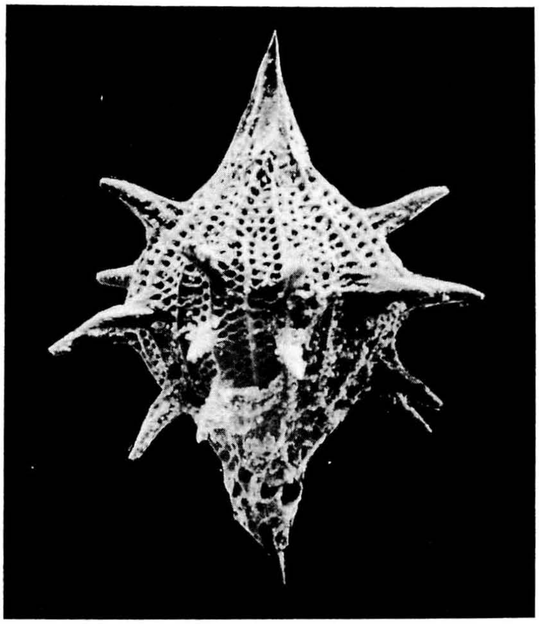
ISSN 0031-0204

日本古生物学會 報告・紀事

Transactions and Proceedings of the Palaeontological Society of Japan

New Series No. 137



日本古生物学会

Palaeontological Society of Japan

April 30, 1985

The fossil on the cover is *Unuma* (*Spinunuma*) *echinatus* ICHIKAWA and YAO, a Middle Jurassic multisegmented radiolaria from Unuma, Gifu Prefecture, central Japan (photo by A. YAO, x 260).

All communication relating to this journal should be addressed to the
PALAEONTOLOGICAL SOCIETY OF JAPAN
c/o Business Center for Academic Societies,
Yayoi 2-4-16, Bunkyo-ku, Tokyo 113, Japan

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 137, pp. 1—18, pls. 1—3, April 30, 1985

790. THE BIVALVE FAUNA FROM THE MIYANOHARA FORMATION (LOWER CENOMANIAN) OF SAKAWA AREA, SHIKOKU*

TOMOKO MATSUDA

Doshimaru 2-12-232, Wakamatsu-ku, Kitakyushu, 808

Abstract. This paper deals mainly with the description of the bivalve species from the upper part of the Miyanohara Formation (Lower Cenomanian) of the Sakawa area, Shikoku. They are 19 species of 15 genera, including 4 new species. The occurrence of several trigoniids, *Pterotrigonia* (?*Scabrotrigonia*) *pustulosa*, *P.* (*Ptilotrigonia*) *mifunensis* and *P.* (*Ptil.*) *amakusensis* already described by Tashiro and Matsuda (1983b) suggests that the fauna is referable to the upper Lower Cenomanian. This conforms well with the previous age determination (K4a2) by ammonites (Matsumoto, 1977). This bivalve fauna is closely similar to that of the S-IV Formation (Tashiro and Matsuda, 1983a) of the Goshonoura Group in Shishijima island of Kyushu, that of the Middle part of the Nagase Formation (Tashiro et al., 1982) of Shikoku, and that of the Misakubo Formation of the Akaishi Mountains.

Introduction

The Upper Cretaceous Miyanohara Formation is very narrowly distributed in the neighbourhood of Miyanohara (Sakawa district) in Shikoku (Text-fig. 1). This formation is composed of the lower part and the upper part in the latter of which the described fossils occur. Several molluscan fossil localities are probably of the same horizon. The specimens were mainly collected at the easternmost locality (Text-fig. 1) where those of Hirata's and Katto's collection were also obtained. Although several bivalve fossils from the Miyanohara Formation were described by Amano (1956), more numerous bivalve specimens have recently been collected from the upper part of the formation. In the present paper I describe 19 species of 15 genera, including 4 new species, and discuss their biostratigraphical implications, including the correlation of the Miyanohara Formation with the Cenomanian strata of Kyushu, Akaishi and Hokkaido.

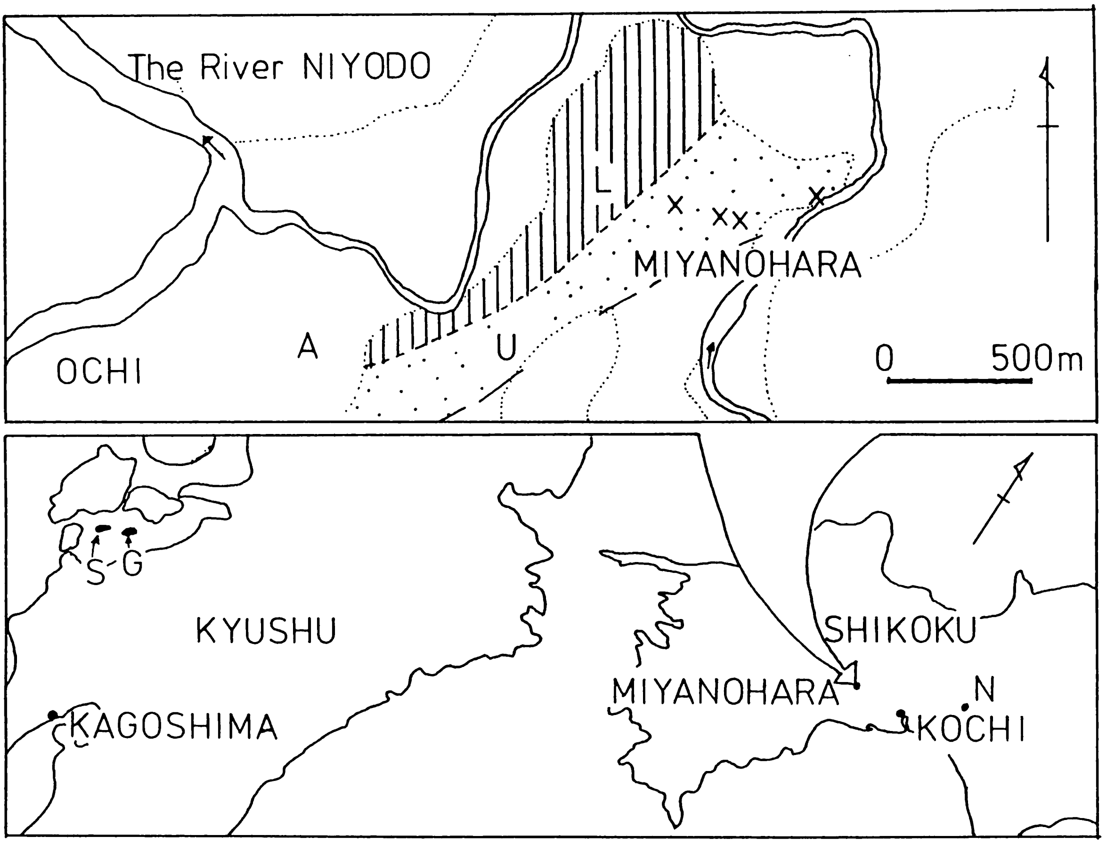
Repository:—The following abbreviations are used for the indication of the institutions where the described specimens are kept.

KSG:	Department of Geology, Faculty of Science, Kochi University, Kochi
HPC:	Hirata's Palaeontological Collections in the Makino Botanical Garden, Godaisan of Kochi

Before going further, I wish to express my sincere thanks to Prof. Masayuki Tashiro of Kochi University, for his continuous encouragement, valuable suggestions and kind supply of the specimens from Hokkaido and Kyushu and to Prof. Emeritus Tatsuro Matsumoto of Kyushu Univ., for his reading of the draft with instructive suggestions. Thanks are also due to Dr. Itaru Hayami of the Univ. of Tokyo, for his kind advice, to Prof. Jiro Katto of Kochi Univ., for

---

*Received November 28, 1983; read October 24, 1982 in Tsu City.



Text-fig. 1. Map showing the fossil localities of the Miyanohara Formation at Miyanohara in Sakawa.
U: Upper member of the Miyanohara Formation; L: Lower member of the Miyanohara Formation; A: Alluvium.
Below is the index map showing also relevant localities.
S: Shishijima island; G: Goshonoura island; N: Nagase.

his supply of some specimens from the Miyanohara Formation, to the staff of the Hirata's Palaeontological Collections in the Makino Botanical Garden, Godaisan of Kochi, for the inspection of several specimens which were collected by the late Mr. Motome Hirata from the Miyanohara and Nagase Formations.

Systematic description

Class Bivalvia

Subclass Palaeotaxodonta

Order Nuculoida

Superfamily Nuculacea Gray

Family Nuculidae Gray

Genus *Nucula* Lamarck, 1799

Subgenus *Pectinucula* Quenstedt, 1930

Nucula (*Pectinucula*) *kochiensis* Tashiro et Matsuda

Plate 1, Figs. 1—8

1956. *Nucula* sp.; Amano, *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, no. 1, p. 64, pl. 1, fig. 9.
1982. *Nucula* (*Pectinucula*) *kochiensis* Tashiro et Matsuda; *Trans. Proc. Palaeont. Soc.*

Japan, n.s., no. 127, p. 396, pl. 62, figs. 7, 11—15, text-fig. 3.

Material:—KSG 3361, external mould of right valve; KSG 3360 and KSG 3362—KSG 3364, internal mould of right and left valves; they are collected from Miyanohara of Sakawa. Another specimen, KSG 3365, external mould of right valve, from Yunokuchi at Shishijima.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3360	R. in. mould	15.0	11.5	—
KSG 3361	R. ex. mould	13.5	11.0	3.0
KSG 3362	L. in. mould	13.5	9.0	—
KSG 3363	R. in. mould	14.0	10.5	—
KSG 3364	L. in. mould	14.5	13.0	—
KSG 3365	R. ex. mould	18.5	15.0	5.5

Remarks:—These specimens are undoubtedly identified with *Nucula* (*Pectinucula*) *kochiensis* Tashiro et Matsuda (1982), from the Fukigoshi Formation of the Monobe area in Shikoku, judging from the radial ribs on the disk, trigonal outline and features of the hinge structure. As to *Nucula* sp. from the Miyanohara Formation Amano (1956) did not describe the ornamentation on the disk, but it is probably identical with this species in view of the hinge structure and shell outline.

Occurrence:—Medium- and fine-grained sandstone of the Miyanohara Formation at Miyanohara in Sakawa area. This species is known from the siltstone of the S-I and S-III Formations of the Goshonoura Group at Hegushi and Yunokuchi of Shishijima.

Superfamily Nuculanacea Adams et Adams

Family Nuculanidae Adams et Adams

Genus *Portlandia* Mörch, 1857

Portlandia (s. 1.) *nagaseana* Tashiro et Matsuda

Plate 1, Figs. 9, 10

1982. *Portlandia* (s. 1.) *nagaseana* Tashiro et Matsuda; *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 127, p. 399, pl. 62, figs. 23—25, text-fig. 5.

Material:—KSG 3366 and KSG 3367, internal moulds of left valves, from Miyanohara of Sakawa.

Measurements (in mm):—

Specimen		Length	Height
KSG 3366	L. in. mould	16.0	11.0
KSG 3367	L. in. mould	18.0	11.5

Remarks:—These specimens are referable to *Portlandia* (s. 1.) *nagaseana* Tashiro et Matsuda (1982), from the Fukigoshi Formation in Shikoku by the same features of the outline and hinge structure.

Occurrence:—Rarely found in medium-grained sandstone of the Miyanohara Formation at Miyanohara, Sakawa.

Subclass Pteriomorphia

Order Arcoida

Superfamily Arcacea Lamarck

Family Cucullaeidae Stewart

Genus *Cucullaea* Lamarck, 1801

Subgenus *Idonearca* Conrad, 1862

Cucullaea (*Idonearca*) *ezoensis ezoensis* Yabe et Nagao

Plate 2, Figs. 11—16

1928. *Cucullaea ezoensis* Yabe et Nagao, *Sci. Rept. Tohoku Imp. Univ.*, ser. 2, vol. 9, no. 3, p. 81, pl. 16, figs. 1—3.

1956. *Cucullaea ezoensis* var. *amaxensis* Matsumoto; Amano, *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, no. 1, p. 6.

1956. *Cucullaea* sp.; Amano, *Ibid.* vol. 1, no. 1, p. 68.

1975. *Cucullaea* (*Idonearca*) *ezoensis ezoensis* Yabe et Nagao; Hayami, *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 31.

1982. *Cucullaea* (*Idonearca*) *ezoensis ezoensis* Yabe et Nagao; Tashiro and Kozai, *Palaeont. Soc. Japan, Sp. Pap.* no. 25, p. 73, pl. 14, fig. 3.

Material:—KSG 3368 — KSG 3370, internal moulds of the right valves, from Miyanohara, Sakawa. KSG 3371, external mould of the right valve, from Kashiwaguri of Shishijima island.

Measurements (in mm):—

Specimen		Length	Height	Thick-ness
KSG 3368	R. in. mould	38.0	ca 35.0	—
KSG 3369	R. in. mould	32.0	ca 28.0	—
KSG 3370	R. in. mould	18.0	12.5	—
KSG 3371	R. ex. mould	18.5	16.5	8.0

Remarks:—Many specimens from the Goshonoura Group of the Shishijima island and the Miyanohara Formation are before me. They are characterized by the subquadrate outline, and their postero-ventral corner are not much projected towards posterior. Although the specimens from the Goshonoura Group of the Shishijima island were identified with *Cucullaea ezoensis* var. *amaxensis* Matsumoto by Amano (1956), they are safely identified with *Cucullaea* (*Idonearca*) *ezoensis ezoensis* Yabe et Nagao, from the Middle Yezo Group in Hokkaido, because of their less projected postero-ventral corner. Likewise, the specimens from the Miyanohara Formation are undoubtedly identified with the same subspecies.

Occurrence:—Rare in the medium-grained sandstone of the Miyanohara Formation at Miyanohara, Shikoku, and the siltstone of the S-I Formation at Hegushi of the Shishijima island; also rare in fine-grained sandstone of the S-V Formation of the Goshonoura Group at Yunokuchi of the Shishijima island; common in the medium-grained sandstone of the S-IV Formation at Hegushi; abundant in the medium-grained sandstone of the S-III Formation of the Goshonoura Group at Kashiwaguri of the Shishijima island.

Family Arcidae Lamarck

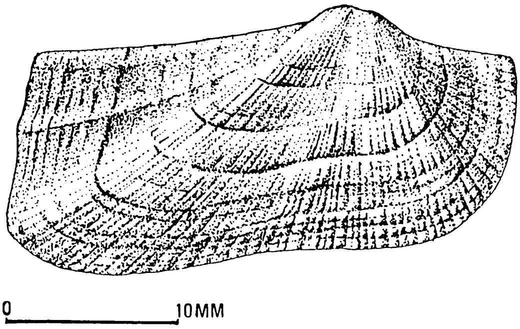
Genus *Arca* Linné, 1758

Subgenus *Eonavicula* Arkell, 1929

Arca (*Eonavicula*) *tashiroi* sp. nov.

Plate 2, Figs. 1—10; Text-fig. 2

1982. *Arca* (*Eonavicula*) sp.; Tashiro and Matsuda, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 127, p. 402, pl. 64, fig. 22.



Text-fig. 2. *Arca* (*Eonavicula*) *tashiroi* sp. nov.
A diagramatic sketch of the holotype. (T. Matsuda delin.)

Material:—Holotype, KSG 3372, external mould of right valve, from Enokuchi of Goshonoura island; paratypes, KSG 3374 and KSG 3375, external and internal moulds, from Miyanohara of Sakawa; the other paratypes, KSG 3373, KSG 3376 and KSG 3377, external and internal moulds from Kashigaguri of Shishijima and Enokuchi of Goshonoura.

Diagnosis:—Shell medium to large for the genus, elongately subquadrate, longer than high, very inflated; umbo prominent, orthogyrous, located at about one third from front of the valve; anterior margin a little convex, subvertical to the dorsal margin; ventral margin horizontal, nearly straight but slightly concave at the middle part; posterior margin nearly straight, obliquely truncated; dorsal margin nearly straight; a shallow radial sulcus extends from the umbo to center of the ventral margin; posterior carinal ridge not angulated but well elevated, especially near the umbo; dorsal carinal ridge weakly elevated; hinge line straight with about 40 small diverging teeth; ligament area wide, triangular, provided with five or more chevron-shaped ligament grooves; disk ornamented with abundant fine radial ribs and numerous laminated concentric ribs; median part of the disk near the radial sulcus somewhat reticulated by two sorts of the ribs; posterior area ornamented with two sorts of the ribs as like as the disk; the concentric ribs are usually waved near the posterior margin; inner margin smooth; both lateral adductor scars weakly impressed.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3372	R. ex. mould	30.0	12.5	5.5
KSG 3373	R. in. mould	27.5	14.0	—
KSG 3374	R. ex. mould	21.5	9.0	5.5
KSG 3375	L. in. mould	24.0	12.5	—
KSG 3376	R. ex. mould	28.5	15.0	7.0
KSG 3377	L. in. mould	15.5	ca 7.0	—

Observation:—This species is very variable in the outline and the strength of the concentric ribs. In mature specimens the concentric laminae are more strongly marked than in the younger specimens, and the secondary radial ribs frequently appear on the ventral part of the disk.

Comparison:—This species is discriminated from *Arca* (*Eonavicula*) *prolata* Amano (1957), from the Hagino Formation in Shikoku by the more numerous radial ribs and strongly laminated concentric ribs. *Arca* (*Eonavicula*) *shinanoensis* Yabe et Nagao (in Yabe, Nagao and Shimizu, 1926), from the Shiroi Formation in Central Japan, is distinguishable from this species in its less inflated and smaller valve. This species resembles *Arca sanctae-crucis* Pictet et Campiche, from the Lower Greensand of England (Woods, 1899), in the numerous laminated concentric ribs on the surface, but differs in its distinct chevron-shaped ligament grooves and less rounded anterior margin. *Arca carteroni* d'Orbigny, from the Lower Greensand of England (Woods, 1899), is similar to this species in its numerous laminated concentric ribs on the surface and several ligament chevrons, but differs in its more elongated outline.

Occurrence:—Medium- to fine-grained sandstone of the Miyanohara Formation at Miyanohara, Sakawa; siltstone of the Fukigoshi Formation of Odochi, Monobe area (see, Tashiro and Matsuda, 1982); siltstone of the S-I Formation at Hegushi of Shishijima island. Fine-grained sandstone of the S-IV Formation at Kashiwaguri of the same island; medium-grained sandstone of the IIb Formation (Matsumoto, 1938), of the Goshonoura Group at Enokuchi of Goshonoura.

Family Glycymerididae Newton

Genus *Glycymeris* da Costa, 1778

Subgenus *Hanaia* Hayami, 1965

Glycymeris (*Hanaia*) *goshonouraensis* Matsukuma

Plate 1, Figs. 11—15

1930. *Glycymeris amakusensis* var. *solida* Nagao; *Jour. Fac. Sci. Hokkaido Imp. Univ.*, ser. 4, vol. 1, no. 1, p. 16, pl. 3, figs. 13, 14.

1956. *Glyceymeris* aff. *amakusensis* Nagao; Amano, *Kumamoto Jour. Sci.* ser. 1, (geol.), vol. 1, no. 1, p. 68, pl. 1, figs. 22—25.

1956. *Glycymeris* sp.; Amano, *Ibid.*, vol. 1, no. 1, p. 70.

1971. *Glycymeris* (*Hanaia*) *solida* Nagao; Tashiro, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 84, p. 233, text-fig. 5, pl. 28, figs. 1—8.

1975. *Glycymeris* (*Glycymerita*) *solida* Nagao; Hayami, *Univ. Mus. Univ. Tokyo Bull.*, no. 10, p. 34.

1979. *Glycymeris goshonouraensis* Matsukuma, *Venus* (*Jap. Jour. Malac.*), vol. 38, no. 2, p. 98.

Material:—KSG 3379, internal mould of left valve, and KSG 3380, left valve, both from Miyanohara of Sakawa; KSG 3378, KSG 3381 and KSG 3382, internal and external moulds, from Hegushi, Shishijima island.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3378	R. ex. mould	24.0	23.0	9.5
KSG 3379	L. in. mould	11.0	9.5	—
KSG 3380	L. valve	16.5	15.0	6.0
KSG 3381	R. in. mould	22.5	ca 16.0	—
KSG 3382	R. in. mould	ca 20.0	ca 19.0	—

Remarks:—Several specimens have been obtained from the Miyanohara Formation. On the other hand, many specimens occur from the S-IV Formation of the Goshonoura Group of the Shishijima island. They are characterized by its asymmetrical hinge structure in the immature stage, inflated valve, round-topped radial ribs on the surface and fine radial ridges on the internal surface. In these characters they are identified with *Glycymeris* (*Hanaia*) *solida* Nagao (Tashiro, 1971) from the Goshonoura Group of the Goshonoura island.

Occurrence:—Rate in the medium- to fine-grained sandstone of the Miyanohara Formation, at Miyanohara, Sakawa; abundant in the fine-grained sandstone of the S-IV Formation of the Goshonoura Group at Hegushi of Shishijima island; common in the fine-grained sandstone of the S-I Formation of the Goshonoura Group at Yunokuchi of the same island.

Order Pterioida

Suborder Ostreina Ferussac

Superfamily Ostreacea Fafinesque

Family Ostreidae Rafinesque

Subfamily Ostreinae Rafinesque

Genus *Crassostrea* Sacco, 1897

Crassostrea kawauchidensis Tamura

Plate 2, Fig. 18

1938. *Ostrea* sp. (sp. nov.); Matsumoto, *Jour. Geol. Soc. Japan*, vol. 45, no. 532, p. 13, text-figs. 1, 2.
1977. *Crassostrea kawauchidensis* Tamura; *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, nat. sci., p. 114, pl. 2, figs. 1—5.
1982. *Crassostrea* aff. *C. kawauchidensis* Tamura; Tashiro and Kozai, *Palaeont. Soc. Japan, Sp. Pap.* no. 25, p. 78.
1982. *Crassostrea kawauchidensis* Tamura; Tashiro and Matsuda, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 127, p. 405, pl. 63, figs. 8, 9, 11.

Material:—KSG 3387, internal mould of the left valve, from Miyanohara of Sakawa.

Remarks:—Although some specimens occur from the Miyanohara Foramtion, they are imperfect or fragmentary. KSG 3387 is measured 34.0 mm in length and 55.0 mm or more in height. This is characterized by its tall and inflated valve, and thick test. These specimens are probably referable to *Crassostrea kawauchidensis* Tamura (1977), originally described from the Mifune Group of Central Kyushu.

Occurrence:—Common in hte medium- to coarse-grained sandstone of the Miyanohara Formation at Miyanohara, Sakawa.

Order Trigonioida

Superfamily Trigoniacea Lamarck

Family Trigoniidae Lamarck

Subfamily Pterotrigoniinae van Hoepen

Genus *Pterotrigonia* van Hoepen, 1929

Subgenus *Scabrotrigonia* Dietrich, 1933

Pterotrigonia (?*Scabrotrigonia*) *pustulosa* (Nagao)

Synonymy, Material, Description and *Occurrence:*—See Tashiro and Matsuda, 1983b, pp. 25—27.

Subgenus *Ptilotrigonia* van Hoepen, 1929

Pterotrigonia (*Ptilotrigonia*) *mifunensis* (Tamura et Tashiro)

Synonymy, Material, Description and *Occurrence:*—See Tashiro and Matsuda, 1983b, pp. 42—45.

Pterotrigonia (*Ptilotrigonia*) *amakusensis* Tashiro et Matsuda

Synonymy, Material, Description and *Occurrence:*—See Tashiro and Matsuda, 1983b, pp. 41—42.

Pterotirigonia (*Ptilotrigonia*) *miyanoharensis* Tashiro et Matsuda

Material, Description and *Occurrence:*—See Tashiro and Matsuda, 1983b, pp. 45, 46.

Subclass Heterodonta

Order Veneroida

Superfamily Lucinacea Fleming

Family Lucinidae Fleming

Subfamily Myrteinae Chavan

Genus *Myrtea* Turton, 1822

Subgenus *Myrtea* Turton, 1822

Myrtea (*Myrtea*) *amanoi* sp. nov.

Plate 1, Figs. 16—21; Text-fig. 3

1956. *Lucina* (?) sp.; Amano, *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, p. 77, text-fig. 2.

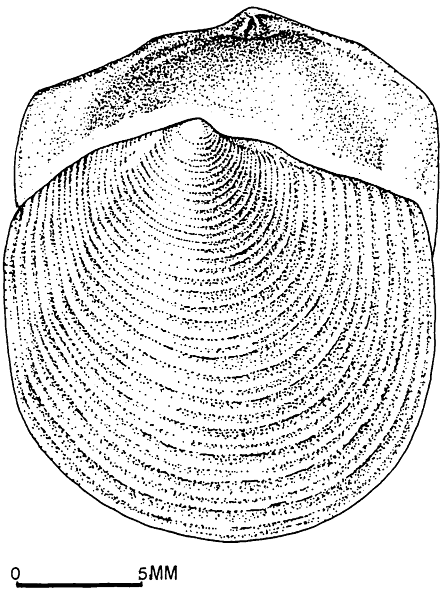
1982. *Myrtea* (*Myrtea*) sp.; Tashiro and Matsuda, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 127, p. 408, pl. 65, fig. 23.

Material:—Holotype, KSG 3389, right valve, from the Fukigoshi Formation at Odochi of Monobe area (see Tashiro and Matsuda, 1982); paratype, KSG 3390, internal mould, from the same locality of the holotype; KSG 3391 and KSG 3392, external moulds, from Miyanohara, Sakawa; KSG 3393, external mould, from Enokuchi, Goshonoura island.

Diagnosis:—Shell small, subovate in outline, slightly longer than high, weakly inflated; umbo small, located at a little posterior than mid-length of the valve; anterior dorsal margin oblong, nearly straight but weakly concave near the umbo; posterior dorsal margin slightly convex; anterior margin weakly arched, truncated, forming an angle of about 120° with the dorsal margin; ventral margin broadly arched; posterior margin nearly straight or slightly convex, vertically truncated from the dorsal margin; apical angle about 120°; lunule narrow, elongated, distinctly separated from the disk by a narrowly angulated ridge, nearly smooth only with growth lines; escutcheon depressed very narrow, smooth; the concentric ribs on the surface roof-shaped, regularly spaced in general, narrower than their flat interspaces; posterior carina weakly extended from the umbo to the postero-ventral corner; hinge plate long; hinge formula is as follows:—

AIII 3a 3b/AIV AII 2 4b

2 subvertical or slightly oblique; 3a small nearly vertical; 3b strong, obliquely extended towards postero-ventral corner; 4b large, elongated, strongly oblique; lateral teeth elongated; anterior adductor scar oblong, weakly impressed; posterior adductor scar small; fine and numerous radial striae appear on the internal surface; inner margin smooth.



Text-fig. 3. *Myrtea* (*Myrtea*) *amanoi* sp. nov.
A diagramatic sketch of the holotype. (T. Matsuda delin.)

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3389	R. ex. mould	17.0	16.0	2.0
KSG 3390	R. in. mould	12.5	11.5	—
KSG 3391	L. ex. mould	17.5	15.0	3.5
KSG 3392	R. ex. mould	18.5	17.0	3.5
KSG 3393	R. ex. mould	14.5	13.5	3.0

Observation:—The concentric ribs number about 40, being more closely spaced near the umbo than on the ventral part in the adult specimens. Fine but distinct growth lines are discernible on the interspace of the ribs on the ventral part of the disk.

Comparison:—This species is discriminated from *Myrtea* (s. l.) *angularis* Tashiro (1976), from the Himenoura Group in Kyushu, in its rounded outline and less numerous concentric ribs on the disk. This species differs from *Myrtea ezoensis* (Nagao) (1938), from the Upper Ezo Group of Hokkaido, in its rounded outline and numerous concentric ribs. This species resembles *Caullucina esbedensis* Freneix (1976), from the Hassi Oum-Esbed of France, in the subovate outline, but differs in its small size and posterior location of the umbo. *Lucina mattiformis* Stephenson (1941), from the Nacatoch Sand of U.S.A., is discriminated from this species, by its rounded outline and angulated posterior carina.

Occurrence:—Siltstone of the Fukigoshi Formation in Monobe area (see Tashiro and Matsuda, 1982): medium- to fine-grained sandstone of the Miyanohara Formation at Miyanohara of Sakawa.

Family Mactromyidae Cox

Genus *Thetis* Sowerby, 1826

Thetis japonica (Yabe et Nagao)

Plate 2, Fig. 17

1927. *Thetironia affinis* (Whiteaves) var. *japonica* Yabe et Nagao; in Yabe, Nagao and Shimizu, *Sci. Rep. Tohoku Imp. Univ.*, ser. 2, vol. 11, no. 1, pl. 5, figs. 7a—b. (without description)

1928. *Thetironia affinis* (Whiteaves) var. *japonica* Yabe et Nagao; Yabe and Nagao, *Ibid.*, vol. 9, no. 3, p. 89, pl. 17, figs. 14a, 14b and 15a.

1975. *Thetis japonica* (Yabe et Nagao); Hayami, *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 122.

1976. *Thetis affinis japonica* (Yabe et Nagao); Tamura and Tashiro, *Atlas of Japanese Fossils*, no. 43—258, pl. Cr.-24, figs. 17, 18.

1981. *Thetis japonica* (Yabe et Nagao); Hayami and Kase, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 121, pp. 37, 38, pl. 5, figs. 2—4.

1982. *Thetis* sp. aff. *T. japonica* (Yabe et Nagao); Tashiro and Matsuda, *Ibid.*, no. 127, p. 409, pl. 65, figs. 20—22.

Material:—KSG 3388, external mould of left valve, from Miyanohara of Sakawa.

Remarks:—A single specimen, (KSG 3388), 27.5 mm long, 25.0 mm height and 11.5 mm thick, was collected from the Miyanohara Formation. Although its hinge structure is not clear, other features are very well preserved. It is certainly referable to *Thetis japonica* (Yabe et Nagao), because of its well inflated valve, rounded outline and smooth surface except for fine growth line.

Occurrence:—Very rare at the medium-grained sandstone of the Miyanohara Formation of Sakawa.

Superfamily Crassatellacea Ferussac

Family Crassatellidae Ferussac

Subfamily Crassatellinae Ferussac

Genus *Pachythaerus* Conrad, 1869

Pachythaerus nagaoi (Matsumoto)

Plate 1, Figs. 22—24

1938. *Crassatella* (*Pachythaerus*) *nagaoi* Matsumoto, *Jour. Geol. Soc. Japan*, vol. 45, no. 532, p. 16, text-figs. 10, 11.

1956. *Crassatellites nagaoi* Matsumoto; Amano, *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, no. 1, pp. 74, 75, pl. 1, figs. 16—20.

1975. *Pachythaerus nagaoi* (Matsumoto); Hayami, *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 130.

Material:—KSG 3395 and KSG 3396, internal and external moulds, from Kashiwaguri of Shishijima Island; KSG 3394, internal mould of imperfect right valve, from Miyanohara of Sakawa.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3394	R. in. mould	32.0	ca 25.0	—
KSG 3395	R. in. mould	24.5	20.0	—
KSG 3396	R. ex. mould	10.5	9.5	3.0

Remarks:—Although a specimen, KSG 3394, from the Miyanohara Formation is an imperfect internal mould, it is referable to *Pachythaerus nagaoi* (Matsumoto), from the Goshonoura Group of Central Kyushu, by its characteristic hinge structure. The specimens from the Shishijima island are also referable to this species as already discussed by Amano (1956).

Occurrence:—Very rare in the medium grained sandstone of the Miyanohara Formation at Miyanohara, Sakawa; rate at the fine-grained sandstone of the S-III and S-V Formations at Hegushi and Yunokuchi of the Shishijima island; abundant in the fine-grained sandstone of the S-IV Formation at Kashiwaguri of the same island.

Genus *Anthonya* Gabb, 1864

Anthonya apicalis Nagao

Plate 1, Figs. 25—31

1938. *Anthonya apicalis* Nagao, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, sec. 4, vol. 4, no. 1—2, p. 75, pl. 2, figs. 6—12.
1956. *Anthonya apicalis shishijimensis* Amano, *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, no. 1, p. 76, pl. 2, figs. 6—12.
1972. *Anthonya apicalis* Nagao; Tamura and Packard, *Mem. Fac. Educ. Kumamoto Univ.*, vol. 20, no. 1, p. 27.
1972. *Anthonya apicalis shishijimensis* Amano; Tamura and Packard, *Ibid.*, vol. 20, no. 1, p. 27.
1975. *Anthonya apicalis* Nagao; Hayami, *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 131.
1975. *Anthonya apicalis shishijimensis* Amano; Hayami, *Ibid.*, no. 10, p. 131.
1981. *Anthonya* sp. cf. *A. apicalis* Nagao; Hayami and Kase, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 121, p. 38, pl. 4, fig. 17.

Material:—KSG 3397 — KSG 3400, internal and external moulds, from Miyanohara, Sakawa; KSG 3401 and KSG 3402, external moulds, from Kashiwaguri and Yunokuchi of Shishijima island; KSG 3403, internal mould, from Katsurazawa, Mikasa.

Measurements (in mm):—

Specimen		Length	Height
KSG 3397	L. ex. mould	30.0	11.5
KSG 3398	L. ex. mould	27.5	10.0
KSG 3399	L. in. mould	23.0	12.5
KSG 3400	R. ex. mould	42.0	22.5
KSG 3401	L. ex. mould	21.0	9.0
KSG 3402	R. ex. mould	23.5	8.5
KSG 3403	L. in. mould	33.0	11.5

Remarks:—Amano (1956) distinguished the specimens from Shishijima island and Miyanohara from *Anthonya apicalis* Nagao (1938) from Hokkaido, as a subspecies, *Anthonya apicalis shishijimensis*. It was said by him that the shell is not so rapidly tapering in its posterior part, not so concave at the dorsal margin, and the anterior margin is more produced. As far as I have observed, several specimens in my hand from the Miyanohara Formation are tapering in the posterior part like the specimens of *A. apicalis* from Hokkaido (Nagao, 1938). Although the dorsal margin is nearly straight in the immature specimens from Miyanohara and Shishijima, it is usually concave in the adult specimens. Hayami (in Hayami and Kase, 1981) has noted that the specimens of *A. apicalis* from the sea bottom off the coast of Kuji have not so prominent umbo and not so regularly spaced ribs on the surface as those from Miyanohara and Shishijima. The adult specimens from the Miyanohara are, however, identical with *A. apicalis apicalis* in its surface ornamentation and the shape of umbo. To sum up, I am inclined to deny the subspecific distinction within *A. apicalis* between the forms from Hokkaido and Southwest Japan.

Occurrence:—Common in the medium-grained sandstone of the Miyanohara Formation at Miyanohara, Sakawa; rare at the fine-grained sandstone and siltstone of the S-IV and S-III Formations at Hegushi and Yunokuchi of Shishijima.

Superfamily Veneracea Rafinesque

Family Veneridae Rafinesque

Subfamily Pitarinae Stewart

Genus *Goshoraia* Tamura, 1977

Goshoraia crenulata (Matsumoto)

Plate 3, Figs. 1—3

1938. "*Callista*" (*Pseudamiantis*) *crenulatus* Matsumoto, *Jour. Geol. Soc. Japan*, vol. 45, no. 532, p. 19, text-figs. 12, 13, pl. 1, fig. 5.
1956. *Pseudamiantis crenulatus* (*Matsumoto*); Amano, *Kumamoto Jour. Sci.*, ser. B, sec. 1, vol. 2, no. 1, p. 78, pl. 1, fig. 26, pl. 2, figs. 13—19.

