile suboval, axial periphery broadly rounded; chambers rounded, inflated, fairly rapidly and almost uniformly increasing in size, four chambers making up each whorl, in all three whorls visible; intercameral sutures depressed, increasingly so during the ontogeny, becoming almost incised between the last few chambers; only two apertures present on the test exterior; primary aperture interiomarginal, a low intraumbilical arch, often with a narrow rim; single spiral supplementary sutural aperture, small hole or crescent-shaped opening with no rim, situated at the junction of the last intercameral suture and spiral sutures; wall calcareous, thick, markedly cancellate and punctate. Maximum diameter of holotype 0.32 mm; paratype (fig. 4a-b) 0.28 mm; paratype (fig. 6a-b) 0.32 mm.

Remarks:—This species is closely related to forms referred by workers to *Globigerinoides trilobus* (REUSS), *G. quadrilobatus* (D'ORBIGNY) and *G. sacculifer* (BRADY), together with various combi-

nations of these names and so-called subspecies. It is distinguished as a separate species because of its single spiral supplementary aperture and a rather high trochospiral test for the genus. There is considerable morphological resemblance between this species and *Globigerina woodi* JENKINS, although the former has a distinct supplementary aperture and, therefore, belongs to the genus *Globigerinoides*. This species has so far been found only in the Nishikurosawa Formation and very little is known about its stratigraphic range and geographic distribution.

Acknowledgements

The samples used for this study were collected in September, 1971, during the U. S.—Japan cooperative field work of marine Neogene sediments exposed along the Sea of Japan coast. Participation of both Japanese and U. S. scientists in the work was made possible with financial support from the Japan Society of the Promotion of Science and the U. S. National Science Foundation (National Science Foundation Grant No. GA 20211).

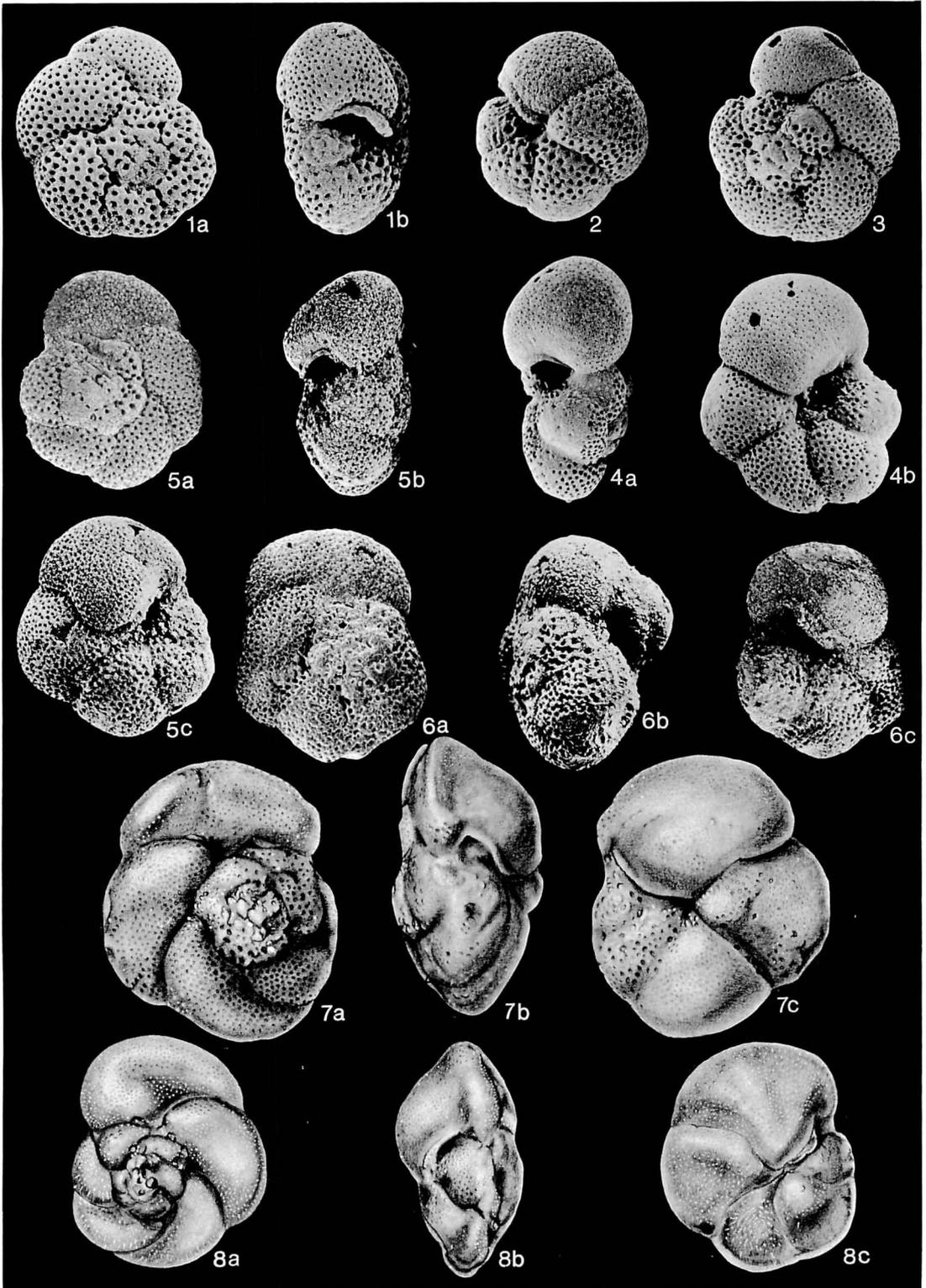
The authors are especially grateful to Dr. Yutaka IKEBE, a member of the Board of Directors of the Japan Petroleum Exploration Company for making available the company facilities for the field work to the project. We wish to thank Dr. Yasumochi MATOBA, Institute of Mining Geology, Akita University for leading the field trip to the Oga Peninsula and indicating the presence of planktonic foraminifera at the Daijima locality.

The joint laboratory work of the authors was made possible by the Japan Petroleum Exploration Company for having made possible S. MAIYA's visit to the Lamont-Doherty Geological Observatory where research on the sample and preparation of the manuscript were conducted.

Miss Dee BREGER took the scanning electron micrographs of the specimens illustrated, and Miss Linda Lee MURPHY typed and proofed the manuscript. This assistance is greatly appreciated. Appreciation is also expressed to Dr. L. H. BURCKLE and Mr. P. R. THOMPSON for critically reviewing the manuscript and making many helpful suggestions.

Explanation of Plate 18

- Figs. 1a-b, 2. *Globorotalia birnageae* BLOW.
1a, Spiral view of hypotype (NSMT 666). 1b, Side view. 2, Umbilical view of hypotype (NSMT 667). $\times 145$.
- Figs. 3, 4a-b. *Globorotalia denseconnexa* SUBBOTINA.
3, Spiral view of hypotype (NSMT 670). 4a, Side view of hypotype (NSMT 671). 4b, Umbilical view. $\times 145$.
- Figs. 5a-c, 6a-c. *Globorotalia quinifalcata* SAITO and MAIYA, new species.
5a, Spiral view of holotype (NSMT 672). 5b, Side view. 5c, Umbilical view. 6a, Spiral view of paratype (NSMT 673). 6b, Side view. 6c, Umbilical view. $\times 145$.
- Fig. 7a-c. *Globorotalia scitula* (BRADY) subsp. *praescitula* BLOW, 1959 [= *Globorotalia praescitula* BLOW], holotype (USNM 625713) reillustrated.
7a, Spiral view. 7b, Side view. 7c, Umbilical view. $\times 149$.
- Fig. 8a-c. *Globorotalia canariensis* (D'ORBIGNY) var. *minima* AKERS, 1955 [= *Globorotalia minima* AKERS], holotype (USNM P4754) reillustrated.
8a, Spiral view. 8b, Side view. 8c, Umbilical view. $\times 145$.



The laboratory work was supported by National Science Foundation Grants GA 35463X and GA 29460. This is Lamont-Doherty Geological Observatory of Columbia University Contribution No. 2003.

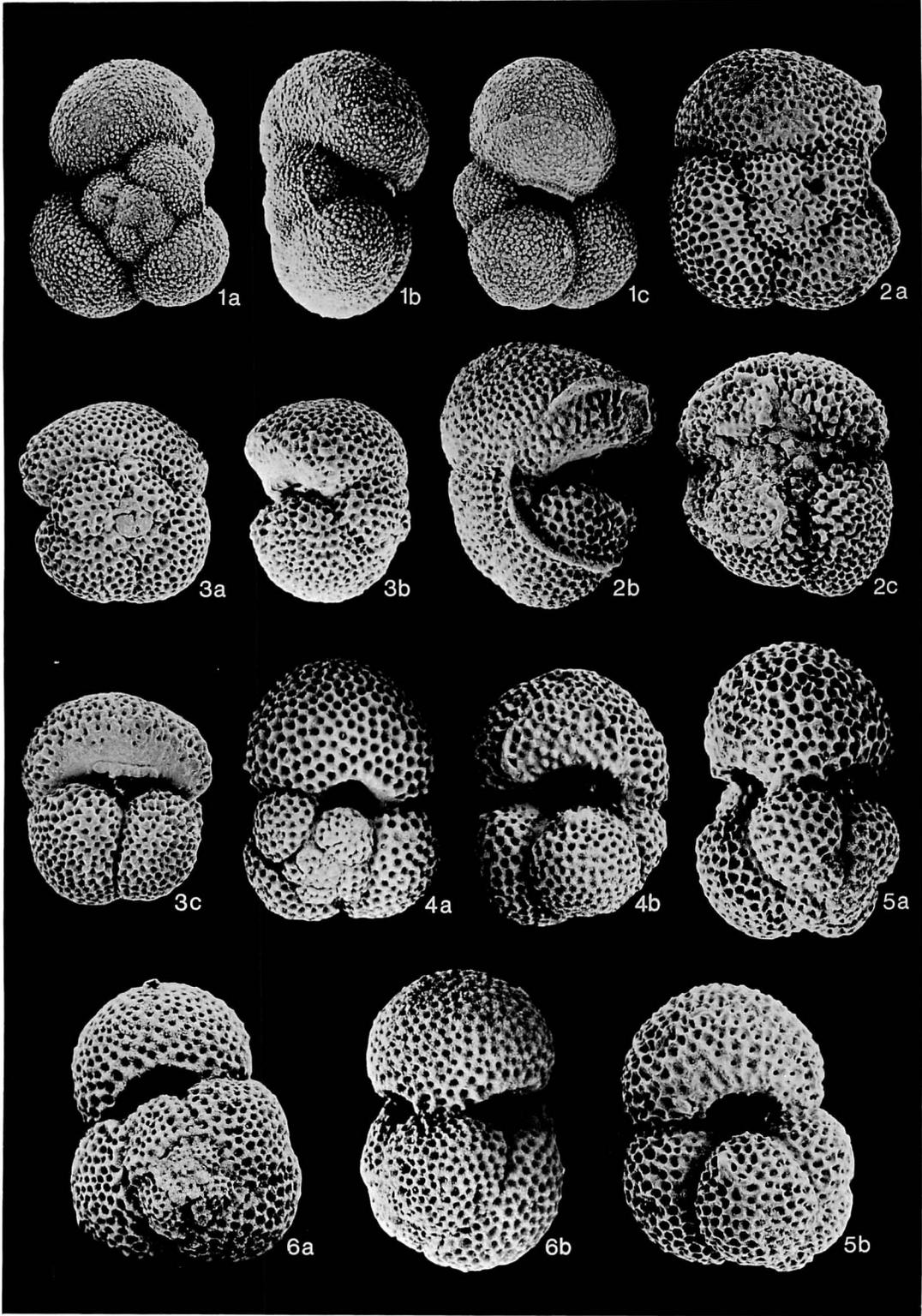
References

- AKERS, W.H. (1955): Some planktonic foraminifera of the American Gulf Coast and suggested correlations with the Caribbean Tertiary. *Jour. Paleont.*, vol. 29, no. 4, pp. 647-664, pl. 65, text-figs. 1-3.
- ASANO, K. (1962): Faunal change of planktonic foraminifera through the Neogene of Japan. *Koninkl. Nederl. Akad. Wetensch., Proc.*, ser. B, vol. 65, no. 1, pp. 114-129, 1 text-fig., tables 1-2.
- , INGLE, J.C., Jr. and TAKAYANAGI, Y. (1968): *Globigerina quinqueloba* NATLAND, origin and distribution in late Cenozoic of the North Pacific. *Giorn. Geol.*, ser. 2, vol. 35 (1967), no. 3 (Comm. Mediterranean Neogene Stratigr., 4th Sess., Proc., pt. 3), pp. 217-246, text-figs. 1-15, table 1.
- BANDY, O.L. and INGLE, J.C., Jr. (1970): Neogene planktonic events and radiometric scale, California. *Geol. Soc. Amer., Spec. Paper* 124, pp. 131-172, pl. 1, text-figs. 1-7.
- BERGGREN, W.A. (1972): A Cenozoic time-scale—some implications for regional geology and paleobiogeography. *Lethaia*, vol. 5, no. 2, pp. 195-215, text-figs. 1-9.
- BLOW, W.H. (1959): Age, correlation and biostratigraphy of the upper Tocuyo (San Lorenzo) and Pozón Formations, eastern Falcón, Venezuela. *Bull. Amer. Paleont.*, vol. 39, no. 178, pp. 69-252, pls. 6-19, text-figs. 1-5, maps 1-4, charts 1-4.
- (1969): Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In: BRONNIMANN, P., and RENZ, H.H., Eds., *Internat. Conf. Planktonic Microfossils, 1st, Geneva (1967), Proc.*, vol. 1, pp. 199-422, pls. 1-54, text-figs. 1-43.
- and BANNER, F.T. (1962): The mid-Tertiary (Upper Eocene to Aquitanian) Globigerinaceae. In: EAMES, F.E., BANNER, F.T., BLOW, W.H., and CLARKE, W.J., *Fundamentals of mid-Tertiary stratigraphical correlation*. London: Cambridge Univ. Press, pt. 2, pp. 61-151, pls. 8-17, text-figs. 6-20.
- and — (1966): The morphology, taxonomy and biostratigraphy of *Globorotalia barisanensis* LEROY, *Globorotalia fohsi* CUSHMAN and ELLISOR and related taxa. *Micropaleontology*, vol. 12, no. 3, pp. 286-302, pls. 1-2, text-figs. 1-4.
- BOLLI, H.M. (1957): Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I. *U.S. Nat. Mus., Bull.*, no. 215, pp. 97-123, pls. 22-29, text-figs. 17-21.
- CHANG, L.S. (1959): A biostratigraphic study of the Miocene in western Taiwan based on smaller foraminifera (Part 1: Planktonics). *Geol. Soc. China, Proc.*, no. 2, pp. 47-72, pls. 1-5, text-figs. 1-5.
- CHITANI, Y. (1925): Geology and physiography of the Oga Peninsula. *Jour. Geogr.*, vol. 37, no. 436, pp. 323-330 [in Japanese].
- EGGER, J.G. (1893): Foraminiferen aus Meeresgrundproben, gelothet von 1874 bis 1876 von S. M. Sch. Gazelle. *K. Bayer. Akad. Wiss., Math.-Physik. Cl., Abh.*, Bd. 18 (1895), Abth. 2, pp. 193-458, pls. 1-21.
- HANZAWA, S. (1935): Some fossil *Operculina* and *Miogypsina* from Japan and their stratigraphic significance. *Tohoku Imp. Univ. Sci. Rept., 2nd ser. (Geol.)*, vol. 18, no. 1, pp. 1-29, pls. 1-3.
- (1950): Paleogeography of North Japan. *Short Papers, Inst. Geol. Paleont., Tohoku Univ.*, no. 2, pp. 74-98, 2 text-figs.
- (1964): The phylomorphogeneses of the Tertiary foraminiferal families, Lepidocyclinidae and Miogypsinidae. *Tohoku Univ. Sci. Rept., 2nd ser. (Geol.)*, vol. 35, no. 3, pp. 295-313, 5 text-figs.
- HATAI, K. (1938): A review of the paleontology of Akita Prefecture (Ugo Province), Northeast Honshu, Japan. *Jap. Jour. Geol. Geogr.*, vol. 15, nos. 1-2, pp. 35-45.
- HUANG, T.Y. (1963): Planktonic foraminifera

- from the Peikang PK-3 well in the Peikang shelf area, Yunlin, Taiwan. *Petrol. Geol. Taiwan*, no. 2, H.H. LING *Jubilee Vol.*, pp. 153-181, pls. 1-6, text-figs. 1-4.
- (1967): Late Tertiary planktonic foraminifera from southern Taiwan. *Tohoku Univ. Sci. Rept., 2nd ser. (Geol.)*, vol. 38, no. 2, pp. 165-192, pls. 15-16, text-figs. 1-6, tables 1-8.
- (1969): Some planktonic foraminifera from a bore at Shihshan, near Taitung, Taiwan. *Geol. Soc. China, Proc.*, no. 12, pp. 103-119, pls. 1-4, text-figs. 1-2, tables 1-2.
- HUZIOKA, K. (1956): Study of Green Tuff (Ryokushoku Gyokaigan). *Kagaku (Science)*, vol. 26, no. 9, pp. 440-446, text-figs. 1-4 [in Japanese].
- (1959): Explanatory text of the geological map of Japan; Toga and Funakawa (Akita-1, 2). *Kawasaki: Geol. Surv. Japan*, pp. 6-61 [in Japanese with English abstract].
- IKEBE, Y. (1962): Tectonic developments of oil-bearing Tertiary and migrations of oil in Akita oil fields, Japan. *Akita Univ., Res. Inst. Undergr. Resour. Rept.*, no. 26, pp. 1-59 [in Japanese].
- JENKINS, D.G. (1960): Planktonic foraminifera from the Lakes Entrance oil shaft, Victoria, Australia. *Micropaleontology*, vol. 6, no. 4, pp. 345-371, pls. 1-5, text-figs. 1-10.
- (1965a): Planktonic foraminifera and Tertiary intercontinental correlations. *Ibid.*, vol. 11, no. 3, pp. 265-277, pls. 1-2.
- (1965b): The origin of the species *Globigerinoides trilobus* (REUSS) in New Zealand. *Cushman Found. Foramin. Res., Contr.*, vol. 16, pt. 3, pp. 116-120, pl. 17, text-figs. 1-3.
- (1971): New Zealand Cenozoic planktonic foraminifera. *New Zealand Geol. Surv., Paleont. Bull.*, no. 42, pp. 1-278, pls. 1-23, text-figs. 1-2, tables 1-58.
- and ORR, W.N. (1972): Planktonic foraminiferal biostratigraphy of the eastern Equatorial Pacific—DSDP Leg. 9. In: HAYS, J.D. *et al.*, *Initial Reports of the Deep Sea Drilling Project, Volume IX*. Washington, D.C.: U.S. Govt. Printing Office, pp. 1059-1193, pls. 1-4, text-figs. 1-9.
- KOTAKA, T. (1957): Preliminary note on the distribution of the Miocene molluscan fauna in the Green tuff region of northern Honshu, Japan. *Saito Ho-on Kai Mus., Res. Bull.*, no. 26, pp. 41-42.
- MATSUMARU, K. (1971): Studies on the genus *Nephrolepidina* in Japan. *Sci. Rept. Tohoku Univ., 2nd ser. (Geol.)*, vol. 42, pp. 97-185, pls. 9-26, text-figs. 1-42.
- MINATO, M., GORAI, M. and HUNAHASHI, M., Eds. (1965): The geologic development of the Japanese Islands. Tokyo: Tsukiji Shokan, pp. 1-442, 30 pls., 137 text-figs., 44 tables.
- NOMURA, S. and HATAI, K. (1938): On some fossils from Akita Prefecture, Northeast Honshu, Japan. *Jap. Jour. Geol. Geogr.*, vol. 16, nos. 1-2, pp. 39-64.
- OLSSON, R.K. (1972): Growth changes in the

Explanation of Plate 19

- Fig. 1a-c. *Globigerinita glutinata* (EGGER).
1a, Spiral view of hypotype with umbilical bulla removed (NSMT 674). 1b, Side view. 1c, Umbilical view. $\times 145$.
- Figs. 2a-c, 3a-c. *Globoquadrina obesa* AKERS.
2a, Spiral view of hypotype with aberrant last chamber removed (NSMT 675). 2b, Side view. 2c, Umbilical view. $\times 102$. 3a, Spiral view of hypotype (NSMT 676). 3b, Side view. 3c, Umbilical view showing a characteristic umbilical tooth. $\times 102$.
- Figs. 4a-6b. *Globigerinoides japonicus* SAITO and MAIYA, new species.
4a, Spiral view of small paratype (NSMT 677). 4b, Umbilical view. 5a, Side view of holotype (NSMT 678). 5b, Umbilical view. 6a, Spiral view of paratype (NSMT 679). 6b, Side view. $\times 128$.