1963. "*Callista*" (*Pseudamiantis*) *crenulatus* Matsumoto; Iwasaki, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 51, p. 94, pl. 15, figs. 4—7.
1975. *Pseudamiantis*? *crenulata* (Matsumoto); Hayami. *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 144.
1977. *Goshoraia crenulata* (Matsumoto); Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, pp. 139—140, text-fig. 14, pl. 9, figs. 9—16.
1981. *Goshoraia crenulata* (Matsumoto); Hayami and Kase, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 121, pp. 39—40, pl. 5.
1982. *Goshoraia crenulata* (Matsumoto); Tashiro and Matsuda, *Ibid.*, no. 127, pp. 410—411, pl. 65, figs. 12, 13.

Material:—KSG 3404 and KSG 3405, external and internal moulds, from Miyanohara, Sakawa; KSG 3406, internal mould, from Hegushi of the Shishijima island.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3404	R. ex. mould	ca 35.0	26.5	6.5
KSG 3405	R. in. mould	31.5	25.0	—
KSG 3406	L. in. mould	—	15.5	—

Remarks:—These specimens are undoubtedly conspecific with *Goshoraia crenulata* (Matsumoto), from the Goshonoura Group in Kyushu (Matsumoto, 1938; Tamura, 1977), because of its fine subinternal radial ribs and numerous irregular concentric striae on the disk, prominent and prosogyrate umbo, subovate outline, finely crenulated inner margin and the same features of the hinge structure.

Occurrence:—Common in the medium-grained sadstone of the Miyanohara Formation at Miyanohara, Sakawa; common in the medium-grained sandstone of the S-III Formation of the Goshonoura Group at Kashiwaguri of the Shishijima island; common in the fine-grained sandstone of the S-IV and S-V Formation of the same Group at Hegushi and Yunokuchi of the same island; common in the siltstone of the S-I Formation of the same group at Hegushi and Katasoba of the same island.

Subfamily Tapetinae Adams et Adams

Genus *Legumen* Conrad, 1858

?*Legumen* sp.

Plate 3, Fig. 7

Compare:—

1982. ?*Legumen* sp.; Tashiro and Matsuda, *Trans. Proc. Palaeont. Soc. Japan, n.s.*, no. 127, p. 411, pl. 65, figs. 8—10.

Material:—KSG 3407, left internal mould, from Miyanohara.

Remarks:—A specimen, KSG 3407, is measured 15.0 mm in length and 9.5 mm in height. This is similar to ?*Legumen* sp. (Tashiro and Matsuda, 1982) from the Fukigoshi Formation in Shikoku, in having the same features of the outline and hinge structure.

Occurrence:—Very rare in the fine-grained sandstone of the Miyanohara Formation at Miyanohara of Sakawa.

Subclass Anomalodesmata Dall

Order Pholadomyoida Newell

Superfamily Pholadomyacea Gray

Family Pholadomyidae Gray

Genus *Pholadomya* Sowerby, 1823

Subgenus *Pholadomya* Sowerby, 1823

Pholadomya (*Pholadomya*) *japonica* Amano

Plate 3, Figs. 4—6

1956. *Pholadomya japonica* Amano, *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, no. 1, p. 80, pl. 2, figs. 1—5.
1975. *Pholadomya* (*Pholadomya*) *japonica* Amano; Hayami, *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 148.

Material:—KSG 3408, conjoined valves, from Miyanohara; KSG 3409, imperfect, conjoined valves, from Yunokuchi of the Shishijima island.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3408	valve	45.0	24.5	13.5
KSG 3409	valve	30.0	31.5	9.0

Remarks:—This species was established by Amano (1956) on the specimen from the Miyanohara Formation. The outline of this species is variable from subquadrate to subovate.

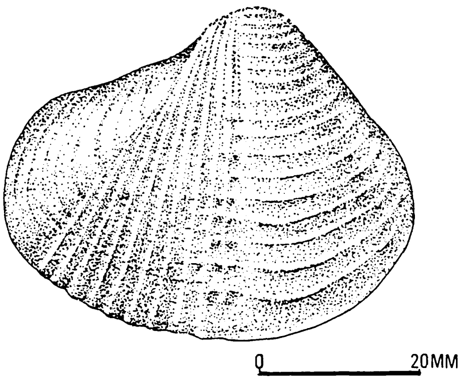
Occurrence:—Rare in the medium-grained sandstone of the Miyanohara Formation at Miyanohara of Sakawa; very rare in the fine-grained sandstone of the S-V Formation of the Goshonoura Group at Yunokuchi of the Shishijima island.

Subgenus *Bucardiomya* Rollier, 1912

Pholadomya (*Bucardiomya*) *hiratai* sp. nov.

Plate 3, Figs. 8—13; Text-fig. 4

Material:—Holotype, KSG 3383, external mould of right valve, from Miyanohara of Sakawa; paratypes, KSG 3384 and KSG 3385, external moulds of right valves, from the same locality; another paratype, HPC 8517, external mould of right valve, from Nagase, Monobe area.



Text-fig. 4. *Pholadomya* (*Bucardiomya*) *hiratai* sp. nov.
A diagramatic sketch from synthetic reconstruction. (T. Matsuda delin.)

Diagnosis:—Shell medium in size, subtrapezoidal or subtriangular in outline, strongly expanded; umbo prominent, located at about two fifths from front of the valve; anterior margin nearly straight, obliquely truncated, forming an angle of about 120° with ventral margin; ventral margin broadly arched; posterior margin narrowly rounded; posterior dorsal margin elongated, weakly concave near the umbo; disk ornamented with about 20 strong concentric ribs on its anterior half, and with distinct radial ribs on its posterior half; the concentric ribs narrower than their interspaces; the radial ribs loosely spaced with about 10 on the posterior marginal part, but closely spaced on the central part of the disk; posterior area broad, nearly smooth without fine growth lines; lunular area smooth.

Measurements (in mm):—

	Specimen	Length	Height	Thickness
KSG 3383	R. ex. mould	37.0	ca 25.0	ca 9.0
KSG 3384	R. ex. mould	27.0	ca 21.0	ca 10.0
KSG 3385	R. ex. mould	—	—	—
HPC 8517	R. ex. mould	25.0	ca 25.0	—

Observation:—The outline of the valve is somewhat variable. The concentric ribs are sometimes weakened near the ventral margin.

Comparison:—This species resembles *Pholadomya* (*Bucardiomya*) *miyamotoi* Nagao (1943), from the Aptian Hiraiga Formation of Northeast Japan, in its outline and radial ribs on the disk, but differs in the absence of granulations on radial ribs and stronger concentric ribs on the

Explanation of Plate 1

Nucula (*Pectinucula*) *kochiensis* Tashiro et Matsuda

Fig. 1. Lateral view of right valve, gum cast of external mould (KSG 3365), x 1.2, loc. Yunokuchi of Shishijima, Kagoshima Prefecture.

Fig. 2. Lateral view of the same specimen, x 1.2.

Fig. 3. Dorsal view of the same specimen, x 1.2.

Fig. 4. Lateral view of left valve, plaster cast of internal mould (KSG 3364), x 1.2, loc. Miyanohara of Sakawa, Kochi Prefecture.

Fig. 5. Lateral view of right valve, plaster cast of internal mould (KSG 3360), x 1.2, loc. ditto.

Fig. 6. Lateral view of right valve, plaster cast of external mould (KSG 3361), x 1.2, loc. ditto.
Fig. 7. Lateral view of left valve, plaster cast of internal mould (KSG 3362), x 1.2, loc. ditto.
Fig. 8. Lateral view of right valve, plaster cast of internal mould (KSG 3363), x 1.2, loc. ditto.

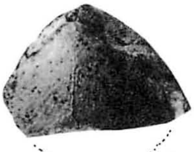
Portlandia (s.l.) *nagaseana* Tashiro et Matsuda
Fig. 9. Lateral view of left valve, plaster cast of internal mould (KSG 3367), x 1.2, loc. Miyanohara.
Fig. 10. Lateral view of left valve, plaster cast of internal mould (KSG 3366), x 1.2, loc. ditto.

Glycymeris (Hanaia) goshonouraensis Matsukuma
Fig. 11. Internal view of left valve, gum cast of internal mould (KSG 3379), x 1.5, loc. Miyanohara.
Fig. 12. Internal view of right valve, gum cast of internal mould (KSG 3382), x 1.2, loc. Hegushi of Shishijima.
Fig. 13. Lateral view of left valve, gum cast of external mould (KSG 3380), x 1.2, loc. Miyanohara.
Fig. 14. Internal view of right valve, gum cast of internal mould (KSG 3381), x 1.5, loc. Hegushi.
Fig. 15. Lateral view of right valve, gum cast of external mould (KSG 3378), x 1.2, loc. Yunokuchi of Shishijima.

Myrtea (Myrtea) amanoi sp. nov.
Fig. 16. Lateral view of right valve, plaster cast of external mould (KSG 3392), x 1.2, loc. Miyanohara.
Fig. 17. Internal view of right valve, gum cast of internal mould (KSG 3390), x 1.5, loc. Fukigoshi of Monobe area, Kochi Prefecture.
Fig. 18. Lateral view of left valve, gum cast of external mould (KSG 3391), x 1, loc. Miyanohara.
Fig. 19. Lateral view of right valve, gum cast of external mould (KSG 3393), x 1.5, loc. Enokuchi of Goshonourajima, Kumamoto Prefecture.
Fig. 20. Lateral view of right valve, gum cast of external mould (KSG 3389), x 1.5, loc. Fukigoshi.
Fig. 21. Lateral view of right internal mould (same specimen with KSG 3389), x 1.5.

Pachythaerus nagaoi (Matsumoto)
Fig. 22. Lateral view of right valve, gum cast of external mould (KSG 3396), x 1.7, loc. Kashiwaguri, Shishijima.
Fig. 23. Internal view of right valve, gum cast of internal mould (KSG 3394), x 1, loc. Miyanohara.
Fig. 24. Internal view of right valve, gum cast of internal mould (KSG 3395), x 1.2, loc. Kashiwaguri of Shishijima.

Anthonya apicalis Nagao
Fig. 25. Lateral view of left valve, gum cast of external mould (KSG 3401), x 1.2, loc. Kushizaki, Shishijima.
Fig. 26. Lateral view of left valve, plaster cast of external mould (KSG 3398), x 1.2, loc. Miyanohara.
Fig. 27. Internal view of imperfect left valve, gum cast of internal mould (KSG 3399), x 1, loc. Miyanohara.
Fig. 28. Internal view of left valve, gum cast of internal mould (KSG 3403), x 1.2, loc. Katsurazawa of Mikasa area, Hokkaido.
Fig. 29. Lateral view of right valve, gum cast of external mould (KSG 3402), x 1.2, loc. Yunokuchi.
Fig. 30. Lateral view of left valve, gum cast of external mould (KSG 3397), x 1.2, loc. Miyanohara, collected by Late Mr. Hirata.
Fig. 31. Lateral view of right valve, gum cast of external mould (KSG 3400), x 1.2, loc. ditto.


1


4


5


6


9


2

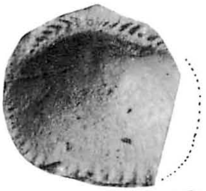

7

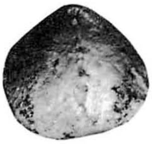

8

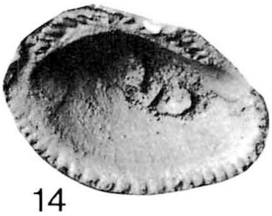

11


10


3


12


13


14


20


17


16


15


21

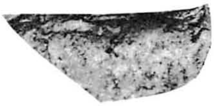

19


18


25

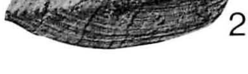

26


22


27


23


28


29


24


30


31

disk. It is distinguished from *P.* (*B.*) *subpedelnalis* Nagao (1943), from the Hiraiga Formation in that the latter has a trigonal outline. It is similar to *P. decussata* (Mantell), from the Chalk Marl of England (Woods, 1909), in its ornament on the disk, but differs in its elongated outline.

Occurrence:—Very rare in the medium-grained sandstone of the Miyanohara Formation at Miyanohara of Sakawa area; rare in the medium-grained sandstone of the Nagase Formation of the Monobe area.

Superfamily Pandoracea Rafinesque

Family Laternulidae Hedley

Genus *Periplomya* Conrad, 1870

Periplomya japonica sp. nov.

Plate 3, Figs. 14–17

Material:—Holotype, KSG 3410, conjoined valves, from Hegushi of Shishijima; paratype, KSG 3411, conjoined valves from the same locality; the other paratypes, KSG 3412 and KSG 3413, external moulds of the left and right valves, from Miyanohara, Sakawa.

Diagnosis:—Shell medium in size, elongatedly ovate, weakly inflated; test very thin; umbo a little prominent, nearly orthgyrous, pointed at a little posterior than mid-length of the valves; anterior dorsal margin oblique, nearly straight; anterior and posterior margins well rounded; ventral margin broadly arched; posterior dorsal margin nearly straight and horizontal, apical angle about 120°; surface with irregular growth striae; two narrow inner buttresses extend radially from the umbo to the venter, of which the anterior one, observable subvertically under the umbo, short with about a ninth of the valve height; the other posterior one stronger and more elongated than the anterior, extended towards but not reaches the postero-ventral corner.

Measurements (in mm):—

Specimen		Length	Height	Thickness
KSG 3410	valve	41.0	25.0	4.0
KSG 3411	valve	32.5	24.5	3.5
KSG 3412	R. ex. mould	22.0	13.0	4.0
KSG 3413	L. ex. mould	21.0	14.0	2.5

Observation:—The H/L ratio of this species is variable from 0.75 to 0.59. The growth striae on the surface are very fine but well marked.

Comparison:—"*Periploma* sp." from the Misakubo Formation of the Akaishi Mountaines (Matsushima and Kitamura, 1981) are probably conspecific with this species in showing the same features of the valve. This species is similar to *Periplomya grandis* Ichikawa et Maeda (1958), from the Izumi Group, in the outline, but differs in its smaller valve and weaker and narrower buttresses. It is discriminated from *P. nagaoi brevis* Ichikawa et Maeda (1958), from the Izumi Group, in that the latter has a more rounded outline. It is similar to "*Thracia*" *robinaldina*? (d'Orbigny), from the Lower Greensand of England (Woods, 1909), in its elongated outline, but is characterized by less inflated valve than that of "*T.*" *robinaldina*?.

Occurrence:—Common in the siltstone of the S-I Formation of the Goshonoura Group at Hegushi of Shishijima, and of the S-III Formation of the same group at Yunokuchi of the same island; very rare in the medium grained sandstone of the Miyanohara Formation at Miyanohara of Sakawa.

Concluding remarks

According to a biostratigraphic study of the Cretaceous pterotrigonians in Japan by Tashiro and Matsuda (1983a), the geological age of the fossiliferous bed of the Miyanohara Formation was determined to be as upper Lower Cenomanian. This is supported by an ammonite, *Sharpeiceras* sp., which suggests the substage K4a2, i.e. upper Lower Cenomanian (Matsumoto, 1977, fig. 3; Matsumoto et al., 1982, fig. 2).

The middle part of the Nagase Formation (Tashiro et al., 1982), which is characterized by the occurrence of *Mantelliceras japonicum* Matsumoto, Muramoto et Takahashi, an indicator of the upper Lower Cenomanian (K4a2), is undoubtedly correlated with the fossiliferous bed of the Miyanohara Formation. This is evidenced by the occurrence of some common bivalve species, i.e., *Pholadomya* (*Bucardiomya*) *hiratai*, *Pterotrigonia* (*?Scabrotrigonia*) *pustulosa* (B form) and *Cucullaea* (*Idonearca*) *ezoensis ezoensis*.

The bivalve fauna of the Misakubo Formation (Matsushima and Kitamura, 1981) is closely similar to this Miyanohara fauna, but *Neithea* sp., *Linotrigonia* sp. and *P.* (*?S.*) *monobeana* are unknown in the latter.

Many species of the Miyanohara fauna, i.e., *Cucullaea* (*Idonearca*) *ezoensis ezoensis*, *Arca* (*Eonavicula*) *tashiroi*, *Glycymeris* (*Hanaia*) *solida*, *P.* (*?S.*) *pustulosa*, *P.* (*Ptil.*) *mifunensis*, *Pachythaerus nagaoi*, *Anthonya apicalis* and *Goshoraia crenulata* are known from S-IV Formation (Tashiro and Matsuda, 1983a) of the Goshonoura Group in Shishijima. In my opinion, the Miyanohara fauna is safely correlated with the fauna of the S-IV Formation.

It can be said that the Miyanohara fauna represents an intervening substage between the fauna of the Members IIb and IIe or S-I Formation of the Goshonoura Group (Uppermost Albian to lower Lower Cenomanian on the evidence of associated ammonites) and that of the Lower Formation of the Mifune Group or the upper part of the Nagase Formation (Middle Cenomanian). It is devoid of *P.* (*Ptil.*) *ogawai*, *P.* (*Ptil.*) *dilapsa*, *P.* (*?S.*) *pustulosa* (A form), *Nipponitrigonia* spp., *Cucullaea* (*Idonearca*)

Explanation of Plate 2

Arca (*Eonavicula*) *tashiroi* sp. nov.

Fig. 1. Internal view of right valve, gum cast of internal mould (KSG 3373), x 2, loc. Enokuchi of Goshonourajima, Kumamoto Prefecture.

Fig. 2. Dorsal view of the same specimen, x 1.8.

Fig. 3. Lateral view of right valve, gum cast of external mould (KSG 3372), x 1.5, loc. ditto.

Fig. 4. Internal view of left valve, gum cast of internal mould (KSG 3377), x 1.5, loc. Kashiwagrui of Shishijima, Kagoshima Prefecture.

Fig. 5. Lateral view of right valve, plaster cast of external mould (KSG 3374), x 1.2, loc. Miyanohara of Sakawa area, Kochi Prefecture.

Fig. 6. Lateral view of imperfect left valve, gum cast of esternal mould, x 1.5, loc. Enokuchi.

Fig. 7. Lateral view of imperfect right falve, gum cast of external mould, x 1.5, loc. ditto.

Fig. 8. Lateral view of right valve, gum cast of external mould (KSG 3376), x 1.5, loc. Kashiwaguri.

Fig. 9. Dorsal view of internal mould (KSG 3375), x 1.5, loc. Miyanohara.

Fig. 10. Lateral view of the same specimen, x 1.5.

Cucullaea (*Idonearca*) *ezoensis ezoensis* Yabe et Nagao

Fig. 11. Lateral view of right internal mould (KSG 3370), x 1.5, loc. Miyanohara.

Fig. 12. Dorsal view of the same specimen, x 1.5.

Fig. 13. Internal view of right valve, gum cast of internal mould (KSG 3369), x 1, loc. ditto.

Fig. 14. Internal view of right valve, gum cast of internal mould (KSG 3368), x 1, loc. ditto.

Fig. 15. Lateral view of right valve, gum cast of external mould, x 1.2, loc. ditto, collected by Late Mr. Hirata.

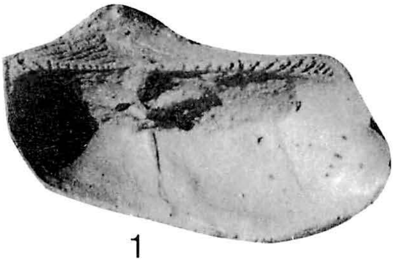
Fig. 16. Lateral view of right valve, gum cast of external mould (KSG 3371), x 1.2, loc. Kashiwaguri.

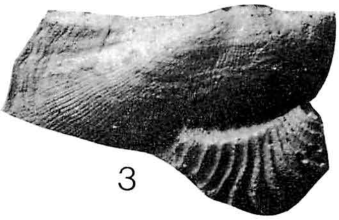
Thetis japonica (Yabe et Nagao)

Fig. 17. Lateral view of left valve, plaster cast of external mould (KSG 3388), x 1, loc. Miyanohara.

Crassostrea kawauchidensis Tamura

Fig. 18. Lateral view of left internal mould (KSG 3387), x 1.2, loc. ditto.

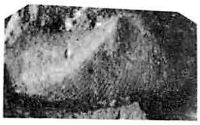

1

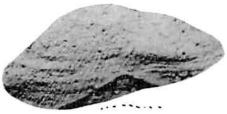

3


4


2


6


5

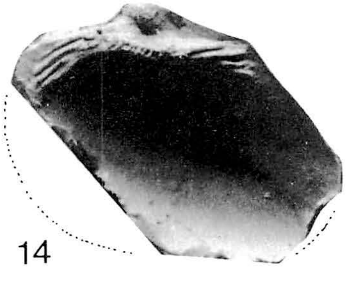

7


8

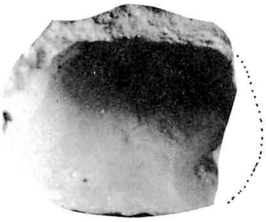

17

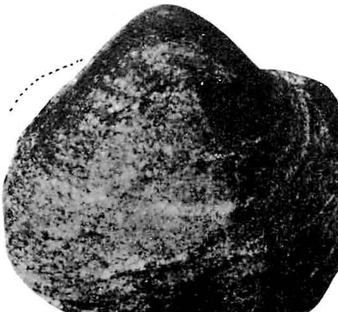

9


12


14


10


13


15


16


18

Table 1. List of bivalves from the Miyanohara Formation and their known distribution in their parts of Japan

Bivalves from the Miyanohara F.		Kyushu							Shikoku		A	K	Mk
		IIb	IIe	S-I	S-III	S-IV	S-V	M	Fu	Na			
Nucula (*Pectinucula*) *kochiensis*	○			○		○			○	○			
Portlandia (s. l.) *nagaseana*	△								○				
Cucullaea (*Idonearca*) *ezoensis ezoensis*	△			○	○	○	○			○			○
Arca (*Eonavicula*) *tashiroi*	△	○		○		○			○				
Glycymeris (*Hanaia*) *goshonourensis*	△	○	○	○	○	○	○			○			
Crassostrea kawauchidensis	○							○	○				
Pterotrigonia (?*Scabrotrigonia*) *pustulosa*	◎	○	○	○	○	○	○			○			○
P. (*Ptilotrigonia*) *mifunensis*	◎				○	○	○	○			○		○
P. (*Ptil.*) *amakusensis*	△	○	○										
P. (*Ptil.*) *miyanoharensis*	○										○		
Myrtea (*Myrtea*) *amanoi*	△	○							○				
Thetis japonica	△								○			○	○
Pachythaerus nagaoi	△	○			○	○	○						
Anthonya apicalis	◎					○	○					○	○
Goshoraia crenulata	○	○	○	○	○	○	○	○	○			○	○
?*Legumen* sp.	△								○				
Pholadomya (*Pholadomya*) *japonica*	○	○				○	○						
Pholadomya (*Bucardiomya*) *hiratai*	△									○			
Periplomya japonica	△			○		○					○		
Geological age		UMA	LLC		ULC		?MC	MC	LLC	ULC	LC	LC	MC

IIb, IIe: Goshonoura Group in the island of Goshonoura, S-I, S-III, S-V: Goshonoura Group in Shishijima, M: Lower Formation of the Mifune Group (after Tamura, 1977), Fu: Upper Member of the Fukigoshi Formation (after Tashiro and Matsuda, 1982), Na: Middle Member of the Nagase Formation (after Tashiro and Kozai, 1982), A: Misakubo Formation (after Matsushima and Kitamura, 1981), K: Cenomanian rock from the sea bottom off the coast of Kuji (after Hayami and Kase, 1981), Mk: Mikasa Formation, UMA: uppermost Albian, LLC: lower Lower Cenomanian, LC: Lower Cenomanian, ULC: upper Lower Cenomanian, MC: Middle Cenomanian. △: very rare, ○: rare, ◎: abundant.

ezoensis amaxensis and *Anthonya japonica*, characteristic elements of the former (i.e. Uppermost Albian to lowest Cenomanian). On the other hand, *P.* (*Ptil.*) *higoensis*, *Cymbophora okadakensis*, *Glycymeris* (*Hanaia*) *hokkaidoana* and *Anthonya mifunensis* which are characteristic species of the latter (i.e. Middle Cenomanian), have not yet been found in the Miyanohara fauna. In addition to these facts, the Miyanohara fauna contains many species which are common with the faunas of the Lower and Middle Cenomanian strata in various areas of Japan as shown in Text-fig. 5.

Through this study the detailed change of the bivalve fauna from the late Albian to the Cenomanian has been made clear. This would be a foundation for further careful comparison between various areas within the Japanese province.

References

Amano, M. (1956): Some Upper Cretaceous fossils from Southwestern Japan (part 1). *Kumamoto Jour. Sci.*, sec. 1, (geol.), vol. 1, no. 1, p. 63—86, pls. 1—2.

——(1957): The Lower Cretaceous fauna from Hagino in Southern Shikoku, Japan. *Ibid.*, vol. 1, no. 2, p. 77—121, pls. 1—2.

Freneix, S. (1976): Les Mollusques bivalves crétacés du Bassin côtier de Tafaya (Maroc méridional). *Le Bassin côtier de Tafaya (Maroc méridional), tome III Paléontologie Notes & M. Serv. géol. Maroc*, no. 228, p. 49—255.

Hayami, I. (1975): A systematic survey of the Mesozoic bivalvia from Japan. *Univ. Mus. Univ. Tokyo, Bull.*, no. 10, p. 1—249, 10 pls.

—— and Kase, T. (1981): Cenomanian molluscs in a sandstone block form the sea bottom off the southern coast of Kuji, Northeast Japan. *Trans. Proc. Palaeont. Soc. Japan*, n.s., no. 121, p. 29—50, pls. 4—5.

Ichikawa, K. and Maeda, Y. (1958): Late Cretaceous pelecypods from Izumi Group, Part 2, Orders Taxodontida, Priodontida, Dysodotida, Desmodontida and Adapedontida. *Jour. Inst. Polytech. Osaka City Univ.*, ser. G., p. 71—122, pls. 3—7.

Iwasaki, Y. (1963): *Pseudamiantis*, a pelecypod genus. *Trans. Proc. Palaeont. Soc. Japan*, n.s., no. 51, p. 91—101, pls. 14, 15.

Matsukuma, A. (1979): Glycymeridid bivalves from Japan and adjacent areas, part 1.

Explanation of Plate 3

Goshoraia crenulata (Matsumoto)

Fig. 1. Dorsal view of internal mould (KSG 3406), x 1.2, loc. Hegushi of Shishijima, Kagoshima Prefecture.

Fig. 2. Lateral view of right valve, gum cast of external mould (KSG 3404), x 1, loc. Miyanohara of Sakawa area, Kochi Prefecture.

Fig. 3. Internal view of right valve, gum cast of internal mould (KSG 3405), x 1, loc. ditto.

Pholadomya (Pholadomya) japonica Amano

Fig. 4. Lateral view of right valve, plaster cast of external mould, x 1, loc. Miyanohara, collected by Mr. Hirata.

Fig. 5. Lateral view of left external mould (KSG 3409), x 1, loc. Hegushi.

Fig. 6. Lateral view of left external mould (KSG 3408), x 1, loc. Miyanohara.

?*Legumen* sp.

Fig. 7. Internal view of left valve, gum cast of internal mould (KSG 3407), x 1, loc. ditto.

Pholadomya (Bucardiomya) hiratai sp. nov.

Fig. 8. Lateral view of imperfect right valve, plaster cast of external mould (KSG 3384), x 1, loc. ditto, collected by Prof. Katto.

Fig. 9. Lateral view of imperfect right valve, plaster cast of external mould (KSG 3385), x 1, loc. ditto, collected by Prof. Katto.

Fig. 10. Lateral view of imperfect right valve, plaster cast of external mould (HPC 8517), x 1, loc. Nagase, Monobe area, Kochi Prefecture, collected by Mr. Hirata.

Fig. 11. Lateral view of imperfect right valve, plaster cast of holotype (external mould) (KSG 3383), x 1, loc. Miyanohara, collected by Mr. Hirata.

Fig. 12. Lateral view of the same specimen, x 1.

Fig. 13. Dorsal view of the same specimen, x 1.

Periplomya japonica sp. nov.

Fig. 14. Lateral view of left valve, plaster cast of external mould (KSG 3413), x 1.8, loc. Miyanohara.

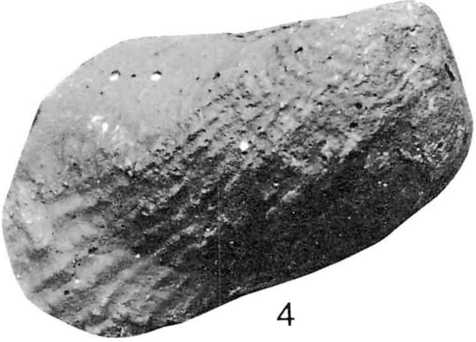
Fig. 15. Lateral view of right valve, plaster cast of external mould (KSG 3412), x 1.2, loc. ditto.

Fig. 16. Lateral view of right external mould (KSG 3411), x 1, loc. Hegushi.

Fig. 17. Lateral view of left external mould (KSG 3410), x 1, loc. ditto.


1

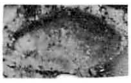

2


4


3


5


6

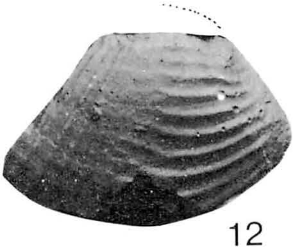

7

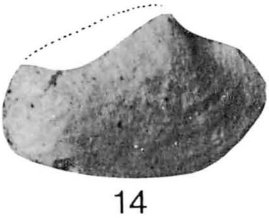

8


9


11


10


12


14


16


13


15


17

Venus (*Jap. Jour. Malac.*), vol. 38, no. 2, p. 95—128.

Matsushima, N. and Kitamura, K. (1981): Bivalve fossils from the Lower Cretaceous Misakubo Formation. *Shimoina Educ. Com. Nat. Sci.*, vol. 4, p. 99—112, 5 pls. (in Japanese).

Matsumoto, T. (1938): Preliminary notes on some of the more important fossils among the Goshonoura fauna. *Jour. Geol. Soc. Japan*, vol. 45, no. 532, p. 13—26, pls. 1, 2.

——(1977): Zonal correlation of the Upper Cretaceous of Japan. *Palaeont. Soc. Japan, Spec. Pap.*, no. 21, p. 63—74.

—— and Tashiro, M. (1975): A record of *Mortoniceras* (Cretaceous ammonite) from Goshonoura Island, Kyushu. *Trans. Proc. Palaeont. Soc. Japan*, n.s., no. 100, p. 230—238, pl. 25.

——, Obata, I., Tashiro, M., Ohta, Y., Tamura, M., Matsukawa, M. and Tanaka, H. (1982): Correlation of marine and non-marine formations in the Cretaceous of Japan. *Pal. Soc. Japan, Fossils*, p.1—26 (in Japanese).

—— and Tashiro, M. (1982, ed.): Multidisciplinary research in the Upper Cretaceous of the Monobe area, Shikoku. *Palaeont. Soc. Japan, Spec. Pap.*, no. 25, p. 1—123, 23 pls.

Nagao, T. (1930): On some Cretaceous fossils from the island of Amakusa, Kyushu, Japan. *Jour. Fac. Sci. Hokkaido Imp. Univ.*, ser. 4, vol. 1, no. 1, p. 1—25, 3 pls.

—— (1938): Some molluscan fossils from the Cretaceous deposits of Hokkaido and Japanese Saghalien, Part 1, Lamellibranchiata and Scaphopoda. *Ibid.*, vol. 4, no. 2, p. 117—142, pls. 14—16.

—— (1943): *Pholadomya* from Japan. *Jour. Geol. Soc. Japan*, vol. 50, no. 596, p. 153—160, pls. 12, 13.

Stephenson, L. W. (1941): The larger invertebrate fossils of the Navarro Group of Texas. *Texas Univ. Publ.*, no. 4101, p. 1—641, pls. 1—95.

Tamura, M. (1977): Cenomanian bivalves from the Mifune Group, Japan. Pt. 2. *Mem. Fac. Educ. Kumamoto Univ.*, vol. 26, sec. 1, p. 107—144, pls. 1—3.

—— and Packard, E. L. (1972): The genotype species of *Anthonya* Gabb. *Ibid.*, vol. 20, p. 22—30, pl. 1.

—— and Tashiro, M. (1976): Mesozoic bivalves of Japan. *Atlas of Japanese fossils*, no. 43—258.

Tashiro, M. (1971): Upper Cretaceous glycymerids in Japan. *Trans. Proc. Palaeont. Soc. Japan*, n.s., no. 84, p. 225—242, pls. 27, 28.

—— (1976): Bivalve faunas of the Cretaceous Himenoura Group in Kyushu. *Palaeont. Soc. Japan, Spec. Pap.*, no. 19, p. 1—102, 12 pls.

—— and Kozai, T. (1982): Bivalve fossils from the Upper Cretaceous of the Monobe area, Shikoku. *Ibid.*, no. 25, p. 69—92, pls. 12—14.

—— and Matsuda, T. (1982): The bivalve fossils from the Cretaceous Fukigoshi formation of the Monobe area, Shikoku. *Trans. Proc. Palaeont. Soc. Japan*, n.s., no. 127, p. 393—418, pls. 62—65.

—— and —— (1983a): The biostratigraphy of the Cretaceous pterotrigonians in Japan. *Res. Rep. Kochi Univ.*, vol. 31, nat. sci., p. 25—60, pls. I—II.

—— and —— (1983b): A study of the pterotrigoniae from Japan. (I) Taxonomy. *Mem. Fac. Sci. Kochi Univ.*, ser. E, Geol., vol. 4, p. 13—52, pls. 1—13.

Woods, H. (1899—1913): *A monograph of the Cretaceous Lamellibranchia of England.* vol. 1 (1899—1903), xliii+227 pp., 42 pls.; vol. 2 (1904—1913), 473 p., 62 pls. Palaeontogr. Soc. London.

Yabe, H. and Nagao, T. (1928): Cretaceous fossils from Hokkaido; Annelida, Gastropoda and Lamellibranchiata. *Sci. Rep. Tohoku Imp. Univ.*, ser. 2, vol. 9, no. 9, p. 77—96, pls. 16, 17.

——, —— and Shimizu, S. (1926): Cretaceous mollusca from the Sanchu graben in the Kwanto Mountainland, Japan. *Ibid.*, vol. 9, No. 2, p. 33—76, pls. 12—15.

Akaishi 赤石, Enokuchi 江ノ口, Fukigoshi 吹越, Godaisan 五台山, Goshonoura 御所浦, Hagino 萩野, Hegushi 幣串, Himenoura 姫ノ浦, Hiraiga 平井賀, Izumi 和泉, Kashiwaguri 柏栗, Katasoba 片側, Katsurazawa 桂沢, Kochi 高知, Hokkaido 北海道, Kyusyu 九州, Mifune 御船, Mikasa 三笠, Misakubo 水窪, Miyanohara 宮ノ原, Monobe 物部, Nagase 永瀬, Odochi 大栃, Sakawa 佐川, Shikoku 四国, Shiroi 白井, Shishijima 獅子島, Ezo エゾ, Yunokuchi 湯ノ口

四国高知県・佐川地域の宮ノ原層 (Lower Cenomanian) から産する二枚貝化石については，Amano (1956) により数種が記載されているが，今回新種を含む多くの二枚貝化石を採集できたので，あらためて記載する。

本化石ファウナは，三角貝 *Pterotrigonia* (*?Scabrotrigonia*) *pustulosa*, *P.* (*Ptilotrigonia*) *mifunensis*, *P.* (*Ptil.*) *amakusensis*, ならびにアンモナイト *Shapeiceras* sp. の産出から upper Lower Cenomanian と思われる。

また，本化石ファウナは，九州の御所浦層群，四国の永瀬層，赤石地域の水窪層，北海道の三笠層など日本における各地の Lower Cenomanian の地層の化石ファウナと類似しており，特に九州獅子島の御所浦層群，S-IV層の化石ファウナとはよく一致する。 松田智子

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 137, pp. 19—24, pl. 4, April 30, 1985

791. MULTILAMINAR COLONIES OF BRYOZOANS FROM JAPAN. I. "ECTOPROCTALITH" OF *ANTROPORA TINCTA* (HASTINGS)*

YASUO NISHIZAWA

Department of Earth Sciences, Faculty of Science, Chiba University, Chiba, 260

Abstract. A massive, multilaminar colony of *Antropora tincta* (Hastings) attached to a gastropod shell from the Jizodo Formation (Middle Pleistocene) and its hydrodynamic system is described. It has regularly spaced mounds like monticules and shows a high degree of colonial integration. The zooids overgrown by subsequent zooid layers have thin and concave "frontal walls".