- Globorotalia fohsi* lineage. *Eclogae geol. Helv.*, vol. 65, no. 1, pp. 165-184, text-figs. 1-12.
- PARKER, F.L. (1962): Planktonic foraminiferal species in Pacific sediments. *Micro-paleontology*, vol. 8, no. 2, pp. 219-254, pls. 1-10.
- (1964): Foraminifera from the Experimental Mohole drilling near Guadalupe Island, Mexico. *Jour. Paleont.*, vol. 38, no. 4, pp. 617-636, pls. 97-102, tables 1-3.
- SAITO, T. (1963): Miocene planktonic foraminifera from Honshu, Japan. *Tohoku Univ. Sci. Rept., 2nd ser. (Geol.)*, vol. 35, no. 2, pp. 123-209, pls. 53-56, text-figs. 1-15, tables 1-6.
- SHINBO, K. and MAIYA, S. (1971): Neogene Tertiary planktonic foraminiferal zonation in the oil-producing provinces of Japan. In: *Stratigraphic correlation between sedimentary basins of the ECAFE region (Second volume)*. United Nations, Mineral Resources Development Series, no. 36 (1970), pt. B, pp. 135-142, text-figs. B12, 1-2, tables B12, 1-2.
- STAINFORTH, R.M. (1948): Applied micro-paleontology in coastal Ecuador. *Jour. Paleont.*, vol. 22, no. 2, pp. 113-151, pls. 24-26.
- SUBBOTINA, N.N., PISHVANOVA, L.S. and IVANOVA, L.V. (1960): Stratigraphy of the Oligocene and Miocene deposits of the Fore-Carpathians on the basis of foraminifera. *Leningrad: Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst. (VNIGRI), Microfauna of the U.S.S.R., Trudy, N.S.*, vupusk 153, sbornik 11, pp. 5-127, pls. 1-14 [in Russian].
- TAKAYANAGI, Y. and SAITO, T. (1962): Planktonic foraminifera from the Nobori Formation, Shikoku, Japan. *Tohoku Univ. Sci. Rept., 2nd ser. (Geol.), Spec. Vol.*, no. 5, pp. 67-106, pls. 24-28, text-figs. 1-2, table 1.
- UJIIÉ, H. (1966): "Evolutionary line" of Miocene miogypsinid populations: Re-study of the Japanese miogypsinids Part 2. *Nat. Sci. Mus. Tokyo, Bull.*, vol. 9, no. 3, pp. 413-430, pls. 1-6.
- YABE, H. (1927): Marine Tertiary of the Kwanto Mountainland and of the Echigo and Akita oil-fields. *Jap. Jour. Geol. Geogr.*, vol. 5, no. 3, pp. 95-105, text-figs. 1, 2.
- (1933): Geological age of the *Miogyp-sina* and *Operculina* bed of Nishikurosawa. *Ibid.*, vol. 11, nos. 1-2, pp. 25-26.

621. MARINE DIATOM FLORA OF THE PLIOCENE TATSUNOKUCHI
FORMATION IN MIYAGI PREFECTURE*

ITARU KOIZUMI

Institute of Geological Sciences, College of General Education, Osaka University

宮城県，鮮新統・竜ノ口層中の海棲珪藻植物群： 仙台周辺から北上河谷に沿い，脊梁山脈と北上山地との間の低地帯に広く分布する竜ノ口層中の化石珪藻群集の解析とその結果とを述べる。出現する珪藻種の頻度による相関係数によって Q モード・クラスタ分析を行なつて，試料を類似性の強い 6 つの群に区分し得た。試料の層位的位置からみて，これらの群は竜ノ口層の下部・中部および上部をそれぞれ代表するものである。これとは別に，珪藻種の生態的特徴と各試料での上位 5 位までの優勢種にもとづく群集の解析から，下部および上部を代表する群に属する珪藻群集は，中部のものよりも浅い浅海域で形成された群集であることが分る。結局のところ，竜ノ口層中の珪藻群集は主に環境要因（水深など）の垂直変化によって規定されたものであろう。

小泉 格

Introduction

In a previous paper (KOIZUMI, 1972) Pliocene marine diatoms from the Tatsunokuchi Formation in Fukushima Prefecture was described and analysed. The present paper is to report the results of the study extended further north to deal with the diatoms assemblages from the same formation developed in Miyagi Prefecture including that exposed in the Tatsunokuchi Gorge in Sendai, the type locality of the Tatsunokuchi Formation.

In the lowland terrain located between the Kitakami massif and the Ōu range of Miyagi Prefecture, the Pliocene Sendai Group (IWAI, 1949) is extensively distributed. The group, about 200m in total thickness, is predominated by non-marine deposits of sand, mud, gravel

and lignite seams accumulated during the upward movement of the Ōu Range started in the Miocene and continued through the Pliocene time. The Tatsunokuchi Formation, composed mainly of grey siltstone and about 50 m in thickness, represents the lower part of the group and is known to be the only unit exclusively of marine origin among the Sendai Group.

Stratigraphic note

Table 1 shows the stratigraphic relationship and terminologies of the rock units of the Sendai Group developed in Miyagi Prefecture. The time-stratigraphic correlation of the Kameoka and Tatsunokuchi formations as defined at type area with those correlatives in such areas of the northern part of Miyagi Prefecture as Sanbongi, Wakuya and Wakayanagi have been sufficiently borne

* Received March 20, 1973; read January 16, 1973, at Sendai.

Table 1. Stratigraphic sequence and correlation of the formations of the Sendai Group in the areas of Sendai, Sanbongi, Wakuya and Wakayanagi.

AGE GROUP	SENDAI	SANBONGI	WAKUYA	WAKAYANAGI
	Shibata, 1962	Shibata, 1962	Takahashi & Matsuno, 1969	Matsuno, 1967
PLIOCENE Sendai Group	Dainenji Formation (30)	Ojojigahara Formation (50)	Takashimizu Formation (30)	Takashimizu Formation (35)
	Yagiyama Formation (20)		Onuki Formation (50 - 80)	Tsukidate Formation (0 - 50)
	Hirosegawa Tuff (10)	Ojikakura Tuff		Kazawa Formation (5 - 55)
	Kitayama Formation (1 - 10)	Sanbongi Formation(16) (=Kitayama Formation)		Tatsunokuchi Formation (40)
	Tatsunokuchi Formation (50 - 60)	Omori Formation(30) (=Tatsunokuchi Formation)	Kameoka Formation (40)	
	Kameoka Formation (10 - 20)	Okuda Formation(30) (=Kameoka Formation)		

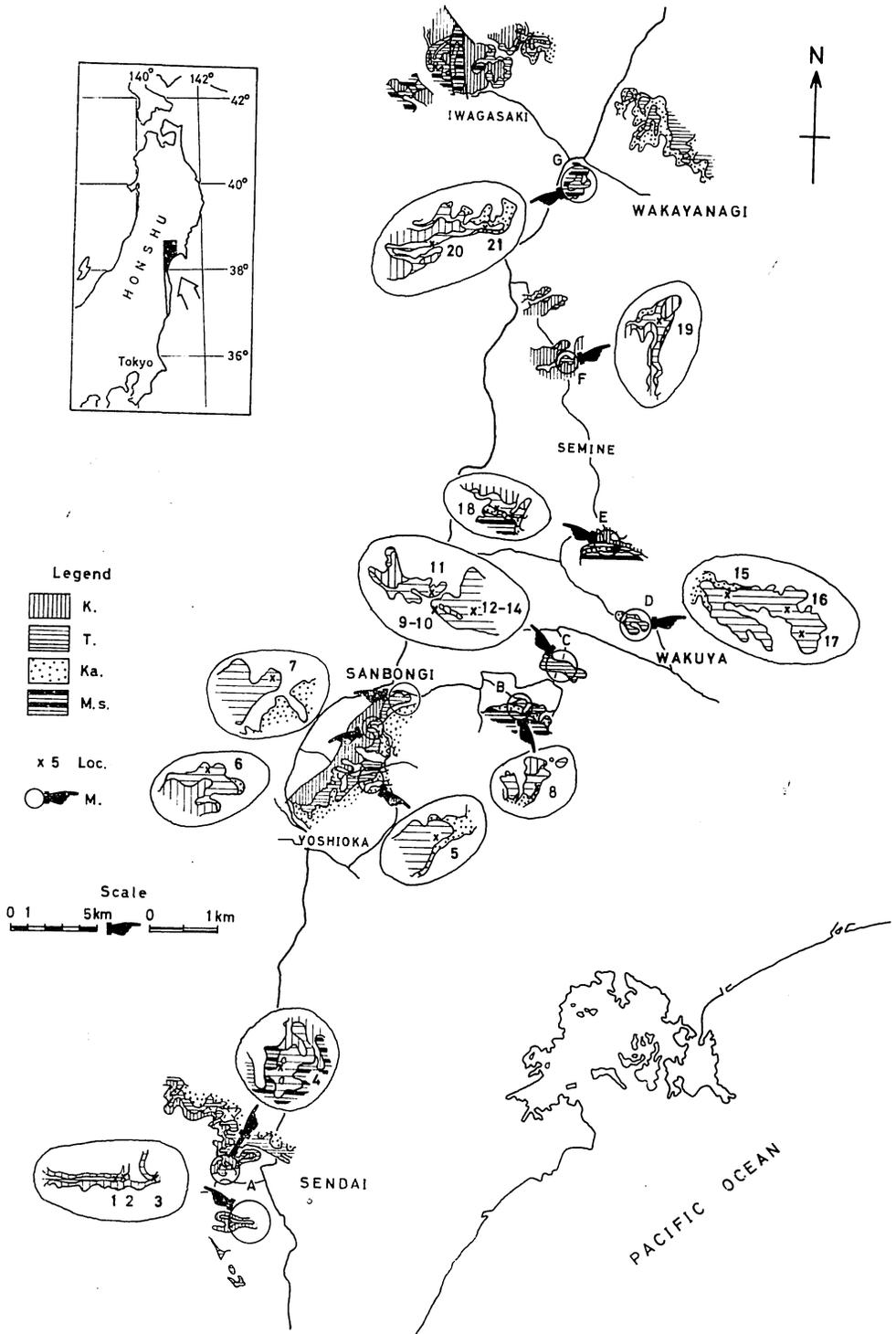
out by previous studies made independently of diatoms in various disciplines of stratigraphy (*e.g.* HANZAWA *et al.*, 1953; HANZAWA *et al.*, 1962; KITAMURA and SHIBATA, 1963; MATSUNO, 1967; ISHIDA *et al.*, 1969; TAKAHASHI and MATSUNO, 1969); at those localities given in Fig. 1 the Tatsunokuchi Formation is conformable or partially interfingers with underlied Kameoka Formation and is covered unconformably with the Kitayama Formation and the correlative formations.

Kameoka Formation: The main part of the formation consists of conglomerate, sandstone, siltstone and mudstone intercalating tuff and lignite seams. Such plant fossils as *Glyptostrobus europaeus*, *Sequoia sempervirens*, *Fagus crenata*, *Quercus crispula* and *Cinnamomum scheuchzeri* (OKUTSU, 1955) found from the formation indicate its age to be early Pliocene (SHIBATA, 1962). There is no paleontological evidence indicating positively the formation is marine origin; from the lithology and by the occurrence of plant fossils, it seems reasonable to judge that this unit is lagoonal and partly terrestrial in origin.

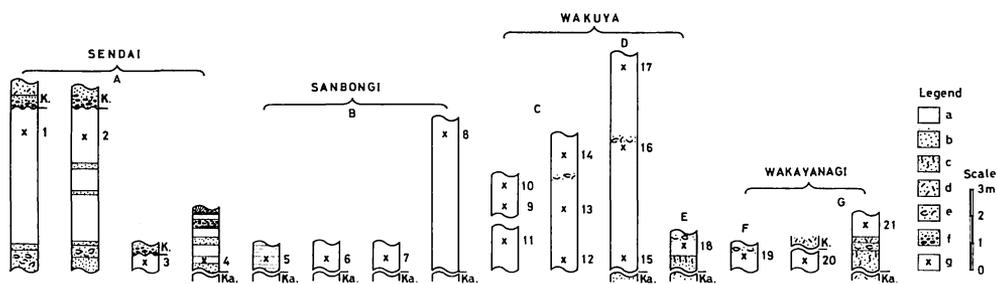
Tatsunokuchi Formation: The formation consists mainly of tuffaceous bluish gray or bluish green siltstone or mud-

stone intercalated with sandstone and tuff layers. The silt and mudstones containing diatoms are massive and show no stratification. The geologic structure of the formation is rather simple; it lies almost horizontally throughout the distributed area. Within the Sendai Group the formation is characteristic by the yield of many kinds of fossil marine animals. Especially well known is its molluscan fauna, that by containing such species as *Anadara tatsunokutiensis*, *Dosinia tatsunokutiensis*, *Fortipecten takahashii* together with many other thick-shelled shallow water forms, represent "the Tatsunokuchi Fauna" of Pliocene (NOMURA, 1938). Mainly by the molluscan fauna, it belongs to the lower part of the Miyagian by HATAI (1962) and HATAI and MASUDA (1966); its age being early Pliocene according to NODA (1966).

Kitayama Formation and its correlatives: The formation and its correlatives consist mainly of basal conglomerate and sandstone intercalating partly siltstone and lignite beds as well as carbonaceous siltstone. The formation in the Sendai area is known to contain such plant fossils as *Alnus*, *Fagus* and *Sequoia*. From its lignites pollen assemblages dominated by those of *Alnus*, *Sequoia*-type and *Sciadopitys* have been



Text-fig. 1. Partial geologic map showing the locations of the samples studied. Legend: K. Kitayama Formation and the correlative formations; T. Tatsunokuchi Formation; Ka Kameoka Formation; M.s. Miocene strata; Loc. Locality of the samples; M. magnification of the circular parts.



Text-fig. 2. Columnar sections showing the stratigraphic position of the samples studied. Legend: a, siltstone; b, sandstone; c, sand-pipe; d, tuffaceous sandstone; e, molluscan fossils; f, conglomerate; g, position of samples studied. Abbreviation: K., Kitayama Formation and the correlative formations; Ka., Kameoka Formation.

reported (HANZAWA *et al.*, 1953). The formation may be terrestrial, possibly brackish water in part, in origin.

The geographic and stratigraphic positions of the samples examined are shown in the geologic map (Text-fig. 1) and the columnar sections (Text-fig. 2), respectively.

Diatom flora in the Tatsunokuchi Formation

The method of study once described by KOIZUMI (1968) is followed in the present study.

Among the 21 samples from the Tatsunokuchi Formation, the distribution of the 80 diatom taxa distinguished is shown in Table 2. The ecology of each taxon is based upon the information mainly from the literatures of HUSTEDT (1927 *et seq.*, 1930), JOUSÉ (1962), SIMONSEN (1962) and HENDEY (1964).

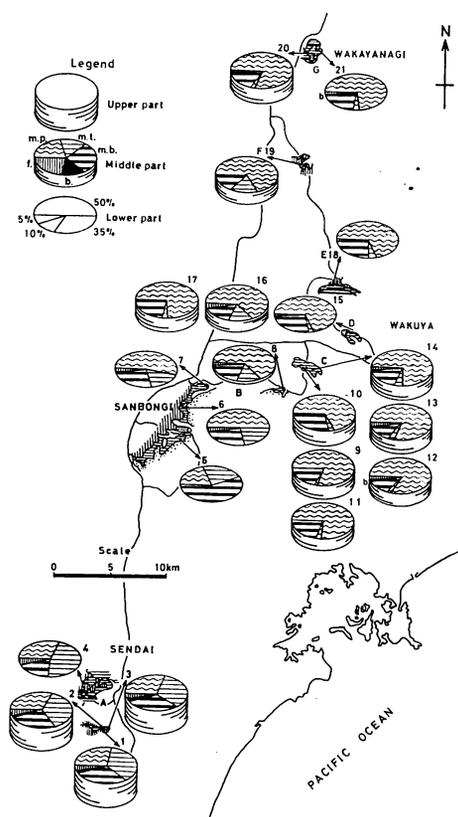
As shown by Table 2, the diatom assemblage in the present study is common in having, in considerable number, the neritic, tychopelagic and benthonic species. The feature has been pointed out as one of the characteristics of the

Pliocene marine diatom assemblages found from the land based sequences of the circum-Pacific regions (*e.g.* LOHMAN, 1937; JOUSÉ, 1962; MERTZ, 1966; SHESHUKOVA-PORENTZKAYA, 1967; KOIZUMI, 1968). The composition of diatom assemblage in the formation reflects largely the environmental changes throughout the depositional time, with chronological changes playing a minor role. The general tendency read from a glance of the distribution table (Table 2) is that marine tychopelagic and benthonic diatoms are dominant in the southern half of the area, while planktonic diatoms in the northern half. However, the relative stratigraphic positions within the Tatsunokuchi Formation of the diatom-bearing samples vary with local sections (Text-fig. 2). Accordingly the relative stratigraphic levels of each set of samples have to be taken into the consideration for the analysis of the assemblage as a whole. Text-fig. 3 is to show the proportions in each sample of the association of fresh-water, brackish-water, marine benthonic, marine tychopelagic and marine planktonic diatoms, that varies geographically and stratigraphically.

Table 2. Distribution of the diatoms from the Tatsunokuchi Formation in Miyagi Prefecture.

Abbreviation : B. s., Brackish-water species; b., benthonic form.

Species	Samples																					
	A				B				C				D			E		F		G		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Fresh water species																						
1. <i>Achnanthes lanceolata</i>			2	1				1								1						
2. <i>Cocconeis diminuta</i>								1														
3. <i>C. disculus</i>	1											1										
4. <i>C. placentula</i>													1									
5. <i>Cyclotella chaetoceros</i>		2	1				3							1								
6. <i>C. kurtzingiana</i>	1							2									1					
7. <i>C. ocellatus</i>																					1	
8. <i>C. stelligera</i>	2		3																			
9. <i>Epithemia zebra</i>												1										
10. <i>Fragilaria harrissonii</i>													1									
11. <i>F. lapponica</i>												1		1								
12. <i>Gomphonema dugur</i>												1		1								
13. <i>Melosira granulata</i>	1	4	3	2			1	1									1		1			
14. <i>M. varians</i>			1														2				3	
15. <i>Pinnularia alpina</i>								1									1					
16. <i>Mastogloia</i> sp.1			1																			
17. <i>Navicula hungarica</i>												1										
18. <i>N. lanceolata</i>	2		3																		1	
B. s.																						
19. <i>Actinocyclus ehrenbergi</i>	4	2	3	3	65		4	2	5	4	2	2	1	13	42	11	3	4	3		2	
20. <i>A. ehrenbergi</i> v.	1	1	4		6			1	1	1	2	1			3				1		4	
21. <i>Actinocyclus splendens</i>				2																	2	
22. <i>A. undulatus</i>	62	38	48	15	26	33	32	22	16	32	18	8	13	17		10	27	14	14	19	28	
23. <i>A. undulatus</i> v.	3	18	11	21	24	16	9	2	10	21	14	10	9	4		10	11	9	4	4	2	
24. <i>Biddulphia aurita</i>									1	2	1											
25. <i>Cocconeis californica</i>	b						1	2							2							
26. <i>C. costata</i>	b		3				1	3	1			2		1	1	1		3			1	
27. <i>C. pseudomarginata</i>	b							1	1												1	
28. <i>C. scutellum</i>	b	1	1		2		3	1	1		1			3	3	3	1		1	1	1	
29. <i>Coscinodiscus lacustris</i>																						
30. <i>Cyclotella striata</i>					1	4	6	5							12		1		1	1	2	
31. <i>Diploneis smithii</i>	b	1		1			1						1				1					
32. <i>Grammatophora angulosa</i>	b						1				1		1									
33. <i>Hyalodiscus scoticus</i>		3		4			2															
34. <i>Melosira albicans</i>				1			2															
35. <i>M. sulcata</i>		2	5				1	6	3												5	
36. <i>Navicula distans</i>	b							6	2									24				
37. <i>Nitzschia granulata</i>											1						1		2		2	
38. <i>Plagiogramma fesselata</i>	b		2					1			1	1									1	
39. <i>Pleusigma affine</i>	b																					
40. <i>Podosira maxima</i>	b			1																		
41. <i>Rhaphoneis angustata</i>	b	16	14	22	14	36	31	6	6							31	5				4	
42. <i>R. margarialimbata</i>	b	25	21	9	12		5	7	10							2						
43. <i>R. surirella</i>	b	19	14	19	30	6	13	7	16							4	2	5		1	1	
44. <i>R. tatsunokuchiensis</i>	b	2	2	22					1	1	1	1	2			1	1		45	4	1	
45. <i>Surirella fastuosa</i>	b			7																		
46. <i>Trachyneis aspera</i>	b	1	4	1								1										
Marine																						
planktonic forms																						
47. <i>Actinocyclus curvatus</i>				1				2		1	1			1	3		1	3			1	
48. <i>A. divisus</i>		1	1																		2	
49. <i>Asteromphalus hyalina</i>							1	1			1			2	2							
50. <i>Bacteriastrium</i> spp. (2 forms)	2												2	2								
51. <i>Chaetoceros cinctus</i>					1	3	1	2				3	4	2	1		1		5	1	2	
52. <i>C. coronata</i>			1						2	1	1	1	1	1							1	
53. <i>C. furcellatus</i>							1	4	1			1	2			1					2	
54. <i>C. lorenzianus</i>																						
55. <i>C. subsecundus</i>												1										
56. <i>Coscinodiscus excentricus</i>	1	4	4	3		1	2		2	3	5	4	1	2	5	1		5			2	
57. <i>C. marginatus</i>				2	3				1													
58. <i>C. oculus iridis</i>	2	1	3	1				2	2			1	1	1		1			3		2	
59. <i>C. radiatus</i>												1	1	1							1	
60. <i>C. stellaris</i> v.		2	2				2			2	1	1	1	4		4			1		2	
61. <i>C. temperi</i>			2						5	25	17	15	11	18	13	15	11		12	24	40	
62. <i>Denticula kantschatica</i>		3	1		5	2			6	3		1	1	1		2		6	1			
63. <i>D. seminae</i>				1				2	1			1	1	1	2		5					
64. <i>Hemidiscus weissflogi</i>				1				4	6							1			2			
65. <i>Nitzschia extincta</i>	1	1				20	10	11		17	15	24	27	23	19	14	18	40	10	15	7	39
66. <i>N. reinholdii</i>											2			3								
67. <i>N. sicula</i>			3					1	2	2	3	5	1	3	1		2			1	3	
68. <i>Rhizosolenia</i> spp. (5 forms)	2		2		2	2	5	4								1	4	2	3			2
69. <i>Stephanopyxis turris</i>				2				3	3													
70. <i>Thalassionema nitzschioides</i>	18	10	10	30	5	32	33	38	37	33	26	33	23	21	23	9	39	39	34	43	28	
71. <i>T. nitzschioides</i> v.		4	4			4	3	13	12	6	1	12	10	9	7	4	14	8		7	5	
72. <i>Thalassiosira antiqua</i>	12	18	16	13	14	16	14	19	47	36	54	65	64	53	54	55	24	24	42	46	7	
73. <i>T. decipiens</i>	4	6	4	4	1	1	11	1	4	5	2	4	5	2	3	5	8	2	3	3	2	
74. <i>T. kryophila</i>																1			3			
75. <i>T. lineata</i>	5	3	3	1	6	2		5	3	6	8	1	4	5	13	3	8	9	2	4	9	
76. <i>T. nidulus</i>		1	1	1				4													2	
77. <i>T. nördenskiöldii</i>		1	5				1	1				1	5	3		1			1	4	4	
78. <i>T. zabelinae</i>		2		2																		
79. <i>T. spp.</i> (4 forms)			5	9			3	1	1			4		4	5					3	4	
80. <i>Thalassiothrix longissima</i>	1	1				2			1		1				1	2	3	1		5	3	2
Diatom number ($\times 10^6/1g.$)	1.3	0.6	0.4	0.7	32.0	2.6	2.4	3.5	8.0	16.0		5.3	3.5	9.2	5.4	8.0			16.0	6.4	4.6	



Text-fig. 3. Figure showing geographically and stratigraphically the proportions in an association of f., fresh-water species; b., brackish-water species; m.b., marine benthonic species; m.t., marine tychopelagic species and m.p., marine planktonic species in number of specimens.

Cluster analysis and explanation

The Q-mode (sample by sample comparison) cluster analysis is applied in order to group the aggregate of the samples that have similar associations of species among different localities and horizons. In similarity coefficient there are two kinds of qualitative and quantitative coefficients, and the comparison between two coefficients was once dis-

cussed by UJIIÉ and KUSUKAWA (1969). In the present study the correlation coefficient as one of the quantitative coefficient is used.

Correlation Coefficient

$$= \frac{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^2}}$$

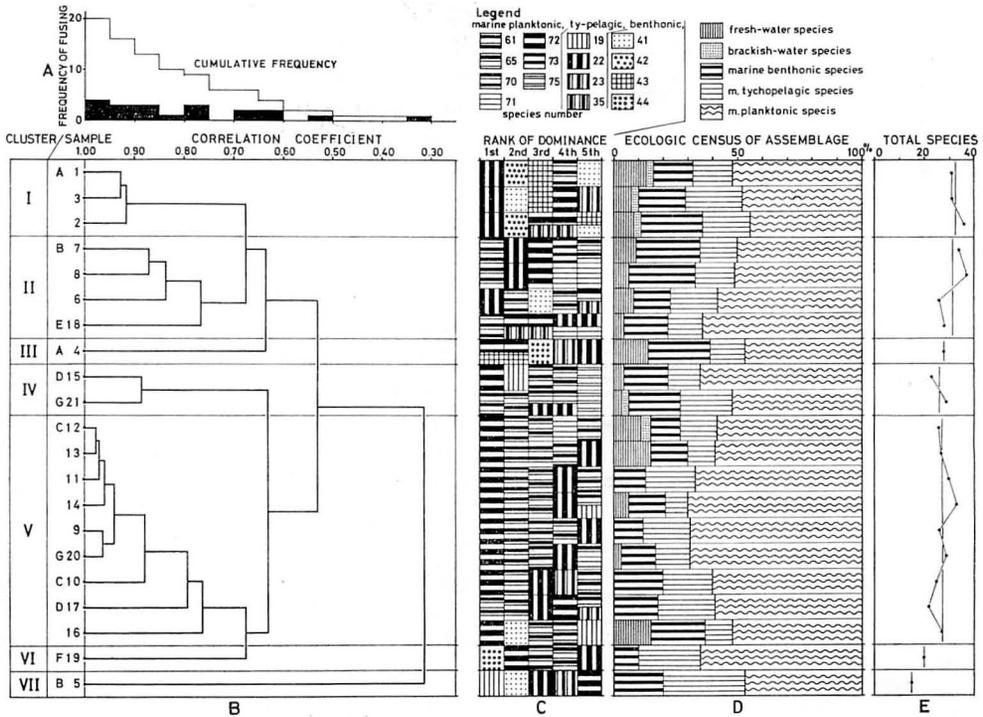
where: x_i is the relative frequency of a certain taxon in one sample X , and y_i that of the equivalent taxon in another sample Y , to be compared with each other; \bar{x} and \bar{y} are means by x_i and y_i , respectively; n is the total number of taxa found in all samples under comparison ($n=80$).

The result is shown in the dendrogram of Text-fig. 4-B. Seven clusters from I to VII could be distinguished, if any level within the interval between 0.70 and 0.75 was chosen based upon a break in the frequency of the fusing and flat in the cumulative distributions of the frequency as indicated in Text-fig. 4-A.

As recognized in Text-fig. 3, the seven clusters at the 0.70 to 0.75 level are more closely related to stratigraphic horizons than to geographic distributions of samples.

Cluster I is represented only by the upper part of the formation. Clusters II, III, IV and VII are restricted to the lower part. Cluster VI which consists of single sample joins the large Cluster V at a little lower level than the chosen level. And these clusters are represented by the middle part of the formation.

This division of the clusters is quite reasonable also from the viewpoint of the ecologic analyses of diatom assemblage as summarized in Text-figs. 4-C and -D. From the comparisons of the occurrences of fresh-water, brackish-



Text-fig. 4. Figures showing the sample clusters and ecologic census of diatom assemblages related with them. **A:** Distribution of frequency and cumulative frequency of fusing in the dendrogram (**B**). **B:** Dendrogram of sample similarities based upon the Correlation Coefficient computed from the relative frequencies of diatom species. **C:** Ranks of dominance of diatom species. **D:** Proportions of an association in terms of the salinity of water and the mode of living of the constituting species in number of species. **E:** Number of total species.

water and marine species in the assemblages, fresh-water species are considered to be allochthonous species that were transported by rivers and then by normal wave currents into the marine sedimentary basin. OSHITE (1959) shows that fresh-water diatoms occur, to a great extent in comparison with the present figures, abnormal marine fine-grained clastic sediments. The proportions of brackish-water species are very weak; namely, the diatom assemblage is mostly composed of marine species. Each cluster is ecologically explained by the ratio in number of species and speci-

mens among benthonic, tyhopelagic and planktonic species. The ratio is related to the depth of the sedimentary basin in general, and the ratio increases with the decreasing depth of the normal marine sedimentary basin (JOSÉ, 1962).

Summary and discussion

As the result of the Q-mode cluster analysis using the correlation coefficient, three aggregates of samples were distinguished. They represent the lower, middle and upper parts of the Tatsunokuchi Formation, respectively, among

different localities and horizons. The diatom assemblage was ecologically analyzed based upon the rank of dominance of species and the proportions in the association of fresh-water, marine benthonic-tychopelagic and marine planktonic species in number of species and of specimens. The result of this analysis explains well these three aggregates of the samples in the viewpoint of geological history of the formation.

By the nature of diatoms being autotrophic algae, marine benthonic species can not vegetate on the sea bottom beyond the reach of sufficient light. This depends on the transparency of sea water in the basin, but in turbid coastal water 50 m in water depth would be a reasonable guess for the maximum depth. From the predominant occurrences of benthonic species, constant occurrences of fresh-water species, and further by the presence of lignite seams and sand-pipes immediately below the sampling horizon for the lower part, and by the presence of unconformity with basal conglomerate immediately above the sampling horizon for the upper part, the diatom assemblages of the lower and upper part of the formation can be concluded to have been accumulated in shallower sea water of the depth less than 50 m.

The foraminiferal assemblages from the formation in the western border of Sendai consist mainly of the eulittoral and littoral species (TAKAYANAGI, 1950).

CHINZEI and IWASAKI (1967), in discussing the paleoecology of Neogene shallow sea molluscan faunae of Northeast Japan, distinguished two types of the molluscan assemblages, the shallow sea or near-shore type and the off-shore type, and explained the two types in the Tatsunokuchi Formation as of geographical control. From the present

study, stratigraphic control of the assemblage has been revealed.

Acknowledgements: The writer is greatly indebted to Dr. Taro KANAYA, Nikko for his critical reading of the manuscript. Hearty thanks are also due to Dr. Kōjirō NAKASEKO, Osaka University for his help and encouragement, Miss Taeko ZENRI for typing the manuscript and Mrs. Mineko KOIZUMI for scrutinizing the manuscript.

References

- CHINZEI, K. and IWASAKI, Y. (1967): Paleoecology of shallow sea molluscan faunae in the Neogene deposits of Northeast Honshu, Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 67, pp. 93-113.
- HANZAWA, S., HATAI, K., IWAI, J., KITAMURA, N. and SHIBATA, T. (1953): The geology of Sendai and its environs. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 25, pp. 1-50.
- , ONUKI, Y. and KITAMURA, N. (1962): The geological map of Miyagi Prefecture, scale 1:200,000. Miyagi Prefecture.
- HATAI, K. (1962): Mizuho-Tō. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.), spec. vol.*, no. 5, pp. 329-348.
- and MASUDA, K. (1966): The stratigraphic position of *Trilophodon sendaicus* MATSUMOTO in the Mizuho-Tō of Sendai City, Miyagi Prefecture. *Saito Ho-on Kai Mus., Res. Bull.*, no. 35, pp. 1-10.
- HENDEY, N. I. (1964): An introductory account of the smaller algae of British coastal waters. *Fishery Investigations. ser. 4, part 5, Bacillariophyceae (Diatoms)*, pp. 1-317. London.
- HUSTEDT, F. (1927 et seq.): Die Kieselalgen Deutschlands, Oesterreichs und der Schweiz mit Berücksichtigung der über Länden Europas sowie der anderenzen den Meeresgebiet. *In Dr. RABENHORST'S Kryptogamen-Flora von Deutschland, Oesterreichs und der Schweiz. vol. 7, Teil I, pp. 1-920; Teil II, pp. 1-736; Teil III, pp. 1-411, not yet completed. Leipzig.*

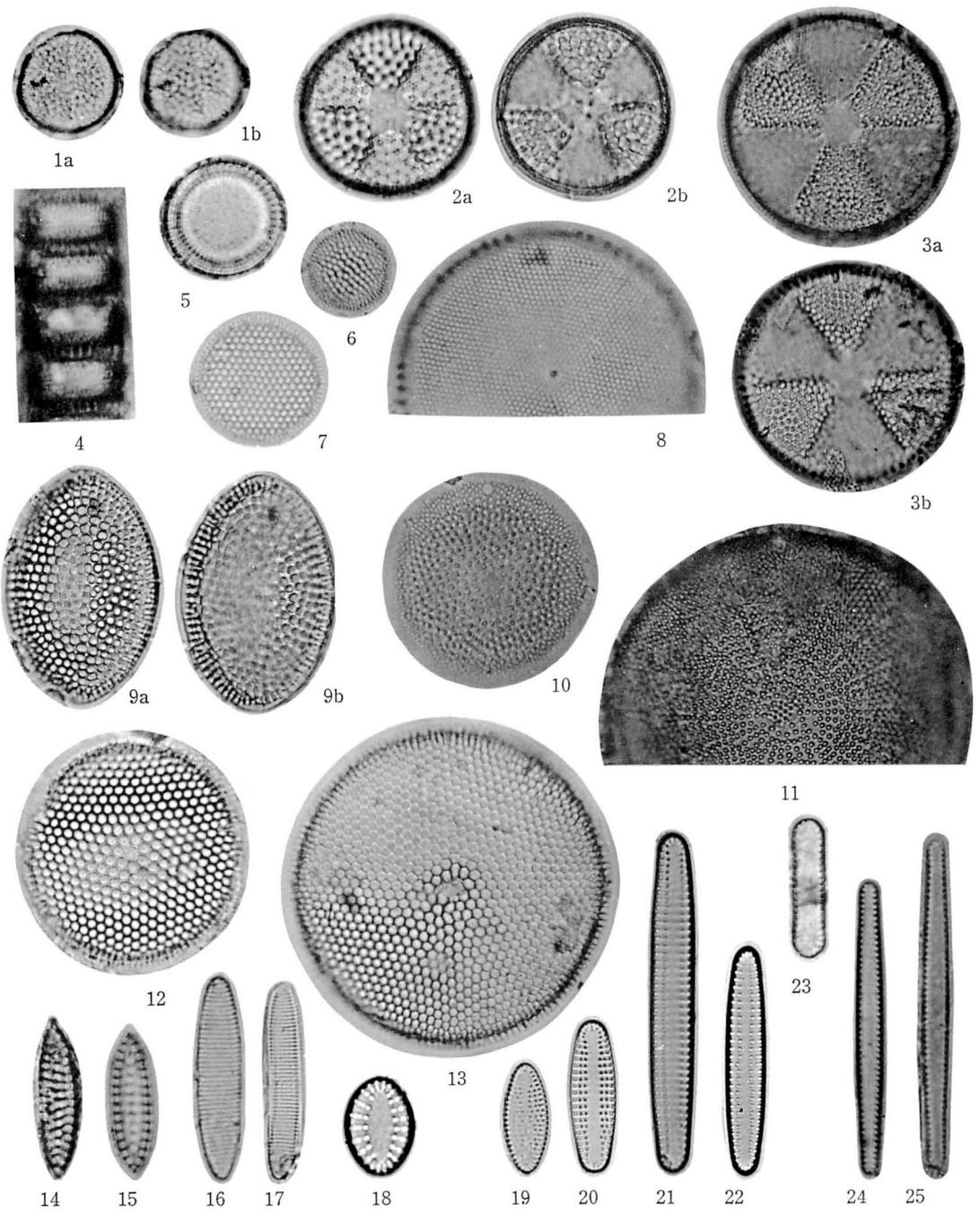
Explanation of Plate 20

15 taxa occupied the 1st to 5th ranks of dominance in each assemblage, as shown in Text-fig. 4-C, are illustrated.

(All figures, $\times 1000$)

- Figs. 1a, 1b. *Actinoptychus undulatus* (BAIL.) RALFS var., slide no. 7254, G39-OS*, 17μ in diameter, from A-4.
- Figs. 2a, 2b. *Actinoptychus undulatus* (BAIL.) RALFS var., slide no. 7210, L44-3E, 29μ in diameter, from D-15.
- Figs. 3a, 3b. *Actinoptychus undulatus* (BAIL.) RALFS, slide no. 7214, H42-1SW, 38μ in diameter, from D-17.
- Fig. 4. *Melosira sulcata* (EHR.) KÜTZ., slide no. 7207, Q47-ON, 16μ in diameter, from E-19.
- Fig. 5. *Melosira sulcata* (EHR.) KÜTZ., slide no. 7207, K43-2E, 19μ in diameter, from E-19.
- Fig. 6. *Thalassiosira decipiens* (GRUN.) JOERG., slide no. 7238, T39-2NW, 15μ in diameter, from B-7.
- Fig. 7. *Thalassiosira lineata* JOUSÉ, slide no. 7224, L47-ON, 21μ in diameter, from C-11.
- Fig. 8. *Thalassiosira lineata* JOUSÉ, slide no. 7224, E49-4NW, 50μ in diameter, from C-11.
- Figs. 9a, 9b. *Coscinodiscus temperi* BRUN, slide no. 7210, U43-ON, 39μ in length of apical axis, from D-17.
- Fig. 10. *Actinocyclus ehrenbergi* RALFS, slide no. 7214, S48-ON, 34μ in diameter, from D-15.
- Fig. 11. *Actinocyclus ehrenbergi* RALFS, slide no. 7252, R42-1E, 60μ in diameter, from B-5.
- Fig. 12. *Thalassiosira antiqua* (GRUN.) A. CL., slide no., 7252, H42-ONE, 36μ in diameter, from B-5.
- Fig. 13. *Thalassiosira antiqua* (GRUN.) A. CL., slide no., 6031, M44-O, 54μ in diameter, from D-17.
- Fig. 14. *Rhaphoneis tatsunokuchiensis* KOIZUMI, slide no., 7216, S45-4W, 26μ in length of apical axis, from C-11.
- Fig. 15. *Rhaphoneis tatsunokuchiensis* KOIZUMI, slide no., 7224, N49-OE, 23μ in length of apical axis, from C-9.
- Fig. 16. *Nitzschia extincta* KOZ. and SHESHUK., slide no., 7210, D44-4W, 23μ in length of apical axis, from D-17.
- Fig. 17. *Nitzschia extincta* KOZ. and SHESHUK., slide no., 7210, M44-ONW, 31μ in length of apical axis, from D-17.
- Fig. 18. *Rhaphoneis margaritalimbata* MERTZ., slide no., 7254, M40-OW, 17μ in length of apical axis, from A-4.
- Fig. 19. *Rhaphoneis surirella* (EHR.) GRUN., slide no., 7254, 031-4N, 19μ in length of apical axis, from A-4.
- Fig. 20. *Rhaphoneis surirella* (EHR.) GRUN., slide no., 7252, W42-ON, 26μ in length of apical axis, from B-5.
- Fig. 21. *Rhaphoneis angustata* PANT., slide no., 7210, Q44-3SE, 56μ in length of apical axis, from D-17.
- Fig. 22. *Rhaphoneis angustata* PANT., slide no. 7254, K29-ON, 38μ in length of apical axis, from A-4.
- Fig. 23. *Thalassionema nitzschioides* GRUN. var., slide no. 7249, N43-OS, 23μ in length of apical axis, from B-8.
- Fig. 24. *Thalassionema nitzschioides* GRUN., slide no., 7208, P39-ONW, 49μ in length of apical axis, from E-18.
- Fig. 25. *Thalassionema nitzschioides* GRUN., slide no., 7202, K29-ON, 56μ in length of apical axis, from G-21.