Introduction

Nodular cheilostome colonies have been reported from the Cenozoic age by Canu and Bassler (1923), Hoffmeister *et al.* (1967), and Banta (1972). Recently, Rider and Enrico (1979) described such colonies as ectoproctaliths which are "highly spherical ectoproct colonies that begin development on various kinds of primary substrates." The growth-form of ectoproctaliths can be included in the Celleporiform morphotype (Canu and Bassler, 1920; Lagaaij and Gautier, 1965; Schopf, 1969) because they are composed of numerous, concentric layers of zooids. Rider and Cowen (1977) subdivided the celleporiform into two categories, namely, Celleporiform A ectoproctaliths composed of numerous zooid layers of anascan species, and Celleporiform B ectoproctaliths developed from the zooïd columns of ascophorans. Banta (1972) studied frontal bud formation in an ascophoran species: *Schizoporella unicornis floridana* Osburn.

In this article, a Celleporiform A ectoproctalith of *Antropora tincta* (Hastings), from the Jizodo Formation (Middle Pleistocene), is described and its hydrodynamics are discussed.

Before going further, I would like to express my sincere thanks to Professor Sumio Sakagami of Chiba University for his constant guidance and his kindness in reading this manuscript, and to Dr. Tomoko Hayami of Ehime University for her kind guidance and encouragement. I am particularly indebted to Dr. Patricia L. Cook of British Museum (Natural History) for her kindness in critical reading this manuscript. I am also indebted to Messrs. Shinji Arakawa and Kiyoshi Ishii of Chiba University for their kind advice and assistance.

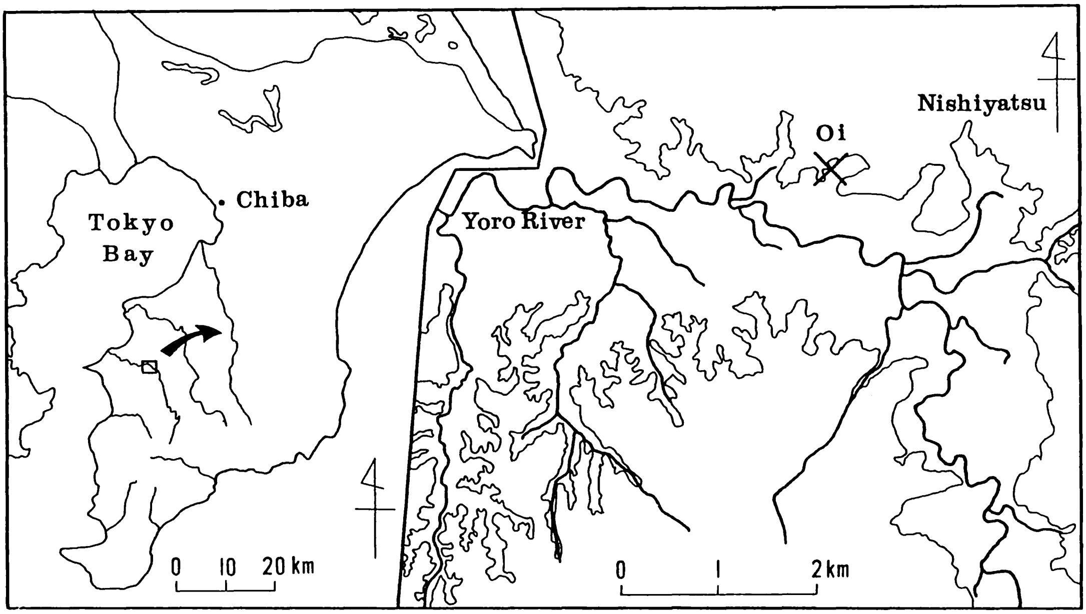
Locality of Specimen

The Jizodo Formation (Mid. Pleistocene) distributed in the central part of Chiba Prefecture, Japan consists of shallow marine sediments and contains many kinds of fossils, such as bivalves, gastropods and bryozoans which have been reported by Ogose (1959), Aoki and Baba (1980) and Sakakura (1935).

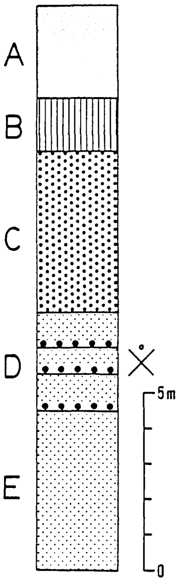
A single specimen of massive, nodular colony of *Antropora tincta* was collected from loose, cross-bedded, coarse sands of the Jizodo Formation at Oi, about one kilometer west of Nishiyatsu. The locality and the columnar section

---

*Received November 29, 1983; read January 23, 1983 at Tokyo



Text-fig. 1. Map showing the locality (x) of sample studied.



Text-fig. 2. Columnar section of the Jizodo Formation at Oi and showing the horizon collected bryozoan colony studied. A: cross-bedded, medium sands, B: highly bioturbated muds, C: cross-bedded, coarse sands with gravels and shells, D: medium sands with gravels and shell fragments, E: cross-bedded, fine to medium sands.

taken at the outcrops at Oi are shown in Text-fig. 1 and 2, respectively.

Ectoproctalith of *Antropora tincta* (Hastings)

According to Rider and Enrico (1979), the Celleporiform A ectoproctaliths are known to be produced by only two genera, namely, *Membranipora* Blainville and *Conopeum* Gray. The specimen from the Jizodo Formation is, however, produced by *Antropora tincta* (Hastings) (Pl. 4, Figs. 1—3). Osburn (1950) reported multilaminar colonies of *A. tincta*, and Banta (1973) and Buss (1979, 1981) described that *A. tincta* can overgrow a pre-existing layer. This is the first find of the nodular colony of the genus *Antropora* Norman.

In this specimen, the primary substratum is a gastropod shell surrounded by approximately 70 further zooid layers (Pl. 4, Fig. 5). The colony of *A. tincta* is similar to that of *Membranipora flabellata* Canu in the mechanism of colonial development (see Rider and Enrico, 1979), but it differs in the smaller dimensions of subcolonies (Pl. 4, Fig. 11). The primary substratum may have been more easily overturned by wave and/or current action than flat substrata or rocks. The stratum comprised this nodular colony is composed of cross-bedded, coarse sands, and it is considered that the sediments was deposited under strong current and/or wave action as mentioned by Arakawa (1983).

It is clear that the previous zooids have "frontal walls" which are continuous with vertical walls (Pl. 4, Fig. 4). They are thin and concave. By use of a needle, the "frontal walls" of pre-existing zooids can be easily separated from the basal walls of overgrown zooids. This separation suggests that the frontal membranes became calcified as "frontal walls", before the overgrowth of the next layer of zooids. There is a semicircular area in the distal part of frontal wall and it seems to be reflected by the shape and size of an operculum. Thus it is possible that the overgrown zooids may first become closed by calcification, although it is not certainly known when the closure occurred.

The present colony is encrusted by two other cheilostomes, *Verminaria areolae* Sakakura (Pl. 4, Fig. 9) and *Stephanosella vitrea* Osburn (Pl. 4, Fig. 10).

Hydrodynamics

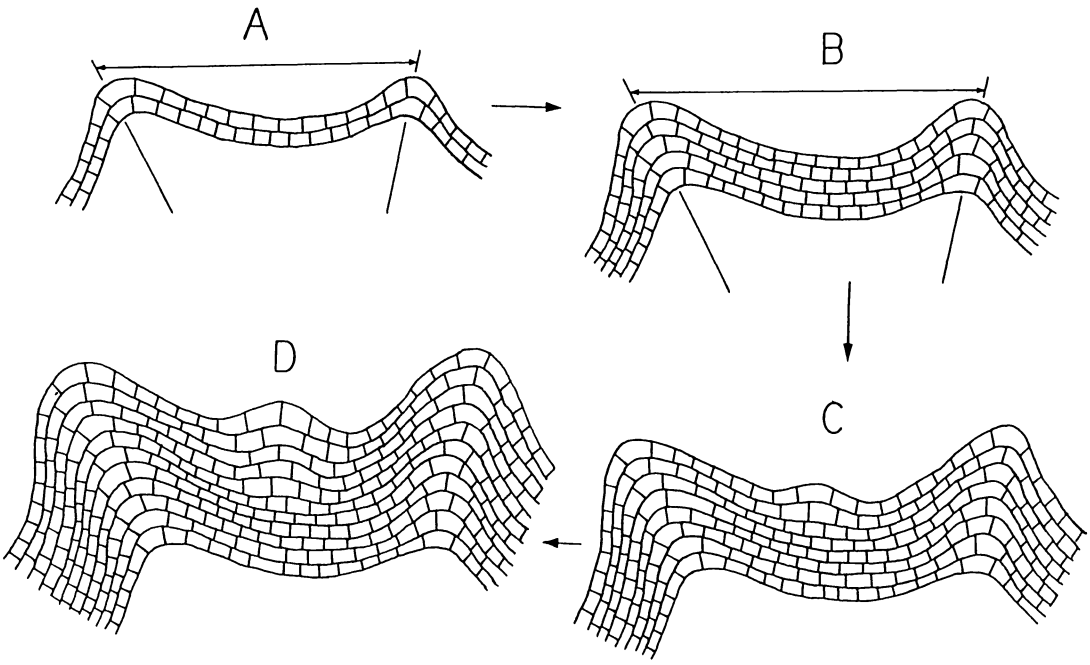
Most of marine bryozoans generate colony-wide current patterns to gather food particles and to remove fecal pellets and sediments. Since Banta, McKinney and Zimmer (1974) pointed out the significance of colony-wide current patterns, they have also been studied by other authors (Cook, 1977, 1979; Cook and Chimonides, 1980; Winston, 1978, 1979; Lidgard, 1981). Taylor (1975) reconstructed the water current system of the fossil cyclostome *Reptomultisparsa incrustans* which produced regularly spaced mounds like the monticules known in trepostomatous bryozoans.

In the nodular colony of *Antropora tincta* there are numerous raised areas spaced in a rhombic pattern (Pl. 4, Fig. 6). Distance between the nearest mounds (center-to-center) is about 4.6 mm and it is comparable to the center-to-center distance between the nearest chimneys (4.56 mm) in *Membranipora villosa* Hincks (Lidgard, 1981). The distance is, however, larger than those in *Membranipora* sp. by Banta *et al.* (1974) and also in *Cleidochasma contractum* (Waters), *Schizoporella cornuta* (Gabb and Horn), *Hippoporina porosa* (Verrill), *Cryptosula pallasiana* (Moll) and *Parasmittina nitida* (Verrill) by Cook (1977), and it is smaller than that in *Membranipora membranacea* (Linnaeus) by Cook and Chimonides (1980). Cook and Chimonides (1980) mentioned that the difference in distance between chimneys is directly related to the large size of the zooids in the population they studied of *M. membranacea* at least. Therefore, the mounds may represent areas where excurrent water flow is expelled, and it may be that the polypides form fixed clusters enhanced by the regular patterning of the colonial skeleton. Thus the nodular colony of *A. tincta* seems to be a highly integrated colony (see Cook, 1979). According to Winston (1979) who divided many marine bryozoans from Florida and Panama into seven groups based on the type of colonial behaviour pattern, polypides in *A. tincta* form temporary clusters or permanent clusters enhanced by an irregular patterning of the zoarium. The difference of the types of behaviour pattern between fossil and recent specimens may be caused by the environmental difference, or the colony may produce regularly spaced mounds as zooid layers increase in number.

There are two kinds of zooids in *A. tincta*: the large and small (see Table 1). Mean length of large and small zooids are 0.453 mm and 0.350 mm, respectively. The raised areas contain irregularly arranged large zooids (Pl. 4, Figs. 7, 8) and the intervening channels consist of small zooids which are arranged closely in a quincunx pattern. The mounds distributed all over the

Table 1. Zooecial measurements (in mm).

	Mean zooid length	Mean zooid width
Zooids at the mounds	0.453	0.305
Zooids at the channels	0.350	0.225



Text-fig. 3. Diagrammatic reconstruction of the development of mounds.

surface of the zoarium are low or high. The diagrammatic reconstruction of the development of raised areas is shown in Text-fig. 3. A) There are two mounds and the distance between them is suitable to establish a current system. B) As the distance becomes broader with accumulation of zooid layers, it becomes difficult to maintain feeding efficiency. The mounds become higher because the large zooids of new layer overgrow the pre-existing one. C) A group of large zooids occurs between two high mounds. D) Consequently a low mound is produced. Recently, Cook and Chimonides (1980) described that the mean length of chimney zooids and other autozooids are 0.95 mm and 0.72 mm, respectively, in *Membranipora membranacea*.

Most cheilostome zooids have been considered to be hermaphroditic. Marcus (1938) reported that there are male, female and sterile zooids in *Hippothoa hyalina* (Linnaeus). Gordon (1968) found the male zooids in *Hippodinella adpressa* (Busk), but it is impossible to distinguish them from other zooids in dead or fossil specimens. According to Cook (1968),

---

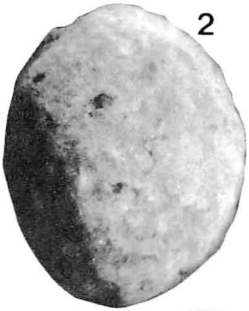
Explanation of Plate 4

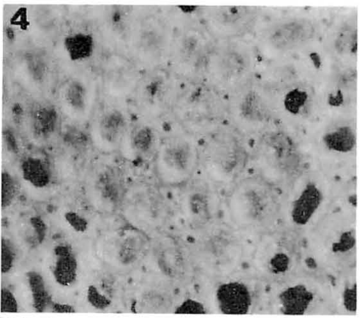
Figs. 1—8, 11. *Antropora tincta* (Hastings)

1—3. Showing the three dimensional views of the ectoproctalith, natural size. 4. Autozooids with "frontal wall", x20. 5. Inside of the zoarium, showing a gastropod shell and zooid lamination, natural size. 6. Another side of the zoarial surface, showing the development of the regularly spaced mounds, natural size. 7, 8; Enlarged part of the mounds, x20. 11. Zoarial surface showing pseudoancestrulae, subcolonies and boundaries between subcolonies, x10.

Figs. 9, 10. *Verminaria areolae* Sakakura and *Stephanosella vitrea* Osburn. Specimens of two other species of bryozoan encrusting the colony of *Antropora tincta*, x10.


1

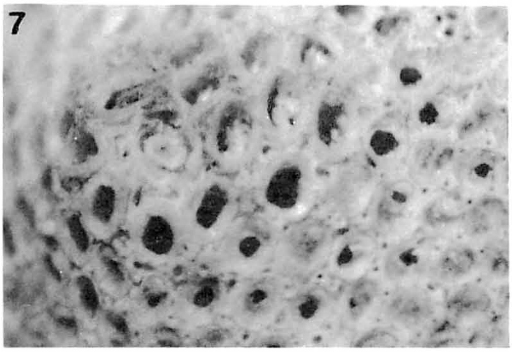

2

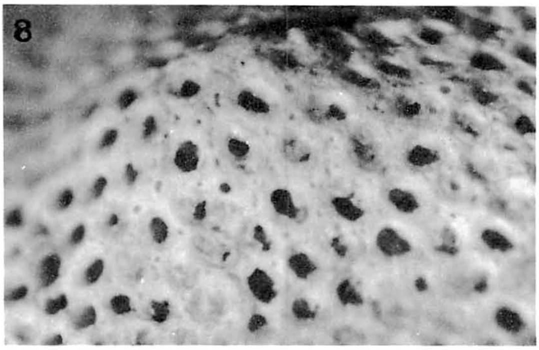

4

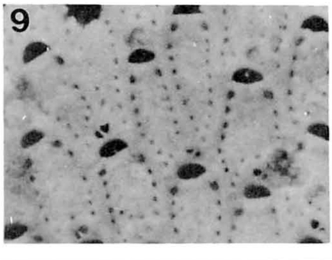

3

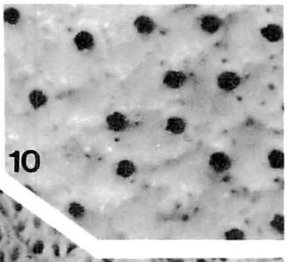

5

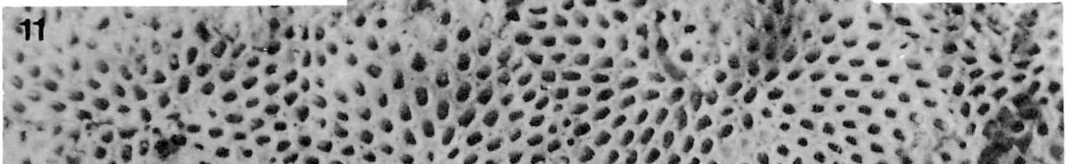

6


7


8


9


10


11

there are two kinds of zooids in *Hippoporidra senegambiensis* (Carter). One of them, "cortical zooids" are larger and have a small number of tentacles lacking cilia. Silén (1977) considered that these zooids may have a male function though the spermatozoa were not found in living or preserved specimens. The facts of the tentacles lacking cilia and of the cortical zooids occurred at the centers of the protuberances suggest that these areas represent chimneys and that male zooids are in a suitable position for the release of spermatozoa (Banta *et al.*, 1974; Cook, 1977). Thus there seems to be a relationship between mounds and reproduction (see Cook, 1977). But such relationship is not known in *Antropora tincta*, and further research is necessary.

References

Aoki, N. and Baba, K. (1980): Pleistocene molluscan assemblages of the Boso Peninsula, Central Japan. *Sci. Rep., Inst. Geosci., Univ. Tsukuba, Sec. B*, vol. 1, p. 107—148.

Arakawa, S. (1983): Sedimentary facies of the Jizodo Formation (Pleistocene), Boso Peninsula. *Clastic Sediments* (*Jour. Clastic Sediments Research Group in Japan*), no. 2, p. 8—15 (in Japanese).

Banta, W. C. (1972): The body wall of cheilostome Bryozoa, V. Frontal budding in *Schizoporella unicornis floridana. Mar. Biol.*, vol. 14, p. 63—71.

——(1973): The significance of areolae in cheilostome Bryozoa. in Larwood, G. P. (ed.) *Living and Fossil Bryozoa*, p. 209—219. Academic Press, London.

——, McKinney, F. K. and Zimmer, R. L. (1974): Bryozoan monticules; excurrent water outlet? *Science*, vol. 185, p. 783—784.

Buss, L. W. (1979): Bryozoan overgrowth interactions — the interdependence of competition for space and food. *Nature*, vol. 281, p. 475—477.

——(1981): Mechanisms of competition between *Onychocella alula* (Hastings) and *Antropora tincta* (Hastings) on an eastern Pacific rocky shoreline. in Larwood, G. P. and Nielsen, C. (eds.) *Recent and Fossil Bryozoa*, p. 39—49. Olsen and Olsen, Fredensborg.

Canu, F. and Bassler, R. S. (1920): North American Early Tertiary Bryozoa. *U.S. Nat. Mus. Bull.*, vol. 106, p. 1—879, pls. 1—162.

——(1923): North American Later Tertiary and Quaternary Bryozoa. *Ibid.*, vol. 125, p. 1—302, pls. 1—47.

Cook, P. L. (1968): Observations on Living Bryozoa. *Atti. Soc. Ital. Sci. Nat.*, vol. 108, p. 155—160.

——(1977): Colony-wide water currents in living Bryozoa. *Cah. Biol. Mar.*, p. 31—47.

——(1979): Some problems in interpretation of heteromorphy and colony integration in Bryozoa. in Larwood, G. P. and Rosen, B. R. (eds.) *Biology and Systematics of Colonial Organisms*, p. 193—210, Academic Press, London.

——and Chimonides, P. J. (1980): Further observations on water current patterns in living Bryozoa. *Cah. Biol. Mar.*, p. 393—402.

Gordon, D. P. (1968): Zooidal Dimorphism in the Polyzoan *Hippopodinella adpressa* (Busk). *Nature*, vol. 219, p. 633—634.

Hoffmeister, J. E., Stockman, K. W. and Multer, H. G. (1967): Miami Limestone of Florida and its Recent Bahamian counterpart. *Bull. Geol. Soc. Amer.*, vol. 78, p. 175—190.

Lagaaij, R. and Gautier, Y. V. (1965): Bryozoan assemblages from marine sediments of the Rhône delta, France. *Micropaleont.*, vol. 11, no. 1, p. 39—58.

Lidgard, S. (1981): Water flow, feeding, and colony form in an encrusting cheilostome. in Larwood, G. P. and Nielsen, C. (eds.) *Recent and Fossil Bryozoa*, p. 135—142, Olsen and Olsen, Fredensborg.

Marcus, E. (1938): Bryozoarios marinhos brasileiros II, *Bolm Fac. Filos. ciênc. Univ. S. Paulo Zool.*, vol. 2, p. 1—196.

Ogose, S. (1959): On the type of mixture of molluscan fossil-coenosis in the Zizôdô Sand at Atebi, Hukuta-mati, Kimitu-gun, Tiba Prefecture, South Kantô, Japan. *Jour. Geol. Soc. Japan*, vol. 65, no. 760, p. 31—46.

Osburn, R. C. (1950): Bryozoa of the Pacific Coast of America. Part I. Cheilostomata-Anasca. *Allan Hancock Pacific Exped.*, vol. 14, p. 1—269, pls. 1—29.

Rider, J. and Cowen, R. (1977): Adaptive architectural trends in encrusting ectoprocts. *Lethaia*, vol. 10, p. 29—41.

Rider, J. and Enrico, R. (1979): Structural and functional adaptations of mobile anascan ectoproct colonies (ectoproctaliths). in Larwood, G. P. and Abbott, M. D. (eds.) *Advances in Bryozoology*, p. 297—319. Academic Press, New York.

Sakakura, K. (1935): Pliocene and Pleistocene Bryozoa from the Boso Peninsula (1). *Imp. Univ. Tokyo, Fac. Sci., Jour., Sec. II*, vol. 4, p. 1—48, pls. 1—7.

Schopf, T. J. M. (1969): Paleoecology of ectoprocts (bryozoans). *Jour. Paleont.*, vol. 43, p. 234—244.

Silén, L. (1977): Polymorphism. in Woolacott, R. M. and Zimmer, R. L. (eds.) *Biology of Bryozoa*, p. 184—232. Academic Press, New York.

Taylor, P. D. (1975): Monticules in a Jurassic cyclostomatous bryozoan. *Geol. Mag.*, vol. 112, no. 6, p. 601—606, 1 pl.

Winston, J. E. (1978): Polypide morphology and feeding behavior in marine ectoprocts. *Bull. Mar. Sci.*, vol. 28, p. 1—31.

——(1979): Current-related morphology and behaviour in some Pacific coast bryozoans. in Larwood, G. P. and Abbott, M. D. (eds.) *Advances in Bryozoology*, p. 247—268, Academic Press, New York.

Jizodo 地蔵堂, Nishiyatsu 西谷, Oi 大井

日本産こけ虫の多層性群体。その１。*Antropora tincta* (Hastings) の “Ectoproctalith”：房総半島第四系地蔵堂層から産出した塊状で多層性の *Antropora tincta* (Hastings) の群体 (Ectoproctalith) について，その構造と水流系を記載した。群体表面には，孔丘部 (monticules) に似た突起が規則的に配列しており，高度の統合が存在したことを示している。被覆された個虫には薄くてくぼんだ「表壁」がみられる。

西澤康男

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 137, pp. 25—49, pls. 5—7, April 30, 1985

792. LATE PERMIAN AMMONOIDS FROM THE SOUTHERN KITAKAMI MASSIF, NORTHEAST JAPAN*

MASAYUKI EHIRO

Department of Earth Science, College of General Education, Tohoku University,
Sendai 980

and

YUJI BANDO**

Department of Geology, Faculty of Education, Kagawa University,
Takamatsu 760

Abstract. Biostratigraphical correlation among the Upper Permian sections of the Southern Kitakami, Transcaucasia, Iran and South China is discussed based on the ammonite fauna of the Upper Permian Toyoman Series distributed in the Utatsu and Okago districts of the Southern Kitakami Massif. Thirteen species belonging to nine genera are described. Among them, one new family, Paratirolitidae, and two new species, *Medlicottia kitakamiensis* and *Prototoceras japonicum*, are proposed.

The lowermost part of the Toyoman Series contains Dzhulfian ammonites, such as *Araxoceras* cf. *A. rotoides* and *Prototoceras japonicum* sp. nov. The Lower and Middle Toyoman are correlated to the Dzhulfian in Transcaucasia and Iran, and to the Wujapingian in South China, taking the occurrence of *Araxoceras* cf. *A. kiangsiense* from the middle part (Murata and Bando, 1975) into consideration. It is highly probable that the Upper Toyoman is correlated to the Dorashamian in Transcaucasia and Iran, and to the Changxingian in South China based on the occurrence of *Paratirolites* ? sp.

Introduction

Ammonoid fossils, as well as fusulinids, have been considered to be useful in subdivision and world-wide correlation of the Permian rocks. They are of increasing use and value in Upper Permian stratigraphy in Transcaucasia and Northwestern Iran (Ruzhentsev and Sarycheva, 1965; Teichert et al., 1973; Stepanov et al., 1969), Abadeh in Central Iran (Bando, 1979; Iranian-Japanese Research Group, 1981) and South China (Chao, 1965; Zhao et al., 1978).

In the Japanese Islands, ammonoids have been scarcely reported from the Permian, particularly from the upper part. Up to date, only seven specimens have been found and all are from the Southern Kitakami Massif, Northeast Japan.

The Permian system in the Southern Kitakami Massif is divided into three Series, namely, the Sakamotozawan, Kanokuran and Toyoman

---

*Received Feb. 20, 1984; read Oct. 23, 1983 at Kumamoto.

**Deceased.

in ascending order (ex. Minato et al., 1978). The Toyoma Formation, the type of the Toyoman Series, was proposed by Mabuti (1932, MS) for a thick shale formation exposed in Toyoma-cho, Tome-gun, Miyagi Prefecture. The Toyoma Formation and its correlatives are distributed in the seven separated areas in the southern part of the Southern Kitakami Massif (Fig. 1). They are composed mainly of black shale and contain some intercalation of sandstone and conglomerate, showing rather uniform lithological facies. They had long been thought to be almost barren of fossils, with the exception of few sporadic occurrence of molluscs, conularids, trace fossils and plants. Therefore, the Toyoman Series had tentatively been assigned to be Late Permian without any positive fossil evidence.

Murata (1969) correlated the Toyoman Series to Middle Ochoan of North America and to Chideruan (Chhidruan) of Salt Range on the basis of similarity of Bellerophontacean fossils. Further, it was biostratigraphically divided into three zones, namely, *Euphemitopsis kitakamiensis-Astartella toyomensis* zone, *Palaeoneilo ogachiensis-Phestia kon'noi* zone and *Kitakamispira hanzawai-Nuculopsis mabutii* zone in ascending order by Murata (in Working Group, 1975; Murata and Bando, 1975).

Since 1975, several important fossils, such as ammonites, smaller foraminifers and fusulinids, were reported from the Upper Permian in the Southern Kitakami Massif. These fossils are as follows:

Araxoceras cf. *A. kiangsiense* Chao — from *Palaeoneilo ogachiensis-Phestia kon'noi* zone at Hiraiso coast (Murata and Bando, 1975).

Eumedlicottia sp. and *Artinskia* sp. — from the middle and upper part of the Toyoman Series at Okago (Bando, 1975).

Colaniella parva fauna in association with *Palaeofusulina* sp. — from the upper part of the Toyoman at Mt. Nabekoshi, northern part of Kesennuma (Tazawa, 1975; Ishii et al., 1975) and at Tanoura, Utatsu (Murata and Shimoyama, 1979).

Stacheoceras cf. *S. trimurti* Diener — from *Euphemitopsis kitakamiensis-Astartella toyomensis* zone at Toyoma (Working Group, 1975).

Xenodiscus cf. *X. carbonarius* Waagen — from the lowermost Toyoman ? at Okago (Ehiro and Bando, 1978).

Rotodiscoceras sp. — from the upper Toyoman at Senmatsu (Ehiro and Bando, 1980).

In addition, *Propinacoceras* aff. *P. galilaei* Gemmellaro described by Hayasaka (1963) from the h Member of the Iwaizaki Limestone, in which *Abadehella-Colaniella* assemblage was obtained (Ishii et al., 1975), may also be an Upper Permian (Abadehian) ammonite. Detailed stratigraphic horizon of *Propinacoceras* is after Koizumi (1975).

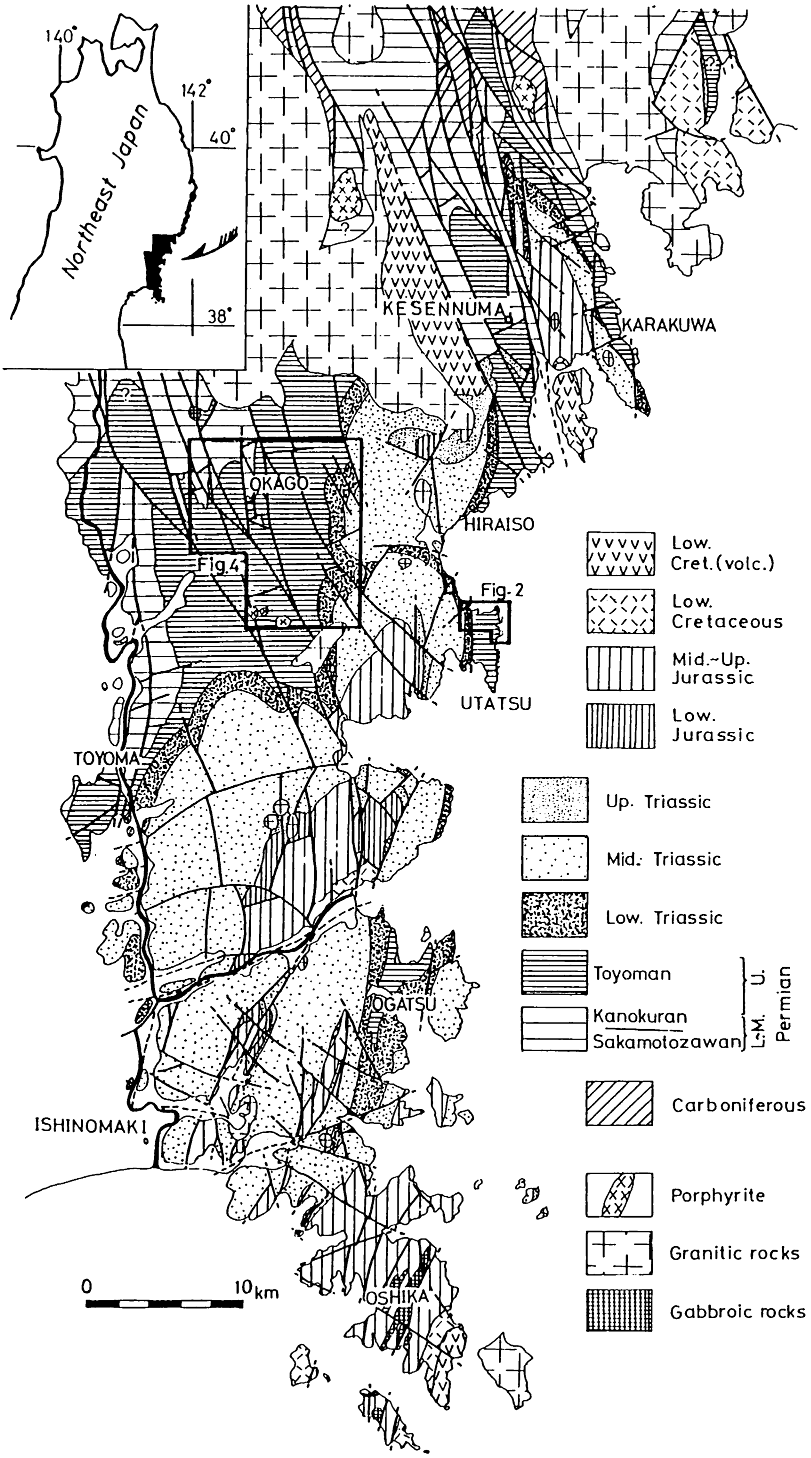
Recently, many ammonite specimens belonging to 9 genera and 13 species were collected from the Upper Permian in the Utatsu and Okago districts, Southern Kitakami Massif. The purpose of this paper is to clarify the biostratigraphy of the Toyoman Series based on the ammonite fauna and to attempt the correlation of the Upper Permian distributed in the Tethys Province.

Stratigraphy and Marine Fauna of the Upper Permian in Utatsu and Okago

1) Utatsu District

The Permian strata in this district are distributed in the eastern peninsula of Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture (Fig. 1). They form a nearly homoclinal structure, dipping to the west in various degrees (Fig. 2). Slaty cleavage is well developed. It strikes N-S and dips steeply toward E or W.

The Permian of this district was divided into the Kanokura and Toyoma Formations (Murata and Shimoyama, 1979). The latter was subdivided lithologically into the Lower, Middle and Upper. However, present investigation has revealed that it is difficult to divide the Permian lithologically into four units mentioned above. It could be classified only into two units, the Suenosaki Formation below and the Tanoura



Text-fig. 1. Compiled geologic map of the southern part of the Kitakami Massif. The studied areas are shown in the squares.

Formation above (Fig. 3). The latter is roughly corresponds to the Upper Member of the Toyoma Formation by Murata and Shimoyama (1979).

The Suenosaki Formation, which attains more than 800 meters in thickness, is typically developed along the northern coast of the peninsula, from the northeastern cape (Suenosaki) to the eastern coast of Tanoura. The Formation is mainly composed of shale and sandy shale, frequently associated with sandstone laminas. It contains also some beds of sandstone and conglomerate. The sandstones are mostly of calcareous and dominant in the lower part. They are often involved in the slump structure and thin out laterally. The conglomerates or pebbly shales occur in two horizons in the lower part. They consist of well rounded pebbles to cobbles of various kinds of rocks in shale matrix and thin out laterally. Besides them, two types of thin bedded, lenticular or nodular calcareous rocks are frequently intercalated. One of them is phosphorous shale and the other is limestone, composed of fibrous sparite. The lower limit of the Formation is unknown, because it is below the sea level.

Murata and Shimoyama (1979) reported the following fossils from the same stratigraphic sequence:

Lepidolina kumaensis Kanmera and *L. multiseptata* (Deprat) — from the calcareous sandstone of the lowermost part (Loc. 1, Fig. 2).

Euphemitopsis kitakamiensis Murata, *Pseudopermophorus uedai* Nakazawa and Newell and *Astartella toyomensis* Nakazawa and Newell — from shale matrix of the both conglomerates (Loc. 4, 6—8).

Palaeoneilo ogachiensis Hayasaka, Nuculida and *Neocalamites* sp. — from shale of the middle part (Loc. 9).

In addition to this previous work, we collected some ammonites in association with *Euphemitopsis-Astartella* fauna from shale and calcareous nodules in the lower conglomeratic beds (Loc. 2, 3, 5). They are as follows:

Stacheoceras iwaizakiense Mabuti	Loc. 2, 3, 5
Pseudogastrioceras sp.	Loc. 3
Araxoceras cf. *A. rotoides* Ruzhentsev	Loc. 3
A. sp.	Loc. 3
Prototoceras japonicum Bando and Ehiro sp. nov.	Loc. 3
P. spp.	Loc. 3

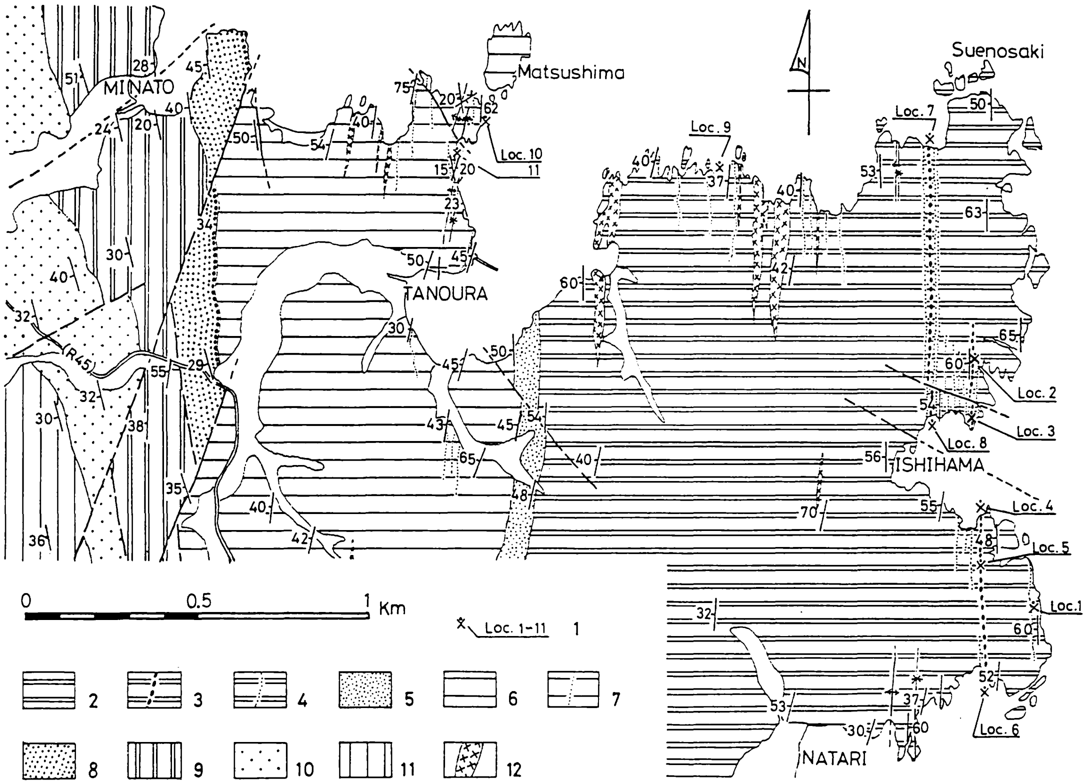
The Tanoura Formation conformably overlies the Suenosaki Formation. It is typically distributed along the eastern and northwestern coast of Tanoura, and attains more than 600 meters in thickness. The basal part of the formation is composed of alternation of sandstone and shale, 50 to 70 meters thick. The main part consists of shale, often associated with sandstone laminas, and contains lenticular sandstones, showing slump structure, in the lower part. Two types of calcareous rocks found in the Suenosaki Formation also occur in the formation. The uppermost part of the Tanoura Formation is in fault contact with Lower Triassic formations in many places, but in some places, e.g. at the northwestern hill of Tanoura, it is covered by the Lower Triassic Hiraiso Formation with unconformity.

The lower part of the Tanoura Formation (loc. 10, 11) yields the following fossils (Murata and Shimoyama, 1979):

Colaniella aff. *C. inflata* (Wang), *Palaeofusulina* sp., *Bellerophon (B.) yabei* Murata, *Kitakamispira hanzawai* Murata (MS) and *Nuculopsis mabutii* Murata (MS).

2) Okago District

In this district the Permian formations are widely distributed. They are bordered by granitic rocks, the Senmaya Mass at the north and covered unconformably by the Lower Triassic Hiraiso Formation at the eastern and southern part. In the western half of the district the Permian strata are complexly folded and faulted, and slaty cleavage is clearly recognized in fine-grained rocks. While in the eastern part, they dip gently eastward and show rather simple geologic structure. Slaty cleavage become grad-



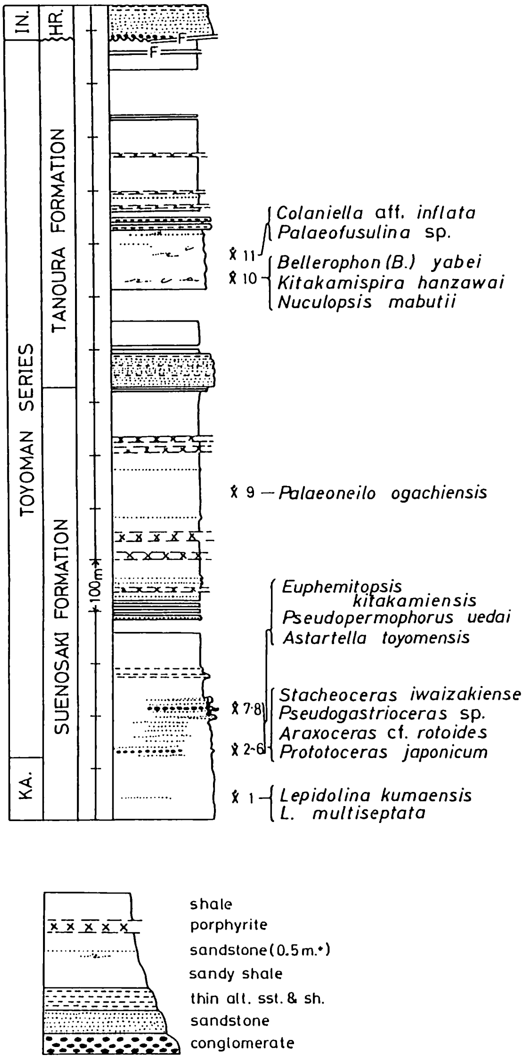
Text-fig. 2. Geologic map of the northern part of the Utatsu District. 1. fossil localities, 2—4. Suenosaki Formation (2. shale, 3. conglomerate, 4. sandstone), 5. lower part of the Tanoura Formation (alternation of sandstone and shale), 6—7. main part of the Tanoura Formation (6. shale, 7. sandstone), 8—11. Triassic formations (8. Hiraiso Formation, 9. Osawa Formation, 10. Fukkoshi Formation, 11. Isatomae Formation), 12. porphyrite.

ually indistinct toward the east.

The main part of the Permian formations in this district had been referred to the Lower and Middle Triassic formations by Bando (1956, MS, quoted partially by Onuki, 1956) and Onuki and Bando (1959) on the basis of the lithological similarlity to the Triassic formations and the occurrence of "*Pecten*", *Pseudomonotis*, *Eumorphotis*, *Deltopecten*, etc. at Senmatsu and *Episageceras* at Okago. However, after reexamination of these fossils, it became clear that *Pseudomonotis* sp. and *Deltopecten* sp. are both referred to *Aviculopecten* ? *onukii* Murata (Murata, 1969) and *Episageceras* sp. to *Eumedlicottia* sp. (Bando, 1975), both Permian in age. Moreover, Permian age of these formations was confirmed by the discovery of Permian ammonites at Okago and Senmatsu by the authors (Ehiro and Bando, 1978, 1980).

The Middle and Upper Permian in the Okago district are divided into four formations; the Higashifukakaya, Shinden, Okago and Senmatsu in ascending order (Ehiro, 1979; Ehiro and Bando, 1980). All four are in conformable contact.

The Higashifukakaya Formation occurs in the northern part of this district. It conformably overlies the Nishikori Formation, which yields *Pseudoschwagerina (Robustoschwagerina) shellwieni* Hanzawa. The thickness attains more than 1000 meters. The formation is composed of massive and bedded shales. The latter is interlaminated or very thinly interbedded with sandstones, some of which show graded bedding.



Text-fig. 3. Geologic columnar section of the Upper Permian along the northern and eastern coast of Utatsu.

Upper part of the formation contains lenticular conglomerate and sandstone. The conglomerate has well rounded pebbles to boulders of various kinds of rocks, i.e., shale, sandstone, granitic rocks, porphyrites, chert and limestone. Limestone lens in the conglomerate at Konakogi (Loc. 1, Fig. 4) yields *Pseudofusulina* sp. and *Lepidolina* sp.

The Shinden Formation, 200 to 300 meters in thickness, is exposed in the northern part. The formation is composed of sandstone, alternation of sandstone and shale, and bedded shale interlaminated with sandstone. The sandstones are grey to dark grey and coarse to very coarse grained wacke. Calcareous sandstones are intercalated in places. At the west of Fujisawa and the upper reaches of Matsukozawa, east of Yonekawa, it is intercalated with lenticular conglomerate. This formation is barren of fossils.

The Okago Formation is widely distributed. The main part of the formation is approximately 800 to 1000 meters thick. It consists of bedded shale interlaminated or very thinly interbedded with sandstones, most of which show graded bedding, and occasionally contains thin beds of sandstone. The shale often changes laterally into thin alternation of shale and sandstone. The lower middle part is intercalated with alternation of sandstone and shale, 50 to 70 meters thick. Uppermost part of the formation is composed of massive or nearly massive black shale. The thickness ranges from 80 to 300 meters and thins toward the south.

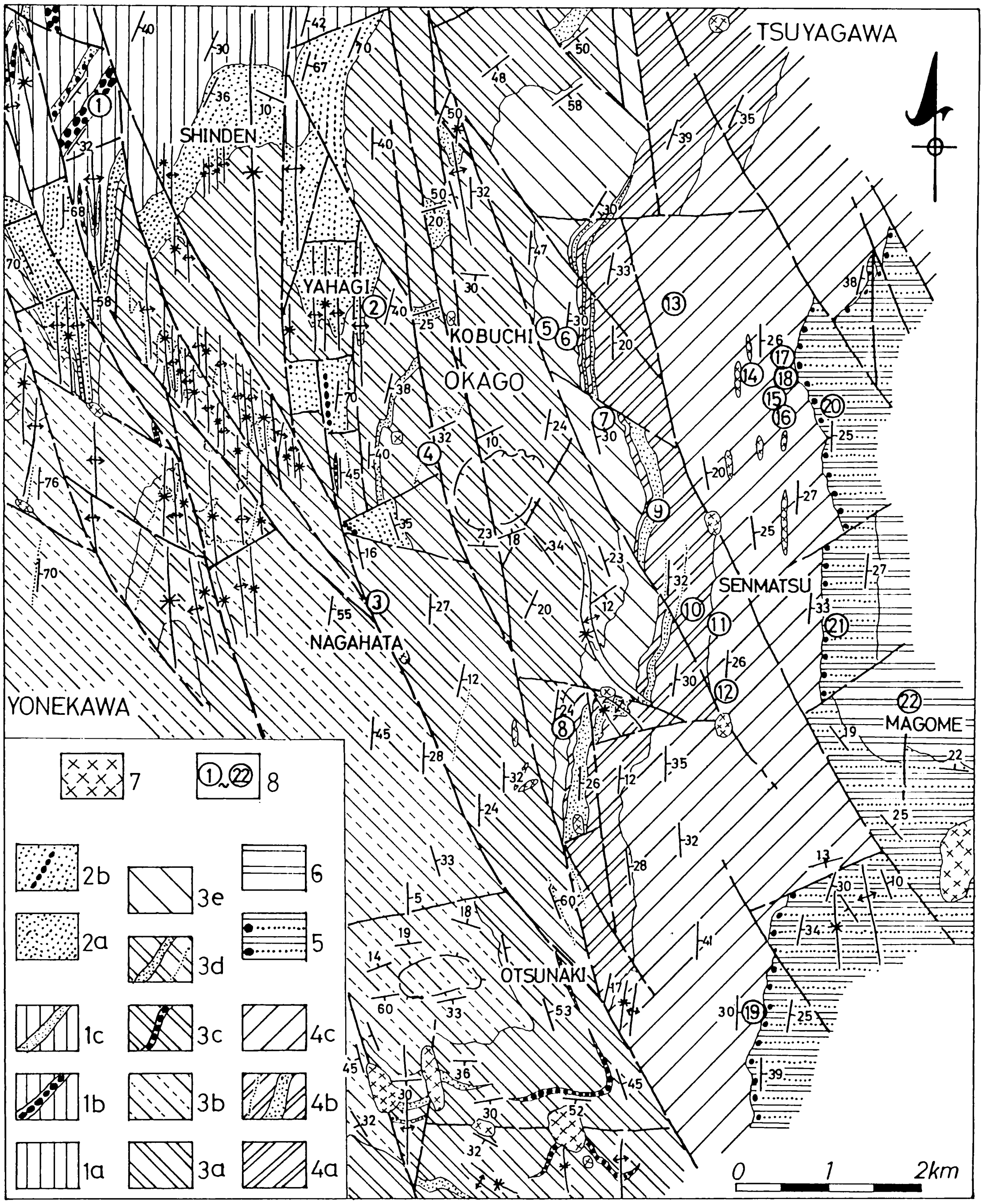
The Okago Formation yields the following fossils:

Xenodiscus cf. *X. carbonarius* Waagen — from shale of the lowermost part at Yahagi, Okago (Loc. 2, Fig. 4) (Ehiro and Bando, 1978).

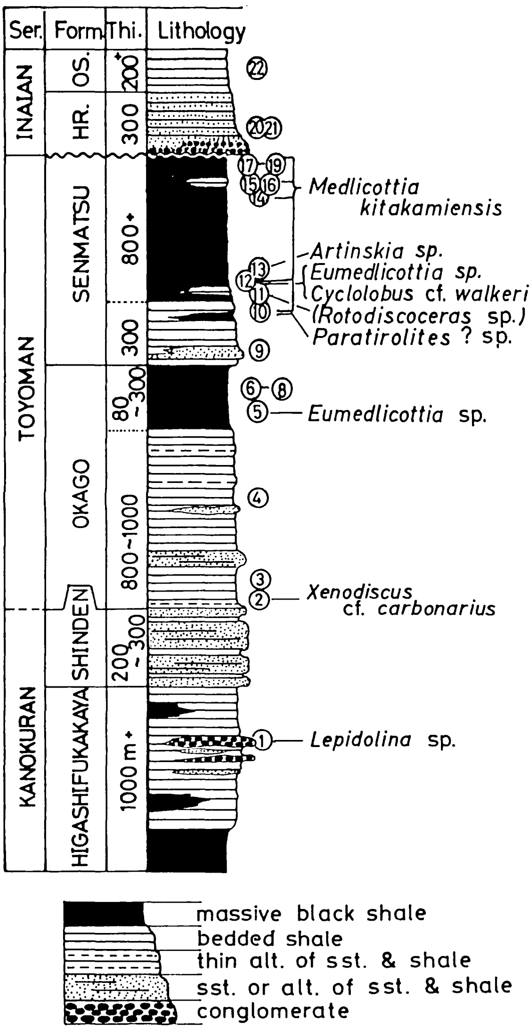
Euphemitopsis kitakamiensis Murata, *Warthia* sp., *Straparollus (Euomphalus) uedai* Murata, *Mourlonia (M.) toyomensis* Murata, *Spiroscala* sp., *Limipecten bandoi* Murata, *Pseudopermophorus uedai* Nakazawa and Newell and *Astartella toyomensis* Nakazawa and Newell — from shale of the lower part at Nagahata (Loc. 3) (Murata, 1969). Exact horizon of these fossils in the column is not known, because of the complicated geologic structure and lack of key bed.

Aviculopectin ? *onukii* Murata — from shale of the middle part at Yamashita, Okago (Loc. 4).

Eumedlicottia sp. — from shale of the uppermost part at Kobuchi, Okago (Loc. 5) (Bando, 1975).



Text-fig. 4. Geologic map of the Okago District. 1. Higashifukakaya Formation (1a. shale, 1b. conglomerate, 1c. sandstone), 2. Shinden Formation (2a. sandstone and shale, 2b. conglomerate), 3. Okago Formation (3a. bedded shale of the main part, 3b. massive shale in the Yonekawa district, 3c. conglomerate, 3d. sandstone, 3e. massive shale of the uppermost part), 4. Senmatsu Formation (4a. bedded shale, 4b. sandstone, 4c. massive shale), 5—6. Triassic formations (5. Hiraiso Formation, 6. Osawa Formation), 7. porphyrite, 8. fossil localities.



Text-fig. 5. Compiled geologic columnar section of the Middle and Upper Permian in the Okago District.

Paraconularia sp., *Spiroscala* sp., *Straparollus (Euomphalus) uedai* Murata and *Aviculopecten ? onukii* Murata — from shale of the uppermost part at some localities (Loc. 6—8).

The uppermost formation of the Permian in this district is the Senmatsu Formation. It occurs in the eastern half of the district and the total thickness exceeds 1100 meters. The lower part of the Formation, about 300 meters in thickness, is mainly composed of bedded shale interlaminated or very thinly interbedded with sandstone, and contains alternation of sandstone and shale in the lower part. The latter is 100 meters in maximum thickness and thins toward the north. The sandstones in the alternation are medium- to very coarse-grained and partially contains plant fragments. The upper part of the formation consists massive or nearly massive black shale, about 800 meters thick, that grades downward into bedded shale of the lower part. Calcareous rocks mentioned in the Utatsu district are also intercalated in the formation but in lesser amount. The formation is covered unconformably by the Lower Triassic Hiraiso Formation.

The Senmatsu Formation yields the following fossils:

Straparollus (Euomphalus) sp., *Spiroscala* sp., *Nuculopsis* sp., *Phestia* sp. and *Paracalamites* sp. — from the alternation in the lower part at north of Unazawa, Okago (Loc. 9).

Aviculopecten ? onukii Murata, *Medlicottia kitakamiensis* Bando and Ehiro sp. nov., and *Paratirolites* ? sp. — from shale of the upper part of the lower part at Kiridoshi, Senmatsu (Loc. 10).

Rotodiscoceras sp. — from shale of the lowest part of the upper part at Kiridoshi (Loc. 11) (Ehiro and Bando, 1980). This specimen is under reexamination, so that it is not discussed in this paper.

Paraconularia sp., *Straparollus (Euomphalus) uedai* Murata, *Spiroscala* sp., *Palaeoneilo* sp., *Aviculopecten ? onukii* Murata, *Eumedlicottia* sp., *Medlicottia kitakamiensis* Bando and Ehiro sp. nov., *Cyclolobus* cf. *C. walkeri* Diener and plant fragments — from shale or calcareous nodules in the lower part of the upper part at Iwanosawa, Senmatsu (Loc. 12).

Artinskia sp. — from shale of the upper part at the south of the Kuromori-toge (Loc. 13) (Bando, 1975).

Paraconularia siitai (Sugiyama), *Straparollus (Euomphalus) uedai* Murata, *Spiroscala* sp., *Aviculopecten ? onukii* Murata, *Palaeoneilo ogachiensis* Hayasaka, *Nuculopsis* sp. and

Paracalamites iwatensis Kon'no — from shale of the upper part at several localities in Senmatsu (Murata, 1967, 1969; Murata and Shimoyama, 1979; Kon'no, 1973).

Medlicottia kitakamiensis Bando and Ehiro sp. nov. — from shale of the upper and uppermost part near Nagasakiyama, Senmatsu and uppermost part near Takizawa-toge, southwest of Magome (Loc. 14—19).

Faunal Consideration and Correlation

Before going to the discussion of the present fauna, the definition of the Toyoman Series must be considered in some detail, because, up to date, it has not been defined precisely, particularly on the basis of biostratigraphic criteria. For instance, Minato et al. (1978) proposed a biostratigraphic scheme for the Permian in the Southern Kitakami Massif based mainly on fusulinids and devided the Permian into three series and six stages. They subdivided the Toyoman into the Maehaman and Nabekoshian Stages. However, in the subdivision the base of the Toyoman Series and the boundary between the Maehaman and Nabekoshian Stages were not defined clearly. Smaller foraminifers and fusulinids have only been known from a few localities and horizons of the series, because of the Toyoman Series consists mainly of black shale. Further, the black shale facies often extends to the lower horizons. Therefore, smaller foraminifers and fusulinids are not effectual in the biostratigraphic subdivision of the Upper Permian in the Southern Kitakami Massif. At present, we consider that the base of the Toyoman is defined as the base of *Euphemitopsis kitakamiensis-Astartella toyomensis* zone by Murata (in Working Group, 1975; Murata and Bando, 1975).

Among the ammonite fauna from the lower part of the Suenosaki Formation, *Araxoceras* cf. *A. rotoides*, *A.* sp., *Prototoceras japonicum* sp. nov. and *P.* spp. are of great importance. *Araxoceras* and *Prototoceras* are characteristic ammonoids of the Dzhulfian. The species of *Araxoceras* have been known from Unit 3 (Beds with *Araxoceras*) of the Dzhulfian in Transcaucasia (Ruzhentsev and Sarycheva, 1965), the Lower Julfa bed in Julfa, northwestern Iran (Stepanov et al., 1969), the Dzhulfian bed in Abadeh, Central Iran (Bando, 1979), the Wujapingian in South China (Chao, 1965; Zhao et al., 1978) and the middle Toyoman in the Southern Kitakami, Japan (Murata and Bando, 1975). *Prototoceras* have been known from Unit 3 and 4 (Beds with *Vedioceras*) of the Dzhulfian in Transcaucasia (Ruzhentsev and Sarycheva, 1965), the Dzhulfian and Dorashamian in Abadeh (Bando, 1979) and the Wujapingian in South China (Chao, 1965; Zhao et al., 1978). None of these ammonites known as *Araxoceras* fauna has been reported pre-Dzhulfian formations.

The Lower Toyoman Series together with the uppermost part of the underlying Kanokuran Series has been correlated to the Abadehian by the fossils previously reported (Murata and Shimoyama, 1979; Iranian-Japanese Research Group, 1981). In the Utatsu district, however, the *Araxoceras* fauna was obtained from a horizon about 80 meters above the horizon of *Lepidolina kumaensis*, in association with *Euphemitopsis kitakamiensis-Astartella toyomensis* fauna, and no molluscan fossils characterized the *Euphemitopsis-Astartella* fauna have been collected below this horizon. Therefore, this horizon is regarded to be the base of the Toyoman Series, and the lowest part of the Toyoman is correlated to the Dzhulfian, not Abadehian. The Abadehian in the Kitakami Massif may be limited to the uppermost part of the underlying Kanokuran Series, namely, *Lepidolina kumaensis* Zone. From the middle part of the Toyoman Series, *Araxoceras* cf. *A. kiangsiense* was reported (Murata and Bando, 1975), accordingly the Lower and Middle Toyoman are correlated to the Dzhulfian (Wujapingian).

Xenodiscus cf. *X. carbonarius* was collected from the lowermost part of the Okago Formation. *Xenodiscus carbonarius* was originally reported from the Middle Productus Limestone (Kalabagh Member of the Wargal Formation) in Salt Range as *Ceratites carbonarius* by Waagen (1872). It is later described from the Chhidru Formation, which conformably overlies the Wargal Formation, as *Xenodiscus carbonarius* (Waagen, 1879). It is now known from the Kuling Shale in Central Himalayas, the Zewan Formation in Kashmir and the Abadeh Formation in Iran (Spinosa et al., 1975; Bando, 1979). The Kalabagh-Chhidru, the Kuling and the Zewan have been considered to be of equivalent age by many authors. The Kalabagh-Lower Chhidru and Upper Chhidru are correlated to the Abadehian and Dzhulfian, respectively (Iranian-Japanese Research Group, 1981). Therefore, the stratigraphic range of *Xenodiscus carbonarius* is considered to be from Abadehian to Dzhulfian.

Euphemitopsis kitakamiensis-Astartella toyomensis fauna was reported (Murata, 1969) from the lower part of the Okago Formation, above the horizon of *Xenodiscus*. This fauna belongs to Early Dzhulfian in age as discussed already. Thus the boundary between the Abadehian and the Dzhulfian in the Okago district is probably located near the boundary between the Shinden and Okago Formations, although the exact horizon is not determined.

Of the ammonite fauna from the Senmatsu Formation, *Paratirolites* ? sp. and *Cyclolobus* cf. *C. walkeri* are important for correlation. On the other hand, *Eumedlicottia* sp. and *Medlicottia kitakamiensis* sp. nov. are less useful comparatively. The species of *Eumedlicottia* are common throughout Middle and Upper Permian and have long ranges. *M. kitakamiensis* may be the first record of the genus *Medlicottia* from the Upper Permian.

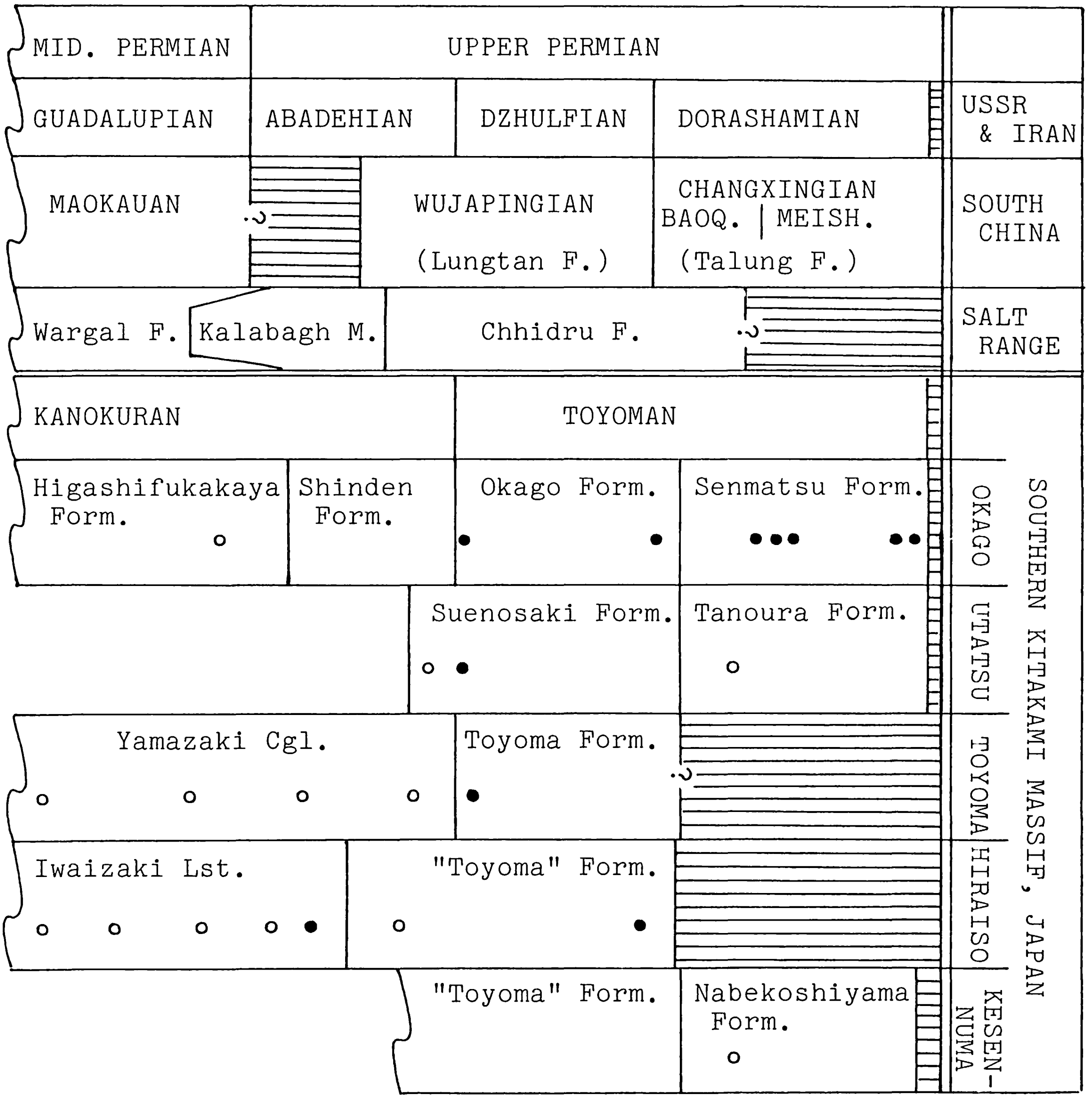
Paratirolites is a characteristic ammonite of the Dorashamian (Rostovtsev and Azaryan, 1973) in Transcaucasia and Iran (Ruzhentsev and Sarycheva, 1965; Stepanov et al., 1969; Teichert et al., 1973; Bando, 1979). It is also known from Madagascar (Tozer, 1969) and Lower Changxingian in South China (Zhao et al., 1978). In addition, Tozer (1979) concluded that *Shizoloboceras* described from the Upper Changxingian (Zhao et al., 1978) is probably a synonym of *Paratirolites*. The Kitakami specimens are rather poorly preserved, but from the shell ornamentation and general character of whorls they seem to belong to *Paratirolites*. Accordingly, it is highly probable that the Senmatsu Formation is correlated to the Dorashamian and Changxingian.

The occurrence of *Cyclolobus* cf. *C. walkeri* just above the horizon of *Paratirolites* ? sp. is of interest. At present, *Cyclolobus walkeri* is known from the Chitichum Limestone in Tibet, Kuling Shale in Central Himalayas, Chhidru Formation in Salt Range, Zewan Formation in Kashmir and Ambilobé Formation in Madagascar (Furnish and Glenister, 1970; Furnish et al., 1973). The stratigraphic range of genus *Cyclolobus* has been considered to be from Abadehian to Dzhulfian by many authors, although there is an opinion that the age of *Cyclolobus* is Guadalupian (Zhao et al., 1978; Zhao, 1980). Present specimens of *Cyclolobus* were collected from the Senmatsu Formation, which conformably overlies the Dzhulfian Okago Formation. Therefore, it is evident that they are of Late Permian age. Moreover, present data may indicate that *Cyclolobus* ranges up into the Dorashamian (Changxingian), because of it is associated with *Paratirolites* ? sp.

The precise correlation of the Upper Permian sequences between the Utatsu and Okago districts is difficult. However, coarse grained rocks are dominant both in the lower part of the Tanoura Formation and the lower part of the Senmatsu Formation. The lower part of the Nabekoshiyama Formation in northern part of Kesennuma, which yields *Palaeofusulina* sp. and *Colaniella parva* fauna (Ishii et al., 1975; Tazawa, 1975), is also composed mainly of sandstone. They may be correlated each other based on the lithologic similarity. Further biostratigraphic studies are needed on the boundary between the Dzhulfian and the Dorashamian in the Southern Kitakami Massif.

Correlation of the Upper Permian formations in the Southern Kitakami Massif and those in the Tethys Province is given in Table 1.

Table 1. Correlation chart of the Upper Permian in the Southern Kitakami Massif, Northeast Japan, South China, Salt Range, Iran and Transcaucasia.
● — horizon of ammonites, ○ — horizon of smaller foraminifers and fusulines.



MID. PERMIAN	UPPER PERMIAN			
GUADALUPIAN	ABADEHIAN	DZHULFIAN	DORASHAMIAN	USSR & IRAN
MAOKAUAN		WUJAPINGIAN (Lungtan F.)	CHANGXINGIAN BAOQ. | MEISH. (Talung F.)	SOUTH CHINA
Wargal F.	Kalabagh M.	Chhidru F.		SALT RANGE
KANOKURAN		TOYOMAN		SOUTHERN KITAKAMI MASSIF, JAPAN
Higashifukakaya Form. ○	Shinden Form.	Okago Form. ● ●	Senmatsu Form. ●●● ●●	OKAGO
		Suenosaki Form. ○ ●	Tanoura Form. ○	UTATSU
Yamazaki Cgl. ○ ○ ○ ○		Toyoma Form. ●		TOYOMA
Iwaizaki Lst. ○ ○ ○ ○ ●	"Toyoma" Form. ○ ●			HIRAISO
		"Toyoma" Form.	Nabekoshiyama Form. ○	KESEN-NUMA

Acknowledgments

The writers wish to thank Professor Kei Mori of the Institute of Geology and Palaeontology, Faculty of Science, Tohoku University for his valuable discussion and reading the first draft of the manuscript. Thanks are also due to Professor Masafumi Murata of the Department of Geology, Faculty of Science, Kumamoto University, and Dr. Shoichi Shimoyama of the Department of Geology, Faculty of Science, Kyushu University, for their valuable suggestions on geological problems.

Systematic Description

by Yuji Bando and Masayuki Ehiro

Specimens here described are kept in the Department of Geology, Faculty of Education, Kagawa University.

Table 2. Measurements in mm [*Stacheoceras iwaizakiense*]

	D	H	W	U	H/D	W/H	U/D
TY-8306	38	18	17	3	0.48	0.95	0.08
Mabuti's type specimen (IGPS, 51723)	37.2	23	18.3	—	0.62	0.79	—

D: Diameter of shell, H: Height of whorl, W: Width of whorl, U: Diameter of umbilicus.

Superfamily Cyclolobaceae Zittel, 1895

Family Vidrioceratidae Plummer and Scott, 1937

Genus *Stacheoceras* Gemmellaro, 1887

Type species:—*Stacheoceras mediterraneum* Gemmellaro, 1887.

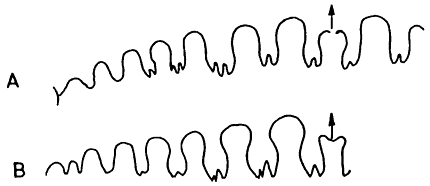
Stacheoceras iwaizakiense Mabuti

Pl. 5, Figs. 3a—c, 4a—b; Text-fig. 6A

1935. *Stacheoceras iwaizakiense* Mabuti, p. 147, pl. 14, figs. 1—7.
1975. *Stacheoceras iwaizakiense*, Koizumi, p. 68, pl. 15, figs. 4a—d.

Description:—Shell involute, subglobular to subdiscoidal, with broadly rounded venter, closed umbilicus and rounded-convex sides. Shell surface smooth and ventral shoulders indistinct, because of globular form of conch. Suture well preserved as shown in Fig. 6A. The ventral lobe broad and bifid symmetrically. The first lateral lobe also bifid, the second and third trifid, and the fourth bifid. The umbilical lobe consists of small lobes to the umbilicus.

Remarks:—Two specimens were examined. They are clearly identified with *S. iwaizakiense* Mabuti (1935), which was reported from the basal part of the Iwaizaki Limestone, in which *Monodiexodina matsubaishi* occurred from the lower part, at Iwaizaki, Kitakami Massif, in the form of conch. The suture line of the present specimens is also similar to that of the type species by Mabuti as illustrated in Fig. 6.



Text-fig. 6. Suture lines of *Stacheoceras iwaizakiense* Mabuti.
A. Present specimen (TY-8306), H=16 mm.
B. Type specimen by Mabuti (1935, pl. XIV, fig. 5), No. 51723 (Tohoku Univ., Sendai), H=14 mm.

The outline of the siphonal saddle of the present specimens is slightly different from that of the type species. However, the general outline of suture is very similar between both specimens. Mabuti compared the present species with *S. arthaberi* Smith from the Lower Permian of Bitauni in Timor (Smith, 1927, p. 50, pl. 13, figs. 15—17). The present specimens from the Suenosaki Formation occurred together with *Araxoceras* cf. *A. rotoides* Ruzhentsev in the locality at Ishihama. Therefore, the horizon of the present specimens belongs to the Dzhulfian of the Upper Permian and the biostratigraphic horizon of *S. iwaizakiense* is considered to be extended upward from the Kungurian to the Dzhulfian.