* The position of a specimen in a strewn slide read by the England Finder.



- (1930): Die Susswasser-Flora Mitteleuropas. In *Bacillariophyta (Diatomeae): Heft 10*, pp. 1-466. Jena.
- ISHIDA, T., OIKE, S., ONODERA, S., TAKEUTI, S., NAKAGAWA, H., NANASAKA, O. and MATSUYAMA, T. (1969): Quaternary changes in the sea level in the Tohoku region, Japan. In *Quaternary system of Japan. Assoc. Geol. Collab. Japan, Monogr. no. 15*, pp. 37-83. Tokyo.
- IWAI, J. (1949): Stratigraphy of the Cenozoic formations of Sendai and the environs. *Chikyū Kagaku (Earth Sciences)*, no. 1, pp. 1-5.
- JOUSÉ, A. P. (1962): Stratigraphical and paleogeographical studies in the north-western part of the Pacific Ocean. *Izd. Akad. Nauk S. S. S. R.* pp. 1-258. Moscow.
- KITAMURA, N. and SHIBATA, T. (1963): The guide-book prepared for the field trip in the Senboku area. For the 70th annual meeting of Geol. Soc. Japan., pp. 1-26.
- KOIZUMI, I. (1968): Tertiary diatom flora of Oga Peninsula, Akita Prefecture, Northeast Japan. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 40, no. 3, pp. 171-240.
- (1972): Marine diatom flora of the Tatsunokuchi Formation in Fukushima Prefecture. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 86, pp. 340-359.
- LOHMAN, K. E. (1937): Pliocene diatoms from the Kettleman Hills, California. *U. S. Geol. Survey, Prof. Papers 189-C*, pp. 81-94.
- MATSUNO, K. (1967): Geology of the Wakayanagi district. In *Quadrangle ser.*, scale 1:50,000, Akita (6) no. 69. *Geol. Survey, Japan.* pp. 1-24.
- MERTZ, D. (1966): Mikropalaeontologische und sedimentologische Untersuchung der Pisco Formation Sudperus. *Palaeontographica*, Bd. 118, Abt. B, pp. 1-51.
- NODA, H. (1966): The Cenozoic Arcidae of Japan. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 38, no. 1, pp. 1-161.
- NOMURA, S. (1938): Molluscan fossils from the Tatsunokuchi shell bed exposed at Goroku cliff in the western border of Sendai. *Ibid.*, vol. 19, pp. 235-275.
- OKUTSU, H. (1955): On the stratigraphy and paleobotany of the Cenozoic plant beds of the Sendai area. *Ibid.*, vol. 26, pp. 1-114.
- OSHITE, K. (1959): Sedimentological study of diatoms in marine deposits from the adjacent seas of Japan. *Hokkaido Gakugei Univ., Jour., sect. B*, vol. 10, no. 2, pp. 417-495.
- SHESHUKOVA-PORENTZKAYA, V. S. (1967): Neogene marine diatoms of Saghaline and Kamtchatka. *Izd. Leningr. Univ.* pp. 1-327. Leningrad. [in Russian]
- SHIBATA, T. (1962): Geology of the Sendai and Nanakita-Sanbongi areas, Miyagi Prefecture. *Sci. Rep. Tohoku Univ., 2nd ser. (Geol.)*, vol. 5, no. 3, pp. 239-301.
- SIMONSEN, R. (1962): Untersuchungen zur Systematik und Ökologie der Bodendiatomeen der westlichen Ostsee. In *Internationale Revue der Gesamten Hydrobiologie*; WOLTERECK, R. (Ed.), *Beih. 1*, pp. 1-44. Berlin.
- TAKAHASHI, H. and MATSUNO, K. (1969): Geology of the Wakuya district. In *Quadrangle ser.*, scale 1:50,000, scale 1:50,000, Akita (6) no. 78, *Geol. Survey, Japan.* pp. 1-26.
- TAKAYANAGI, Y. (1950): Pliocene smaller foraminifera from western Sendai. *Short Papers IGPS*, no. 2, pp. 23-28.
- UJIIÉ, H. and KUSUKAWA, T. (1969): Analysis of foraminiferal assemblages from Miyako and Yamada Bays, northeastern Japan. *Natl. Sci. Mus. Tokyo, Bull.*, vol. 12, no. 3, pp. 735-772.

Kameoka	亀岡
Kitakami	北上
Kitayama	北山
Miyagi	宮城

Ōu	奥羽
Sendai	仙台
Tatsunokuchi	竜ノ口

ERRATA

KOIZUMI, I., Marine Diatoms Flora of the Pliocene Tatsunokuchi Formation in Fukushima Prefecture. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, No. 86, pp. 340-359, 1972.

The dendrogram in Text-fig. 3 of page 345 is corrected as follows: The group consists of Ōk. 3, Ōk. 1-2 and T. 34 is fused together with the group consists of Tomioka 33 and Ōkuma 2-2, and two samples of Ōk. 2-3 and T. 36 at the 0.61 level of the Jaccard Coefficient.

622. HOLOCENE TO UPPERMOST PLEISTOCENE PLANKTONIC
FORAMINIFERS IN A PISTON CORE FROM OFF SAN'IN
DISTRICT, SEA OF JAPAN*

HIROSHI UJIIÉ

Department of Paleontology, National Science Museum, Tokyo 160

and

MASAKI ICHIKURA

Kamishirane Junior High School, Yokohama 241

山陰沖産ピストン・コア中の完新統一最上部更新統浮遊性有孔虫：日本海より得た約40本のピストン・コアのうち25本の予察的検討をおこない、炭酸石灰補償深度が非常に浅いことを知り、日本海特有の溶存酸素に富む冷水塊に帰因すると推察する。いっぽう、同深度より浅い鳥取市沖水域より得たコア（V28-265）は、920 cm に及ぶ全長にかけて、ほぼくまなく浮遊性有孔虫を産出する。卓越する“*Globigerina*” *pachyderma* の coiling ratio から、コア頂部より約120 cm のところに完新世・更新世境界（約11,000年前）を認め、それを境にして古水温の上昇、還元的条件から酸化的条件へなどの古環境の急変があることを示唆する。もう一つの優勢種である *Globigerina umbilicata* は、ほぼ同コア更新統のみに限られ、中・高緯度地方の上部鮮新統ないし更新統の示準種となるかもしれない。ただし、V28-265 は、Riss-Würm 間氷期には達していないらしい。（氏家 宏・市倉賢樹）

Introduction and acknowledgements

In the course of study on forty piston cores from the Sea of Japan, we found an interesting core which was taken from just north off Tottori City, San'in district of southwestern Honshu. Unlike the other cores that are mostly devoid of foraminiferal shells, the core, V28-265, contains abundant planktonic foraminifers throughout the length and indicates a definite Holocene-Pleistocene boundary at a level between 107 cm and 135 cm below the top. Besides, the

biofacies including other kinds of microfossils and the lithofacies of this core provide us with some evidence of significant environmental change of the Sea from the latest Pleistocene to Recent.

The origin and development of the Sea of Japan have interested many authors because the Sea has the oceanic type crust transferred from the continent type crust during the Neogene Tertiary period; the area was a part of the Asiatic continent at least until a certain time of the Paleogene. Thenceforth the area, particularly its eastern half, has changed to the oceanic type sea, despite of its shape indicating a marginal sea, through the process of the oceani-

* Received March 23, 1973; read January 16, 1973 at Sendai.

zation (e. g., BELOUSSOV and RUDITCH, 1961) or through the splitting-off of the Japanese Islands toward the Pacific Ocean (e. g., MURAUCHI, 1966); the latter idea is related to the ocean-floor spreading theory. Therefore, the previous investigations have been focused upon the judgement which one of the above two ideas is correct, mainly on the basis of comprehensive geophysical measurements. On the other hand, there are rather few studies of the sediment samples, especially of long cores, that should inform the geologic age of the measured physical properties and the historic change of paleoenvironment of the Sea. Along with the prospecting of the earliest marine sediments under the sea bottom, the researches on the derivation of oceanic condition into the area would offer critical answers to the origin of the Sea of Japan as an ocean.

The core V28-265 treated here may give only the information about the latest history of the Sea but may suggest its essential characters during the glacial and post-glacial periods; the assumptions presented in this paper may be applicable not only to every glacial or inter-glacial period but also to the pre-glacial period including the earliest age of the Sea of Japan.

This study was worked out as a part of the project entitled "Study of sedimentary deposits of the Sea of Japan and surrounding terrains" under the Japan-U. S. Cooperative Science Program (4R006). We express our sincere thanks to all the participants from the Lamont-Doherty Geological Observatory of Columbia University for their kind cooperation, and also to the Japanese participants for their discussion on the results. We are also indebted to Dr. William N. ORR, University of Oregon, Eugene, Oregon and to Dr. James C.

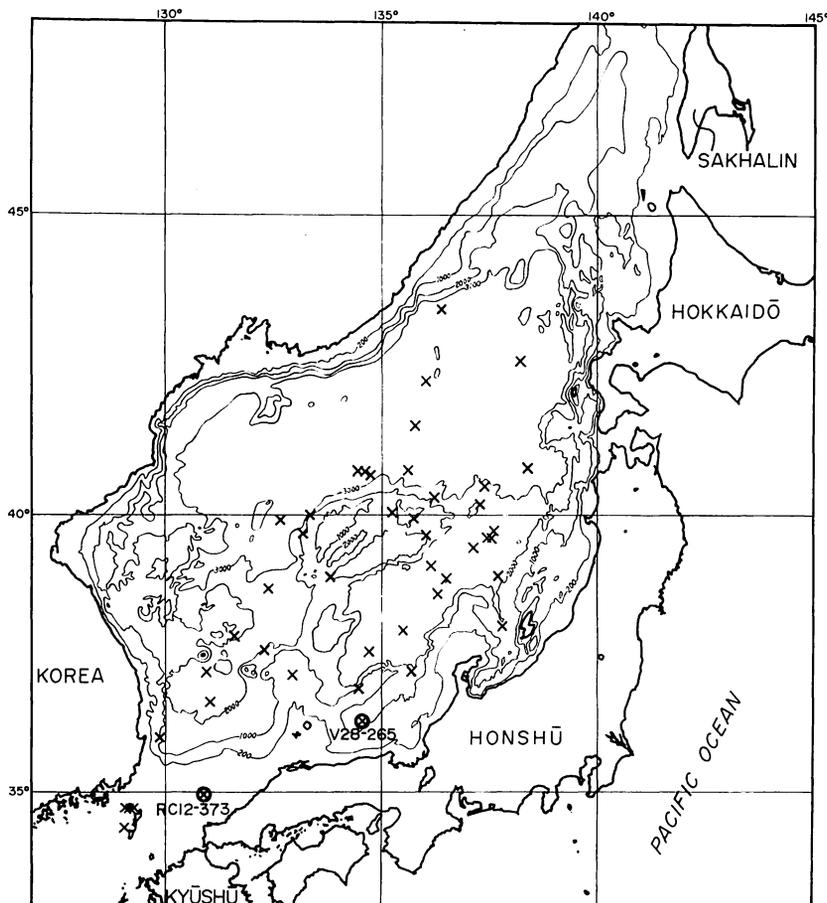
INGLE, Jr., Stanford University, California, for furnishing us the topotypes and hypotypes of *Globigerina umbilicata* ORR and ZAITZEFF from the Rio Dell Formation, along Centerville Beach south of Eureka, California. The manuscript was reviewed by Miss Reiko FUSEJIMA of the National Science Museum of Tokyo.

Outline of the present environment of the Sea of Japan

The Sea of Japan is a typical marginal sea separated from the Pacific Ocean by the Japanese Islands Arc. The four outlets to the Pacific are shallower than 130 m, but the northern half of the Sea where the bottom is rather flat measures more than 3,000 m in water depth with the oceanic type of crust underneath. On the other hand, the southern half has a continental rise east of Korea and the Yamato and Kita-Yamato banks at the middle, thus being characterised by the complicated relief implying different origins of the bed rocks.

Warm currents called the Tsushima Current and the East Korea Current, enter through the Tsushima Straits into the Sea of Japan where they seem to diminish so quickly that their influence on the microfaunal or microfloral assemblages on the sea bottom appears to be very small except for the narrow areas along the coast of Japan.

In contrast with the warm currents, the cold water mass has much greater influence on the sea bottom throughout the whole area of the Sea. A part of this mass persists as a descent of the Liman Cold Current, a portion of which flows into the Sea through the strait between Sakhalin and the Asiatic mainland and, to a greater extent, it is



Text-fig. 1. Location map of the studied piston cores.
Bathymetry is shown in meters.

generated off the Asiatic continent particularly in winter season. The oxygen-rich surface water chilled by the Siberian Air Mass that is developed well in winter becomes heavier, sinks down to the deep, and moves toward the south. Since every southern outlet is shallow, this cold water mass cannot get out of the Sea of Japan and remains there, producing a powerful effect on the biotic and lithologic aspects of the sea bottom.

The present cold and oxygen-rich water is recognized in the hydrologic

observations cited by NIINO *et al.* (1969). NIINO *et al.* emphasized the effect of oxygenation on the sea bottom sediments, in which the content of organic carbon is very low and the color of the sediments changes from olive to brownish at a very shallow depth, differing from the case of other normal oceans.

As far as the top samples of 25 piston cores treated by us are concerned, a similar change of color from olive to brown or yellowish brown was recognized between ca. 2,338 m and 2,226 m of water depth; that is much shallower

Table 1. 25 piston cores showing the approximate depths of the color change in the top portions, of the lysocline, and of the calcium carbonate compensation.

Core No.	Water Depth (m)	Foraminiferal Shells	Color in General Aspect
V28-281	3588	Absent	Top 36 cm: yellowish brown to brown; the other: olive, partly grey
V28-273	3533	Absent	Top 34 cm: yellowish brown to brown; the other: olive, partly grey
RC12-385	3469	Absent	Top 11 cm: brown; the other: olive, partly grey
RC12-386	3497	Absent	Top 25 cm: yellowish brown to brown; the other: olive, partly grey
V28-271	3382	Absent	Top 35 cm: yellowish brown to brown; the other: olive, partly grey
RC12-382	3027	Absent	Top 30 cm: yellowish brown to brown; the other: olive, partly grey
RC12-393	3010	Absent	Top 64 cm: yellowish brown to brown; the other: olive, partly grey
V28-267	2831	Absent	Top 30 cm: yellowish brown; the other: olive, partly grey
V28-268	2692	Absent	Top 20 cm: yellowish brown to brown; the other: olive
V28-274	2677	Absent	Top 47 cm: yellowish brown to brown; the other: olive, partly grey
RC12-384	2635	Absent	Top 34 cm: yellowish brown; the other: olive
RC12-389	2650	Absent	Top 22 cm: yellowish brown; the other: olive, partly grey
RC12-388	2459	Absent	Top 38 cm: brown; the other: olive
RC12-394	2338	Absent	Top 2 cm: yellowish brown; the other: olive partly grey
RC12-377	2226	Absent	Olive throughout
RC12-383	2113	Absent	Olive, partly grey
RC12-374	2111	Absent	Olive throughout
RC12-380	1596	Partly dissolved	
RC12-381	1437	Partly dissolved	Olive throughout
RC12-376	1426	Partly dissolved	Olive throughout
RC12-378	1401	Partly dissolved	Olive throughout
V28-265	1218	Present throughout	Olive, partly grey
RC12-390	1103	Present throughout	Olive throughout
RC12-379	1010	Present throughout	Olive throughout
RC12-387	838	Present throughout	Olive throughout

than the averaged depth (4,000 to 5,000 m) of the oceans.

The oxidizing effect seems to be more distinct in the calcium carbonate compensation. As shown in Table 1 the surface samples of the 25 cores suggest a very shallow depth of the compensation, at a level between 1,596 m and 1,437 m, and also that of the lysocline somewhere between 1,401 m and 1,218 m. Generally the calcium carbonate compensation depth is regarded as the function of the water depth accompanied by higher solubility owing to increasing pressure, of the carbon dioxide pressure in water, and of the sinking rate of calcium carbonate shells or skeletons. In the case of the Sea of Japan, however, it appears that the rich dissolved oxygen in water affects most effectively the compensation, different from ordinary instances such as summarized by BERGER (1971).

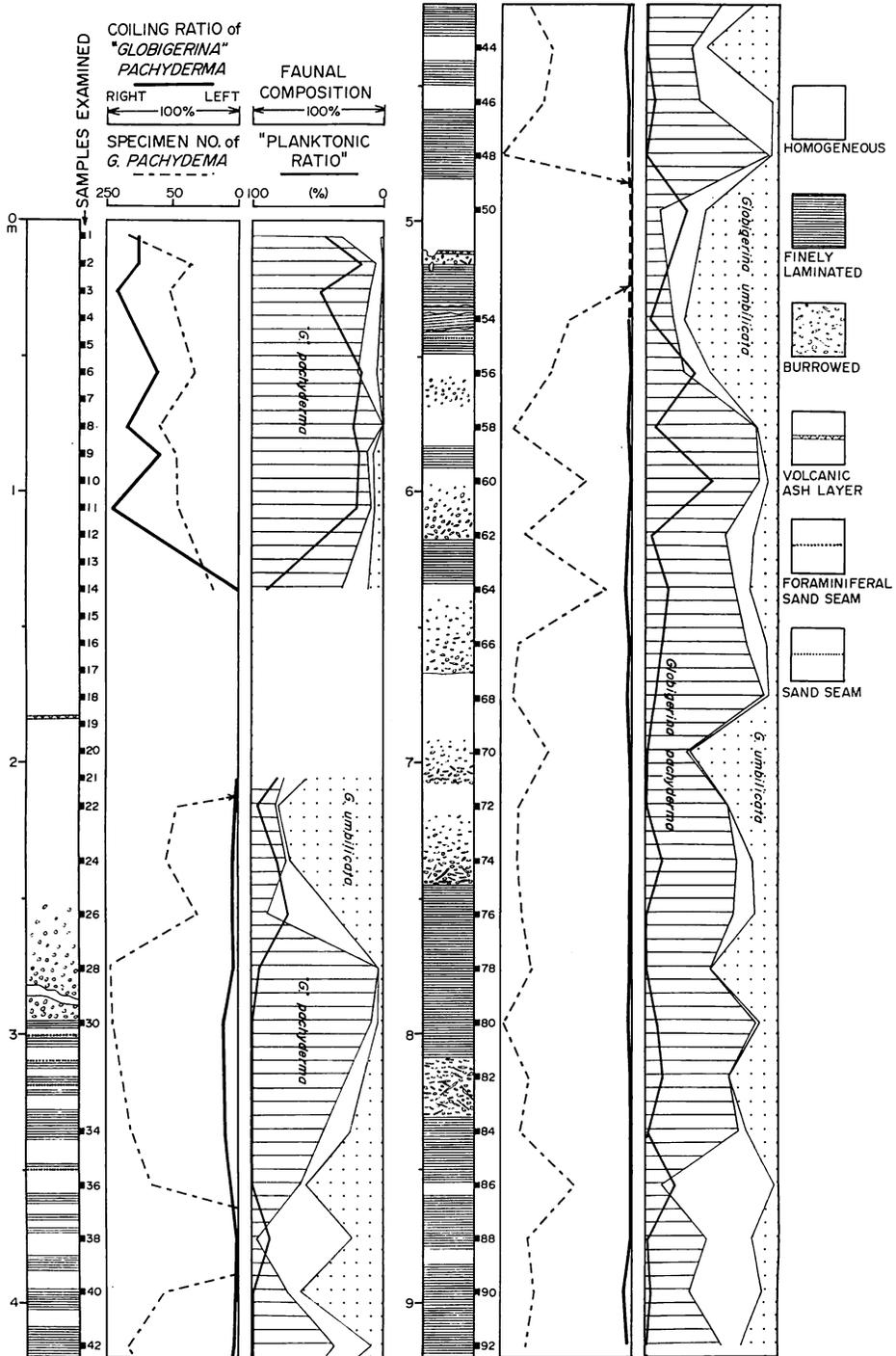
We would like to conclude that the present day hydrology of the Sea of Japan is characterized by extraordinarily oxygenated condition of water. This may be supported by NIINO *et al.* (1969) who measured very low organic carbon content mostly less than 1% in the surface sediments of the deep floor of the Sea.

Core V28-265 and materials for this study

V28-265, a piston core, was taken at Lat. 36°17'N., Long. 134°34'E, from the water depth of 1,218 m so that the calcareous shells of planktonic foraminifers remain unaffected by leaching out almost throughout the whole length of 920 cm. Lithology of the core on a half-cut face was described by N. FUJI of Kanazawa University at the Lamont-Doherty Geo-

logical Observatory of Columbia University as his task of the Japan-U. S. Cooperative Project and, at the same time, described and photographed by J. RIGAUD of the Observatory as a routine work there. The three kinds of documentation compiled by us are summarized in the columnar section of Text-figure 2. The core is olive-colored throughout, with a slight variation, and is composed of silty clay to clayey silt, intercalated with rare seams of sand, one of which consists of foraminiferal shells. Two acidic ash layers 1 cm thick each occur at 183-184 cm and 511-512 cm below the top. Upper one-third of the core is completely homogeneous, whereas lower two-thirds are predominated with very thinly laminated clay frequently accompanying homogeneous or burrowed layers. Among the laminated, burrowed, and homogeneous types of layers there seems to be no definite relationship but, in the interval ranging from about 590 cm to 740 cm below the top, the burrowed layer grades upward into the homogeneous one and lies on the laminated one. This relation might imply the origin of the homogeneous clay that may have been produced through the mixing of laminated clay by some burrowing worms. Concerning the preservation of foraminiferal shells, however, we could not find any evidence supporting this process, although BERGER and SOUTAR (1970) recognized some of the evidences.

All cores from the Sea of Japan were vertically cut into four portions, and a quarter of every core was presented to the participants from Japan for study. For the foraminiferal study 2 cm thick portions of this quarter of core were taken at stratigraphic intervals of 10 cm between 5-7 cm and 215-217 cm, and at intervals of 20 cm between 225-227 cm



Text-fig. 2. Foraminiferal analysis of the core V28-265.

and the bottom (see Text-figure 2, for the exact position of samples). After weighed in dry condition, all samples were washed through a 200 mesh screen. From the dried residue on the screen, the 200-odd specimens of planktonic foraminifers were picked out at random under the binocular microscope (see UJIIÉ, 1962, for the method of random sampling of individuals and for the statistical meaning of the 200-odd total number of specimens).

Foraminiferal assemblages

The core V28-265 contains many foraminifers sufficient for analysis, except for the part between ca. 145 cm and ca. 200 cm below the top. The absence of foraminifers in this part may be ascribed to the fact that pyroclastics are developed there, particularly in the part around an ash layer at 183-184 cm, as indicated by a considerable amount of volcanic glass fragments found in the residue of washed samples. Also, an environmental condition might be another explanation of this particular part. As will be mentioned in the next section, this part seems to have been deposited in an anoxic condition of the bottom water where calcite shells of foraminifers may have been dissolved by the presumably high content of carbon dioxide.

From 45 samples we identified 7,733 specimens belonging to 11 species of planktonic foraminifers as recorded in Table 2. The faunal composition of all but one samples is quite similar and simple, with predominance of very few cold water tolerant taxa. An exception is the top sample where common occurrence of "*Globoquadrina dutertrei*" and rare *Globigerinoides ruber* and *Globoquadrina* sp. A suggests a slightly warmer

condition. These general aspects present a contrast with the faunas in the Tsushima Straits where the subtropical elements are dominant (UJIIÉ, 1973). Since such subtropical faunas were found all over the length (500 cm) of the core RC12-373 from on the shelf off Yamaguchi Prefecture, the Tsushima Warm Current may diminish quickly between the localities of RC12-373 and V28-265. According to the preliminary check of the 25 cores mentioned above, the cold water mass appears to affect on planktonic foraminifers of the Sea of Japan as a whole in much greater extent than the warm water currents do; this view agrees with that from the hydrologic observation as mentioned already.

It is noticeable that the "cold water fauna" is predominated only by two species, i. e., "*Globigerina pachyderma*" and *Globigerina umbilicata*. The "*G. pachyderma*" dominant fauna has been recognized in the Recent Arctic (GREEN, 1960; BÉ, 1960) and Antarctic Oceans (e. g., BÉ, 1969). In these seas, moreover, they are predominantly left coiling shells (more than 90%). The species is also common in the subarctic and subantarctic regions and in some upwelling areas in middle latitudes, although the right coiling shells predominate there.

The change in the coiling direction of "*Globigerina pachyderma*" as a paleoclimatic indication was observed first in the deep sea cores of the Atlantic Ocean (ERICSON, 1969) and in 12 cores from off California and 2 land sections in southern California (BANDY, 1960). Particularly using the sea bottom cores from off California, BANDY revealed a distinct change from the sinistral-dominant population to the dextral-dominant one at about 11,000 yrs B.P. based on the carbon-14 dating, and he regarded it as an index of the Holocene-

Table 2. Occurrence chart of planktonic

	1	2	3	6	8	9	11	13	14	15	21	22	24	26	28	30	34	36	38	
<i>Globigerina pachyderma</i> (EHRENBERG) left	36	8	5	11	11	18	2	1	18	1	3	44	55	26	218	183	120	76	1	
<i>Globigerina pachyderma</i> (EHRENBERG) right	109	24	48	17	57	26	41						2	1	5	22	12	4		
<i>Globigerina umbilicata</i> ORR & ZAITZEFF	6		1	2		4	3		3		7	177	154	82	7	9	60	127	6	
<i>Globigerina</i> cf. <i>bulloides</i> D'ORBIGNY	1		1																1?	
<i>Globigerina quinqueloba</i> NATLAND	10		1	1					2			2		26		3	14	1	6	
<i>Globigerina</i> cf. <i>angusti-</i> <i>tumbilicata</i> BOLLI	16	1	1					1	2	1	1			15		4	15	5	10	
<i>Globigerina</i> sp.	2																			
<i>Globigerinita glutinata</i> (EGGER)	2			1?															9	
<i>Globigerinita uvula</i> (EHRENBERG)	5	1		1					1		1			7	70		2	11	1	
<i>Globigerinoides ruber</i> (D'ORBIGNY)	1																			
" <i>Globoquadrina</i> " <i>dutertrei</i> (D'ORBIGNY)	26		2	2		1													2?	4?
<i>Globoquadrina</i> sp. A	2					1	1													1?
Total	216	34	59	35	68	50	47	2	26	2	12	223	218	220	230	225	241	218	25	
Benthonic total	243	161	62	167	223	219	184	2	3	0	3	10	53	82	13	0	0	0	4	

Pleistocene boundary. We noticed a quite similar change of coiling ratios between Samples 11 and 14 of V28-265 (Sample 12 is devoid of the species and 13 contains only one sinistral specimen), namely, between 107 cm and 135 cm below the top of the core. The ratios calculated here are warranted by the statistically sufficient number of specimens per sample as shown in Text-figure 2 and Table 2. Exceptionally in Samples 21, 38, and 50, the 100% left coiling is represented by 3, 1, and 1 individuals, respectively.

Along with the coiling variation, some morphological variations are recognized between sinistral and dextral "*Globigerina*" *pachyderma* of V28-265. While

the sinistral forms are dominantly provided with less lobulate four chambers per whorl (see example, in Plate 21, fig. 1), many dextral ones have four and a half, or rarely five, chambers which are so lobulate in general shape that they somewhat resemble "*Globoquadrina*" *dutertrei* (Plate 21, fig. 3). The former type of variation was also found in the Antarctic Ocean (BANDY and THEYER, 1971), especially in the region south of the Antarctic Convergence (KENNETT, 1968). On the other hand, the latter variation with a greater number of more lobulate chambers have been found in the "sinistral-dominant" populations of the subantarctic region and the Arctic Ocean (KENNETT, 1968,

foraminifers in the core V28-265.

40	42	44	46	48	50	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
61	142	67	87	243	1	46	74	179	31	132	18	156	178	77	154	164	145	112	230	123	155	40	129	102	129
1	4	4	2	7		1		4		4	1	3	5	1	1	1	2	2	7	1				6	4
141	23	113	10	15	5	155	128	38	3	41	6	18	16	165	92	47	39	119	41	72	51	9	56	38	63
1	1	2	1											1?		1?			1?		4?				
1						12	23			21		19				15	11					65	50	82	20
13	22	10	74	1	2	1	13		1	11	1	8	1	1		4	8		1		6	165	29	71	11
														1		1?						1			
		1?	1?		1?					2?															
5	41	9	42			2	12		1	15		2	2			5	15		1		2	49	11	23	3
		2?	1?							1?												4?	1?		
223	233	208	218	266	9	217	250	221	36	225	28	206	202	246	247	237	221	233	280	196	219	330	279	322	230
0	0	0	17	0	4	8	147	16	37	10	6	29	16	1	2	33	0	0	28	28	3	97	5	15	0

1970). With regard to the grade of the encrusting process of shells, there is no difference between the two types of variation in the case of V28-265, both types being rather thinly encrusted, notwithstanding BANDY's (1972) opinion. BANDY was inclined to conclude that the variants with highly thickened walls have been developed in the glacial Pleistocene and are present-day diagnostic of deep polar waters. However, we agree with BANDY's view that "*Globigerina*" *pachyderma* [his *Globorotalia* (*Turborotalia*) *pachyderma*] includes *Globigerina bulloides borealis* BRADY, *Globigerina incompta* CIFELLI, and *Globorotalia pseudopachyderma* CITA, PREMOLI SILVA and ROSSI as its younger

synonyms.

Apart from the morphologic variations mentioned hitherto, the predominance of coiling direction seems to be an expressivity of the phenotypes reflecting different water temperatures. Therefore, the quick change from the sinistral-dominant population to the dextral-dominant one at about 120 cm below the top of V28-265 is thought to show a paleoclimatic change from the glacial Peistocene to post-glacial Holocene. At the same time, constant occurrence of the sinistral population from the boundary down to the bottom of the core may imply absence of any interglacial or interstadial warm stage. When ca. 1 cm per 1,000 years of the sedimentation rate

estimated for the Holocene part* of V28-265 is applied to the lower part, the bottom will be of about 92,000 yrs B.P. If this would be true, there should be the Riss—Würm interglacial stage, though we do not intend to employ such a short chronology as was maintained by EMILIANI (1966, 1970) who compressed the four glaciations from the Günz to the Würm stages within the last 0.4 million years and placed the upper limit of the Riss—Würm interglacial stage at ca. 60,000 yrs B.P. Many authors (see BERGGREN, 1972), however, considered that the four events occurred within the last 0.7 million years. In the same way as EMILIANI but on the basis of new data and different interpretation of the insolation change and the ^{18}O record of the deep sea cores, BROECKER (1966; BROECKER and VAN DONK, 1970) ascribed the high stands of sea to the retreat of glacier at about 80,000 yrs B.P. In 28 piston cores from the western Gulf of Mexico, KENNETT and HUDDLESTON (1972) recognized planktonic foraminiferal faunas indicating an abrupt climatic change which corresponds to that from the interglacial to the glacial around 90,000 yrs B.P. In the case of V28-265, therefore, the age about 92,000 yrs B.P. for the bottom might be an overestimation; this is quite reasonable because the estimated rate of sedimentation must be higher during the glacial stage accompanied by lowering of sea level, particularly in a marginal sea such as the Sea of Japan.

Another dominant taxon of planktonic

* The top of the core may represent the present day, because the stratigraphical changes of diatom floras, of pollen-assemblages and of the uranium content of the core well correspond with those of the other cores from the Sea, respectively (after unpublished data by the participants of this project).

foraminifer in V28-265 is *Globigerina umbilicata* ORR and ZAITZEFF that was recently (1971) described from the Upper Pliocene in the northernmost part of California. Fortunately we were able to compare our specimens with topotype specimens from the upper Rio Dell Formation on Centerville Beach near Eureka through the courtesy of W.N. ORR and with many specimens in a washed sediment sample from the middle Rio Dell Formation, about 1,900 feet stratigraphically below the type locality, by kindness of J.C. INGLE, Jr. INGLE (personal communication dated December 4, 1972) also found this taxon in the Pliocene and Pleistocene cores which were taken from the northeastern Pacific by Leg 18 cruise of the Deep Sea Drilling Project. As shown in Plates 21 and 22, these specimens from the northeastern Pacific region are identical with our specimens from V28-265. Our materials, however, are seldom accompanied by *Globigerina bulloides*, whereas in the northeastern Pacific *G. umbilicata* never predominates over the always associated *G. bulloides* so that INGLE thought the former taxon to be a phenotypic variant of the latter and to be called *Globigerina bulloides umbilicata*. Nevertheless, so far as our specimens are concerned, we are inclined to treat *G. umbilicata* as an independent taxon, especially because of the number of its chambers per whorl ranging from three or four in juvenile stage to five or six in full grown stage, as stated in the original description, different from *G. bulloides* which is provided with three and a half to four chambers per whorl throughout the ontogeny. Moreover, the heavily thickened shell of *G. umbilicata* may be one of the most important specific characters. ORR and ZAITZEFF (1971) considered this thickening to be of secondary [after the death?], but we

think differently since other associated taxa, particularly "*G.*" *pachyderma*, never have such heavily thickened shells.

A stratigraphically interesting thing is that the occurrence of *G. umbilicata* is limited almost to the Pleistocene portion which yielded a considerable number of specimens (Table 2, Text-figure 2); in the Holocene portion of the core, only a few and probably juvenile small specimens are found. Re-examination may be required for the occurrence of so-called *Globigerina bulloides* previously reported in the Pliocene and Pleistocene faunas of the Sea of Japan region including the land sections. Later, this species will be an index fossil of the probably upper Pliocene to Pleistocene beds in the mid-to high-latitude areas.

In this paper, we do not intend to report or discuss the details of the benthonic foraminifers. However, we would like to point out an interesting fact that the benthonic faunas become suddenly dominant over the planktonics after the Pleistocene as seen in the change of "planktonic ratio" of Text-figure 2. The ratio is a ratio of the total number of planktonics to all specimens including benthonics which were encountered during the picking-out of the 200-odd planktonic specimens per sample. The distinct change of the ratio at about 120 cm below the top of the core may reflect the environmental change toward the present-day oxygenated condition from the Pleistocene, in which an anoxic condition is supposed as shown in the next section.

The Holocene benthonic fauna is characterized by the common occurrence of *Israndiella*, *Cassidulina*, *Trifarina* and *Epistominella levicula* RESIG and by the absence of Elphidiidae. This general aspect of faunal composition well agrees

with that of "A province" classified by TROITSKAJA (1970). She treated 74 surface samples from the greater part of the Sea of Japan and divided the faunal provinces of benthonic foraminifer into three; A province characteristic in the continental shelf off the Asiatic mainland, B in the continental slope and central basin, and C in the Yamato and Kita-Yamato Banks. The Pleistocene benthonic fauna of V28-265 is very poor in numbers of taxa and specimens in comparison with the Holocene one, but its composition is not different essentially from the latter, except for the characteristic occurrence of some bolivine forms.

Environment suggested by the core V28-265

As stated in the second section of this paper, the Recent Sea of Japan is not affected largely by the warm current as a whole, different from some previous opinions, most of which were dependent on the data obtained from the region near the coasts of the Japanese Islands. Planktonic foraminifers in the Holocene portion of V28-265 also do not indicate a warm environment. Such a cool temperate condition seems to be supported by other microfossils in the core, such as radiolarians, diatoms, coccoliths, and pollens, according to the Japanese participants in the same project.

Thus, no contrastive difference can be expected between the Holocene and Pleistocene parts of the core so far as the paleoclimatic interpretation of these microfossils is concerned, except for the coiling direction of "*Globigerina*" *pachyderma*. However, the detailed analyses of diatoms and pollens revealed the floral change around 138 cm and 123 cm below

the top, respectively, due to increasing temperature since the latest Pleistocene.

More remarkable and interesting environment would be inferred for the latest Pleistocene part. One of the greatest glaciations appeared to have occurred in the latest Pleistocene (e. g., FLINT, 1971); it resulted in a marked lowering of the sea level so that the shallow (less than ca. 130 cm) outlets of the Sea of Japan toward the open oceans rose almost above the sea level, and so they might have made the obstruction against the incoming surface water from the open ocean. This obstructive effect seems to be reflected in the fact that radiolarians, most typical pelagic microorganisms, are scarce or absent in the Pleistocene part. This situation might have affected the ratio of pelagic diatoms to benthonic ones; namely, the ratio is lower in the Pleistocene part than in the Holocene in general.

The Sea of Japan turned into an enclosed sea like a huge lagoon or lake may have been provided with anoxic condition, which would be accentuated by decreased chilling effect of the Siberian Air Mass on the surface water during the glacial stage. Such a phenomenon was first suggested by MIYAKE

et al. (1968) who recorded an extremely high content of uranium in the "Pleistocene" part of a short core from the northern part of the Sea. In an anoxic condition, uranium in sea water is reduced from hexavalent to tetravalent state, to be readily precipitated to the sea bottom. In V28-265, Y. SUGIMURA found very high values of the uranium content such as 9.8 and 9.6 ppm at 150-160 cm and 200-210 cm below the top.