Occurrence and geological horizon:—Lower part of the Suenosaki Formation (Lowermost Toyoman) at the eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8202, 8306. Coll. M. Ehiro, 1982, 1983.

Family Cyclolobidae Zittel, 1895

Genus *Cyclolobus* Waagen, 1879

Type species:—Phylloceras oldhami Waagen, 1872.

Cyclolobus cf. *C. walkeri* Diener

Pl. 5, Figs. 1a—c, 2; Text-fig. 7

Compare:—

1903. *Cyclolobus (Krafftoceras) walkeri* Diener, p. 12—14, 162, pl. 1, figs. 3a—d.
1903. *Cyclolobus (Krafftoceras) kraffti* Diener, p. 165—167, pl. 6, figs. 9a—c.
1903. *Cyclolobus (Krafftoceras) haydeni* Diener, p. 167—169, pl. 6, figs. 7a—b, 8a—b.
1921. *Cyclolobus walkeri,* Diener, p. 27.
1936. *Cyclolobus walkeri,* Besairie, p. 105, pl. 4, figs. 6—9.
1940. *Cyclolobus walkeri,* Miller and Furnish, p. 45.
1970. *Cyclolobus walkeri,* Furnish and Glenister, p. 165—173, text-figs. 2A—D, pls. 2, figs. A—D, 3, figs. A—E, 4, figs. H—J.
1980. *Cyclolobus walkeri,* Zhao, pl. 1, figs. 6—7.

*Description:—*Shell involute, subglobose and subdiscoidal conch, with rounded venter, convex sides and small umbilicus. Surface ornamented by fine growth lines which slightly bi-projected from umbilical margin to venter. Outer whorl embraced completely inner whorls. Suture partly well preserved as illustrated in Fig. 7. Ventral lobe deepest and divided by broad bi-branched siphonal saddle, about 2/3 height of ventral lobe, into narrowly distinct lobes. Siphonal saddle also denticulated and at a portion of 1/3 height most denticulated compared with others. External and lateral saddles simply denticulated and lateral lobes also denticulated, about 7—8 points. Auxiliary series badly injured by weathering. General character of sutures arrange in parabolic form and apex of external saddle bi-partites.

*Remarks:—*Two specimens were examined. In the general characters of conch, the present specimens are clearly compared with *Cyclolobus walkeri* Diener based on the characteristic features of septa, especially in the form of siphonal saddle, the form of umbilicus and on the fine ornamentation of shell surface. The holotype of *C. walkeri* (Diener, 1903, pl. 1, fig. 3a—d) was reported from the fine grained white limestone of Chitichum in Tibetan Himalays. It is stored in the Museum of Geological Survey of India in Culcatta. In Kashmir, Furnish et al. (1973) reported *C. walkeri* from the upper part of the Zewan Formation at Guryul Ravine section. In 1970, Furnish and Glenister described *C. walkeri* from the Chhidru Formation of the Salt Range and concluded that the genus *Cyclolobus* is an index fossil of post-Guadalupian of the Upper Permian. Another locality of *C. walkeri* is in Madagascar. According to Furnish and Glenister (1970, p. 172), more than 150 specimens of *C. walkeri* have been collected from nodules in argillaceous strata at Ankitohazo (Ankitokazo) near Ambilobé in northern Madagascar. One of the authors (Bando, 1979) also described *Cyclolobus* sp. from the Abadeh Formation in Ku-e-Hambest, Abadeh region, in Central Iran. The Iranian *Cyclolobus* resembles *C. walkeri* in the general character of conch, but it is unable to observe their suture owing to poor preservation (Bando, op. cit.).

Cyclolobus is here first described in Japan.

*Occurrence and geological horizon:—*From calcareous nodules of the Senmatsu Formation (Upper Toyoman) at Iwanosawa, Senmatsu,

Table 3. Measurements in mm [*Cyclolobus* cf. *C. walkeri*]

	D	H	W	U	H/D	W/H	U/D
TY-8003	69	30	29	5?	0.43	0.96	0.16?
TY-8004	—	50?	—	16?	—	—	—

Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture. Upper Permian. Reg. No. GLKU-TY-8003, 8004. Coll. M. Ehiro, 1980.

Superfamily Goniatitaceae de Haan, 1825

Family Paragastrioceratidae Ruzhentsev, 1951

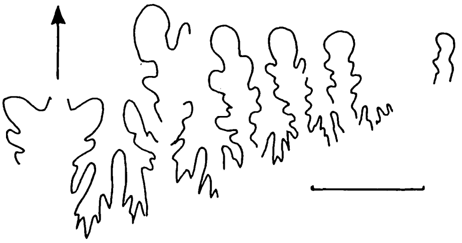
Genus *Pseudogastrioceras* Spath, 1930

Type species:—Goniatites abichianus von Möller, 1900. (in Arthaber)

Pseudogastrioceras sp.

Pl. 5, Fig. 5a—b

*Remarks:—*Only single specimen was examined. Characteristic concentric striae are observed on the shell surface of the present specimen. These concentric striae are considerably densely spaced and almost run parallel with outline of the whorls. These striae are observed on the shell of *Pseudogastrioceras*, *Agathiceras*, *Adrianites* and *Retiogastrioceras*. Of these Permian ammonoid genera the present specimen belongs to *Pseudogastrioceras* in the form of umbilicus, that is narrow funnel-shaped with distinct umbilical shoulders, and the features of whorl. The specimen resembles *Pseudogastrioceras abichianus* (von Möller) (Abich, 1878, p. 9, pl. 1, figs. 1—3, pl. 2, fig. 2, 2a, as *Goniatites striatus* Martin; Möller, 1879, p. 239, as *Goniatites abichianus* von Möller; Stepanov et al., 1969, pl. 6, figs. 1a—b; Teichert et al., 1973, p. 401, pl. 4, figs. 2—4) in the general character of the shell, although it is unable to determine the species name because of missing the sutures in the present specimen.



Text-fig. 7. Suture line of *Cyclolobus* cf. *C. walkeri* Diener from the Senmatsu Formation (TY-8003). Bar scale is 10 mm.

*Occurrence and geological horizon:—*Lower part of the Suenosaki Formation (Lowermost Toyoman) at the eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8303. Coll. M. Ehiro, 1983.

Superfamily Medlicottiaceae Karpinsky, 1889

Family Medlicottidae Karpinsky, 1889

Genus *Medlicottia* Waagen, 1880

Type species:—Goniatites orbignyana de Verneuil, 1845.

*Remarks:—*The genus *Medlicottia* was first proposed by Waagen (1880) based on *Goniatites orbignyana* de Verneuil from the Artinskian beds of Ural. About ten species of the genus *Medlicottia* have been reported from the Lower and Middle Permian of the Ural, Salt Range, Sicily, Timor and North America, up to date. *Medlicottia* is closely related to *Artinskia*, *Eumedlicottia* and *Episageceras*. The ancestral genus of *Medlicottia* may be *Propinacoceras* and the intermediate genus between *Propinacoceras* and *Medlicottia* is *Artinskia*. *Eumedlicottia* is a little advanced form in comparison with *Medlicottia* as shown in the suture which is characterized by development of slight notches in the side of the saddles (Spath, 1934; Bando, 1979). *Medlicottia* has some variabilities in the form of venter. The ventral shoulders of the conch are generally smooth. However, in some species, such as *M. costellifera* Miller and Furnish

Table 4. Measurements in mm [*Pseudogastrioceras* sp.]

	D	H	W	U	H/D	W/H	U/D
TY-8307	34	17	10?	7	0.50	0.59?	0.21

(1940, p. 57, pl. 7, figs. 2—4, pl. 8, fig. 4, pl. 9, fig. 3), two rows of small ventral nodes, lateral extensions of which continue as ribs across the ventral portion of the flanks, are prominent. *Artinskia* and *Propinacoceras* have also two distinct rows of ventral nodes, lateral extensions of which are across the ventral part from the ventral shoulders to the median part of the venter. These characters of the ventral nodes are prominent in the genus *Artinskia* and *Propinacoceras* rather than those of *Medlicottia*. In addition, the genus *Medlicottia* is clearly distinguished from the genera *Artinskia* and *Propinacoceras* in the form of external saddle.

Miller and Furnish (1940, p. 40) stated that *Artinskia* seems to have arisen from *Uddenites* and the sutures of *Propinacoceras* are more or less intermediate between those of typical *Uddenites* and those of typical *Artinskia*, and the suture of *Artinskia* passes through a *Propinacoceras* stage during their ontogenetic development. We think that the evolutional evidence is suggested in the change of sutures of the external and lateral saddles from *Uddenites* to *Artinskia* or *Medlicottia*, and those of *Eumedlicottia* are higher stage of evolution as well as those of *Episageceras*.

Occurrence and geological horizon:—Permian, especially Artinskian to Dzhulfian. Urals, Sicily, Timor, North America and Japan.

Medlicottia kitakamiensis sp. nov.

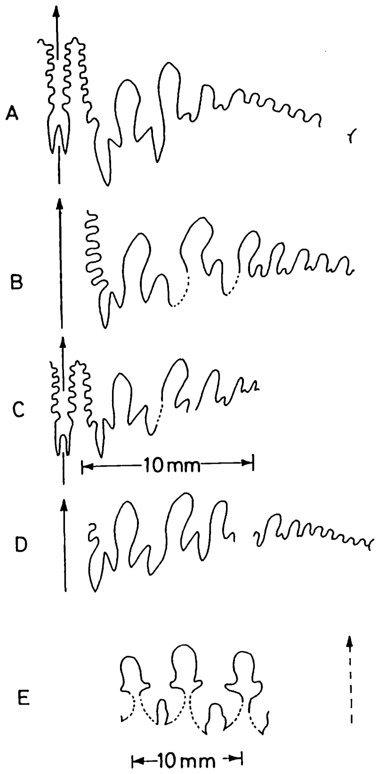
Pl. 6, Figs. 1—7, Text-figs. 8A—D

Description:—Shell involute, discoidal, laterally compressed, with closed umbilicus, slightly convex sides, and narrowly concave venter with two rows of prominent small ventral nodes extending from ventral sides, about 4/5 height, crossing venter, to median part of venter, like *Artinskia* or *Propinacoceras*. Main part of shell surface almost smooth except for nodes ornamentation of ventral sides. Suture typical types of *Medlicottia*, consisting of narrow ventral lobe, high narrow denticulated external saddle, a bifid lateral lobe, and of numeous auxiliary lobes and saddles.

Remarks:—Eleven specimens were examined. Shell ornamentation and sutures of the present specimens are well preserved. But in some specimens, ventral parts and umbilicus are ill-preserved. The present new species has two rows of prominent small ventral nodes extending from ventral sides as in *Artinskia* or *Propinacoceras* but the suture of the present species has a character of *Medlicottia*, especially in those of external saddle. However the species of *Medlicottia* described up to date have no distinct ventral nodes except for *M. costellifera* Miller and Furnish (Miller and Furnish, 1940, p. 57, pl. 7, figs. 2—4; pl. 8, fig. 4; pl. 9, fig. 3) from the Leonard Formation in the Glass Mountain and Finlay Mountain, Texas in North

Table 5. Measurements in mm [*Medlicottia kitakamiensis* sp. nov.]

	D	H	W	U	H/D	W/H	U/D
TY-8001 (Holotype)	40	20?	—	2?	0.50?	—	0.05?
TY-8002	48	23?	—	3?	0.48?	—	0.06?
TY-8101	54	24?	—	—	0.44?	—	—
TY-8102	49	21	—	2	0.43	—	0.04
TY-8103	69	35	12?	5?	0.51	0.35?	0.07?
TY-8105	49	23	—	—	0.48	—	—
TY-8107	32	18	—	2?	0.56	—	0.06?



Text-fig. 8. Suture lines of *Medlicottia* and *Eumedlicottia*.
A—D. *Medlicottia kitakamiensis* Bando and Ehiro, A. TY-8001 (Holotype), H=19 mm, B. TY-8107, H=18 mm, C. TY-8106, H unknown, D. TY-8104, H=23 mm. E. *Eumedlicottia* sp., TY-8005, H unknown.

America. The ornamentation of small ventral nodes of *M. costellifera* is more indistinct than that of the present new species and projected forward in the ventral margin. Regarding the suture line, the present new species has 6—7 denticulations in the external saddle, as in those of *M. costellifera* and *M. kingolum* Miller and Furnish (1940, p. 60, pl. 4, figs. 5—7), while the species of *Artinskia* and *Neogeoceras* have 5 denticulations in the external saddle.

Occurrence and geological horizon:—From shale of the middle and upper part of the Senmatsu Formation (Upper Toyoman). Kiridoshi, Iwanosawa and Nagasakiyama in Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture, and near Takizawa-toge, southwestern part of Magome, Motoyoshi-cho, Motoyoshi-gun, Miyagi Prefecture. Upper Permian. Reg. No. GLKU-TY-8001 (Holotype), 8002, 8101—8109. Coll. M. Ehiro, 1980, 1981.

Genus *Eumedlicottia* Spath, 1934

Type species:—*Medlicottia bifrons* Gemmellaro, 1887.

Eumedlicottia sp.

Pl. 6, Fig. 8, Text-fig. 8E

Remarks:—Single specimen was examined. The shell is a fragment of the outer whorl and shell ornamentation is missing. Only sutures are well preserved. Inner whorl and their sutures are slightly preserved. Sutures clearly belong to that of *Eumedlicottia* and consist of numerous lateral saddles and are subdivided lateral lobes. Lateral saddles bifurcate at half height of both wings, but their bifurcation is not distinct in the sutures of the inner whorls.

Judging from the suture, the present specimen is similar to *Eumedlicottia primas* (Waagen) from Timor, but it is difficult to determine the specific name because of poor preservation of the material.

Occurrence and geological horizon:—From shale of the middle part of the Senmatsu Formation (Upper Toyoman) at Iwanosawa, Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture. Upper Permian. Reg. No. GLKU-TY-8005. Coll. M. Ehiro, 1980.

Superfamily Otocerataceae Hyatt, 1900

Family Araxoceratidae Ruzhentsev, 1959

Genus *Araxoceras* Ruzhentsev, 1959

Type species:—*Araxoceras latissimum* Ruzhentsev, 1959.

Araxoceras cf. *A. rotoides* Ruzhentsev

Pl. 7, Figs. 1a—c

Table 6. Measurements in mm [*Araxoceras* cf. *A. rotoides*]

	D	H	W	U	H/D	W/H	U/D
TY-8301	43(24)	20(10)	15	10(8)	0.46	0.75	0.23

Compare:—

1963. *Araxoceras rotoides* Ruzhentsev, p. 57, fig. 1a, pl. V, figs. 1a—b.
1965. *Araxoceras rotoides,* Shevyrev, in Ruzhentsev and Sarycheva, pl. XVIII, fig. 2.
1969. *Araxoceras rotoides,* Stepanov et al., pl. IX, figs. 3a—b.
1979. *Araxoceras rotoides,* Bando, p. 119, pl. I, figs. 2a—b, pl. II, figs. 2, 4, 5a—b.

*Description:—*Shell rather involute, discoidal, laterally compressed, with broadly tabulated venter, but slightly convexed to median ridge? on venter. Umbilicus width is about 1/4 of total diameter of shell and umbilical rim likes ear-lobe. Shell sides concave and ventral margin sharply edged. Cross section of whorl high-trapezoidal form. Maximum width at umbilical margin about 15 mm, and height of whorl about 20 mm in last whorl. Shell surface ornamented with slight radial striations from umbilicus. Suture unknown.

*Remarks:—*Single specimen was examined. The present material is slightly deformed laterally, but the general characters of the shell are well-preserved.

The present specimen is compared with *Araxoceras rotoides* Ruzhentsev (Ruzhentsev, 1963) in the shell form, although the suture is missing in the former. *A. rotoides* has been recorded from the Dzhulfian beds of Transcaucasia and Iran (Ruzhentsev, 1963; Stepanov et al., 1969). Recently, *A. rotoides* was described by Bando (1979) from the *Araxoceras tectum* Zone of the Upper Dzulfian bed at Kuh-e-Hambest in Abadeh, Central Iran. The related species, *"Prototoceras" longilobatum* Zhao, Liang et Zheng (Zhao et al., 1978, p. 96, pl. 5, figs. 4—6) was reported from the Laoshan Shale of the "Loping" Series in South China. In South China araxoceratid ammonoids occur commonly from the Wujapingian which is probably correlated to the Dzhulfian of Transcaucasia and Iran.

*Occurrence and geological horizon:—*From calcareous nodule in the lower part of the Suenosaki Formation (Lowermost Toyoman) at the eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8301. Coll. M. Ehiro, 1983.

Araxoceras sp.

Pl. 7, Fig. 2a—b

*Description:—*Shell rather involute, discoidal, rather depressed, with slightly convexed tabulated venter. Sides concave from umbilical margin to ventral shoulders. Umbilical margin sharply elevated. Ventral margin also sharply edged and cross section of whorl showing low-trapezoidal form. Diameter of shell about 18 mm, maximum width of shell about 14 mm at umbilical margin, height of whorl about 10 mm and diameter of umbilicus about 5 mm. Suture unknown.

*Remarks:—*Single fragmental specimen was examined. More than half of the whorl is missing in the present specimen, but the umbilicus, ventral part and shell surface are all well-preserved. Judging from the general characters of the shell the present specimen is similar to *Araxoceras tectum* Ruzhentsev (1963, p. 38, pl. V, fig. 2a—b; Shevyrev, 1965, pl. XVIII, fig. 1a—b, in Ruzhentsev and Sarycheva), which commonly occurs from the Dzhulfian beds in Armenia and Iran, but it is difficult to identify with the species mentioned above. On the other hand, the described specimens of *"Prototoceras" plicatum* Chao et Liang (Zhao et al., 1978, p. 93, pl. 4, figs. 34—36) resemble the present specimen in the whorl characters, but it is also difficult to compare the latter with the formers because of the poor

Table 7. Measurements in mm [*Prototoceras japonicum* sp. nov.]

	D	H	W	U	H/D	W/H	U/D
TY-8201	25?(18)	11(5)	7	6	0.56	0.63	0.24

state of preservation.

Occurrence and geological horizon:—From nodule in the lower part of the Suenosaki Formation (Lowermost Toyoman) at the eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8302. Coll. M. Ehiro, 1983.

Family Otoceratidae Hyatt, 1900

Genus *Prototoceras* Spath, 1930

Type species:—*Ceratites tropitus* Abich, 1878.

Prototoceras japonicum sp. nov.

Pl. 7, Fig. 3a—c, Text-fig. 9A

Description:—Shell involute, discoidal, laterally compressed, with tricarinate venter. Sides flat or slightly concave from umbilical margin to distinct ventral shoulders. Umbilicus funnel-shaped and umbilical margin projected. Diameter of umbilicus about 1/5 of total diameter of shell. Surface ornamented with falcoid striations on flanks. Suture ceratitic, consisting of entire lateral saddles and slightly denticulated lateral lobes. Ventral lobe rather shallow and divided into two points by small entire median-saddle.

Remarks:—Single specimen was examined. The present species from the Suenosaki Formation resembles *Prototoceras acutum* Ruzhentsev (1959, p. 63, 1*a*, 2*a*) in the general characters of shell, but it is clearly distinguished from the latter in having wider umbilicus and shorter umbilical lobe. The present species resembles also *P. trochoides* (Abich) (= *Ceratites trochoides* Abich, 1878, p. 14, pl. 1, fig. 6, 6a) from the Dzhulfian beds in Armenia, but the detailed comparison is difficult, because the ventral part of the Armenian form is not well preserved.

Occurrence and geological horizon:—From calcareous nodule in the lower part of the Suenosaki Formation (Lowermost Toyoman) at the eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8201 (Holotype). Coll. M. Ehiro, 1982.

Prototoceras sp. A

Pl. 7, Fig. 4a—b, Text-fig. 9B

Description:—Shell laterally compressed, discoidal, with slightly tricarinated venter and slightly projected umbilical rim. Sides concave without ornamentation. Umbilicus funnel-shaped. Maximum width at umbilical margin and diameter of umbilicus about 1/4 of total diameter of shell. Diameter of shell about 18 mm, height of whorl 7 mm, width of whorl probably 7 mm and diameter of umbilicus about 5 mm. Suture rather goniatitic, consisting of large lateral saddles, narrow lateral lobe and shallow umbilical series. Ventral lobe considerably deep with small arched-shape median-saddle.

Remarks:—Single specimen was examined. The present specimen is poor in preservation, but the general shape of the shell and the character of the suture line may indicate that the present specimen belongs to the genus *Prototoceras*, although the specimen at hand is very small compared with the species of *Prototoceras* which have been described from the Dzhulfian beds of Transcaucasia and Iran. The present specimen more or less resembles *P. tropitum* (Abich) illustrated by Ruzhentsev (1959, p. 62, figs. 1—2) in the general character of the shell and suture.

Occurrence and geological horizon:—Lower part of the Suenosaki Formation (Lowermost Toyoman) at Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8303. Coll. M. Ehiro, 1983.

Prototoceras sp. B

Pl. 7, Fig. 5a—b

Description:—Shell laterally compressed, discoidal, with slightly rounded venter and flat or slightly concave sides. Umbilicus funnel-shaped and umbilical margin slightly projected. Width of umbilicus about 1/3 of total diameter of the shell. Shell surface ornamented by fine growth striae which projected on ventral shoulders and diminished on venter. Suture unknown.

Remarks:—Single small specimen, half volution of outer whorl, was examined. The present specimen belongs to *Prototoceras*, judging from the shell feature and whorl shape, but it is difficult to determine the specific name, because of the poor state of preservation.

Occurrence and geological horizon:—At the eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. From the calcareous nodule in the lower part of the Suenosaki Formation (Lowermost Toyoman). The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8304. Coll. M. Ehiro, 1983.

Prototoceras sp. C

Pl. 7, Fig. 6a—b, Text-fig. 9C

Description:—Shell laterally compressed, discoidal, with tricarinated venter and slightly concave flanks. Umbilicus not clear. Suture well preserved, consisting of entirely rounded broad lateral saddles and narrowly denticulated lateral lobes. Ventral lobe divided by broadly rounded siphonal saddle. Umbilical lobe considerably long without denticulation.

Remarks:—Single fragmentary specimen was examined. The general features of the shell and sutures of the present specimen are included in those of *Prototoceras*, but it is impossible to determine the specific name, because of the poor preservation. Only the element of suture is similar to that of *P. japonicum* sp. nov. or *P. parallelum* Ruzhentsev (1959, p. 63, figs. 1d—e, 2d) from Armenia.

Occurrence and geological horizon:—From the lower part of the Suenosaki Formation (Lowermost Toyoman) at Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture. The Dzhulfian of the Upper Permian. Reg. No. GLKU-TY-8305. Coll. M. Ehiro, 1983.

Superfamily Xenodiscaceae Frech, 1902

Family Xenodiscidae Frech, 1902

Genus *Xenodiscus* Waagen, 1879

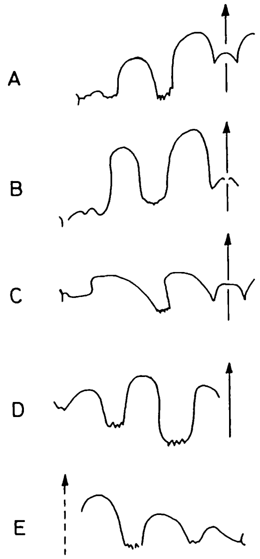
Type species:—*Xenodicus plicatus* Waagen, 1879.

Xenodicus cf. *X. carbonarius* Waagen

Pl. 7, Fig. 9, Text-fig. 9D

Compare:—

1872. *Ceratites carbonarius* Waagen, p. 355, pl. 1, figs. 2—3.
1879. *Xenodiscus carbonarius*, Waagen, p. 35,



Text-fig. 9. Suture lines of *Prototoceras*, *Xenodiscus* and *Paratirolites* ? A. *Prototoceras japonicum* Bando and Ehiro, TY-8201, H=9 mm, B. *P.* sp. A, TY-8303, H=5 mm, C. *P.* sp. C, TY-8305, H=7 mm, D. *Xenodiscus* cf. *X. carbonarius* Waagen, TY-7701, H=7 mm, E. *Paratirolites* ? sp., TY-8204, H=12 mm ?

pl. 2, figs. 2—5.
1970. *Xenodiscus carbonarius*, Kummel, p. 189, pl. 2, figs. 4—9.
1978. *Xenodicus* cf. *carbonarius* Waagen, Ehiro and Bando, p. 37—38, figs. 2 (1, 2).
1979. *Xenodiscus carbonarius*, Bando, p. 131, pl. V, fig. 7.

Description:—Shell evolute, laterally compressed, discoidal, with narrowly rounded venter and wide umbilicus with abruptly rounded umbilical shoulders. Shell surface ornamented by slightly sigmoidal fine striations running from umbilical margin to ventral margin, rather slightly prominent on lower half height of whorl and half height of it becoming slightly indistinct. Sutures primitive form of ceratitic, consisting of slightly serrated lateral lobes (1st and 2nd) and entirely rounded external and lateral saddles. Ventral lobe missing and auxiliary lobe simple. Denticulation in lateral lobes observed slightly 3—4 points at bottom, and first lateral lobe widest and deepest than that of second.

Remarks:—Single specimen was examined. Only one side of the specimen is preserved. The present specimen illustrated here was already reported by us (Ehiro and Bando, 1978) from the lowermost part of the Okago Formation. The general character of the shell is similar to that of *Xenodiscus carbonarius* which was originally described from the upper division of the Productus Limestone of Chhidru in the Salt Range, Pakistan (Waagen, 1879). The horizon of *X. carbonarius* belongs to the uppermost part of the Wargal Formation (Kalabagh Member) and to the Chhidru Formation in the Salf Range (Furnish, 1966; Kummel, 1970; Fatmi, 1973; Spinosa et al., 1975). In the Abadeh Region, Central Iran, *X. carbonarius* occurs from the basal part of the Abadeh Formation (Unit 4 by Taraz, 1974) (Bando, 1979), that is the type section of the Abadehian Stage of the Upper Permian.

Occurrence and geological horizon:—From shale of the lowermost part of the Okago Formation (Lowermost Toyoman ?) at Yahagi, Kami-okago, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture. Upper Permian. Reg. No. GLKU-TY-7701. Coll. M. Ehiro, 1977.

Table 8. Measurements in mm [*Xenodiscus* cf. *X. carbonarius*]

	D	H	W	U	H/D	W/H	U/D
TY-7701	47?(38)	13(12)	—	26(17)	0.28?(0.32)	—	0.05?(0.45)

Explanation of Plate 5

Figs. 1a—c, 2. *Cyclolobus* cf. *C. walkeri* Diener . . . . p. 37
1. GLKU-TY-8003, lateral (a), front (b) and ventral (c) views, x 0.9.
2. GLKU-TY-8004, lateral view of shell fragment, x 1.

The specimens illustrated in Figs. 1 and 2 were collected from the lower horizon of the upper part of the Senmatsu Formation at Iwanosawa, Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture.

Figs. 3a—c, 4a, b. *Stacheoceras iwaizakiense* Mabuti . . . . p. 36
1. GLKU-TY-8306, lateral (a), front (b) and ventral (c) views, x 1.1.
2. GLKU-TY-8202, lateral view (a), x 1, and suture line on ventral part (b), x 1.5.

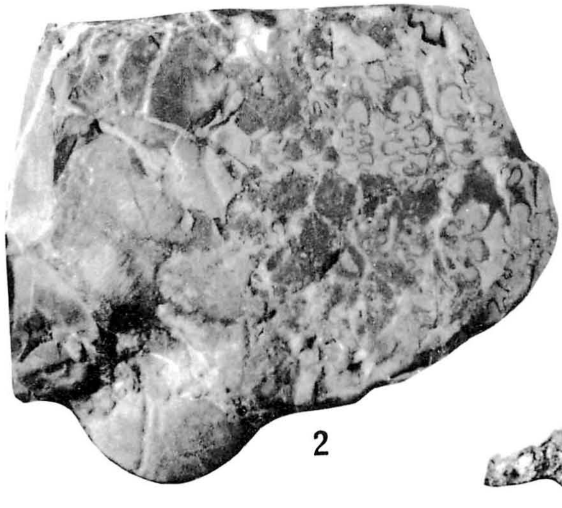
Figs. 5a, b. *Pseudogastrioceras* sp. . . . . p. 38
GLKU-TY-8307, lateral (a) and ventral (b) views, x 1.3.

The specimens illustrated in Figs. 3, 4 and 5 were collected from the lower part of the Suenosaki Formation at eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture.


1a


1b


1c


2


5a


5b


4b


3a


3b


3c


4a

Family Paratirolitidae nov.

Remarks:—The present new family is proposed based on the following items: 1) *Dzhulfites* Shevyrev (in Ruzhentsev and Sarycheva, 1965, type species: *Dzhulfites spinosus* Shevyrev) is synonymous with *Paratirolites* Stoyanow (1910) (Teichert and Kummel, in Teichert et al., 1973; Bando, 1979; Tozer, 1981). Therefore, the Family name "Dzhulfitidae" is preferable to change into Paratirolitidae, 2) the genus *Paratirolites* is more common than other genera in occurrence and 3) the type species of *Dzhulfites*, *D. spinosus* Shevyrev (in Ruzhentsev and Sarycheva, 1965, p. 173, pl. 21, fig. 9; pl. 22, fig. 1), is very similar to *Paratirolites kittli* Stoyanow.

Genus *Paratirolites* Stoyanow, 1910

Type species:—*Paratirolites kittli* Stoyanow, 1910.

Paratirolites ? sp.

Pl. 7, Figs. 7, 8, Text-fig. 9E

Description:—Shell evolute, discoidal, with broadly rounded venter and distinct umbilical margin. Sides are ornamented by considerably widely spaced radial ribs which are distinct on shell surface from umbilical margin to half height of whorls, and each ribs diminish at surface of half height of whorls. Suture slightly preserved on shell, but ventral suture unknown.

Remarks:—Two specimens were examined. The present specimens are rather poorly preserved, but the shell ornamentation and general character of whorls indicate that it may belong to *Paratirolites*, although it is difficult to determine the species, because of missing their ventral suture and precise whorl section due to lateral deformation. Judging from the shell ornamentation, broadly rounded venter and the form of umbilicus, forcibly to say, the present specimens resemble *Paratirolites abichi* (Shevyrev) (in Ruzhentsev and Sarycheva, 1965, p. 181, pl. 26, fig. 4a—b, as *Abichites*).

Occurrence and geological horizon:—From shale of the upper part of the lower part of the Senmatsu Formation (Upper Toyoman) at Kiridoshi, Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture. Upper Permian. Reg. No. GLKU-TY-8203, 8204. Coll. M. Ehiro, 1982.

Table 9. Measurements in mm [*Paratirolites* ? sp.]

	D	H	W	U	H/D	W/H	U/D
TY-8204	46?	16?	—	17	0.35?	—	0.37?
TY-8203	40?	14?	—	14	0.35?	—	0.35?

References

Abich, H. W. (1878): *Geologische Forschungen in den kaukasischen Ländern.* Th. 1, Eine Bergkalkfauna aus der Araxesenge bei Djoulfa in Armenien. 126 p. Alfred Hölder, Wien.

Bando, Y. (1956): Geology of the Fujisawa District, Higashiiwai gun, Iwate Prefecture (Graduation thesis, Tohoku Univ., MS, in Japanese).

—— (1975): On some Permian Medlicottidae from the Toyoma Formation in the Kitakami Massif. *Mem. Fac. Educ., Kagawa Univ.*, Pt. II, vol. 25, p. 67—81.

—— (1979): Upper Permian and Lower Triassic ammonoids from Abadeh, Central Iran. *Ibid.*, vol. 29, p. 103—138.

Besairie, H. (1936): Recherches géologiques à Madagascar, Première suite; La géologie du Nord-ouest, Chap. 3, Les fossiles. *Acad. Malgache Mém.*, fasc. 21, p. 105—207.

Chao, K. (1965): The Permian ammonoid-bearing formations of South China. *Scientia Sinica*, vol. 14, p. 1813—1825.

Diener, C. (1903): Permian fossils of the Central Himalayas. *Mem. Geol. Surv. India, Palae-*

ont. Indica, ser. 15, vol. 1, pt. 5, p. 1—204.

—— (1921): Ammonoidea Permiana. *Fossilium Catalogus*, I. Animalia, pars 14, 36 p.

Ehiro, M. (1979): Geology of Fujisawa-cho. *In* the Editorial Committee for the history of Fujisawa-cho, *The History of Fujisawa-cho*, vol. 1, p. 661—690. Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture (in Japanese).

—— and Bando, Y. (1978): Discovery of *Xenodiscus* from the Permian Toyoma Formation of southern Kitakami Massif. *Jour. Geol. Soc. Japan*, vol. 84, p. 37—38 (in Japanese).

—— and —— (1980): Discovery of *Rotodiscoceras* from the Upper Permian of southern Kitakami Massif and its significance. *Ibid.*, vol. 86, p. 484—486 (in Japanese).

Fatmi, A. N. (1973): Lithostratigraphic units of the Kohat-Potwar Province, Indus Basin, Pakistan. *Mem. Geol. Surv. Pakistan*, vol. 10, p. 1—80.

Furnish, W. M. (1966): Ammonoids of the Upper Permian *Cyclolobus*-zone. *Abhandl. N. Jahrb. Geol. Pläont.*, vol. 125, p. 265—296.

—— and Glenister, B. F. (1970): Permian ammonoid *Cyclolobus* from the Salt Range, West Pakistan. *In* Kummel, B. and Teichert, C. (eds.), Stratigraphic boundary problems: Permian and Triassic of West Pakistan. *Kansas Univ. Geol. Dept., Spec. Publ.*, 4, p. 153—175.

——, Glenister, B. F., Nakazawa, K. and Kapoor, H. M. (1973): Permian ammonoid *Cyclolobus* from the Zewan Formation, Guryul Ravine, Kashmir. *Science*, vol. 180, p. 188—190.

Hayasaka, I. (1963): Some Permian fossils from Southern Kitakami. III. *Proc. Japan Acad.*, vol. 39, p. 594—599.

Iranian-Japanese Research Group (1981): The Permian and the Lower Triassic Systems in Abadeh Region, Central Iran. *Mem. Fac. Sci., Kyoto Univ., ser. Geol. Mineral.*, vol. 47, p. 61—133.

Ishii, K., Okimura, Y. and Nakazawa, K. (1975): On the Genus *Colaniella* and its biostratigraphic significance. *Jour. Geosci. Osaka City Univ.*, vol. 19, p. 107—138.

Koizumi, H. (1975): *Palaeozoic Cephalopods of Japan.* 149 p. Teiseki Bunko, Chiba (in Japanese).

Kon'no, E. (1973): New species of *Pleuromeia* and *Neocalamites* from the Upper Scythian Bed in the Kitakami Massif, Japan — with a brief note on some Equisetacean Plants from the Upper Permian Bed in the Kitakami Massif. *Sci. Rep. Tohoku Univ.*, ser. 2, vol. 43, p. 99—115.

Kummel, B. (1970): Ammonoids from the Kathwai Member, Mianwali Formation, Salt Range, West Pakistan. *In* Kummel, B. and Teichert, C. (eds.), Stratigraphic boundary problems: Permian and Triassic of West Pakistan. *Kansas Univ. Geol. Dept., Spec. Publ.*, 4, p. 177—192.

Mabuti, S. (1932): Stratigraphy of the Paleozoic rocks of the Tabashine-yama Massif, southern part of the Kitakami Massif (Graduation thesis, Tohoku Univ., MS, in Japanese).