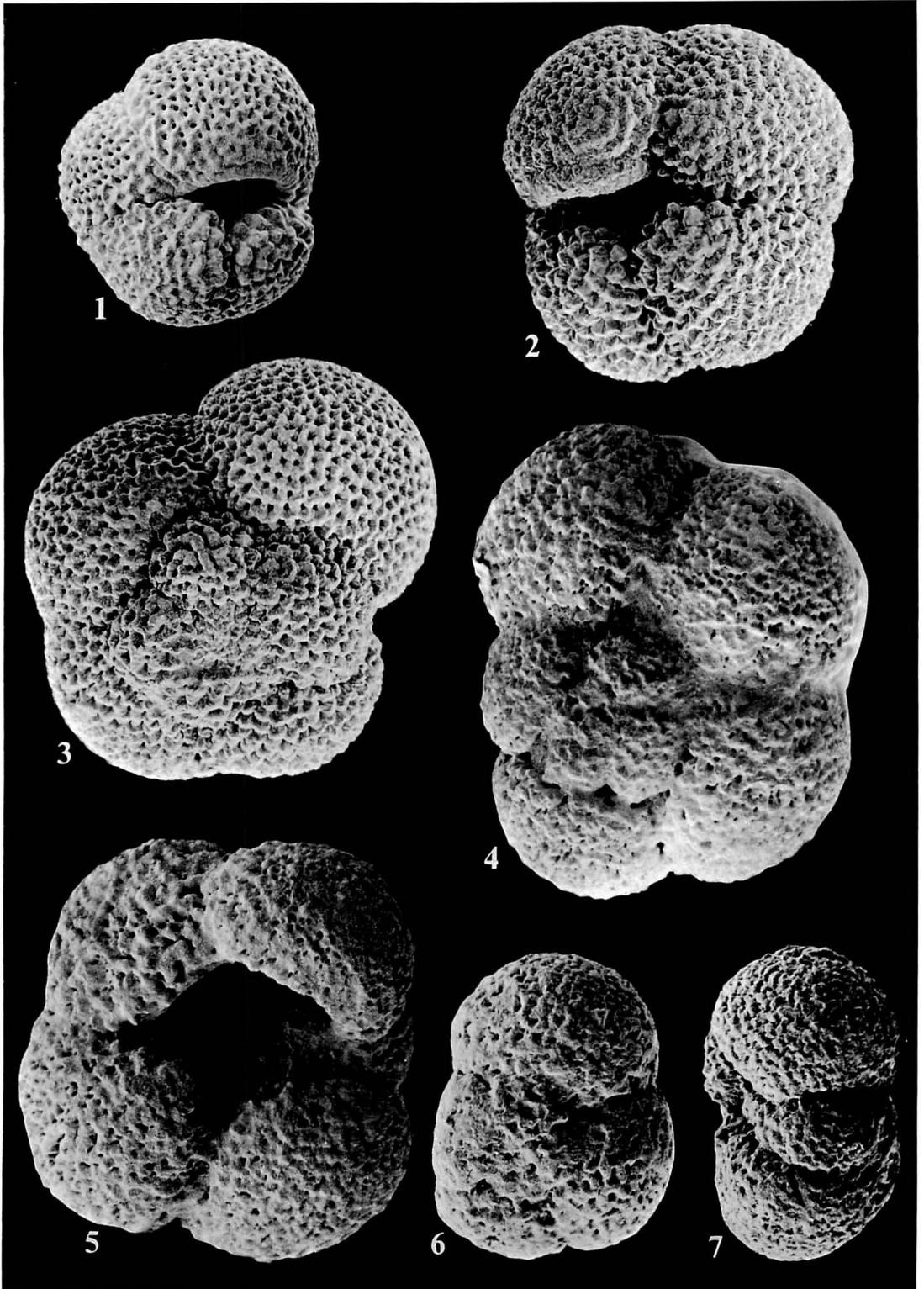
The reduced environment may be represented by the scarcity of benthonic foraminifers and the common occurrence of framboidal pyrite in the Pleistocene portion of the core. Absence of foraminifers in the uppermost Pleistocene of the core also reflects a large-scale reduction that should produce high pressure of carbon dioxide in the bottom water and calcareous shells would be dissolved. Similar effect of dissolution seems to have acted on the probably Pleistocene part of the other cores which came from the water deeper than the compensation depth of the Sea of Japan. Unless the dissolution took place, the part should contain foraminiferal shells because the highly oxygenated condition like the existing state could not be expected in the Pleistocene portion. The

Explanation of Plate 21

Figs. 1-3. "*Globigerina*" *pachyderma* (EHRENBERG).

1: Umbilical side of a sinistral form (NSMT-Micropal. Coll. 580), from Sample 40, 395-397 cm below the top of the core V28-265; 2: Umbilical side of a dextral form with less lobulate chambers (NSMT-MC 606); 3: Spiral side of a dextral form with lobulate chambers (NSMT-MC 605), both from Sample 8, 75-77 cm below the top of the core; all $\times 200$.

Figs. 4-7. *Globigerina umbilicata* ORR and ZAITZEFF from the middle Rio Dell Formation, 1,570 feet south of Guthrie Creek, Humboldt County, California. 4: Spiral side of a full grown specimen (NSMT-MC 592), $\times 180$; 5: Umbilical side of adult specimen (NSMT-MC 593), $\times 180$; 6: Spiral side of juvenile specimen, already with thickened wall (NSMT-MC 596), $\times 200$; 7: Lateral and apertural side of young specimen (NSMT-MC 594), $\times 150$.



situation is different from the case of an anaerobic basin off California reported by BERGER and SOUTAR (1970) who recognized that the plankton shells are preserved better there than in the adjacent areas under the normal condition. Anoxic influence may be the color of the probably Pleistocene parts of the cores deeper than ca. 2,500 m of the Sea of Japan; namely, the color of the parts turns olive from brown or yellowish brown of the probably Holocene parts (Table 1). However, it may be difficult to locate the Holocene base by this color change alone, since the change is partly due to post-burial reaction with pore solution.

The explanation of the presumed environment for the core V28-265 given in this paper is largely dependent upon the unpublished data obtained by the participants of the project. Somewhat more detailed data and discussion will be published as a short synthesized paper in the near future (UJIIÉ *et al.*, 1973).

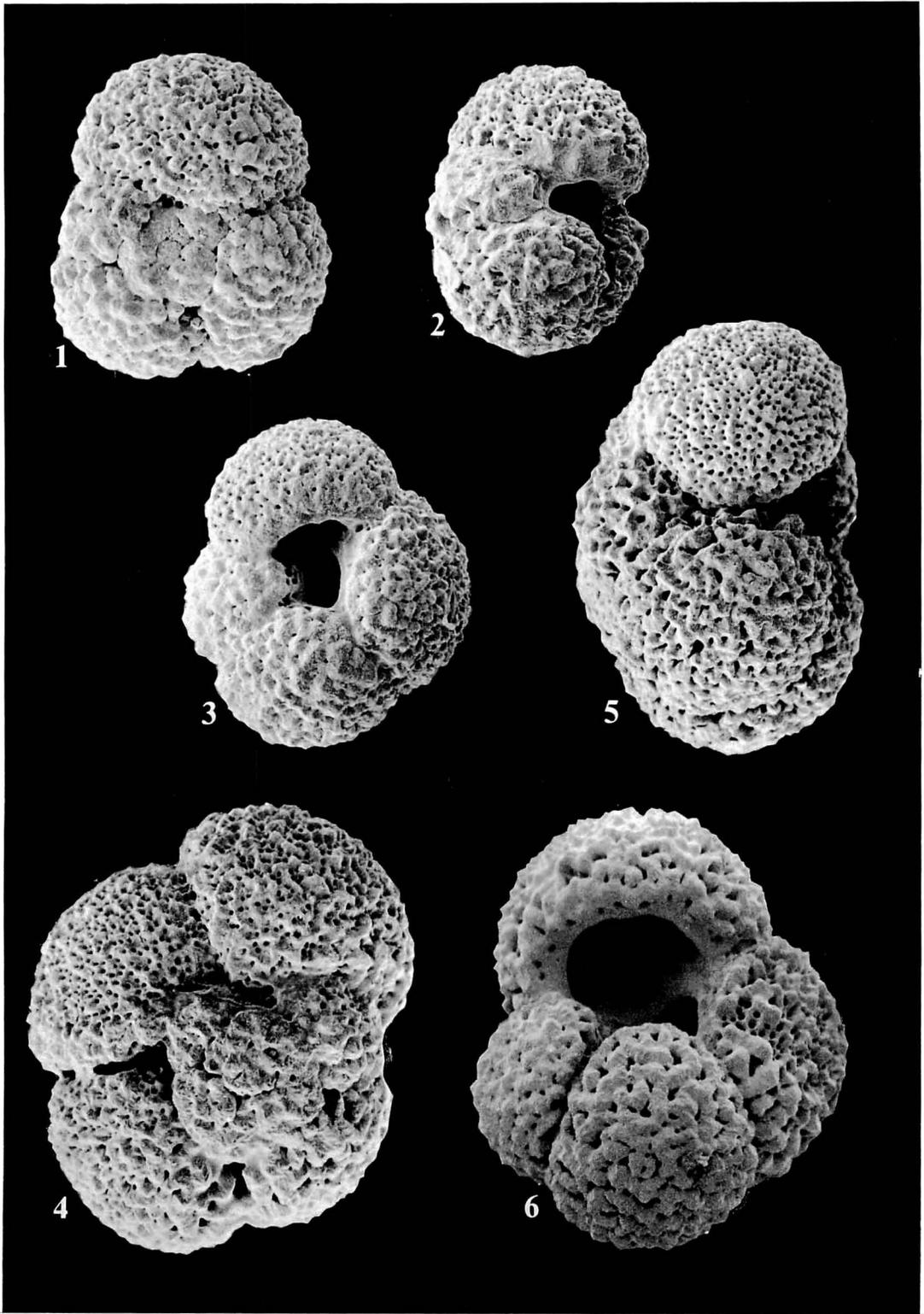
References

- BANDY, O.L. (1960): The geologic significance of coiling ratios in the foraminifer *Globigerina pachyderma* (EHRENBERG). *Jour. Paleont.*, vol. 34, no. 4, pp. 671-681.
- (1972): Origin and development of *Globorotalia (Turborotalia) pachyderma* (EHRENBERG). *Micropaleontology*, vol. 18, no. 3, pp. 294-318, pls. 1-8.
- and THEYER, F. (1971): Growth variation in *Globorotalia pachyderma* (EHRENBERG). *Antarctic Jour. U.S.*, vol. 6, no. 5, pp. 172-174.
- BÉ, A. W. H. (1960): Some observations on Arctic planktonic Foraminifera. *Contr. Cushman Found. Foram. Res.*, vol. 11, pt. 2, pp. 64-68.
- (1969): Planktonic Foraminifera. In Amer. Geogr. Soc.: Distribution of selected groups of marine invertebrates in waters south of 35°S Latitude, Folio 11, pp. 9-12.
- BELOUSSOV, V. V. and RUDITCH, E. M. (1961): Island arcs in the development of the earth's structure. *Jour. Geol.*, vol. 69, pp. 647-658.
- BERGER, W. H. (1971): Sedimentation of planktonic Foraminifera. *Mar. Geol.*, vol. 11, pp. 325-358.
- and SOUTAR, A. (1970): Preservation of plankton shells in an anaerobic basin off California. *Geol. Soc. America, Bull.*, vol. 81, pp. 275-282.
- BERGGREN, W. A. (1972): Late Pliocene-Pleistocene glaciation. In BERGGREN, W. A. [ed.]. Initial Reports of the Deep Sea Drilling Project, vol. 12, pp. 953-963.
- BROECKER, W. S. (1966): Absolute dating and the astronomical theory of glaciation. *Science*, vol. 151, pp. 299-304.
- and VAN DONK, J. (1970): Insolation changes, ice volumes, and the O¹⁸ record in deep-sea cores. *Rev. Geophys. Space Phys.*, vol. 8, no. 1, pp. 169.
- EMILIANI, C. (1966): Isotopic paleotemperature. *Science*, vol. 154, no. 3750, pp. 851-857.
- (1970): Pleistocene paleotemperatures. *Ibid.*, vol. 168, pp. 822-825.
- ERICSON, D. B. (1969): Coiling direction of *Globigerina pachyderma* as a climatic index. *Science*, vol. 130, pp. 219, 220.
- FLINT, R. F. (1971): Glacial and Quaternary geology. xii+892 pp., J. Wiley & Sons, Inc., N. Y.
- GREEN, K. E. (1960): Ecology of some Arctic Foraminifera. *Micropaleontology*, vol. 6, no. 1, pp. 57-78, pl. 1.
- KENNETT, J. P. (1968): Latitudinal variation in *Globigerina pachyderma* (EHRENBERG) in surface sediments of the southwest Pacific Ocean. *Ibid.*, vol. 14, no. 3, pp. 305-318, pl. 1.
- (1970): Comparison of *Globigerina pachyderma* (EHRENBERG) in Arctic and Antarctic areas. *Contr. Cushman Found. Foram. Res.*, vol. 21, pt. 2, pp. 47-49, pls. 8, 9.
- and HUDDLESTON, P. (1972): Abrupt climatic change at 90,000 yr BP: Faunal

- evidence from Gulf of Mexico cores. *Quaternary Res.*, vol. 2, pp. 384-395.
- MIYAKE, Y., SUGIMURA, Y. and MATSUMOTO, E. (1968): Inonium-thorium chronology of the Japan Sea cores. *Rec. Oceanogr. Works Japan*, vol. 9, no. 2, pp. 189-195.
- MURAUCHI, S. (1968): Origin of the Japanese Islands. *Sei-En*, no. 5, pp. 20-23 [in Japanese].
- NIINO, H., EMERY, K.O. and KIM, C.M. (1969): Organic carbon in sediments of Japan Sea. *Jour. Sed. Petrol.*, vol. 39, no. 4, pp. 1390-1398.
- ORR, W.N. and ZAITZEFF, J.B. (1971): A new planktonic foraminiferal species from the California Pliocene. *Jour. Foram. Res.*, vol. 1, no. 1, pp. 17-19, pl. 1.
- TROIJSKAJA, T.S. (1970): Environmental conditions and distribution of foraminifers in the Japan Sea. *Rep. Inst. Geol. Geophys., Siberian Div., Acad. Sci. USSR*, fasc. 71, pp. 136-160, 8 pls. [in Russian; translated in Japanese by Y. KUWANO].
- UJIIÉ, H. (1962): Introduction to statistical foraminiferal zonation. *Jour. Geol. Soc. Japan*, vol. 68, no. 803, pp. 431-450.
- (1973): Sedimentation of planktonic foraminiferal shells in the Tsushima and Korea Straits between Japan and Korea. *Micropaleontology*, vol. 19, no. 4 (in press).
- , SUGIMURA, Y., FUJI, N., OINUMA, K., KOIZUMI, I. and SUGANO, K. (1973): Latest Quaternary environment of the Sea of Japan suggested by a piston core. *Science* (in press).

Explanation of Plate 22

Figs. 1-6. *Globigerina umbilicata* ORR and ZAITZEFF from the core V28-265, $\times 200$ excluding fig. 6. 1: Spiral side of juvenile specimen (NSMT-MC 586), from Sample 40, 395-397 cm below the top; 2: Lateral and apertural side of juvenile specimen (NSMT-MC 587), from Sample 40; 3: Umbilical side of young specimen (NSMT-MC 585), from Sample 40; 4: Umbilical side of adult (NSMT-MC 582), from Sample 56, 555-557 cm below the top; 5: Lateral and apertural side of adult (NSMT-MC 583), from Sample 40; 6: Umbilical side of adult (NSMT-MC 584), from Sample 56, $\times 180$.



623. LATE LOWER CARBONIFEROUS *EOSTAFFELLA* AND
HEXAPHYLLIA FROM CENTRAL OREGON, U. S. A.*

KIMIYOSHI SADA

Department of Geology, Faculty of General Education,
Hiroshima University, Hiroshima 730

and

WILBERT R. DANNER

Department of Geological Sciences, The University
of British Columbia, Vancouver, Canada

Oregon 州の中央部より産する *Eostaffella* と *Hexaphyllia*: Oregon 州のほぼ中央部に位置する Crook County の Suplee 地域に分布している Coffee Creek Formation の石灰岩層より、筆者らは *Eostaffella* と北米大陸からこれまでに報告された例のない *Hexaphyllia* を識別したので、ここに報告する。記載された種は *Eostaffella oregonensis* SADA and DANNER, n. sp., *E.* sp. A と *Hexaphyllia* sp. である。これらの属種によって構成される Suplee *Eostaffella* 化石動物群は Late Mississippian (Chesterian) 時代のものと考えられる。佐田 公好・DANNER, W.R.

Introduction

The primitive fusuline *Eostaffella* occurs in organoclastic limestones of the Coffee Creek Formation and in an unnamed oolitic limestone in the Suplee area, Crook County, central Oregon. Two species of *Eostaffella* are associated with *Hexaphyllia*, an index coral of Viséan (Late Mississippian) age known in Europe and Asia but previously unreported from North America. (We have also collected a different species of *Hexaphyllia* from a limestone body in the Cache Creek Group near the community of Rayleigh north of Kamloops,

British Columbia, Canada, but it will be described in a later paper when its associated fauna has been studied in detail.)

The Coffee Creek Formation has been studied by PACKARD (1928, 1929, 1932), MERRIAM and BERTHIAUME (1940, 1943), MERRIAM (1942), DANNER (1965) and by BUDDENHAGEN (1967). It was named by MERRIAM and BERTHIAUME (1940, 1943). MERRIAM (1942) described rugose corals from the Formation having a close affinity to species from the Eurasian Lower Carboniferous and concluded that the Formation belonged to the Lower Carboniferous (Mississippian). In 1962 DANNER collected organoclastic limestone consisting of coarse brachiopod shells and shell fragments in a finer

* Received April 3, 1973; read Oct. 28, 1972 at Matsuyama.

grained matrix from MERRIAM's type locality (S2) of the coral fauna in the Coffee Creek Formation. This limestone contains numerous calcareous foraminifera including two species of *Eostaffella* and species of *Endothyra*. Oolitic limestone cropping out $3\frac{1}{2}$ miles to the northeast, north of the South Fork of Trout Creek and just east of the northernmost of the Suplee area Devonian limestones was collected in 1966. It also contains *Endothyra* and *Eostaffella*. DANNER's material was studied by SADA during his stay as a post-doctoral Fellow (1967-1969) at the University of British Columbia.

This paper contains the description of the species of *Eostaffella* as *Eostaffella oregonensis* SADA and DANNER, n. sp., *E. sp. A* and *Hexaphyllia* from MERRIAM's type locality (S2) of the coral fauna in the Coffee Creek Formation north of Grindstone Creek.

The slides used as figured specimens for this paper have been deposited with the Division of Paleontology, U.S. National Museum, Washington, D. C. Limestone specimens containing the faunas will be kept in the stratigraphic-paleontologic reference collections of the University of British Columbia Department of Geological Sciences.

Field work in the Suplee area by DANNER and laboratory work by SADA were financially supported by the National Research Council of Canada and the Committee on Research of the University of British Columbia as part of a long term study of western Cordilleran Late Paleozoic faunas. DANNER wishes to acknowledge assistance in the field from Professor Glenn ROUSE of the University of British Columbia, student Kurt Nielsen and Boy Scouts Lyall Bailey and Vladimir Krajina. Permission to collect in the area was gra-

ciously granted by the Hudspeth Ranch Company. We also want to express our appreciation to Dr. Dorothy HILL of the University of Queensland for her information on *Hexaphyllia*. Further work on this project was carried out while DANNER was visiting Professor at Hiroshima University under the auspices of the Japan Society for the Promotion of Science.

Geology

The Coffee Creek Formation in the Suplee area consists of scattered outcrops of complexly folded and faulted marine limestone and sandstone forming ridges and knobs in the semi-arid sage brush landscape. It is part of a sequence of Devonian, Mississippian, Pennsylvanian, Permian and Triassic rocks forming an inlier overlain by later Mesozoic and Cenozoic rocks. MERRIAM and BERTHIAUME (1940, 1943) described the Coffee Creek Formation as a sequence 274 to 304 meters thick composed of: "well-bedded fairly pure limestone, carbonaceous limestone, argillaceous to sandy limestone and calcareous sandstone." They gave the following detailed description of 23 meters of limestone at the type locality:

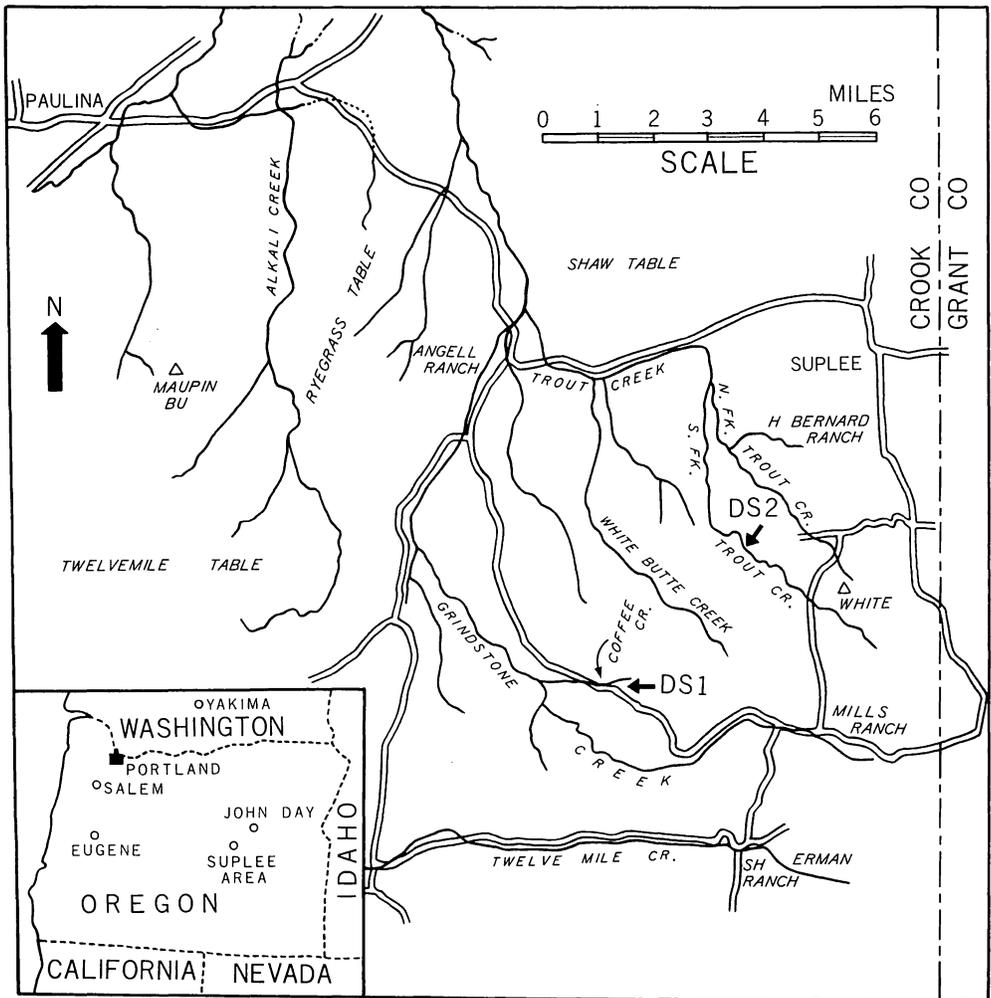
"Within the upper 40 feet very dark gray to black argillaceous and carbonaceous limestones are in places rather thin-bedded. These deposits are locally packed with the brachiopod *Striatifera*. Forty-five feet from the top of the limestone section is a bed of very sandy limestone with *Striatifera* immediately below which lies the main *Gigantella* horizon. The usually large productid *Gigantella* is very profuse here in a fine-grained and rather pure limestone of deep neutral gray; the large brachiopod is apparently restricted at this point to a bed varying in thickness from one to two feet. Within and below the *Gigantella* bed soli-

tary and compound rugose corals are abundant; these are embedded in the gray limestone or immediately below in argillaceous limestones weathering to a light grayish brown. In the lower 30 feet of this section these argillaceous layers are interbedded with the purer gray limestones, while toward the base sandy limestones and calcareous sandstone predominate."

DANNER (1965) noted that part of the limestone is oolitic, contains encrusting

algae, *Endothyra*, echinoid spines and that some of the fossils are silicified. BUDDENHAGEN's geologic map (1967) of the central Oregon inlier shows the areal distribution of the Coffee Creek Formation in detail.

The second locality (DS2) in the unnamed limestone lies about 3½ miles northeast of the Coffee Creek type locality and consists of a small exposure of oolitic and organoclastic limestone



about 31 meters downslope from an outcrop of Devonian reef limestone. The oolitic limestone contains *Eostaffella* and *Endothyra* and the organoclastic limestone contains unidentified fragments of bryozoa and brachiopods. The age is either Late Mississippian or Early Pennsylvanian. The oolitic limestone is overlain by chert grit.

Discussion of the *Eostaffella* fauna in the Coffee Creek Formation

MERRIAM (1942) described four species of rugose corals from the Coffee Creek Formation. The described species are *Dibunophyllum oregonensis* MERRIAM, *Lithostrotion (Lithostrotion) packardi* MERRIAM, *Lithostrotion (Siphonodendron) oregonensis* MERRIAM and *Campophyllum readi* MERRIAM. Brachiopods were also listed, namely, *Gigantella* sp., *Striatifera* sp. and *Spirifer* cf. *striatus* (MARTIN). Based on these species MERRIAM (1942; MERRIAM and BERTHIAUME, 1943) thought the age of the fauna to be roughly Viséan in terms of British succession. MERRIAM also listed *Tetrataxis* sp., small loxonemoid gastropods, and lithistid sponge spicules in the limestone. Our species of *Eostaffella* are found in the limestone associated with the corals at Loc. DS1 (MERRIAM's type locality "S2").

Eostaffella oregonensis SADA and DANNER, n. sp. shows a certain similarity in general outline and some internal character of the shell to *Eostaffella thompsoni* (ANISGARD and CAMPAU) from Upper Mississippian in Michigan, *E. mosquensis* ROZOVSKAYA from Upper Viséan in Russia, *E. hohsienica* CHANG from the uppermost of Lower Carboniferous in China and *E. kanmerai* (IGO) ranging from Late Chesterian to Mor-

rowan in Japan. *Eostaffella oregonensis* seems to be nearly equivalent to these species in its evolutionary stage of the shell. *Eostaffella* sp. A, now being held off from final identification because of lack of well preserved material, resembles *E. cooperi* (D. ZELLER) from Uppermost Chesterian in Illinois.

Eostaffella oregonensis and *E.* sp. A are found in association with *Hexaphyllia* sp. in the Coffee Creek Formation. This is worth noting as *Hexaphyllia*, one of the more important coral fossils for the determination of geologic age is, as far as we can determine, known only in Lower Carboniferous sequences in Europe and Asia. All of the known species of *Hexaphyllia* have been described from Lower Carboniferous of Scotland (DUNCAN, 1867), Lower Carboniferous of Central Russia (STUCKENBERG, 1904) and Lower Carboniferous of Japan (YABE and SUGIYAMA, 1939; KANMERA, 1952; MINATO, 1955).

Concerning the range of *Hexaphyllia*, Dr. D. HILL states (personal communication): "I think I can safely say that there is no proven evidence that it existed beyond the Viséan into the Namurian. My view would be, until it can be shown otherwise, that it is a very good indication of Viséan age."

From all of these considerations, it would seem that the *Eostaffella* fauna (Loc. DS1) in the Coffee Creek Formation of Oregon is of Late Mississippian (Viséan) (Chesterian) age.

Localities

DS1: MERRIAM's locality "S2" in the Coffee Creek Formation north of Grindstone Creek. On limestone ridge $\frac{1}{2}$ mile east of Mills' Sheep Camp $1\frac{3}{8}$ miles S. 47 degrees E. of Wade Butte in the NW $\frac{1}{4}$ of section 30, T. 18 S., R. 25 E. and north of the road.

DS2: Small limestone outcrop about 31 meters downslope and east of northernmost outcrop of Devonian reef limestone. On hillside north side of South Fork of Trout Creek. SE $\frac{1}{4}$ section 9, T. 18 S., R. 25 E. (See DANNER, 1968, Fig. 16, p. 840.)

Systematic Paleontology

Family Ozawainellidae THOMPSON
and FOSTER, 1937

Genus *Eostaffella* RAUSER-
CHERNOUSSOVA, 1948

Type species:—*Eostaffella parastruvei*
RAUSER, 1948.

Synonym:—*Paramillerella* THOMPSON,
1951.

Eostaffella oregonensis SADA
and DANNER, n. sp.

Pl. 23, figs. 1-10, 14-16

Description:—The shell of *Eostaffella oregonensis* SADA and DANNER, n. sp. is large for the genus and discoidal in shape, having a broadly rounded periphery. The lateral slopes are convex. The mature specimens of five volutions are 213 to 275 microns in length and 492 to 709 microns in width, giving the form ratios of 0.36 to 0.43. The immature specimens of three and one half to four volutions are 174 to 215 microns long and 367 to 437 microns wide, showing the form ratios of 0.47 to 0.49. The holotype of five and one half volutions (pl. 23, fig. 1, Rg. No. CF-C-46c) measures 268 microns in length and 700 microns in width. Its form ratio is 0.38. The inner and outer volutions are generally involute but the last volution is rarely and partly evolute.

The outside diameter of the proloculus

ranges from 29 to 54 microns. The diameters of the whorls of the 1st to the 5th volution of nine specimens are 66-108, 113-199, 190-298, 318-461 and 492-709 microns, respectively. The radius vectors of the 1st to the 5th volution are 27-54, 53-95, 89-143, 159-280 and 254-389 microns, respectively, for nine specimens. The spirotheca is composed of a distinct tectum and inner and outer dense layers. The thickness of the spirotheca of the 1st to the 5th volution of nine specimens is 4-9, 4-14, 7-20, 19-30 and 14-31 microns, respectively. The thickness of the proloculus wall varies from 2 to 9 microns. The septa are fairly thick and slightly bend anteriorly. The septal counts of the 1st to the first half of the 5th volution of the specimen (CF-C-15a) illustrated as fig. 16 on Pl. 23 are 6, 10, 11, 16 and 7, respectively. The chomata are distinct.

Remarks:—*Eostaffella oregonensis* resembles *E. thompsoni* (ANISGARD and CAMPAU) (1963, pl. 9, figs. 7-8, 11-12, 15, pl. 10, figs. 3-5, 7) described from Upper Mississippian in Arenac County, Michigan. However, *E. thompsoni* has a larger shell at maturity and larger proloculus. *Eostaffella oregonensis* is somewhat similar to *E. mosquensis* (ROZOVSKAYA 1963, pp. 93-94, pl. 16, figs. 16-17, figs. 1-5) in shell shape. These two forms, however, can be easily distinguished by the smaller shell of the mature specimens of *E. oregonensis*, its shorter length of the shell and smaller form ratio. In general outline and development of the shell, *Eostaffella oregonensis* resembles *E. hohsienica* CHANG (1962, pp. 440-441, pl. 1, figs. 4-6, 12, 13, 18-21) from the Hochow Limestone, the uppermost of Lower Carboniferous, near the town of Xiangquan, Hohsien, Anhui Province in China. However, *E. oregonensis* differs from *E. hohsienica*, for it

Table 1. Table of Measurements of *Eostaffella oregonensis* SADA and DANNER, n. sp.

Specimen	Rg. No.	Pl.	fig.	L.	W.	R.	Prol.	Diameter of whorl							
								1	2	3	3½	4	4½	5	5½
1	CF-C-46c	23	1	0.268	0.700	0.38	0.029	0.070	0.120	0.204		0.370		0.581	0.700
2	CF-C-34a	23	4	0.275	0.709	0.38	0.029	0.076	0.156	0.285		0.401		0.709	
3	CF-C-20a	23	2	0.228	0.624	0.36	0.044	0.085	0.167	0.275		0.427		0.624	
4	CF-C-11a	23	3	0.218	0.577	0.37	0.042	0.085	0.167	0.285		0.461	0.577		
5	CF-C-18a	23	8	0.256	0.587	0.43	0.046	0.066	0.133	0.228		0.368		0.587	
6	CF-C-29b	23	5	0.209	0.501	0.41	0.038	0.076	0.153	0.251		0.394	0.501		
7	CF-C-5a	23	7	0.213	0.492	0.43	0.035	0.066	0.113	0.190		0.318		0.492	
8	CF-C-17b	23	10	0.174	0.367	0.47	0.047	0.108	0.199	0.298	0.367				
9	CF-C-46a	23	9	0.215	0.437	0.49	0.054	0.085	0.166	0.285		0.437			

Specimen	Radius vector						Thickness of spirotheca						
	1	2	3	4	5	6	0	1	2	3	4	5	6
1	0.027	0.053	0.089	0.159	0.254	0.370	0.009	0.006	0.007	0.014	0.024	0.031	0.023
2	0.044	0.085	0.147	0.280	0.389		0.002	0.004	0.012	0.009	0.020	0.023	
3	0.048	0.089	0.146	0.237	0.337		0.008	0.008	0.013	0.014	0.030	0.028	
4	0.038	0.074	0.129	0.215	0.334		0.004	0.009	0.013	0.013	0.024	0.022	
5	0.038	0.077	0.131	0.209	0.330		0.004	0.003	0.010	0.016	0.021	0.014	
6	0.038	0.061	0.102	0.184	0.285		0.005	0.004	0.004	0.007	0.021	0.009	
7	0.033	0.066	0.104	0.183	0.292		0.007	0.006	0.009	0.013	0.019	0.016	
8	0.054	0.095	0.126	0.190			0.009	0.007	0.011	0.010	0.011		
9	0.040	0.080	0.143	0.239			0.008	0.009	0.014	0.020	0.019		

(Measurements in millimetres)

has shorter length of the shell, smaller form ratio at maturity, more arcuate periphery and more primitive chomata. In some respects *Eostaffella oregonensis* is somewhat similar to *E. kanmerai* (IGO, 1957, pp. 175-177, pl. 1, figs. 20-26, pl. 2, fig. 14; SADA, 1964, pp. 230-231, pl. 21, figs. 8, 16, 17; SADA, 1967, pp. 144-145, pl. 12, figs. 1-10; SADA, 1969, pp. 120-121, pl. 12, figs. 1-13, pl. 13, figs. 1-2) from Japan. However, *E. kanmerai* has a smaller shell at maturity, shorter axis of coiling and thinner spirotheca.

Occurrence:—*Eostaffella oregonensis* SADA and DANNER, n. sp. is abundant in thin sections and associated with *E. sp. A*, *Endothyra* sp., other foraminifera, *Hexaphyllia* sp. and *Dibunophyllum oregonensis* MERRIAM. Fossil locality DS1.

Geological age:—Late Mississippian (Chesterian).

Eostaffella sp. A

Pl. 23, figs. 11-13

Description:—The shell of *Eostaffella* sp. A is small and discoidal, and possesses a short axis of coiling and rounded periphery. The inner two or three volutions are endothyroid coiling but the outer ones are involute. The specimen (Rg. No. CF-C-50b) illustrated as fig. 11 on Pl. 23 is 142 microns in length and 308 microns in width. Its form ratio is 0.46. The proloculus is very small and its outside diameter is 28 microns. The diameters of the whorls of the 1st to the 4th volution of a specimen are 61, 95, 174 and 247 microns, respectively. The radius vectors of the 1st to the 5th volution are 26, 49, 76, 123 and 190 microns, respectively. The spirotheca consists of a tectum and inner and outer dense layers and its thickness of the 1st to the 4th volution is 5 to 17

microns. The chomata are very small.

Remarks:—*Eostaffella* sp. A differs from *Eostaffella oregonensis* SADA and DANNER, n. sp. in several respects. The former species has a smaller shell, fewer number of volutions, slower expansion of the shell for the corresponding volution, smaller proloculus, thinner spirotheca and endothyroid coiling in its inner volutions. In general shell shape and some internal character *Eostaffella* sp. A resembles *Eostaffella cooperi* (D. ZELLER) (1953, pp. 194-195, pl. 27, figs. 1-11) from the Kinkaid limestone of Uppermost Chesterian in Illinois. However, we put off the final identification until we can obtain better preserved material.

Occurrence:—*Eostaffella* sp. A is rare and associated with *E. oregonensis* SADA and DANNER, n. sp., *Endothyra* sp., other foraminifera, *Hexaphyllia* sp. and *Dibunophyllum oregonensis* MERRIAM. Fossil locality DS1.

Geological age:—Late Mississippian (Chesterian).

Order Heterocorallia SCHINDEWOLF, 1941

Family Heterophylliidae DYBOWSKI, 1873

Genus *Hexaphyllia* STUCKENBERG, 1904

Type species:—*Hexaphyllia prismatica* STUCKENBERG, 1904.

Hexaphyllia sp.

Pl. 24, figs. 1-2

Description:—The corallum is hexagonal in transverse section and has six prominent longitudinal ridges in position corresponding to the outer borders of the septa. The corallum is small in transverse section. The specimens illus-

trated as fig. 1 (Rg. No. CF-C-2) and fig. 2 (Rg. No. CF-C-101) on Pl. 24 are 0.50 mm. and 0.75 mm. in diameter, respectively. The calice is not preserved. The wall consists of the thin primary wall and thick stereozone lining the inner surface of the former. The corallum is divided by six septa in subequal intervals in transverse section. Two opposite septa meet at the center of the corallum and each of four septa forms Y shape in both sides of the two opposite septa.

Remarks.—We collected only four transverse sections of *Hexaphyllia* from the Coffee Creek Formation. Two of them are illustrated herein. They have striking similarities in the form of the corallite and the arrangement of the septa. The present species is somewhat similar to *Hexaphyllia mirabilis* (DUNCAN) (1867, p. 646, pl. 31, figs. 5a-5h) from the Lower Carboniferous in Scotland. However, *H. mirabilis* can be distinguished from the present species by having six distinct longitudinal ridges with spine-like processes. *Hexaphyllia* sp. differs from *H. prismatica* STUCKENBERG (1904, pp. 72-73, Taf. 3, figs. 5a-5d) from the Lower Carboniferous in Central Russia in its septal arrangement. In the general outline of the corallum and the septal arrangement, *Hexaphyllia* sp. somewhat resembles *H. elegans* YABE

and SUGIYAMA (1939, pp. 500-501, pl. 26, figs. 1-3) from the Lower Carboniferous of Kitakami Mountainland. However, the former species differs from the latter in having more prominent ridges and smaller diameter of the corallum. The present species seems to be a new species belonging to genus *Hexaphyllia*. The final determination of the present species, however, must be postponed until more material is obtained.

Occurrence.—*Hexaphyllia* sp. is rare in thin section and the species associated with it are *Eostaffella oregonensis* SADA and DANNER, n. sp., *E. sp. A*, *Endothyra* sp., other foraminifera and *Dibunophyllum oregonensis* MERRIAM. Fossil locality DSl.

Geological age.—Late Mississippian (Chesterian).

References

- ANISGARD, H.W. and CAMPAU, D.E. (1963): *Paramillerella thompsoni*, n. sp. from Michigan and a redefinition of *Paramillerella*. *Contr. Cushman Found. Foram. Res.*, vol. 14, no. 3, pp. 99-108.
- BUDDENHAGEN, H.J. (1967): Structure and orogenic history of the southwestern part of the John Day Uplift, Oregon. *The Ore Bin.*, vol. 29, no. 7, pp. 129-138.
- CHANG, L. (1962): Fusulinids from the Hoshow Limestone, Hoshien, Anhui. *Acta*

Explanation of Plate 23

All ×100

Figs. 1-10, 14-16. *Eostaffella oregonensis* SADA and DANNER, n. sp.