—— (1935): On the occurrence of *Stacheoceras* in the Kitakami mountainland, Northeast

Explanation of Plate 6

Figs. 1—7. *Medlicottia kitakamiensis* Bando and Ehiro, sp. nov. p. 39

1. GLKU-TY-8101, x 1; 2. GLKU-TY-8102, x 1; 3. GLKU-TY-8105, x1; 4. GLKU-TY-8001 (Holotype), x1; 5. GLKU-TY-8106, x1; 6. GLKU-TY-8103, x 0.8; 7. GLKU-TY-8107, x 1.4.

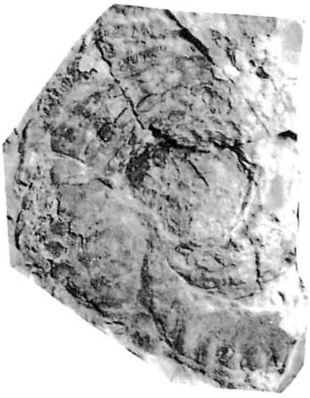
Fig. 8. *Eumedlicottia* sp. . . . . p. 40

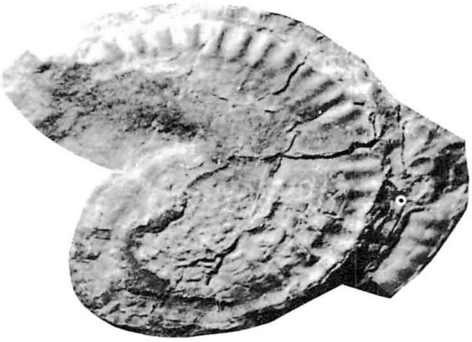
GLKU-TY-8005, lateral view of shell fragment, x 1.8.

The illustrated specimens in Figs. 1, 2, 6 and 7 were collected from the uppermost part of the Senmatsu Formation near Nagasakiyama, Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture. The specimens of Figs. 3 and 5 from the uppermost part of the Senmatsu Formation near Takizawa-toge, southwestern part of Magome, Motoyoshi-cho, Motoyoshi-gun, Miyagi Prefecture. The specimens illustrated in Figs. 4 and 8 from the lower horizon of the upper part of the Senmatsu Formation at Iwanosawa, Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture.


1


2

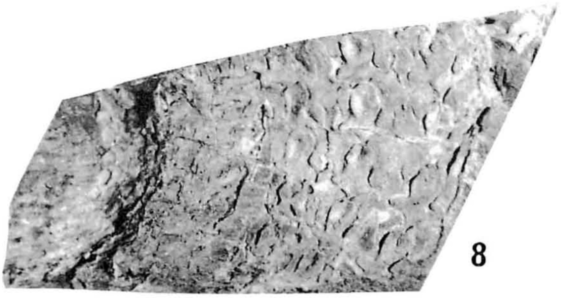

3




5


6


7


8

Honsyu, Japan. *Saito Ho-on Kai Mus. Res. Bull.*, no. 6, p. 143—149.

Miller, A. K. and Furnish, W. M. (1940): Permian ammonoids of the Guadalupe Mountain region and adjacent areas. *Geol. Soc. America Spec. Paper*, no. 26, 242 p.

Minato, M., Kato, M., Nakamura, K., Hasegawa, Y., Choi, D. R. and Tazawa, J. (1978): Biostratigraphy and correlation of the Permian of Japan. *Jour. Fac. Sci., Hokkaido Univ.*, ser. 4, vol. 18, p. 11—47.

von Möller, V. (1879): Uever die bathrologishe Stellung des jüngeren paläozoischen Schichtensystems von Djoulfa in Armenien. *Neues. Jb. Miner. Geol. Paläont.*, p. 225—243.

Murata, M. (1967): Some Permian Conulariidae from the Kitakami Massif, Northeast Japan. *Saito Ho-on Kai Mus. Res. Bull.*, no. 36, p. 9—17.

——(1969): Molluscan fauna of the Toyoma Formation (Late Permian). *Ibid.*, no. 38, p. 1—22.

——and Bando, Y. (1975): Discovery of Late Permian *Araxoceras* from the Toyoma Formation in the Kitakami Massif, Northeast Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 97, p. 22—31.

——and Shimoyama, S. (1979): Stratigraphy near the Permian-Triassic boundary and the Pre-Triassic unconformity in the Kitakami Massif, Northeast Japan. *Kumamoto Jour. Sci., Geol.*, vol. 11, p. 11—31 (in Japanese with English abstract).

Onuki, Y. (1956): Geology of the Kitakami Massif. *In* Iwate Prefecture (ed.), *Explanatory text of geologic map (scale 1:100,000) of Iwate Prefecture.* 189 p. Sasaki Print. Publi. Co. Ltd., Sendai (in Japanese).

——and Bando, Y. (1959): On the Inai Group of the Lower and Middle Triassic System (Stratigraphical and Palaeontological studies of the Triassic System in the Kitakami Massif, northeastern Japan: 3). *Contr. Inst. Geol. Palaeont., Tohoku Univ.*, no. 50, p. 1—69 (in Japanese with English abstract).

Rostovtsev, K. O. and Azaryan, N. R. (1973): The Permian-Triassic boundary in Transcaucasia. *In* Logan, A. and Hills, L. V. (eds.), The Permain and Triassic Systems and their mutual boundary. *Mem. Canad. Soc. Petrol. Geol.*, no. 2, p. 89—99.

Ruzhentsev, V. E. (1959): Classification of the Superfamily Otocerataceae. *Paleont. Zhurnal*, no. 2, p. 56—67 (in Russian).

——(1963): New data about the Family Araxoceratidae. *Ibid.*, no. 3, p. 56—64 (in Russian).

——and Sarycheva, T. G. (eds.) (1965): Development and change of marine organisms at the Palaeozoic-Mesozoic boundary. *Trudy Paleont. Inst., Acad. Nauk SSSR*, no. 108, p. 1—312 (in Russian).

Smith, J. P. (1927): Permian ammonoids of Timor. *Jaarboek. v. h. Mijnwezen in Ned.-Indië, Verhandl.* I, p. 1—58.

Spinosa, C., Furnish, W. M. and Glenister, B. F. (1975): The Xenodiscidae, Permian ceratitoid ammonoids. *Jour. Paleont.*, vo. 49, p. 239—283.

Spath, L. F. (1934): The Ammonoidea of the Trias (1); *Catalogue of the Fossil Cephalopoda in the British Museum (Nat. Hist.),* Pt. 4, p. 1—521.

Stepanov, D. L., Golshani, F. and Stöcklin, J. (1969): Upper Permian and Permian-Triassic boundary in North Iran. *Rept. Geol. Surv. Iran*, no. 12, p. 1—72.

Taraz, H. (1974): Geology of the Surmaq-Deh Bid Area, Abadeh Region, Central Iran. *Ibid.*, no. 37, p. 1—148.

Tazawa, J. (1975): Uppermost Permian fossils from the Southern Kitakami Mountains, Northeast Japan. *Jour. Geol. Soc. Japan*, vol. 81, p. 629—640.

Teichert, C., Kummel, B. and Sweet, W. (1973): Permian-Triassic Strata, Kuh-e-Ali Bashi, Northwestern Iran. *Bull. Mus. Comp. Zool.*, vol. 145, p. 359—472.

Tozer, E. T. (1969): Xenodiscacean ammonoids and their bearing on the discrimination of the Permo-Triassic boundary. *Geol. Mag.*, vol. 106, p. 348—361.

——(1979): The significance of the ammonoids *Paratirolites* and *Otoceras* in correlating the Permian-Triassic boundary beds of Iran and the People's Republic China. *Canad. Jour. Earth Sci.*, vol. 16, p. 1524—1532.

——(1981): Triassic Ammonoidea: Classification, evolution and relationship with Permian and Jurassic forms. *In* House, M. R. and Senior, J. R. (eds.), *The Ammonoidea,* p.

65—100. Academic Press, London.

Waagen, W. (1872): On the occurrence of *Ammonites*, associated with *Ceratites*, and *Goniatites* in the Carboniferous deposits of the Salt Range. *Mem. Geol. Surv. India*, vol. 9, p. 351—358.

—— (1879—1880): Salt Range fossils: Productus Limestone fossils. *Mem. Geol. Surv. India, Palaeont. Indica*, ser. 13, vol. 1, pts. 1, 2; p. 1—72, 73—183.

Working Group on the Permian-Triassic Systems (1975): Stratigraphy near the Permian-Triassic boundary in Japan and its correlation. *Jour. Geol. Soc. Japan*, vol. 81, p. 165—184 (in Japanese with English abstract).

Zhao, J. (1980): Origin, classification, evolution and distribution of the Family Cyclolobidae. *Acta Palaeont. Sinica*, vol. 19, p. 79—90 (in Chinese with English summary).

——, Liang, X. and Zheng, Z. (1978): Late Permian Cephalopods of South China. *Palaeont. Sinica*, no. 154, 194 p. (in Chinese with English summary).

Fujisawa 藤沢, Fukkoshi 風越, Higashifukakaya 東深萱, Hiraiso 平磯, Isatomae 伊里前, Ishihama 石浜, Iwaizaki 岩井崎, Iwanosawa 岩の沢, Kanokura 叶倉, Kesennuma 気仙沼, Kiridoshi 切通, Kobuchi 小淵, Konakogi 粉香木, Kuromori 黒森, Magome 馬籠, Matsukozawa 松子沢, Motoyoshi 本吉, Mt. Nabekoshi (Nabekoshiyama) 鍋越山, Nagahata 長畑, Nagasakiyama 長崎山, Nishikori 錦織, Okago 大籠, Osawa 大沢, Sakamotozawa 坂本沢, Senmatsu 千松, Shinden 新田, Suenosaki 末の崎, Takizawa 滝沢, Tanoura 田の浦, Toyoma 登米, Unazawa 右名沢, Utatsu 歌津, Yahagi 矢作, Yamazaki 山崎, Yamashita 山下, Yonekawa 米川

Explanation of Plate 7

Figs. 1a—c. *Araxoceras* cf. *A. rotoides* Ruzhentsev . . . . p. 40
GLKU-TY-8301, lateral (a), ventral (b) and front (c) views, x 1.2.

Figs. 2a, b. *Araxoceras* sp. . . . . p. 41
GLKU-TY-8302, lateral (a) and front (b) views, x 1.2.

Figs. 3a—c. *Prototoceras japonicum* Bando and Ehiro, sp. nov. p. 42
FLKU-TY-8201, lateral (a, b) and ventral (c) views, x 1.9.

Figs. 4a, b. *Prototoceras* sp. A . . . . p. 42
GLKU-TY-8303, lateral (a) and ventral (b) views, x 2.

Figs. 5a, b. *Prototoceras* sp. B . . . . p. 43
GLKU-TY-8304, lateral (a) and ventral (b) views, x 2.

Figs. 6a, b. *Prototoceras* sp. C . . . . p. 43
GLKU-TY-8305, lateral (a) and ventral (b) views, x 1.8.

The specimens illustrated in Figs. 1—6 were collected from the lower part of the Suenosaki Formation at eastern coast of Ishihama, Utatsu-cho, Motoyoshi-gun, Miyagi Prefecture.

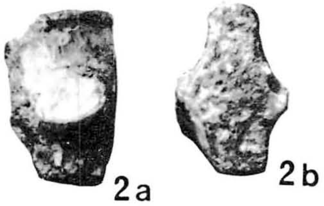
Figs. 7, 8. *Paratirolites* ? sp. . . . . p. 45
7. GLKU-TY-8203, external mold, x 1; 8. GLKU-TY-8204, external mold, x 0.8.

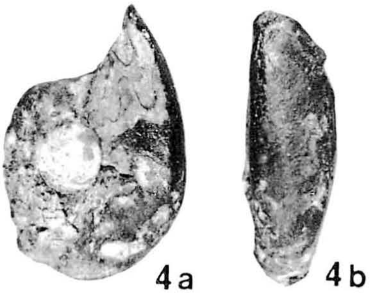
The specimens in Figs. 7 and 8 were collected from the upper horizon of the lower part of the Senmatsu Formation near Kiridoshi, Senmatsu, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture.

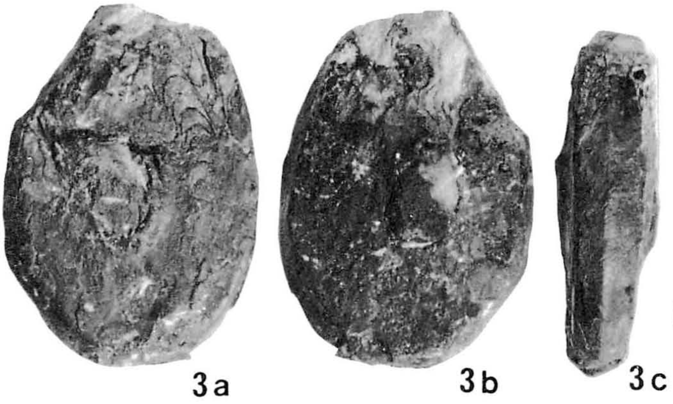
Figs. 9. *Xenodiscus* cf. *X. carbonarius* Waagen . . . . p. 43
GLKU-TY-7701, lateral view, x 1.

The specimen in Fig. 9 from the lowermost part of the Okago Formation at Yahagi, Kamiokago, Fujisawa-cho, Higashiiwai-gun, Iwate Prefecture.


1a
1b
1c


2a
2b


4a
4b


3a
3b
3c


5a
5b


6a
6b


7


8


9

南部北上山地産後期ペルム紀アンモナイト：南部北上山地の歌津および大籠地域に分布する上部ペルム系登米統のアンモナイトフォーナにもとづき，南部北上，トランスコーカシア，イランおよび中国南部の上部ペルム系相互の対比を論じた。9属13種のアンモナイトを記載し，そのなかで1新科 (Paratirolitidae) および2新種 (*Medlicottia kitakamiensis* および *Prototoceras japonicum*) を提唱した。

登米統最下部は *Araxoceras* cf. *A. rotoides* および *Prototoceras japonicum* のようなズルファ期アンモナイトを産する。中部からの *Araxoceras* cf. *A. kiangsiense* の産出 (Murata and Bando, 1975) をあわせて考えると，登米統下部および中部は，トランスコーカシアやイランのズルファ階および中国南部の呉家坪階に対比される。登米統上部は，*Paratirolites*? sp. の産出により，トランスコーカシアやイランのドラシャム階および中国南部の長興階に対比される可能性が高い。 永広昌之・坂東祐司

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 137, pp. 50—63, April 30, 1985

793. OSTRACODA FROM THE PLIOCENE ANANAI FORMATION, SHIKOKU, JAPAN — FAUNAL ANALYSES —*

KUNIHIRO ISHIZAKI

Institute of Geology and Paleontology, Faculty of Science, Tohoku University,
Sendai 980, Japan

and

YOSHIHIRO TANIMURA

Department of Paleontology, National Science Museum
Hyakunin-cho, Shinjuku-ku, Tokyo 160, Japan

Abstract. In a previous study of 35 samples collected from the Pliocene Ananai Formation which is distributed sporadically along the southeastern coast of Shikoku, Japan, 79 ostracode species coming under 42 genera were recognized (Ishizaki, 1983, Table 1). Q-mode principal components factor analysis performed on an initial data matrix in this table shows that ostracode faunas in the formation are characterized fundamentally by four varimax assemblages representing open shelf, Kuroshio, bay mouth, and coastal current habitants.

Principal components factor analysis on the frequency distribution of grain size and the relative abundance of different kinds of grains in different size fractions, both of which resulted from the grain-size analysis of sediments, indicates four distinct factors; tranquil waters, preservation of the piled sediments, and supplies of biogenic and terrestrial materials.

The correlation coefficients calculated among the factor loadings for the sediment and ostracode data, species diversity, and equitability suggest that structural indices such as species diversity and equitability have hardly any significant relation to sedimentological factors but are inherent in respective varimax assemblages.

The second varimax assemblage shows clear geographic differences in its species diversity, equitability, and number of species, suggesting the existence of a gradient in the effect of the then prevailing Kuroshio Current. The temporal shift in the same parameters in the Ono section may also be equated to the secular vicissitudes of water conditions.

Introduction

The Pliocene Ananai Formation, one of the three units of the Tonohama Group, is distributed sporadically in several isolated patches along the southeastern coast of Shikoku in Southwest Japan (Ishizaki, 1983, text-fig. 1). This formation yields various groups of fossils in abundance, including foraminifers, which were studied by Katto *et al.* (1953) and Kurihara (1968) in order

---

*Received Feb. 25, 1984; read June 19, 1983 at Utsunomiya.

to deduce geographic variations in the depositional environments of the formation.

This formation also generally yields fossil ostracodes in great abundance. These were studied by Ishizaki (1983), who gave full descriptions of 11 previously unnamed species together with a list showing the occurrence of all the discriminated species by samples (Table 1). The purpose of the present study is the analysis of fossil ostracode faunas from those 30 samples which yielded 200-odd specimens each by using principal components factor analysis in order to discriminate feasible varimax assemblages based on factor scores, and to determine the distribution of respective assemblages in terms of factor loadings. By doing this we hope to provide a better understanding of secular and geographic variations in the depositional environments of the Ananai Formation.

The structure of the assemblages of various groups has been examined by many authors in order to set down clues to paleoenvironmental analyses. Most of these authors have suggested that the structure of assemblages tends to become more complex in a stable and consistent environment. Buzas and Gibson (1969) concurred with this opinion; however, in their later report, Gibson and Buzas (1973) propounded a different opinion based upon their study of both Recent foraminifers from the Arctic region through to the Gulf of Mexico and fossil ones from the Miocene. The time-stability hypotheses could not fully explain the species diversity found in these samples. Alternatively, they suggested that each environmental regime has its own carrying capacity which seems to be attained relatively rapidly.

In this study, the structure of the ostracode assemblages defined by varimax factor scores higher than 1.28, which were obtained from the principal components factor analysis set forth by Imbrie and Purdy (1962), was examined by using the Shannon-Weaver's information function as somewhat expanded by Buzas and Gibson (1969). We also compared geographical and temporal changes in the structure of the varimax assemblages with lithologic data which may indicate physical aspects of the depositional environments.

Careful examination reveals that the recognition of relevant assemblages per se is a requisite for applying faunal dynamics to fossil assemblages and for assessing environmental conditions in the geologic past.

Faunal Analysis

In this study, 30 of the 35 samples in Table 1 of Ishizaki (1983) were studied. Each of these 30 samples yielded 200-odd ostracode specimens. Additional information concerning the samples is given in that article. The 74 ostracode species selected for this study, with the exception of *Ambocythere japonica* Ishizaki, *Buntonia parascorta* Ishizaki, *Echinocythereis*? *bradyformis* Ishizaki, *Hemicytherura kajiyamai* Hanai, and *Kobayashiina hyalinosa* Hanai from the same table, are those which are represented by ten or more specimens among the 35 samples. The number of specimens refers to the larger number of the two valves.

Analyses of the ostracode data set consisting of 30 columns and 74 rows were made for the Q-mode technique by using the principal components factor analysis set down by Imbrie and

Table 1. Summary of principal components factor analysis on the ostracode data.

Factor	Eigenvalue	Cum. perc.
1	21.741	72.47
2	2.059	79.33
3	1.083	82.94
4	0.971	86.18
5	0.899	89.18
6	0.574	91.10
7	0.472	92.67
8	0.275	93.59
9	0.252	94.43
10	0.221	95.17

Table 2. Varimax scores of the first four factors for ostracode species.

Factors Species	1	2	3	4
Actinocythereis kisarazuensis	0.531	-0.059	0.011	-0.142
Alocopocythere goujoni	0.008	-0.218	-0.026	-0.352
Argilloecia hanaii	-0.069	-0.353	-0.355	0.086
Aurila cymba	0.683	-0.082	-1.106	-2.527
Aurila hataii	0.397	-0.448	1.594	0.275
Aurila munechikai	0.310	0.907	3.936	-0.768
Aurila tosaensis	0.146	-0.136	0.367	-0.875
Aurila uranouchiensis	0.787	-0.196	1.013	-0.616
Bairdoppilata sp.	-0.115	-0.023	-0.156	0.210
Bicornucythere bisanensis	-0.498	0.102	4.471	0.684
Bradleya albatrossia	0.824	-0.087	-0.161	0.116
Bradleya nuda	2.226	-0.585	-1.122	-0.794
Buntonia hanaii	1.182	-0.049	-0.352	0.147
Buntonia scorta	0.615	-0.167	-0.378	0.118
Buntonia u-carinata	0.024	0.489	0.402	0.254
Bythoceratina dipleura	-0.237	-0.052	0.601	-0.078
Bythoceratina hanaii	-0.221	0.076	0.529	0.060
Bythoceratina cf. *orientalis*	0.017	-0.123	0.310	0.140
Callistocythere alata	-0.381	-0.242	-0.173	-0.316
Callistocythere ananaiensis	-0.357	-0.308	-1.165	0.208
Callistocythere japonica	-0.188	-0.091	-0.088	0.066
Callistocythere kattoi	-0.147	1.377	-1.095	-0.610
Callistocythere ovata	0.155	-0.048	0.193	0.016
Callistocythere undata	0.222	-0.248	1.034	-0.073
Callistocythere sp.	0.090	-0.071	-0.046	0.085
Coquimba ishizakii	0.272	-0.067	0.396	0.125
Cornucoquimba tosaensis	1.207	0.340	-0.100	-0.270
Cythere lutea omotenipponica	0.182	-0.018	0.065	0.201
Cytherella japonica	0.665	-0.031	-0.240	0.194
Cytherelloidea hanaii	-0.072	0.131	1.119	0.476
Cytherelloidea sabahebsis	0.762	-0.108	-0.443	-0.059
Cytherelloidea cf. *yakenaensis*	-0.328	-0.527	0.030	0.082
Cytheropteron miurense	1.178	-0.135	1.551	-0.116
Cytheropteron rhombea	-0.014	-0.481	-0.856	-0.903
Cytheropteron uchioi	6.015	-0.126	-1.655	0.720
Doratocythere taiwanensis	-0.045	-0.006	-0.249	-1.068
Hemicytherura cava	0.295	-0.073	-0.161	-0.260
Hemicytherura cuneata	0.622	-0.575	0.601	-0.412
Hemicytherura radiata	0.025	-0.130	-0.077	-0.220
Hirsutocythere? hanaii	-0.057	-0.041	-0.356	0.075
Jugosocythereis sp.	1.578	-0.128	-0.092	-0.615
Krithe hanaii	0.041	-0.178	-0.126	0.484
Krithe producta	0.170	-0.090	-0.543	0.067
Lixouria nipponica	0.663	-0.197	-0.209	0.201
Loxoconcha hattorii	-0.212	0.354	0.266	0.226
Loxoconcha japonica	0.125	-0.162	0.226	0.012
Loxoconcha kattoi	2.257	-0.154	0.578	-0.908
Loxoconcha optima	-0.331	-0.276	0.749	-0.344
Loxoconcha sinensis	0.819	2.593	1.328	0.907
Loxocorniculum mutsuense	0.060	-0.031	0.394	-0.432
Macrocypris decora	0.108	-0.071	-0.101	-0.342
Munseyella oborozukiyo	1.202	0.749	1.492	0.639
Munseyella japonica	0.219	-0.043	0.176	-0.202
Mutilus nodulosum	-0.018	-0.009	-0.137	-0.415
Neonesidea villosa	-0.764	-1.469	1.506	-5.537
Nipponocythere bicarinata	0.291	-0.051	0.619	0.406
Paijenborchella iocosa	0.416	-0.091	-0.414	-0.182
Paijenborchella miurensis	0.964	-0.272	0.341	0.169
Paijenborchella triangularis	0.043	0.104	0.890	-0.025
Paracytheridea cf. *bosoensis*	0.023	0.045	0.472	-0.154
Paracytheridea neolongicaudata	0.616	-0.167	0.445	0.092
Parakrithella pseudadonta	-0.092	0.320	0.737	0.059
Pontocythere japonica	0.300	7.563	-0.519	-1.906
Pontocythere miurensis	0.072	-0.045	0.717	-0.048
Pseudoaurila japonica	0.196	0.001	0.358	-0.430
Pterygocythereis scalaris	0.899	-0.156	0.377	0.298
Schizocythere kishinouyei	2.378	-0.349	2.427	2.541
Semicytherura hanaii	0.105	-0.089	0.097	0.033
Semicytherura henryhowei	0.214	-0.285	0.660	-0.682
Trachyleberis lungkengensis	1.879	-1.002	0.490	-3.417
Trachyleberis? tosaensis	0.369	-0.314	0.460	-1.585
Xestoleberis hanaii	0.602	0.178	0.582	-0.689
Xestoleberis sagamiensis	0.458	-0.118	0.484	-0.876
Xestoleberis sp.	0.062	0.003	0.323	-0.570

Purdy (1962) for an analysis of modern Bahamian carbonate sediments. A summary of the results obtained from the analysis shows that the first four factors account for more than 86% of the total variance (Table 1). Table 2 shows the calculated scores of the first four factors for every ostracode species. Species having factor scores of 1.28 or more are within the first 10% of the standardized normal distribution in relation to their contributions to the respective factors. Therefore, this value (1.28) may be regarded as a critical value in grouping varimax assemblages, whose frequency distributions may be equated to the distributions of the factor loadings. By using this procedure, the following varimax assemblages were discriminated:

The first varimax assemblage;

Bradleya nuda Benson
Cytheropteron uchioi Hanai
Jugosocythereis sp.
Loxoconcha kattoi Ishizaki
Schizocythere kishinouyei (Kajiyama)
Trachyleberis lungkangensis Hu and Chen,

the second varimax assemblage;

Callistocythere kattoi Ishizaki
Loxoconcha sinensis Brady
Pontocythere japonica (Hanai)

the third varimax assemblage;

Aurila hataii Ishizaki
Aurila munechikai Ishizaki
Bicornucythere bisanensis (Okubo)
Cytheropteron miurense Hanai
Loxoconcha sinensis Brady
Munseyella oborozukiyo Yajima
Neonesidea villosa (Brady)
Schizocythere kishinouyei (Kajiyama), and

a fourth varimax assemblage;

Schizocythere kishinouyei (Kajiyama).

The modern distributions of the first varimax assemblage is as follows: *Bradleya nuda* is distributed in the northern section; *Cytheropteron uchioi* in the entire area of the studied shelf of the East China Sea, except for one station (Ishizaki, 1981); *Loxoconcha kattoi* only outside of Uranouchi Bay, Kochi Prefecture (Ishizaki, 1968); *Schizocythere kishinouyei* in the southern section, which is affected by southward-flowing countercurrents from the Yellow Sea; and *Trachyleberis lungkangensis* in a wider area than *S. kishinouyei*, extending further north, in the East China Sea (Ishizaki, 1981). An environmental regime common to these species is likely to be an open shelf area.

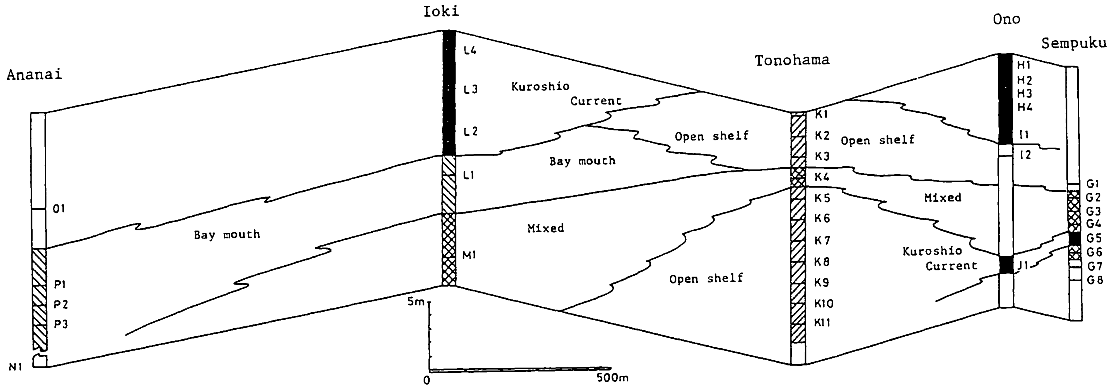
Of the second varimax assemblage, the modern distribution of *Callistocythere kattoi* is not yet known because it was first recorded from the Ananai Formation (Ishizaki, 1983). *Loxoconcha sinensis* is distributed widely in the shelf area of the East China Sea, increasing toward the outer part where the effect of the Kuroshio Current is stronger (Ishizaki, 1981). On the other hand, *Pontocythere japonica* does not significantly occur in the East China Sea in terms of the terminology set down by Ishizaki (1981); it does not occur at all in the Nakanoumi Estuary, Shimane Prefecture (Ishizaki, 1969), nor in Aomori Bay (Ishizaki, 1971). It does occur significantly, however, in the area ranging from the outer half to the mouth of Uranouchi Bay, Kochi Prefecture (Ishizaki, 1968), and has also been reported by Frydl (1982) to occur significantly in Tateyama Bay, Chiba Prefecture. Judging from the known modern distribution of the above two species, this varimax assemblage may represent, to a certain extent, the effect of the Kuroshio Current.

Of the third varimax assemblage, *Aurila hataii* and *Aurila munechikai* are both distributed in the area ranging from the bay mouth to outside Uranouchi Bay, Kochi Prefecture (Ishizaki, 1968), and *Bicornucythere bisanensis* characteristically occurs in great abundance in the bay area. *Cytheropteron miurense* has been reported by Frydl (1982) to occur significantly in Tateyama Bay, Chiba Prefecture. *Neonesidea villosa* occurs in abundance in the area which is affected, to a certain extent, by the Kuroshio Current in the East China Sea (Ishizaki, 1981). The modern distribution of the first four species shows that this varimax assemblage is indicative of the bay mouth regime.

The known distribution of *Schizocythere kishinouyei* suggests that the fourth varimax assemblage is an element which is, to a certain extent, subject to the influence of a coastal current.

It is generally assumed that an inspection of the factor loadings in a cross-section reveals the geographical and temporal distribution of those varimax assemblages in the Ananai Formation.

To test the significance of the factor loadings computed on 74 species, the value of a/a_{SE} was examined if it is greater than 2.00 (the 5 percent level in case of 2-sided test, Sokal and Sneath,



Text-fig. 1. Geologic section of the Ananai Formation, with the distributions of significant highest loadings of each of the first three factors (open shelf, bay mouth, and Kuroshio Current-related assemblages), and that of higher loadings of all the first three factors (mixed assemblage).

1963, p. 313–315). Examination shows that a factor loading higher than 0.052 is significant at that level. All the samples from the Ananai Formation bear significant loadings of all the first three factors. Therefore, in this study, the loadings of each factor were classified into three classes; highest, higher, and significant, using critical values of 0.052 (unity), 0.156 (three times unity), and 0.468 (nine times unity).

Four environmental categories were classified in a section, which cuts through all five localities, on the basis of the highest and higher loadings of the first three factors (Text-fig. 1). These categories are open shelf, bay mouth, Kuroshio Current-affecting, and mixed faunas regimes. The first three regimes were defined by the highest loadings of any of the first three factors, and the last one by the combination of the higher loadings of all the first three factors. The distributions of these regimes in the section (Text-fig. 1) delineate both the vertical and lateral features of the Ananai Formation in relation to the fossil ostracode faunas contained. This figure clearly shows that the bay mouth regime prevailed in the Ananai area in an earlier period of the deposition time of the Ananai

Table 3. Varimax loadings of the first four factors calculated from the ostracode data.

Factors / Samples	1	2	3	4
P 1	0.3478	0.4354	0.6543	0.0518
P 2	0.2942	0.2635	0.7664	-0.3300
P 3	0.3289	0.1914	0.7162	-0.4665
L 4	0.2085	0.8531	0.2634	-0.1066
L 3	0.1215	0.9326	0.0844	-0.1808
L 2	0.2368	0.6635	0.3064	-0.4000
L 1	0.3277	0.3144	0.4748	-0.3117
M 1	0.4122	0.3308	0.3843	-0.3255
K 1	0.6352	0.2472	0.2436	-0.4506
K 2	0.5351	0.2956	0.3279	-0.3922
K 3	0.5573	0.3453	0.2962	-0.5495
K 4	0.2512	0.1664	0.2147	-0.8582
K 5	0.5286	0.2362	0.2422	-0.5880
K 6	0.8324	0.1967	0.1481	-0.2928
K 7	0.6660	0.1484	0.2138	-0.3862
K 8	0.6855	0.1935	0.3871	-0.2827
K 9	0.8697	0.2585	0.2086	-0.1247
K10	0.4348	0.2973	0.2919	-0.4193
K11	0.7952	0.2225	0.2738	-0.0832
H 1	0.2907	0.5130	0.1285	-0.1682
H 2	0.3442	0.4851	0.2181	-0.3614
H 3	0.4380	0.4895	0.1097	-0.3656
H 4	0.2782	0.5301	0.3246	-0.2561
I 1	0.3733	0.7179	0.2824	-0.1574
J 1	0.3625	0.6347	0.2055	-0.2097
G 2	0.3314	0.4016	0.2967	-0.3215
G 3	0.3573	0.2570	0.2538	-0.4835
G 4	0.3676	0.3846	0.2812	-0.1979
G 5	0.3184	0.4970	0.1785	-0.1703
G 6	0.2514	0.3975	0.2539	-0.1932

Table 4. Dry-weight percentage of the sediments in the range of coarser than 0 ϕ to 4.1 ϕ. Numerals on the left margin correspond to those plotted in Text-fig. 2.

Sample / Size		P1	P2	P3	L4	L3	L2	L1	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
1)	-0.0ϕ	-	.01	-	-	.46	-	.12	-	-	-	-	-	-	-	-	-	.20	-
2)	-1.0ϕ	-	.33	-	.05	.69	.10	.38	.25	.38	.66	.07	-	-	1.42	.16	.91	1.08	.10
3)	-1.2ϕ	.15	.11	.11	.03	.24	.14	.13	.79	.12	.22	.04	-	.16	.55	.16	.16	.25	.84
4)	-1.4ϕ	.20	.16	.16	.05	.29	.19	.15	.62	.14	.11	.04	-	.13	.54	.19	.16	.24	1.33
5)	-1.6ϕ	.50	.15	.15	.10	.44	.24	.20	.39	.03	.10	.04	.12	.15	.69	.24	.16	.22	2.10
6)	-1.8ϕ	.40	.28	.28	.11	.87	.30	.22	.44	.07	.10	.04	.15	.18	.54	.40	.41	.20	2.60
7)	-2.0ϕ	.56	.33	.33	.19	.68	.39	.28	.54	.35	.08	.08	.14	.23	.63	.42	.47	.17	2.45
8)	-2.2ϕ	.90	1.20	1.20	.44	1.30	1.70	.99	.96	.61	.15	.11	.34	.32	.71	.95	.77	.37	4.07
9)	-2.4ϕ	1.26	1.56	1.56	.63	1.54	2.52	1.58	1.25	.59	.26	.33	.84	.76	1.29	1.38	1.19	.55	4.68
10)	-2.6ϕ	2.10	2.71	2.71	1.04	2.95	4.23	2.21	2.41	1.08	.70	.78	1.17	1.02	3.20	1.66	2.08	.82	5.69
11)	-2.8ϕ	3.50	4.82	4.82	2.21	5.73	6 36	5.24	4.20	1.97	1.41	2.33	3.51	2.81	5.92	3.22	3.76	1.96	7.11
12)	-3.0ϕ	5.21	6.89	6.89	5.04	9.30	8.22	6.49	7.03	4.64	3.99	6.80	7.94	6.61	8.80	5.17	6.73	6.05	9.13
13)	-3.2ϕ	6.86	10.62	10.62	9.16	11.53	11.02	9.16	8.85	6.79	8.08	10.62	11.62	10.75	11.73	7.98	9.39	10.88	10.61
14)	-3.4ϕ	7.96	11.96	11.96	10.81	11.87	11.51	8.81	10.61	8.65	11.61	13.03	13.16	12.26	12.95	9.24	11.22	12.61	12.29
15)	-3.6ϕ	9.10	9.95	9.95	11.80	11.92	11.32	7.20	11.07	9.46	12.60	13.39	12.36	12.80	13.12	9.86	11.38	12.65	13.13
16)	-3.8ϕ	9.72	6.25	6.25	11.50	10.65	10.79	5.77	10.38	8.62	12.86	12.02	9.42	11.88	12.53	9.25	11.44	9.68	13.47
17)	-4.0ϕ	9.48	6.10	6.10	10.33	9.51	10.52	5.13	10.27	7.75	12.32	9.59	6.86	9.42	11.46	8.42	11.15	7.76	13.40
18)	-4.1ϕ	4.40	3.82	3.82	4.80	4.28	5.16	3.35	4.70	3.26	5.35	3.85	2.80	3.90	5.40	3.80	5.20	3.07	6.37

Formation and in the Ioki area near the middle period. The open shelf regime prevailed in the Tonohama area for almost the entire period of time and the Kuroshio Current-affecting regime in the Ono and Sempuku areas in the earlier short period as well as in later periods in Ioki and Ono areas. The mixed faunas regime dominated the Ioki area in the earliest period, the Tonohama area in the middle period and the Sempuku area over a long period of time. On the other hand, the coastal current-affecting regime, represented by almost significant positive fourth factor loadings, is detected only at P1 in the Ananai area (Table 3).

Sedimentological Analysis

Of the 30 samples which yielded 200-odd ostracode specimens, 27 have been kept in collections in the form of rock samples. An analysis of the sedimentology of those samples was conducted using the automatic grain-size analyser described by Niitsuma (1971). This analysis yielded two kinds of data sets; the grain-size frequency distribution and the relative frequency of the kinds of grains such as shell fragments, foraminiferal tests, quartz grains, rock fragments, and pellets. The former data set consists of the dry-weight percentage of the sediments in each of the 18 fractions ranging from coarser than 0 ϕ to 4.1 ϕ (Table 4). The latter data set is the relative frequency of the different kinds of grains in different size fractions ranging from coarser than 0 ϕ to 4 ϕ (Table 5).

	H1	H2	H3	H4	I1	G2	G3	G4	G5
1)	-	-	-	-	-	-	-	-	-
2)	.21	.05	.25	.16	.07	.12	-	.01	.13
3)	.07	.04	.24	.45	.23	.01	-	.04	.10
4)	.10	.13	.28	.45	.18	.01	.04	.04	.17
5)	.17	.26	.23	.36	.20	.01	.08	.04	.16
6)	.22	.17	.27	.47	.24	.01	.07	.06	.15
7)	.53	.48	.37	.57	.46	.07	.08	.15	.12
8)	.44	.83	.36	.57	.79	.20	.26	.43	.16
9)	1.23	1.84	.66	.80	1.93	.51	.46	1.09	.52
10)	2.79	3.08	1.47	1.45	3.96	1.81	.97	3.06	1.19
11)	4.80	5.28	3.46	2.35	6.81	5.60	3.29	6.85	3.59
12)	7.99	6.79	5.21	3.25	9.13	10.70	8.12	10.70	7.70
13)	10.38	9.01	7.08	4.80	10.98	13.15	11.45	-	9.98
14)	11.33	10.18	8.57	6.90	11.30	12.96	12.48	-	10.07
15)	10.91	10.31	9.34	8.50	11.00	10.85	11.79	-	9.18
16)	9.49	9.10	10.41	9.46	10.11	8.72	9.87	-	7.51
17)	7.58	8.51	11.10	9.93	9.26	7.37	7.36	-	6.34
18)	3.04	3.74	5.35	5.05	4.18	3.10	3.00	-	2.55

A summary of the principal components factor analysis on the grain-size frequency distribution for the Q-mode technique shows that the first two factors account for more than 98% of the total variance (Table 6). The plotted varimax factor scores of the first two factors demonstrate that the sediments in classes 3.4—3.6 ϕ (variable 15), 3.6—3.8 ϕ (16), 3.8—4.0 ϕ (17), and coarser than 4.1 ϕ (18) are all more than 1.28 and, being within the first 10%, contribute greatly to the first factor, and that the sediments of 2.8—3.0 ϕ (variable 12) and 2.6—2.8 ϕ (11) to the second factor (Text-fig. 2). This means that the first factor is indicative of low sediment-settling velocities or tranquil water conditions, while the second factor may possibly represent more complete preservation of the accumulating sediments because the cohesive sediments of such fractions are, in a Hjulstrom effect, erosive and mobile at rather lower current velocities than for both finer and coarser sediments.

This analysis was conducted using 18 variates, where factor loadings of more than 0.199 are significant at a level of 5%. Two classes of the significant factor loadings may be detected by a value of 0.597, three times the critical values of significance. Table 7 gives calculated varimax loadings of the first and second factors. This shows that, except for two (G2 and G4 in the Sempuku area), all samples bear higher loadings than 0.597, representing widespread tranquil water conditions. The loadings of the second factor are higher than 0.597 only at G4 in the Sempuku area and lower, but still significant, at scattered horizons in all five areas, signifying the spasmodically occurring entire preservation of the piled sediments.

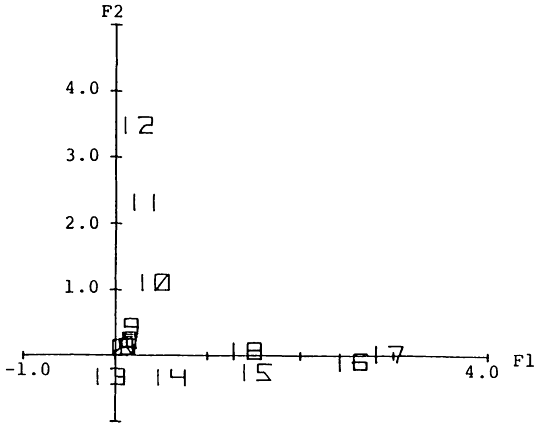
A summary of the principal components factor analysis on the relative frequency of

Table 5. The relative frequency of the kinds of grains in each of the five fractions in the range of coarser than 0 ϕ to 4 ϕ.
Numerals in parentheses correspond to those plotted in Text-figs. 3 and 4.

	Sample / Grains	P1	P2	P3	L4	L3	'L2	L1	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
-0ϕ	SF(10)	-	-	-	-	26.70	-	100.0	-	-	-	-	-	-	-	-	-	100.0	-
-1ϕ	QZ(1)	-	16.70	-	-	25.00	45.05	-	-	33.00	-	-	-	-	-	-	-	-	33.33
	FF(5)	-	11.70	-	62.50	12.50	-	16.67	40.00	20.00	5.00	50.00	-	-	40.00	6.25	64.52	40.00	-
	SF(11)	-	-	-	37.50	37.50	54.95	66.67	60.00	35.00	95.00	50.00	-	-	50.00	87.50	26.88	53.33	33.33
	RF(15)	-	71.70	-	-	5.00	-	-	-	5.00	-	-	-	-	-	6.25	7.53	2.67	23.33
-2ϕ	QZ(2)	40.00	25.02	16.70	31.60	15.40	20.00	8.33	20.00	35.00	-	-	-	-	10.00	-	33.33	1.43	50.00
	FF(6)	30.00	18.72	50.00	36.80	23.10	28.00	33.33	43.00	40.00	41.67	36.08	38.46	76.47	60.00	61.22	27.78	35.71	18.75
	PL(9)	-	-	3.30	-	-	-	-	-	-	-	-	-	-	-	3.06	-	-	-
	SF(12)	25.00	18.72	16.70	15.80	38.50	20.00	41.67	25.00	15.00	41.67	51.55	46.15	17.65	20.00	25.51	22.22	50.00	18.75
	RF(16)	5.00	37.53	6.70	5.30	3.10	12.00	8.33	5.00	3.00	-	-	-	-	5.00	5.10	11.11	2.86	6.25
-3ϕ	QZ(3)	42.10	35.40	35.30	50.00	38.50	76.50	44.44	50.00	70.00	57.89	66.33	61.86	51.55	50.00	54.00	40.40	55.56	63.16
	FF(7)	21.10	7.10	23.50	20.00	22.00	5.90	22.22	20.00	10.00	15.79	15.31	10.31	30.39	20.00	15.00	20.20	5.56	10.53
	SF(13)	21.00	5.10	11.80	15.00	27.50	5.90	22.22	10.00	5.00	10.53	15.31	15.46	10.31	15.00	20.00	10.10	11.11	21.05
	RF(17)	-	35.40	23.50	-	5.50	3.50	-	10.00	10.00	5.26	1.02	2.06	2.06	10.00	-	10.10	5.56	-
-4ϕ	QZ(4)	60.00	40.00	75.00	35.00	63.20	80.65	70.00	58.00	71.00	60.00	70.00	75.00	57.00	55.00	40.00	70.00	60.61	72.16
	FF(8)	10.00	5.00	2.00	25.00	5.30	5.40	7.00	15.00	7.00	10.00	10.00	7.00	15.00	20.00	25.00	2.00	2.02	7.22
	SF(14)	15.00	15.00	3.00	20.00	10.50	3.23	10.00	10.00	10.00	15.00	5.00	10.00	5.00	10.00	25.00	5.00	7.07	10.31
	RF(18)	-	25.00	10.00	-	1.10	5.40	-	10.00	7.00	-	-	1.00	-	5.00	-	2.00	2.02	-

Table 6. Summary of principal components factor analysis on the grain-size distribution of sediments.

Factor	Eigenvalue	Cum. perc.
1	25.433	94.20
2	1.090	98.24
3	0.332	99.47
4	0.088	99.80
5	0.021	99.87
6	0.012	99.92
7	0.007	99.95



Text-fig. 2. Plot of varimax scores of the first versus second factors for the grain-size distribution. Numerals plotted correspond to those on the left margin of Table 4.

shell fragments, foraminiferal tests, rock fragments, quartz grains, and pellets for the Q-mode technique reveals that the first four factors account for more than 90% of the total variance (Table 8). The plotted varimax factor scores of the first four factors show that relatively coarse-grained shell fragments [0—1 ϕ (variable 11) and 1—2 ϕ (12)] have varimax factor scores of more than 1.28 and contribute highly to the first factor (Text-fig. 3), and that rock fragments in classes 0—1 ϕ (variable 15), 1—2 ϕ (16), and 2—3 ϕ (17) contribute to the fourth factor (Text-fig. 4). This proves that these two factors are indicative of the supply of biogenic material consisting mainly of shell fragments and of terrigenous material composed largely of rock

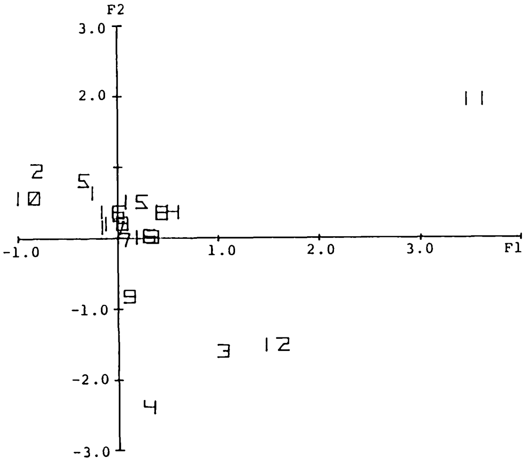
H1	H2	H3	H4	I1	G2	G3	G4	G5
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
75.00	-	15.00	100.0	-	40.00	-	15.00	10.53
25.00	20.00	75.00	-	58.82	20.00	-	75.00	84.21
-	-	5.00	-	29.41	-	-	-	-
5.00	53.00	5.00	20.00	42.37	-	-	-	-
73.00	15.00	15.00	35.00	25.42	20.00	15.38	27.27	17.65
-	-	-	-	-	-	38.46	27.27	-
10.00	15.00	70.00	20.00	11.86	26.00	38.46	36.36	70.59
2.00	10.00	-	10.00	11.86	4.00	-	-	-
23.00	63.00	45.00	48.00	60.00	63.16	63.16	77.32	72.16
35.00	5.00	20.00	20.00	7.00	10.53	10.53	7.22	10.31
25.00	7.00	25.00	10.00	7.00	10.53	8.42	5.15	10.31
10.00	15.00	-	15.00	10.00	2.11	2.11	3.09	2.06
63.00	68.00	40.00	74.00	65.00	85.00	80.00	80.00	80.00
15.00	7.00	20.00	3.00	1.00	3.00	3.00	5.00	5.00
10.00	10.00	20.00	3.00	10.00	2.00	2.00	7.00	5.00
7.00	10.00	-	15.00	7.00	-	-	3.00	-

Table 7. Varimax loadings of the first two factors calculated from the grain-size frequency distribution.

Factors / Samples	1	2
P 1	0.8269	0.1714
P 2	0.5986	0.2235
P 3	0.5984	0.2236
L 4	0.7940	0.0639
L 3	0.7007	0.2546
L 2	0.7335	0.2535
L 1	0.6021	0.2982
K 1	0.7765	0.1918
K 2	0.7795	0.1046
K 3	0.8379	0.0037
K 4	0.7312	0.0885
K 5	0.6283	0.1628
K 6	0.7379	0.0899
K 7	0.7466	0.2117
K 8	0.7719	0.1428
K 9	0.7907	0.1527
K10	0.6763	0.0757
K11	0.7829	0.2580
H 1	0.6732	0.2358
H 2	0.7258	0.2371
H 3	0.8480	0.1412
H 4	0.8942	0.0843
I 1	0.6945	0.2963
G 2	0.5876	0.2803
G 3	0.6501	0.1671
G 4	0.0769	0.9829
G 5	0.6308	0.2301

Table 8. Summary of principal components factor analysis on the relative frequency of the kinds of grains.

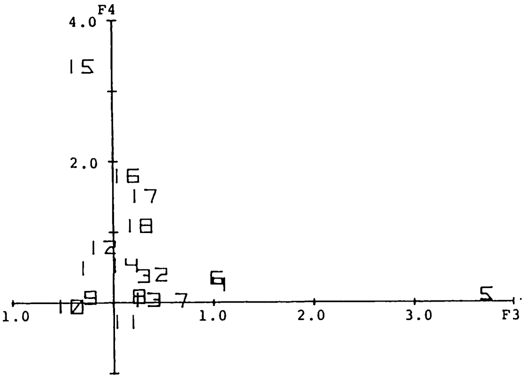
Factor	Eigenvalue	Cum. perc.
1	20.459	75.78
2	1.623	81.79
3	1.372	86.87
4	0.895	90.19
5	0.766	93.03
6	0.605	95.27
7	0.414	96.81
8	0.295	97.90
9	0.214	98.69
10	0.144	99.23



Text-fig. 3. Plot of varimax scores of the first versus second factors for the relative frequency of the kinds of grains. Numerals plotted correspond to those in parentheses in Table 5.

fragments. The meaning of the second and third factors remains to be interpreted.

Table 9 gives the calculated varimax loadings of the first four factors. Except for two (P2 and H4), all samples are characterized by significant loadings of the first factor at a level of 5% (higher than 0.199), which represents deposi-



Text-fig. 4. Plot of varimax scores of the third versus fourth factors for the relative frequency of the kinds of grains. Numerals plotted correspond to those in parentheses in Table 5.

Table 9. Varimax loadings of the first four factors calculated from the relative frequency of the kinds of grains.

Factors / Samples	1	2	3	4
P 1	0.2306	-0.5298	0.3555	0.1736
P 2	0.1264	-0.1968	0.2453	0.8773
P 3	0.2050	-0.5764	0.3916	0.2373
L 4	0.4282	-0.0922	0.7513	0.1127
L 3	0.4791	-0.3464	0.3384	0.1837
L 2	0.5782	-0.2723	0.2250	0.1452
L 1	0.4103	-0.1791	0.2356	0.0673
K 1	0.6085	-0.2023	0.5926	0.1437
K 2	0.4102	-0.3415	0.4373	0.2070
K 3	0.8307	-0.2159	0.2668	0.0764
K 4	0.6039	-0.4089	0.5716	0.1062
K 5	0.3714	-0.7339	0.2963	0.1612
K 6	0.2831	-0.5284	0.3740	0.1225
K 7	0.5582	-0.2263	0.6150	0.1355
K 8	0.7953	-0.0963	0.2915	0.1108
K 9	0.3104	-0.2846	0.7637	0.2129
K10	0.3640	-0.2133	0.3303	0.0988
K11	0.3899	-0.3338	0.2587	0.2897
H 1	0.2767	-0.1834	0.8216	0.1112
H 2	0.3105	-0.4309	0.3064	0.2189
H 3	0.8231	-0.2267	0.2715	0.1293
H 4	0.1142	-0.3308	0.8780	0.1819
I 1	0.5521	-0.2245	0.2647	0.3382
G 2	0.3948	-0.5704	0.5680	0.1161
G 3	0.3339	-0.8056	0.2370	0.1302
G 4	0.7102	-0.4199	0.3176	0.0836
G 5	0.7731	-0.4043	0.2570	0.0941

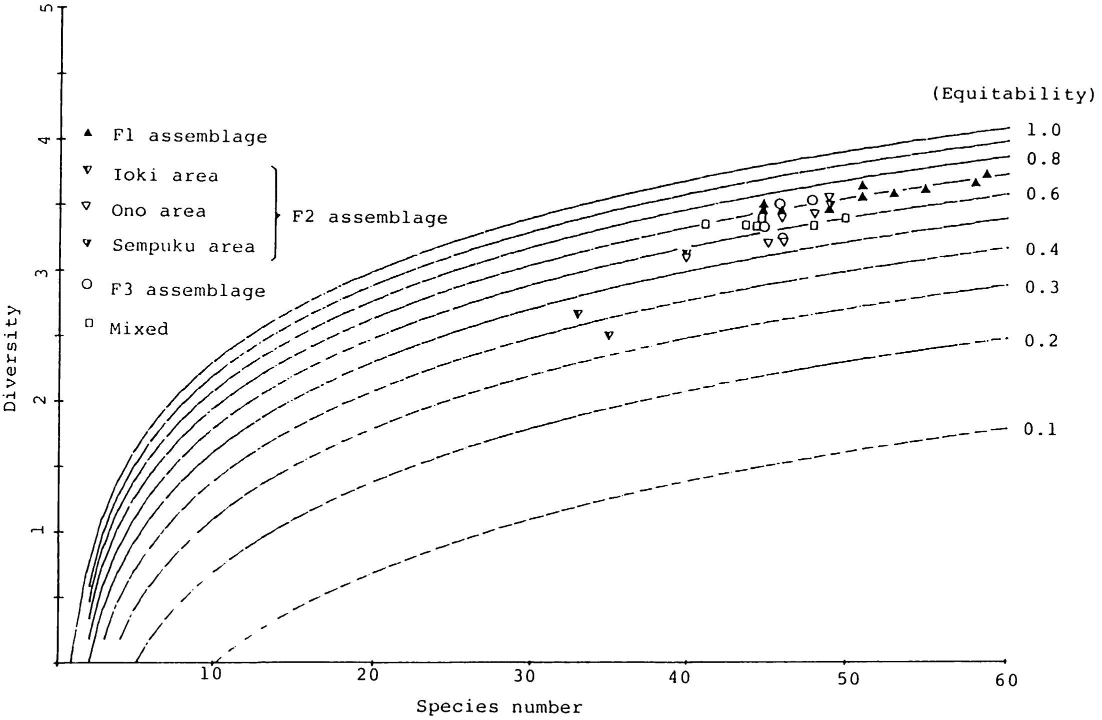
tional environments where biogenic material consisting largely of shell fragments has almost ubiquitously been brought in. In relation to the fourth factor, a significant higher loading is detected at P2 (Ananai) and a significant lower loading at P3 (Ananai), K2, K9, K11 (Tonohama), H2 and I1 (Ono), which signifies that the supply of terrigenous material has not reached the entire area, having remained local and intermittent.

Faunal Structure

Ostracode diversity and equitability are expressed by Shannon-Weaver's information function as somewhat revised by Buzas and Gibson (1969). Those two parameters are given in the following formulae:

$$H(s) = -p_i \ln p_i, \text{ and } E = \frac{e^{H(s)}}{S},$$

where p_i stands for the proportion of the ith species in a sample, and S the number of species. The latter equation equals the formulation, $H(s) = \ln (S \cdot E)$. By this formula, the relationships between the three parameters, diversity, equitability, and number of species in a sample, can be directly depicted in a graph. Text-fig. 5 shows that the first varimax assemblage is characterized by relatively high values of diversity, equitability, and number of species, while the parameter values of the second varimax assemblage are all rather low. The third varimax assemblage lies between the two assemblages on the graph. It is particularly interesting that the mixed fauna of the first three varimax assemblages is also in the intermediate range, never showing the increases in number of species or diversity which might be thought to have been caused by a mixing. Another point of interest is the recognition of three types of changing diversity values: 1) the second varimax assemblage displays changes in diversity depending on both the number of species and equitability; 2) the first varimax assemblage denotes changing diversity values following only the number of species (This may represent an inter-

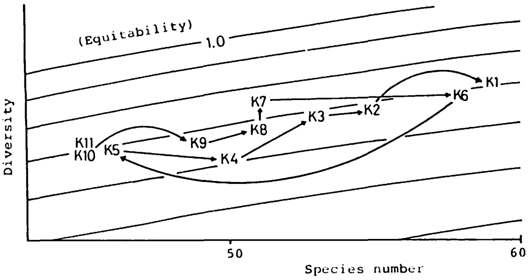


Text-fig. 5. Diagram showing three varimax assemblages and a mixed assemblage discriminated in the Ananai Formation in relation to species diversity, equitability, and number of species.
F1 assemblage, first varimax assemblage; F2 assemblage, second varimax assemblage; F3 assemblage, third varimax assemblage; Mixed, mixed assemblage defined by higher varimax scores all of the first three factors.

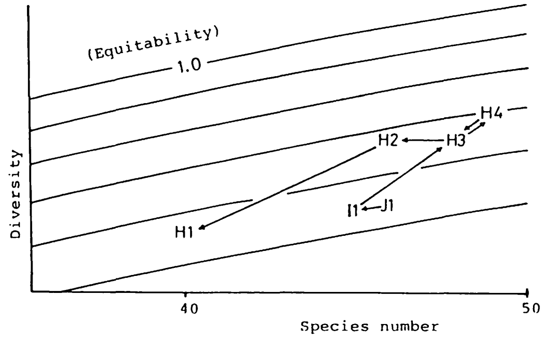
esting inquiry if it reflects the fact that equitability generally remains between 0.7 and 0.8 at its maximum and does not increase because of biological relationships among the taxa which have been in similar ecological situations); 3) the diversity of mixed fauna is particular in being almost constant, with equitability values increasing as the number of species decreases and decreasing as the number of species increases.

The geographic variation in assemblage structures is not clear except in the second varimax assemblage. In the Ioki area, this assemblage, which represents the effect of the then prevailing Kuroshio Current, has structures which are characterized by low values of diversity, equitability, and number of species (Text-fig. 5). On the other hand, in the Sempuku area, assemblage values are rather high for all three parameters, while in the Ono area, all three parameter values are in the intermediate range. Such geographic variation in the second varimax assemblage may be a result of the effect of the Kuroshio Current which has been less intensive westward from the Sempuku area via Ono to the Ioki area.

The temporal variation in assemblage structures was also examined in the Tonohama and Ono areas, where vertical sections display relatively complete successions of single varimax assemblages. In the Tonohama area, the number of species appreciably increases from the lowest sample K11 to K6, but decreases abruptly at K5, immediately below the mixed fauna (K4), showing a similar value to those of K11 and K10 (Text-fig. 6). Passing through the mixing



Text-fig. 6. Up-section variations of assemblage structure in the Tonohama section. Arrowheads stratigraphically upturned.



Text-fig. 7. Up-section variations of assemblage structure in the Ono section. Arrowheads stratigraphically upturned.

fauna, the number of species increases again from K3 to K1 with slightly increasing diversity. Such a variation may suggest that an environmental condition unfavorable to the open shelf assemblage prevailed at and around K4, as indicated by the occurrence of the mixing fauna, to have made assemblage structures simple, meanwhile, even at the top, the environment has still been favorable, under which the structure of the open shelf assemblage has become more stable.

In contrast, in the Ono area, both the number of species and equitability increase with increasing diversity, from lowest samples J1—I1 to H4 (Text-fig. 7). Above H4, diversity is apt to decrease with decreasing numbers of species up to H2, and then abruptly decreases between H2 and H1. In comparison with the diversity in the Tonohama section, such a varia-

Table 10. Correlation coefficients among respective factor loadings of ostracode faunas and sediments, diversity, and equitability.

Gs 1, 2, loadings of the first and second factors calculated from the grain-size frequency distribution; Kinds of grains 3—6, loadings of the first to fourth factors calculated from the relative frequency of the kinds of grains; D 7, diversity; E 8, equitability; Ostracoda 9—12, loadings of the first to fourth factors calculated from the ostracode data.

	Gs		Kinds of grains				D	E	Ostracoda			
	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	-0.882	-0.081	0.255	0.257	-0.023	0.023	-0.067	0.224	0.077	-0.117	-0.004
2	-0.882	1.000	0.165	-0.103	-0.200	0.002	-0.078	-0.004	-0.158	0.078	0.033	0.256
3	-0.081	0.165	1.000	0.315	-0.312	-0.429	0.057	-0.009	0.103	0.068	-0.415	-0.194
4	0.255	-0.103	0.315	1.000	0.204	0.103	-0.119	-0.094	0.046	0.246	-0.042	0.228
5	0.257	-0.200	-0.312	0.204	1.000	-0.171	-0.084	-0.118	0.019	0.076	-0.218	0.109
6	-0.023	0.002	-0.429	0.103	-0.171	1.000	0.075	0.165	-0.062	-0.052	0.547	0.108
7	0.023	-0.078	0.057	-0.119	-0.084	0.075	1.000	0.949	0.620	-0.840	0.185	-0.369
8	-0.067	-0.004	-0.009	-0.094	-0.118	0.165	0.949	1.000	0.569	-0.834	0.240	-0.343
9	0.224	-0.158	0.103	0.046	0.019	-0.062	0.620	0.569	1.000	-0.623	-0.162	0.045
10	0.077	0.078	0.068	0.246	0.076	-0.052	-0.840	-0.834	-0.623	1.000	-0.265	0.449
11	-0.117	0.033	-0.415	-0.042	-0.218	0.547	0.185	0.240	-0.162	-0.265	1.000	0.061
12	-0.004	0.256	-0.194	0.228	0.109	0.108	-0.369	-0.343	0.045	0.449	0.061	1.000

tion may suggest that the environment was optimum at H4, and then became unfavorable for the Kuroshio-related assemblage because of the decreasing effect of the Kuroshio Current, as is shown in its geographic variation in the Ioki area (Text-fig. 5).

Correlations among Parameters

The next step in our study was the clarification of the relationships between the examined respective factor loadings, diversity, and equitability of ostracode faunas and those of grain-size distribution and the kinds of grains through correlation coefficients. Table 10 shows a summary of the analyses. The correlation coefficients were computed on 27 samples, where those of more than 0.136 are significant at a level of 5%. Significant higher correlations were, as a matter of convenience, marked off by values of more than 0.597, three times the critical values of significance.

The third factor loadings of ostracode faunas correlate positively and negatively with the fourth and first factor loadings of the kinds of grains, suggesting that the area which the bay mouth assemblage inhabited has most likely had a supply of terrigenous material consisting mainly of rock fragments rather than biogenic material including shell fragments.

Table 10 points out that community structure as defined by diversity and equitability does not show a close relationship with sedimentological parameters, but does with faunal assemblages per se. For example, diversity has a high positive correlation with the first factor loadings and a high negative correlation with the second factor loadings of ostracode faunas, and equitability has a positive correlation with the first factor loadings, and a negative correlation with the second factor loadings of ostracode faunas. Through the analyses it seems likely that these ostracode faunal parameters have not been modified remarkably by the agents of water movement or reworking which might have taken place.

Remarks

Katto *et al.* (1953) and Kurihara (1968) studied fossil foraminifera from the Ananai Formation and suggested that there were geographic variations in the depositional environments of the formation; shallower in the Ioki area in the west and deeper in the Sempuku area in the east. The present results reveal both geographical and temporal vicissitudes in the environments by means of the distribution of varimax assemblages as well as by variations in faunal structures. The Tonohama area was closely related to the open shelf element rather than the remaining four areas. The Ananai and Ioki areas were related to the bay mouth element, and the environment of the Sempuku area might have largely been intermediate.

In addition, this study delineates four important physical aspects of the Ananai sedimentation: The supply of biogenic material and tranquil water conditions were almost ubiquitous; meanwhile, the supply of terrigenous material, particularly to the environments which the bay mouth assemblage inhabited, and the entire preservation of accumulating sediments were local and intermittent.

One of the results of this study has been the delineation of the temporal changes in some varimax assemblage structures. In general, those structures are much more complex than those of Recent ostracode assemblages (*g.v.* Ishizaki, 1979, fig. 4). The most likely cause of such a difference is the differences in the history of the habitats where ostracode lived. The modern shelf area has a relatively short history, only about 18,000 years since the last glacial episode; on the other hand, the Ananai sedimentation of several million years ago (Pliocene) might have taken place under a stable environment, which presumably, continued for a much longer period of time.

Opinions concerning species diversity have varied. Fischer (1960) considered tropical areas to have had a longer period of climatic stability which allowed biotic rather than abiotic accommodation of species. Many subsequent researchers have held to the hypothesis that under given stable conditions over a long period of time biologic components became more important than physical ones. These ideas are an expansion of Fischer's climatic-stability hypotheses (Margalef, 1963; Hessler and Sander, 1967; Buzas and Gibson, 1969). Meanwhile, Gibson and Buzas (1973) studied modern samples extending from the Arctic to the Gulf of Mexico, in addition to samples from the Miocene strata of the Atlantic Coastal Plain and continental shelf, and suggested that species diversity and equitability have not increased during the last 15 Ma; each environment has its own carrying capacity and this capacity is reached rather quickly.

The intention of those reports has been, primarily, the clarification of the relationship between the species diversity of faunas and the environmental conditions under which they live in order to distinguish paleoenvironments by means of species diversity of fossil faunas.

The examined assemblages in those studies have been holistic ones consisting of various groups in the deep sea (Hessler and Sanders, 1967) or the total foraminiferal assemblages (Gibson and Buzas, 1973). The present study has clarified the point that the structure of assemblages is fundamentally inherent in respective varimax assemblages, and varies greatly among and, to a certain extent, within varimax assemblages due to environmental conditions or increases in their complexity under stable conditions over a longer period of time. Therefore, it is highly possible that, by a close inspection of pertinent assemblages, changes in assemblage structure can be more closely related to particular environmental conditions. In other words, a critical factor in applying faunal dynamics to fossil assemblages and in assessing environmental conditions in the geologic past is the recognition of relevant assemblages per se.

Acknowledgments

The writers are deeply indebted to Professor Yokichi Takayanagi of the Institute of Geology and Paleontology, Tohoku University, for his kind provision of samples for this study, encouragement, and reading of the manuscript. Necessary computation was made through NEAC-ACOS model 1000 computer in the Tohoku University Computer Center.

The works on which this study is based were partly supported by the Grant-in-Aids for Scientific Research of the Ministry of Education, Science, and Culture of Japan (58540501).

References

Buzas, M. A. and Gibson, T. G. (1969): Species diversity: Benthonic Foraminifera in western North Atlantic. *Science*, vol. 163, p. 72—75.

Fischer, A. G. (1960): Latitudinal variations in organic diversity. *Evolution*, vol. 14, p. 64—81.

Frydl, P. M. (1982): Holocene ostracods in the southern Boso Peninsula. *In* T. Hanai (ed.) Studies of Japanese Ostracoda, *Univ. Tokyo, Univ. Museum, Bull.*, no. 20, p. 61—140.

Gibson, T. G. and Buzas, M. A. (1973): Species diversity: patterns in modern and Miocene Foraminifera of the eastern margin of North America. *Geol. Soc. Amer. Bull.*, vol. 84, p. 217—238.

Hessler, R. R. and Sander, H. L. (1967): Faunal diversity in the deep sea. *Deep-Sea Res.*, vol. 14, p. 65—78.

Imbrie, J. and Purdy, E. G. (1962): Classification of modern Bahamian carbonate sediments. *In* W. E. Ham (ed.) Classification of Carbonate Rocks, *Amer. Assoc. Petroleum Geologists* Mem. 1, p. 253—272.

Ishizaki, K. (1968): Ostracodes from Uranouchi Bay, Kochi Prefecture, Japan. *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.)*, vol. 37, p. 131—163.

——(1969): Ostracodes from Shinjiko and Nakanoumi, Shimane Prefecture, western Honshu, Japan. *ibid.*, vol. 41, p. 197—224.

——(1971): Ostacodes from Aomori Bay, Aomori Prefecture, northeast Honshu, Japan. *ibid.*, vol. 43, p. 59—97.

——(1979): Study of Ostracoda from the Pliocene Ananai Formation, Shikoku, Japan — a step toward distinguishing the sedimentary environments —. *In* Serbian Geol. Soc. (ed.) Taxonomy, Biostratigraphy and Distribution of Ostracodes, Proc. VII Intern. Symp. Ostracodes, p. 197—205. *Serbian Geol. Soc.*, Belgrade.

——(1981): Ostracoda from the East China Sea. *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.)*, vol. 51, p. 37—65.

——(1983): Ostracoda from the Pliocene Ananai Formation, Shikoku, Japan — description —. *Trans. Proc. Palaeont. Soc. Japan, new ser.*, no. 131, p. 135—158.

Katto, J., Nakamura, J. and Takayanagi, Y. (1953): Stratigraphical and paleontological studies of the Tonohama Group, Kochi Prefecture, Japan. *Kochi Univ., Res. Rep.*, vol. 2, p. 1—15 (in Japanese with English abstract).

Kurihara, K. (1968): Notes on the benthonic Foraminifera of the Tonohama Group, Shikoku, Japan. *Trans. Proc. Palaeont. Soc. Japan, new ser.*, no. 70, p. 267—283.

Margalef, R. (1963): On certain unifying principles in ecology. *Amer. Naturalist*, vol. 97, p. 357—374.

Niitsuma, N. (1971): Automatic grain-size analyser for sedimentological investigation. *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 72, p. 25—36 (in Japanese with English abstract).

Sokal, R. R. and Sneath, P. H. A. (1963): Principles of Numerical Taxonomy. 359 p., *Freeman and Co.*, San Francisco.