1. Axial section of holotype: Rg. No. CF-C-46c.

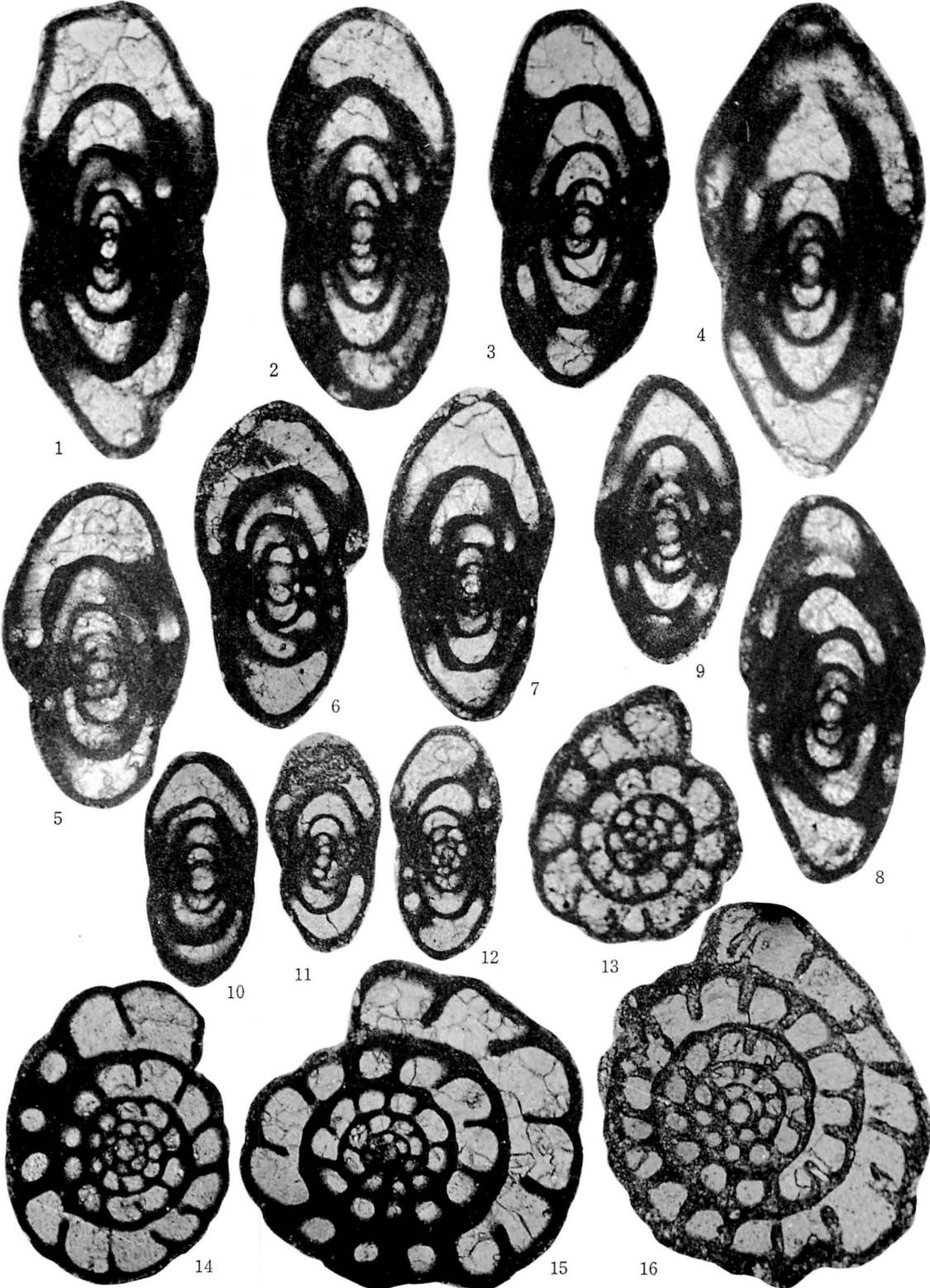
2-10. Axial sections of paratypes: Rg. No. CF-C-20a, CF-C-11a, CF-C-34a, CF-C-29b, CF-C-33a, CF-C-5a, CF-C-18a, CF-C-46a and CF-C-17b, respectively.

14-16. Sagittal sections: Rg. No. CF-C-23a, CF-C-3a and CF-C-15a, respectively.

Figs. 11-13. *Eostaffella* sp. A

11-12. Axial sections: Rg. No. CF-C-50b and CF-C-50a, respectively.

13. Sagittal section: Rg. No. CF-B-7a.



- Paleont. Sinica*, vol. 10, no. 4, pp. 434-442.
- DANNER, W.R. (1965): Limestone of the Western Cordilleran Eugeosyncline of Southwestern British Columbia, Western Washington and Northern Oregon. *Dr. D.N. Wadia Commem. Vol., Mining & Metallurgical Inst. of India*, pp. 113-125.
- (1968): Devonian of Washington, Oregon, and Western British Columbia. *Internat. Dev. Symp. 1967, Calgary*, pp. 827-842.
- (1970): Carboniferous System of the Western Cordillera of Southwestern British Columbia and Northwestern Washington. *Compte Rendu 6e Congrès Internat. Strat. Geol. Carbonif., Sheffield 1967*, vol. 2, pp. 599-608.
- DUNCAN, P.M. (1867): On the Genera *Heterophyllia*, *Battersbya*, *Palaecyclus*, and *Asterosmilia*: The anatomy of their species, and their position in the classification of the selerodermic Zoantharica. *Phil. Trans. R. Soc. London*, vol. 157, pp. 643-651.
- IGO, H. (1957): Fusulinids of Fukuji, southern part of the Hida Massif, central Japan. *Sci. Rep. Tokyo Kyoiku Daigaku, Ser. C*, vol. 5, no. 47, pp. 153-246.
- KANMERA, K. (1952): The Lower Carboniferous Kakisako Formation of southern Kyushu, with a description of some corals and fusulinids. *Mem. Fac. Sci. Kyushu Univ., Ser. D*, vol. 3, no. 4, pp. 157-177.
- MERRIAM, C.W. (1942): Carboniferous and Permian corals from central Oregon. *Jour. Paleont.*, vol. 16, no. 3, pp. 372-381.
- and BERTHIAUME, S.A. (1940): Late Paleozoic history of central Oregon. *Geol. Soc. Am. Bull.*, vol. 51, no. 12, p. 1935.
- and — (1943): Late Paleozoic formations of central Oregon. *Ibid.*, vol. 54, pp. 145-172.
- MINATO, M. (1955): Japanese Carboniferous and Permian corals. *Jour. Fac. Sci. Hokkaido Univ., Ser. 4*, vol. 9, no. 2, pp. 1-202.
- PACKARD, E.L. (1928): A new section of Paleozoic and Mesozoic rocks in central Oregon. *Am. Jour. Sci., 5th Ser.*, vol. 15, pp. 221-224.
- (1929): Discovery of the Baird Mississippian fauna of central Oregon (Abstract). *Geol. Soc. Am. Bull.*, vol. 40, p. 257.
- (1932): A contribution to the Paleozoic geology of central Oregon. *Carnegie Inst. Pub. 418*, pp. 105-113.
- ROSOVSKAYA, S.E. (1963): The fossil types of fusulinids and their ancestors. *Akad. Nauk. USSR, Trudy Paleont. Inst.*, Tome 97, pp. 1-128.
- SADA, K. (1964): Carboniferous and Lower Permian fusulines of the Atetsu Limestone in West Japan. *Jour. Sci. Hiroshima Univ., Ser. C*, vol. 4, no. 3, pp. 225-269.
- (1967): Fusulinids of the *Millerella* Zone of the Taishaku Limestone (Studies of the stratigraphy and microfossil faunas of the Carboniferous and Permian Taishaku Limestone in West Japan, No. 1). *Trans. Proc. Paleont. Soc. Japan, N.S.*, no. 67, pp. 139-147.
- (1969): Microfossils of the lowest part of the Taishaku Limestone (Ditto, No. 4). *Ibid.*, no. 75, pp. 119-129.
- STUCKENBERG, A. (1904): Anthozoen und Bryozoen des unteren Kohlenkalkes von Central-Russland. *Mem. Com. Geol., nov. Ser.* 14, pp. 72-109.
- YABE, H. and SUGIYAMA, T. (1939): Discovery of *Hexaphyllia* in the Lower Carboniferous of Japan. *Jour. Geol. Soc. Japan*, vol. 46, no. 552, pp. 85-88.
- ZELLER, D.E.N. (1953): Endothyroid Foraminifera and ancestral fusulinids from the type Chesteran (Upper Mississippian). *Jour. Paleont.*, vol. 27, no. 2, pp. 183-199.

Explanation of Plate 24

Figs. 1-2. *Hexaphyllia* sp.

1-2. Transverse sections: Rg. No. CF-C-2 ($\times 82$) and CF-C-101 ($\times 67$), respectively
Section (Fig. 2) includes a small bubble at the center of corallum.

Fig. 3. Photomicrograph of oolitic limestone.

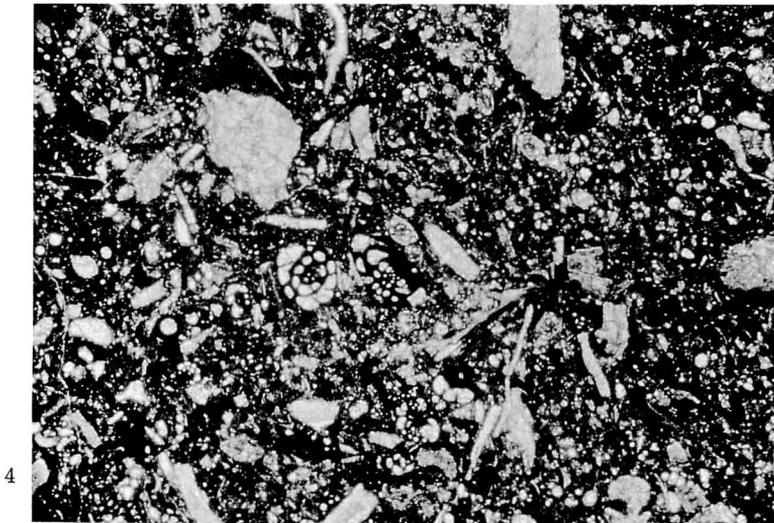
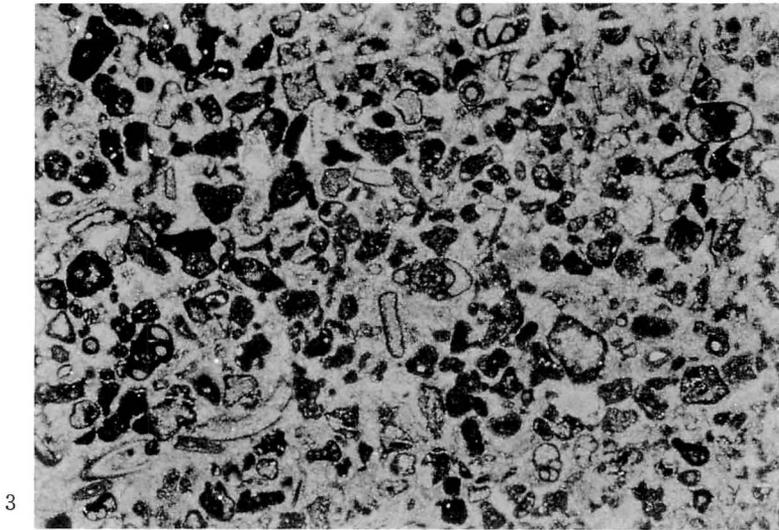
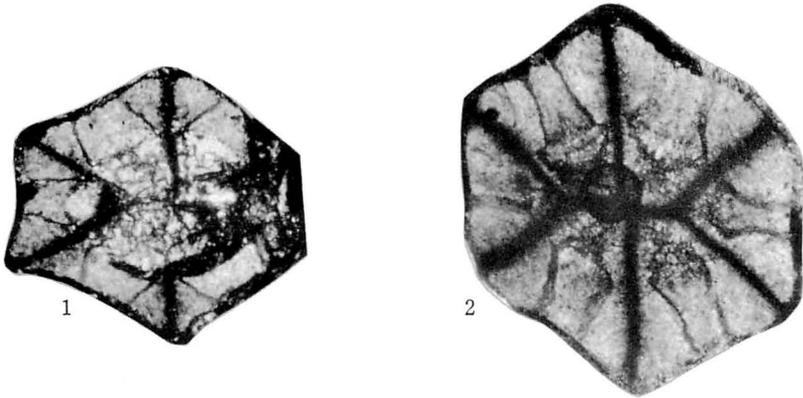
Locality DS2 in Suplee area, central Oregon.

Eostaffella, *Endothyra* and other foraminifera. $\times 20$.

Fig. 4. Photomicrograph of organoclastic limestone.

Locality DS1 in Suplee area, central Oregon.

Eostaffella, *Endothyra*, other foraminifera and shell fragments. $\times 20$.



PROCEEDINGS OF THE PALAEOONTOLOGICAL SOCIETY
OF JAPAN

日本古生物学会 111 回例会は 1973 年 6 月 23 日 (土) に新潟大学教育学部において開催された (参加者 48 名)。また翌 24 日 (日) には胎内川沿いの第三紀層ならびに化石産地の巡検が行われた (案内者 津田禾粒)。

個人講演

- Palynological Study on 200 meters Core Sample of Lake Biwa in Central Japan FUJI, N.
地すべり崩土中の花粉化石について 津田禾粒・山野井徹
新潟県西端部に産出する西頸城植物群 (中新世) について 松尾秀邦
長野県北相木植物群に産出した *Comptoniphylum* について 松尾秀邦
日本産二畳紀コノドント (予報) 猪郷久治・小池敏夫・滝沢 茂
栃木県 葛生町北西秋山付近より産するコノドント 木下 勤・小池敏夫
マレーシア産 上部シルル系と最下部デボン系のコノドント化石について (代読) 猪郷久義・小池敏夫
タイ 国産 下部 二畳系 コノドント 化石 について (代読) 猪郷久義
一の谷 層群 最下部 石炭系産の ザンゴ 化石 補記 (代読) 猪郷久義
福地もつれみる化石 附, 一般みる石炭化の三段階 岡村長之助
福地で確認した三種床板さんご及びそれ等とみる化石との関係 岡村長之助
Biostratigraphical study of the Toyama Formation in the Kitakami Massif, Northeast Japan MURATA, M. & SHIMOYAMA, S.
南部北上山地に産出した 2 種の *Permudaria* (*Brachiopoda*) について 田沢純一
Report of Lower Trias from Pir Panjal, near Qazigund, Kashmir, India, with Description of a few Ammonoids KAPOOR, H.M. & BANDO, Y.
Late Scythian Ammonoids from the Kitakami Massif BANDO, Y. and SHIMOYAMA, S.
An Upper Triassic Nautiloid from Okinawa-jima ISHIBASHI, T.
南九州四万十帯産アンモナイトについて 松本達郎・大塚裕之・大木公彦
Upper Cretaceous pelecypods from the Himenoura Group, Kyushu, Japan. Part 2, Orders Solemyoidea, Mytiloidea, Pterioidea and Trigonioidea. Part 3, Orders Veneroidea and Myoidea TASHIRO, M.
Inoceramus hobetsensis にみられる時代的変異について 野田雅之
第三紀海胆化石 *Astriclypeus* と *Echinodiscus* の系統関係 森下 晶
Molluscan Fossils from the Miocene Eoil Formation, Gampo District, Southeastside of the Korean Peninsula, Korea .. KIM, Bong Kyun, YOON, Sun & NODA, H.
青森県 西津軽地方の 田野沢層産 貝類化石について 小笠原憲四郎
掛川層群にみられる軟体動物化石群の水平的変化 鎮西清高
有孔虫の殻の巻方向に関する問題点 吉本裕一・福留高明
穿孔性腹足類による砂礫質底軟体動物の捕食 松隈明彦
シンポジウム「古生物と古環境」
石炭・二畳紀 *Bryozoa* の zoarium の形態と石灰岩の積成層との関係 .. 高野 修・長谷川美行
Neoschwagerina の進化系列と *Colania* 進化系列の生棲分布の変遷とその意義について .. 石井健一
ジュラ紀アンモナイトの古生物地理 .. 佐藤 正
貝類化石群集と古環境—瑞浪層群を例として— 糸魚川淳二
新潟堆積盆地の古環境とその変遷 中世古幸次郎・新保久弥
古湖底堆積物 (魚沼層群上部) における花粉の産状 山野井徹

日本古生物学会特別号の原稿募集

PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS NUMBER 17 を 1974 年度に刊行したく、その原稿を公募します。適当な原稿をお持ちの方は、次の事項に合わせて申込書を作成し、〒812 福岡市東区箱崎町 九州大学理学部地質学教室気付、日本古生物学会特別号編集委員会（代表者 勘米良亀齢）宛に申し込んで下さい。

- (1) 古生物学に関する論文で、欧文の特別出版にふさわしい内容のもの。同一の大題目の下に数篇の論文を集めたもの（例えばシンポジウムの欧文論文集）でもよい。分量は従来発行の特別号に経費上ほぼ匹敵すること。学会から支出できる経費は 15 万円程度です。学会以外からも経費が支出される見込のある場合には、その金額に応じて上記よりも分量が多くてよい。
- (2) 内容・文章ともに十分検討済の完成した原稿（または完成間近い原稿）で、印刷所に依頼して正確な見積りを算出できる状態にあること。なるべく原稿の写しを申込書とともに提出して下さい。（用済の上は返却致します）。
- (3) 申込用紙は自由ですが、次の事項を明記し、[] 内の注意を守って下さい。
 - (a) 申込者氏名；所属機関または連絡住所・電話番号。〔本会会員であること〕。
 - (b) 著者名；論文題目。〔和訳を付記すること〕。
 - (c) 研究内容の要旨。〔800～1200 字程度、和文で可〕。
 - (d) 内容ならびに欧文が十分検討済であることの証明。〔校閲者の手紙の写しでもよい〕。
 - (e) 本文の頁数（刷上り見込頁数または原稿で欧文タイプ 25 行詰の場合の枚数——ただし、パイカーかエリート字体かを添記すること）；また本文中小活字（8 ポ組み）に指定すべき部分があるときは、そのおよその内訳（総頁に対するパーセント）；挿図・表の各々の数と刷上り所要頁数；写真図版の枚数。
 - (f) 他からの経費支出の見込の有無、その予算額、支出源。〔その見込の証明となる書類またはその写しを添えて下さい〕。〔1974 年度の文部省の刊行助成金を申請希望の場合も、その旨を上記の準じて添記して下さい〕。
 - (g) その他参考事項。原稿が未完成の場合には、申込時における進行状況ならびに完成確約年月日を必ず記して下さい。
- (4) 申込締切 1973 年 10 月 15 日（消印有効）。採否は 1974 年 1 月の評議員会で審議決定の上申込書に回答の予定です。ただしその前または後に、申込者との細部の交渉を、編集委員から求めることがあるかもしれません。
- (5) 印刷予定論文が完全な場合には、決定後できるだけ早く印刷にとりかかる予定です。文部省の刊行助成金（「研究成果刊行費補助金」）を申請希望の場合には、学会から申請（例年は 11 月中旬中に申請締切）し、その採否・金額など決定後印刷にとりかかります。その場合は文部省との約束により、その年の秋（前例では 10 月 20 日）までに初校が全部出なければ、補助金の交付が中止されることになっています。
- (6) 特別号の投稿規定はとくにありません。会誌に準じ、前例を参考とし、不明の点は編集委員会に問い合わせて下さい。経費がかかるので、特別な場合を除き、別刷は作成せず、本刷 25 部を著者に無料進呈します。それ以上は購入（但し著者には割引）ということになります。いくつかの論文を集めて 1 冊にするときには、世話人の方から指示して、体裁上の不統一のないようにして下さい。印刷上の指示事項が記入できるよう、原稿の左右両側・上下に十分空白をとって、タイプで浄書して下さい。

例 会 等 の 通 知

	開 催 地	開 催 日	講 演 申 込 締 切 日
112 回 例 会	東 京 大 学	1973 年 10 月 20 日	1973 年 8 月 20 日
1974 年 総 会 ・ 年 会	九 州 大 学	1974 年 1 月 11-12 日	1973 年 11 月 10 日

- ◎ 1974 年総会・年会（九州大学）では「古無脊椎動物の系統分類に関する最近の進歩」（世話人 高柳洋吉・速水 格）が予定されている。

◎ 本会誌の出版費の一部は文部省研究成果刊行費による。

1973 年 9 月 15 日	印 刷	発 行 者	日 本 古 生 物 学 会
1973 年 9 月 20 日	発 行		文 京 区 弥 生 2-4-16
			日 本 学 会 事 務 セ ン タ ー 内
			(振 替 口 座 東 京 84780 番)
	日 本 古 生 物 学 会 報 告 ・ 紀 事	編 集 者	氏 家 宏
	新 篇 第 91 号	印 刷 者	東 京 都 練 馬 区 豊 玉 北 2 / 13
	900 円		学 術 図 書 印 刷 株 式 会 社 富 田 潔

Transactions and Proceedings of the Palaeontological
Society of Japan

New Series No. 91

September 20, 1973

CONTENTS

TRANSACTIONS

620. SAITO, Tsunemasa and MAIYA, Seijuro: Planktonic Foraminifera of the Nishikurosawa Formation, Northeast Honshu, Japan..... 113
621. KOIZUMI, Itaru: Marine diatom flora of the Pliocene Tatsunokuchi Formation in Miyagi Prefecture..... 126
622. UJIIÉ, Hiroshi and ICHIKURA, Masaki: Holocene to uppermost Pleistocene planktonic foraminifers in a piston core from off San'in district, Sea of Japan..... 137
623. SADA, Kimiyoshi and DANNER, Wilbert R.: Late Lower Carboniferous *Eostaffella* and *Hexaphyllia* from central Oregon, U. S. A. 151
- PROCEEDINGS 161