鮮新統穴内層（四国）の貝形虫ー群集解析ー：四国南東部の沿岸に沿って点在して分布する鮮新統穴内層より得た35サンプルから42属79種の貝形虫化石が認定された (Ishizaki, 1983, 表1)。この表を素データマトリックスとして，Qモードによる主成分因子分析を行った結果は，穴内層の貝形虫群集が，基本的には，4つのバリマックス群集（公海陸棚群集，黒潮系群集，湾口群集および沿岸流系群集）によって特徴づけられることを示す。

堆積物の分析によって得られた粒径頻度分布および粒子の種類の相対比に基づいて主成分因子分析をした結果は，水域環境の静穏さ，沈積物の保存，生物源物質の供給および陸源物質の供給を指示する因子を示唆する。

堆積物と貝形虫についての因子負荷量，種の多様性，均衡度などの間の相関係数は，種の多様性，均衡度が堆積学的要因とはほとんど無関係で，バリマックス群集に固有なものであることを示唆する。

第2バリマックス群集の種の多様性，均衡度，種数には地域性が明瞭に認められ，当時の黒潮の営力の度合いの違いを反映しているものと考えられる。大野セクションにおいてみられる時間的変化も，同様な水域環境の推移を示唆するものと考えられる。　石崎国熙・谷村好洋

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 137, pp. 64—74, pls. 8, 9, April 30, 1985

794. *LARIX* REMAINS FROM PLEISTOCENE STRATA OF NORTHEAST JAPAN, WITH SPECIAL REFERENCE TO THE DISTRIBUTION OF *LARIX* IN THE LATTER HALF OF THE LAST GLACIAL AGE*

KEIJI SUZUKI

Laboratory of Earth Science, Faculty of Education, Fukushima University,
Matsukawa-machi, Fukushima, 960-12

Abstract. The morphological characters of cone and long shoot remains of the genus *Larix* which were obtained from the Pleistocene strata in the northeastern Japan are examined. They are referred to *Larix kaempferi* (Lamb.) Carr., *L. kamtschatica* (Rupr.) Carr. and *L.* cf. *kaempferi* (Lamb.) Carr. The former two species were all obtained from strata of the Last Glacial age and the last species, represented by only one specimen, was collected from the Middle or Early Pleistocene stratum. It is pointed out that the range of geographical distribution of *L. kamtschatica* (Rupr.) Carr. and *L. kaempferi* (Lamb.) Carr. had come closer to each other during the latter half of the Last Glacial than it is at present time.

Introduction

Larix is one of the genera among the family Pinaceae, widely distributed in the cold latitudes of the northern hemisphere, and also one of important plants to investigate minutely the geohistorical changes of the flora and vegetation during the Pleistocene epoch. Fossil cones and twigs of the genus *Larix* have abundantly been found in Pleistocene strata of the Japanese Islands (Miki, 1938, 1956, 1957; Sohma, 1959; Suzuki and Sohma, 1965; Yano and Fujita, 1970; Yano et al., 1975; Yano et al., 1978). Although these fossils have inadequately been described in most cases by these previous workers, they have been reported under such varied names as *L. gmelini* Gordon, *L. dahurica* Turcz. var. *japonica* Maxim., *L. kaempferi* Sarg., and *L. leptolepis* Gordon.

The status of East Asiatic taxa of the genus *Larix* has not fully been evaluated. The need for a monographic treatment of the genus has been evident for many years. Since it is not my intention to revise or add to the taxonomy of the genus, I follow the opinion of Ohwi and Kitagawa (1983) for the Japanese species and that of Komarov (1968) for those species which occur outside of Japan. Accordingly, a population of *Larix* distributed on high mountains of Central Honshu is referred to by the name of *L. kaempferi* (Lamb.) Carr. *L. leptolepis* (Sieb. and Zucc.) Gordon is regarded as a junior synonym of it. Furthermore, a population on the southern Kurile Islands, southern Sachaline and the Ol'ga District in Ussuri Territory is treated as *L. kamtschatica* (Rupr.) Carr., and both *L. gmelini* Gordon and *L. dahurica* Turcz. var. *japonica* Maxim. are regarded as its junior synonyms. The distributional range of *L. kaempferi* (Lamb.) Carr. is thus isolated from that of *L. kamtschatica* (Rupr.) Carr.

The cone and long shoot remains which form the basis of the present study were ob-

---

*Received May 10, 1984.

tained from strata of the Last Glacial age, except for one cone remain from an early Middle or late Early Pleistocene stratum, all distributed in the northeastern Japan. After a careful examination of morphological characters of these cone and long shoot remains, they are found to belong to the following two species and possibly a third one:

1) *Larix kaempferi* (Lamb.) Carr.
2) *Larix kamtschatica* (Rupr.) Carr.
3) *Larix* cf. *kaempferi* (Lamb.) Carr.

Taking both stratigraphical and geographical distributions of these fossil specimens into consideration, the following facts may be pointed out:

1) *L. kamtschatica* (Rupr.) carr. was distributed in the southwestern part of Hokkaido and in the northern part of Tohoku District of Honshu, whereas *L. kaempferi* (Lamb.) Carr. had its distribution in the southern part of Tohoku District and Kanto District both in Honshu, during the latter half of the Last Glacial. Their age is younger than a radiocarbon date of ca. 30,000 y. B.P. during the Last Glacial period.
2) The range of geographical distribution of *L. kamtschatica* (Rupr.) Carr. and *L. kaempferi* (Lamb.) Carr. had come closer to each other during the latter half of the Last Glacial than it is at the present time.
3) The single cone remain from the early Middle or late Early Pleistocene stratum is morphologically similar to the cones of *L. kaempferi* (Lamb.) Carr.

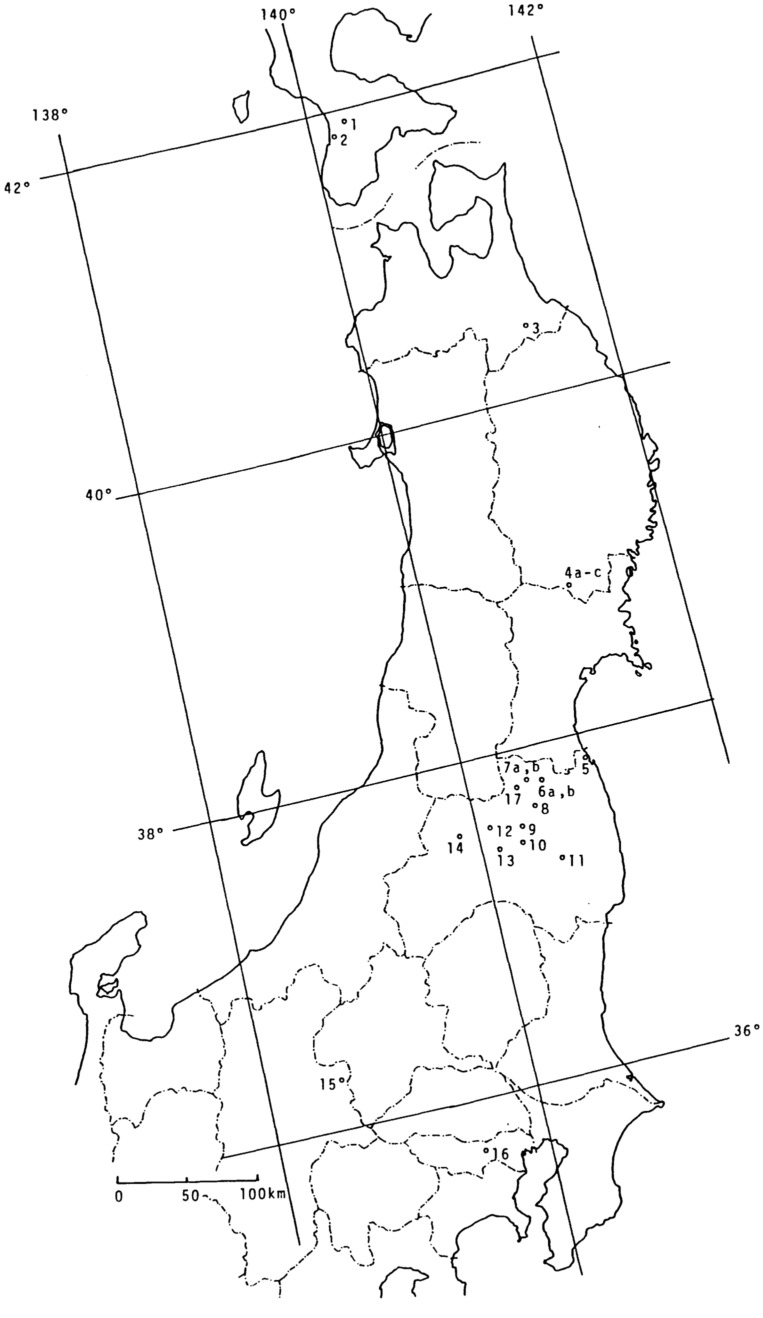
Locality and Stratigraphical Horizon of the Plant-bearing Bed

Those fossil cones and shoots of the genus *Larix* which are described in the present study are obtained by the present writer and his collaborators from twenty-one beds at seventeen localities as shown in Text-fig. 1 and Table 1.

Those fossil specimens identified as *Larix kamtschatica* (Rupr.) Carr. are newly obtained from peat beds intercalated with the terrace deposits at Yosumizawa and the Jinya fluvial terrace deposits at Higashiyama, both in the Oshima Peninsula of southern Hokkaido (Yano et al., 1978). Specimens of the same species were also known under the name of *L. dahurica* Turcz. var. *japonica* Maxim. from a peat bed of the Sambongi Formation at Ootai (Sohma, 1959; Takeuti, 1971). Kanto Loam Research Group and Shinshu Loam Research Group (1962) also obtained specimens of the same species from three beds of the Hanaizumi Formation at Kanamori. These two localities are in the northern part of Tohoku District. Ages of these peat beds can be considered to belong to the latter half of the Last Glacial age on account of stratigraphical data or radiocarbon dates mentioned by these authors.

Those specimens identified as *Larix kaempferi* (Lamb.) Carr. are known from fourteen peat or peaty beds at twelve localities distributed in the southern part of Tohoku District and the Kanto District. All of these beds are of the Last Glacial age. Of these fourteen beds, the following eleven may be thought to represent the latter half of the Last Glacial based on stratigraphical and radiocarbon data. These are: a peat bed of the Fifth terrace deposits in the coastal area of Fukushima Prefecture (Suzuki and Nakagawa, 1971), three peat beds occurring in the upper part of the Fujita Formation of the Fukushima Basin (Yoshida et al., 1969), a peat bed in the lower part of the Ootsuki Formation of the Koriyama Basin (Suzuki and Sohma, 1965), peat beds in the upper part of the Saru-uchi II Formation of the Abukuma Mountainland (Yoshida et al., 1981), a peaty bed of the Sunagawa Formation of the Inawashiro Basin (Yoshida and Suzuki, 1981), a peat bed overlain by Holocene gravel and sand strata in the western part of the Aizu Basin (Suzuki et al., 1977; Suzuki, MS), a silt bed overlying the Kuboma pumice flow bed at Minamikaruizawa of Nagano Prefecture (Unozawa and Sakamoto, 1972), and a peat bed in the Ekoda Formation at Ozaki in Tokyo (Oosawa, 1982, personal communication).

The remaining three of the fourteen beds



Text-fig. 1. Map showing localities from which fossil specimens of the genus *Larix* were recovered.

Locality numbers correspond to those shown in Table 1. All localities except for 6b, 8, 9 and 17 represent strata accumulated during a time of ca. 30,000—13,000 years B.P. in the latter half of the Last Glacial. Localities 6b, 8 and 9 belong to the middle or early part of the Last Glacial (before 32,200 years B.P.) and 17 to an early Middle or late Early Pleistocene (Takada Formation).

Table 1. List of localities yielding fossil *Larix*, radiocarbon dates (years B.P.) and associated plant taxa, in Pleistocene strata of Northeast Japan.

Loc. No.	Locality (Altitude m)	Formation or Bed	^{14}C date	Species of *Larix*	Associated species	Reference
1	Yosumizawa, Assabu-machi, Hiyama-gun, Hokkaido. (70)	River terrace deposits(unnamed)	15,070±490 (Gak-7701)	*L. kamtschatica* (Rupr.) Carr.	*Picea glehni*	Yano and al., 1978
2	Higashiyama, Esashi-machi, Hiyama-gun, Hokkaido. (65)	Jinya terrace deposits	27,860±2,670 (Gak-7214)	*L. kamtschatica* (Rupr.) Carr.	*Picea jezoensis, P. glehni*	Ditto
3	Ootai, Nango-mura, Sannohe-gun, Aomori Pref. (205)	Sambongi Formation	$26,600^{+1,750}_{-1,500}$ (Gak-2845)	*L. kamtschatica* (Rupr.) Carr.	*Picea glehni, Abies sachalinensis, Tsuga* sp.,*Pinus koraiensis, Menyanthes trifoliata*	Sohma, 1959; Takeuti, 1971
4a	Kanamori, Hanaizumi-machi, Nishiiwai-gun, Iwate Pref. (33)	Second peat of Hanaizumi Formation		*L. kamtschatica* (Rupr.) Carr.	*Picea glehni, Taxus cuspidata, Pinus koraiensis, Picea* sp.	Kanto Loam Res. Group and Shinshu Loam Res. Group, 1962
4b	Kanamori, Hanaizumi-machi, Nishiiwai-gun, Iwate Pref. (32)	Third peat of Hanaizumi Formation	21,430±800	*L. kamtschatica* (Rupr.) Carr.	*Picea glehni, P. bicolor, P.* sp., *Pinus koraiensis*	Ditto
4c	Kanamori, Hanaizumi-machi, Nishiiwai-gun, Iwate Pref. (31.5)	Fourth peat of Hanaizumi Formation	$28,070^{+1,100}_{-1,250}$	*L. kamtschatica* (Rupr.) Carr.	*Picea jezoensis, P. bicolor, P.* sp., *Pinus koraiensis*	Ditto
5	Ogawa, Shinchi-mura, Sohma-gun, Fukushima Pref. (12)	Fifth terrace deposits	28,050±1,550 (Gak-1451)	*L. kaempferi* (Lamb.) Carr.	*Picea bicolor* var. *reflexa, Pinus koraiensis*	Suzuki and Nakagawa, 1971
6a	Negishi, Kori-machi, Date-gun, Fukushima Pref. (67)	Lower part of Fujita Formation	>40,350 (Gak-7330)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Abies* sp., *Tsuga* sp. *Thujopsis dolabrata, Betula platyphylla*	Yoshida and al., 1969; Suzuki, MS
6b	Negishi, Kori-machi, Date-gun, Fukushima Pref. (74)	Upper part of Fujita Formation	18,750±500 (Gak-1452)	*L. kaempferi* (Lamb.) Carr.	*Picea jezoensis, P. bicolor, Pinus koraiensis*	Ditto
7a	South of Kori-station, Kori-machi, Date-gun, Fukushima Pref. (78)	Upper part of Fujita Formation	21,660±1,190 (Gak-6053) 24,230±1,380 (Gak-6054)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Phellodendron amurense, Prunus salicina*	Ditto
7b	South of Kori-station, Kori-machi, Date-gun, Fukushima Pref. (76)	Upper part of Fujita Formation	22,000±1,140 (Gak-6055) 25,400±1,150 (Gak-209)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Abies veitchii, Tsuga* sp., *Thujopsis dolabrata*	Ditto
8	Wakamiya-machi, Nihonmatsu-City, Fukushima Pref. (200)	Nihonmatsu Formation	>32,200 (Gak-517)	*L. kaempferi* (Lamb.) Carr.	*Picea bicolor, Pinus koraiensis, Tsuga diversifolia*	Ditto
9	500m north of Kamiza, Motomiya-machi, Adachi-gun, Fukushima Pref.(256)	Lower part of Ootsuki Formation	>32,380 (Gak-9815)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Pinus koraiensis, Tsuga diversifolia, Prunus salicina*	Suzuki and al., 1967; Suzuki, MS
10	Hara, Katabira-machi, Koriyama City, Fukushima Pref. (262)	Lower part of Ootsuki Formation	29,100±2,000 (Gak-495)	*L. kaempferi* (Lamb.) Carr.	*Picea koyamai, P. bicolor*	Suzuki and Sohma, 1965
11	Loc. 1, Saru-uchi, Takine-machi, Tamura-gun, Fukushima Pref.(466)	Upper part of Saru-uchi II Formation	17,570±400 (Gak-6846) 19,320±420 (Gak-6845)	*L. kaempferi* (Lamb.) Carr.	*Picea* sp.,*Abies* sp., *Tsuga* sp.,*Menyanthes trifoliata*	Yoshida and al., 1981
12	Sunagawa,Inawashiro-machi, Yama-gun, Fukushima Pref.(525)	Sunagawa Formation	23,720±980 (Gak-6849)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, P. jezoensis, Pinus koraiensis*	Yoshida and Suzuki, 1981
13	Nakano-iri, Konan-machi, Koriyama City, Fukushima Pref. (560)	Konan Formation	$22,880^{+990}_{-880}$ (TH-753)	*L. kaempferi* (Lamb.) Carr.	*Picea* sp., *Abies* sp., *Tsuga diversifolia*	Suzuki and al., 1982
14	Ookawa-River, Bange-machi, Kawanuma-gun, Fukushima Pref.(172)	Peat bed overlaid by Holocene gravel		*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Menyanthes trifoliata*	Suzuki and al., 1977; Suzuki, MS
15	Cliff of Kumoba-River, Minamikarui-zawa, Karuizawa City, Nagano Pref. (930)	Silt bed overlying Kumoba pumice flow	19,400±500 (Gak-2656) 20,200±700 (Gak-2655)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, P. shirasawae, Abies* sp., *Tsuga* sp., *Menyanthes trifoliata*	Unozawa and Sakamoto, 1972
16	Ozaki, Egota, Nerima-ku, Tokyo Pref. (30)	Peaty bed of Ekoda Formation	13,600±110 (N-3754) 13,700±160 (N-3755)	*L. kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Pinus koraiensis, Ostrya japonica, Alnus* sp., *Prunus* sp.	Personal communication by Osawa, 1982
17	Takatori, Nakano, Fukushima City, Fukushima Pref.(150)	Takada Formation		*L.* cf. *kaempferi* (Lamb.) Carr.	*Picea maximowiczii, Alnus* sp.	Suzuki and Yoshida, 1972

may be assigned to the early half of the Last Glacial, an interval older than ca. 30,000 y. B.P., on account of their radiocarbon dates as well as stratigraphical data. These are: a peaty mud in the lower part of the Fujita Formation of the Fukushima Basin (Yoshida et al., 1969), a peat bed in the Nihonmatsu Formation which forms a terrace in the lowland area along the Abukuma River (Yoshida et al., 1969), and a peat bed at the base of the Ootsuki Formation of the Koriyama Basin (Suzuki, MS), all in Fukushima Prefecture.

A cone remain identified as *Larix* cf. *kaempferi* (Lamb.) Carr. comes from a peaty mud in the upper part of the Takada Formation at the northwestern margin of Fukushima Basin. (Suzuki and Yoshida, 1972). The Takada Formation may be thought to be of early Middle or late Early Pleistocene age based on stratigraphical data and palaeobotanical evidences.

Description of Fossil Specimens

Larix kamtschatica (Rupr.) Carr.

Plate 8, Figs. 1a—j, 2a—f, 3a—i, 4a—g,
5a—e, 6a—o, 7a—j, 8a—r

Larix kamtschatica (Rupr.) Carr., Komarov, 1968, p. 123—124.

Larix gmelini Gordon, Miki, 1957 (part), p. 232—233, pl. 1, figs. Aa and B (not Ab, Ac and Ad).

Larix dahurica Turcz. var. *japonica* Maxim., Sohma, 1959, figs. B-1 and B-2.

Description:—Cones oblongly to elliptically cylindrical, rarely oblongly ovate, 1.0—1.7 cm in length, 0.6—1.0 cm in width, maximum width situated at middle or lower part of its entire length, bearing 15—25 cone-scales and thick cone-stalk. Cone apex truncate or obtusely acute. Cone-scales orbicular to widely ovate, upper margin truncated or emerginated, and not recurving downwards, and each cone scale 0.5—1.0 cm long. Bracts long and rectangular, with needle-like apex.

Long shoot with many short shoots, and intervals between the points where short shoots attached to the long shoot generally narrow.

Remarks and comparison:—Most of the cone specimens are well preserved, whereas some from Ootai (Figs. 3c—e), Higashiyama (Figs. 2d—f) and Hanaizumi (Figs. 6b, n, o; 8l—q) localities are somewhat incomplete. Furthermore, some of the specimens from Yosumizawa (Figs. 1h—j), Higashiyama (Figs. 2b, c) and Ootai (Figs. 3a, b, d) are remarkably flattened, and such specimens having an oblongly ovate shape as those from Hanaizumi (Figs. 6m—o) are somewhat worn away at the outer part of the cone.

These cone specimens are generally small in size and comprise two types, one having a cylindrical and the other having an oblongly ovate form. The former may be an adult state of opening cone, and the latter appears to represent a younger stage.

Those cone specimens from Yosumizawa, Higashiyama and Ootai are specifically identified as the cone of *L. kamtschatica* (Rupr.) Carr. in having a cylindrical form, a fewer number of cone-scales and ovate-to-obvate-shaped cone-scales with an emerginated or truncated upper margin. Most of the cone specimens from those three peat beds of the Hanaizumi Formation are also identified as those of *L. kamtschatica* (Rupr.) Carr. because they exhibit similar morphological characteristics. However, some cone specimens (Figs. 6g, h, k—o) from the third peat bed of the Hanaizumi Formation are somewhat different in having an oblongly ovate form. At a first glance, they appear to be somewhat similar to those of *L. kaempferi* (Lamb.) Carr. but differ in having a fewer number of cone-scales. This feature may be seen in a younger stage of development in the cone of *L. kamtschatica* (Rupr.) Carr. Therefore, none of the abundantly occurring cone specimens from the third peat bed of the Hanaizumi Formation exhibits the typical characters of *L. kaempferi* (Lamb.) Carr.

The long shoots obtained from the peat bed of Jinya terrace deposits are identified as those of *L. kamtschatica* (Rupr.) Carr. by taking into account the close interval between short shoots on the long shoot.

Locality and stratigraphic horizon:—As shown in Table 1, specimens identifiable with the present species are obtained from four localities; two in the Oshima Peninsula, one in Aomori Prefecture, and one in Iwate Prefecture. In Iwate Prefecture, three beds are recognized as the fossil-bearing bed. Those three have been called the second, the third, and the fourth peat bed of the Hanaizumi Formation, respectively. The fossil-bearing beds at these four localities are thought to belong to the latter half of the Last Glacial age (about 15,000—30,000 y B.P. in radiocarbon dates).

Repository:—Stored in the Laboratory of Earth Science, Faculty of Education, Fukushima University.

Other occurrences in Japan:—Fossil female cones have been reported from Pleistocene strata of Hokkaido under the name of *L. gmelini* Gordon. Among them, specimens from the Hiroshima Formation (Yano and Fujita, 1970) in Hiroshima-cho, Sapporo-gun, and from the Oshamanbe terrace deposits (Yano et al., 1975) in Oshamanbe-machi, Yamagoe-gun, are identical with the present materials identified with *L. kamtschatica* (Rupr.) Carr., and these strata are assignable to the latter half of the Last Glacial age. Furthermore, there are fossil records of cones and long shoots described under the name of *Larix gmelini* Gordon from the *Larix* bed at Manchidani in Nishinomiya City (Miki, 1957, p. 232—233, pl. 1, Ac, Ad), Yozawa in Itsukaichi-town (Miki, 1957, p. 232—233, pl. 1, Ab) and a Pleistocene bed in Higashikushiro (Miki, 1957, p. 232—233, pl. 1, B). The cone specimens from the former two localities resemble those from young trees of the extant species, *L. kaempferi* (Lamb.) Carr. Further revision may be needed for these fossil specimens.

Larix kaempferi (Lamb.) Carr.

Plate 9, Figs. 1a—c, 2a—c, 3, 4a—c, 5a—c, 6a—c, 7, 8a—c, 9a, b, 10a—e, 11a, b, 12, 13

Larix kaempferi (Lamb.) Carr., Ohwi and Kitagawa, 1983, p. 60

Larix kaempferi Sargent, Miki, 1938, p. 229, pl. 3, figs. A—C.

Larix leptolepis Murr., Miki, 1956, p. 450, pl. 13, fig. H.

Larix kaempferi Sargent, Miki, 1957, p. 233, pl. 1, C.

Description:—Cones elliptical to ovate, rarely globularly ovate, 1.6—2.5 cm in length, 1.0—1.5 cm in width, maximum width situated below the half way in its entire length, with 25—35 cone-scales, rarely with about 20 cone-scales, and with thick cone-stalk. Cone apex round to obtuse. Cone-axis stout, with stiff hairs. Cone-scales orbicularly fan-shaped, upper margin generally round or recurving downwards, ca. 0.5—0.8 cm long. Bracts short and rectangular, with a needle-like apex. Long shoots having many short shoots, and interval between short shoots on the long shoot generally wide.

Remarks and comparison:—Most of the fossil cone specimens are preserved in somewhat flattened state and some are incomplete. The cone obtained at the Bange locality lacks the upper portion (Fig. 7) and the one from Nakano-iri is missing the lower portion (Fig. 6). However, most of the specimens are well preserved.

Many cone remains are from elliptical to ovate in shape and bear a large number of cone-scales of which upper margin recurves downwards. These characteristics as seen in the fossil cones are identical to those of the extant species, *Larix kaempferi* (Lamb.) Carr., although many of the fossil cones are somewhat smaller than the Recent cones.

The shape of some fossil cones ranges from ovate to globular ovate. These fossil cones are somewhat small in size and have cone-scales of which upper margin recurves less distinctly downwards (Figs. 1, 10e, 13). These features are also found commonly on the cones of young trees of extant *Larix kaempferi* (Lamb.) Carr., as shown in Plate 9, Fig. 15.

Some long shoots obtained from the upper part of the Saru-uchi II Formation and the upper part of the Fujita Formation could be identified as those of *L. kaempferi* (Lamb.) Carr. on account of the wider intervals between short shoots on the long shoot.

Locality and stratigraphic horizon:—As shown in Table 1, the fossil specimens are obtained from twelve localities of which ten are in the southern part of Tohoku District (Fukushima Prefecture), one in the District of Tokyo, and one in Karuisawa City of Nagano Prefecture. Among these ten fossil localities in Fukushima Prefecture, two fossil-bearing beds having a stratigraphical interval of 7 m and 2 m occur at Negishi and south of the Kori Station, respectively.

Among these twelve localities mentioned above, fossil-bearing beds at three localities belong to the first half of the Last Glacial age older than 32,000 y. B.P. based on radiocarbon dates. These are the lower part of the Fujita Formation, the Nihonmatsu Formation and the lower part of the Ootsuki Formation. Eleven fossil-bearing beds at the remaining ten localities belong to the latter half of the Last Glacial spanning a period from ca. 30,000 y. B.P. to 13,000 y. B.P. radiocarbon dates. These are: peat beds of the Fifth terrace deposits in the coastal area of Fukushima Prefecture, upper part of the Fujita Formation, lower part of the Ootsuki Formation, upper part of the Saru-uchi II Formation, the Sunagawa Formation and the Konan Formation, and a peat bed in Bange, a silt bed overlying the Kumoba pumice flow and a peaty bed of the Ekoda Formation.

Repository:—Stored in the Laboratory of Earth Science, Faculty of Education, Fukushima University.

Other occurrence:—The cone remains referred to those species discussed in this study were reported from the conifer bed at Ekoda in Tokyo (Miki, 1957, p. 233, pl. 1, C).

Larix cf. *kaempferi* (Lamb.) Carr.

Plate 9, Figs. 14a—c

Remarks and comparison:—A somewhat poorly preserved cone remain was obtained from the upper part of the Takada Formation assignable to a late Early or early Middle Pleistocene age. This specimen with numerous cone-scales (more than 30) is small in size (1.4 cm long) and has an ovate shape. The upper margin of these cone-scales is somewhat recurved downwards, though some of their outer structures are ragged.

This cone specimen resembles cones of an extant species *L. kaempferi* (Lamb.) Carr., but is distinct in having a large number of cone-scales despite of its small size. Therefore, the present writer is withholding specific identification of this specimen.

Repository:—Stored in the Laboratory of Earth Science, Faculty of Education, Fukushima University.

Geographical Distribution in the Northeast Japan during the Latter Half of the Last Glacial Age

From the preceding chapters, it becomes clear that both *Larix kamtschatica* (Rupr.) Carr. and *L. kaempferi* (Lamb.) Carr. were distributed somewhere in the southwestern Hokkaido, Tohoku and Kanto Districts of northeastern Japan during the latter half of the Last Glacial. However, there is no locality where the specimens of both species occurred together. During that time, *L. kamtschatica* (Rupr.) Carr. had its distribution in the southwestern part of Hokkaido and in the northern part of Tohoku District. On the other hand, *L. kaempferi* (Lamb.) Carr. had been distributed mostly in the southern part of Tohoku District and Kanto District, though its distribution might have been more restricted in time and space in Kanto District. In other words, fossil remain identifiable with *L. kamtschatica* (Rupr.) Carr. has never been found in the southern part of Tohoku District and Kanto District, although remains of the genus *Larix* were obtained from many sites. On the other hand, no remain identifiable with *L. kaempferi* (Lamb.) Carr. has been found in the southwestern part of Hokkaido and in the northern part of Tohoku District, although remains of the genus *Larix* were abundant at four sites. This observation may indicate that geographical ranges of both species had roughly been divided in the middle part of Tohoku District on the eastern side of Ohu Backbone Range. However, it is not clear as to whether these two species had been isolated from each other or occurred together in the vicinity of the boundary. In any case, geographical ranges of these two species had been close to each other far more than they are at the present time.

It is noteworthy that the northern geographical limit of *L. kaempferi* (Lamb.) Carr. during the latter half of the Last Glacial was not greatly different from that at the present time, whereas the southern geographical limit of *L. kamtschatica* (Rupr.) Carr. during that time was greatly shifted from its present distribution. Furthermore, it must also be pointed out that these two species were representatives of lowland floras of northeastern Japan during the latter half of the Last Glacial as evidenced by their presence in the fossil-bearing beds at each locality.

Fossil remains of *Picea bicolor* (Maxim.) Mayr, *P. maximowiczii* Regel and *Abies veitchii* Lindl. occur commonly in association with those of *Larix kaempferi* (Lamb.) Carr. as shown in Table 1. All of these are, however, not found in beds yielding remains of *L. kamtschatica* (Rupr.) Carr. Fossils of *Picea glehni* (Fr. Schm.) Masters and *Abies sachalinensis* (Fr. Schm.) Masters are common in beds bearing those of *Larix kamtschatica* (Rupr.) Carr., whereas they are absent in beds containing remains of *Larix kaempferi* (Lamb.) Carr. Such species as *Pinus koraiensis* Sieb. and Zucc. and *Picea jezoensis* (Sieb. and Zucc.) Carr. have been found in beds bearing remains of *Larix kaempferi* (Lamb.) Carr. or *L. kamtschatica* (Rupr.) Carr. in the Tohoku District, and fossil specimens of *Picea jezoensis* (Sieb. and Zucc.) Carr. have been recovered also in beds yielding remains of *Larix kamtschatica* (Rupr.) Carr. in the southwestern part of Hokkaido. From these observations, it may be suggested that the boundary between the geographical ranges of *Larix kaempferi* (Lamb.) Carr. and *L. kamtschatica* (Rupr.) Carr. had nearly coincided with the respective floral and vegetational boundaries in the northeastern Japan during the latter half of the Last Glacial age.

Acknowledgments

I wish to express my sincere thanks to Prof. Kankichi Sohma, Tohoku University, for his kind advice and giving permission to examine the specimens in his collections, and Prof. Tsunemasa Saito, Yamagata University, for reading the manuscript and his helpful critisism. My thanks are also due to Mr. Makio Yano, Historical Museum of Hokkaido, Mr. Susumu Osawa, Wako-gaku-en High School, and the members of Kanto Loam Research Group and Shinshu Loam Research Group, for their kind assistances. Furthermore, my thanks are extended to Mr. Toshio Watanabe, Fukushima University, for his kind assistance in photographying.

References

Kanto Loam Research Group and Shinshu Loam Research Group (1962): On the Geological Age and Sedimentary Environment of the Hanaizumi Bed. *Earth Science* (*Chikyukagaku*), vol. 16, no. 62, p. 1—10; no. 63, p. 10—18 (in Japanese).

Komarov, L. V. (1968): The Genus *Larix*. in Flora of the U.S.S.R. I, p. 120—124. Jerusalem (translated from Russian edition, 1934, Leningrad).

Miki, S. (1938): On the change of flora of Japan since the upper Pliocene and the floral composition at the Present. *Jap. Journ. Bot.* vol. 9, p. 214—251.

——(1956): Remains of *Pinus koraiensis* S. et Z. and associated remains in Japan. Bot. Mag. Tokyo, vol. 69, p. 447—454.

——(1957): Pinaceae of Japan, with special reference to its remains. *Journ. Inst. Polytech. Osaka City Univ.*, vol. 8, ser. D, p. 221—272, pls. 1—10.

Ohwi, J. and Kitagawa, M. (1983): The Genus *Larix*. in New Flora of Japan, p. 60. Shibundo, Tokyo (in Japanese).

Sohma, K. (1959): On woody remains from a Pleistocene peaty lignite at Otai, Aomori

Prefecture. *Ecol. Rev.*, vol. 15, no. 2, p. 67—70.

Suzuki, K., Manabe, K. and Yoshida, T. (1977): The Late Cenozoic stratigraphy and geologic development of the Aizu Basin, Fukushima Prefecture, Japan. *Mem. Geol. Soc. Japan*, no. 14, p. 17—44 (in Japanese with English abstract).

—— and Nakagawa, H. (1971): Late Pleistocene flora from the Pacific coast of Fukushima Prefecture, Japan. *Sci. Rep. Tohoku Univ., Sec. ser. (Geol.)*, vol. 42, no. 2, p. 187—198, pls. 27—30.

—— and Sohma, K. (1965): The Late Pleistocene stratigraphy and Palaeobotany of the Koriyama Basin. *Sci. Rep. Tohoku Univ., 4th ser. (Biol.)*, vol. 31, no. 3, p. 217—242, pls. 1—3.

——, Takeuti, S. and Seino, A. (1982): Terrace deposits in the southern part of the Inawashiro Basin. *Ann. Rep. Synthetic Study, Fukushima Univ., The Nature of Lake Inawashiro*, no. 3, p. 13—20 (in Japanese with English abstract).

—— and Yoshida, T. (1972): The geohistory of the formation of the Fukushima Basin in the southern part of the Tohoku District, Japan. *Mem. Geol. Soc. Japan*, no. 7, p. 285—295 (in Japanese with English abstract).

Takeuti, S. (1971): ^{14}C Age of the Sambongi Formation at Otai, Aomori Prefecture. *Earth Science (Chikyukagaku)*, vol. 25, no. 4, p. 186—187 (in Japanese).

Unozawa, A. and Sakamoto, T. (1972): Recent history of Minami-Karuizawa, Nagano Prefecture, Central Japan. *Journ. Geol. Soc. Japan*, vol. 78, no. 9, p. 489—494 (in Japanese with English abstract).

Yano, M. and Ishikari Teichitai Research Group (1969): On the remains of *Larix gmelinii* from the Quaternary deposits in the Ishikari Plain, Hokkaido. *The Quaternary Research*, vol. 8, no. 2, p. 44—48 (in Japanese with English abstract).

—— and Fujita, I. (1970): ^{14}C Age of the *Larix* bearing peat bed in the Ishikari Plain, Hokkaido. *Earth Science (Chikyukagaku)*, vol. 24, no. 3, p. 110—111 (in Japanese).

——, Mino, N., Yamada, G., Fuzita, I. and Onoe, H. (1975): On the plant fossils from

---

Explanation of Plate 8

Figs. 1—8. Fossil remains of *Larix kamtschatica* (Rupr.) Carr.

1a—j. Cones, x1.5; Loc. no. 1, Yosumizawa, Assabu-machi, Hiyama-gun, Hokkaido, River terrace deposits; e—j show flattened cones.

2a—f. a—e cones, f long shoot with a cone and short shoots, x1.5; Loc. no. 2, Higashiyama, Esashi-machi, Hiyama-gun, Hokkaido, Jinya terrace deposits; outer parts of cones somewhat destroyed, e and f lacking upper part of cone.

3a—i. a—e cones, x1.0, f—i cone-scales x 1.5; Loc. no. 3, Ootai, Nango-mura, Sannohe-gun, Aomori Prefecture, Sambongi Formation; a somewhat flattened, b—d somewhat destroyed in upper parts, b and d opening cones.

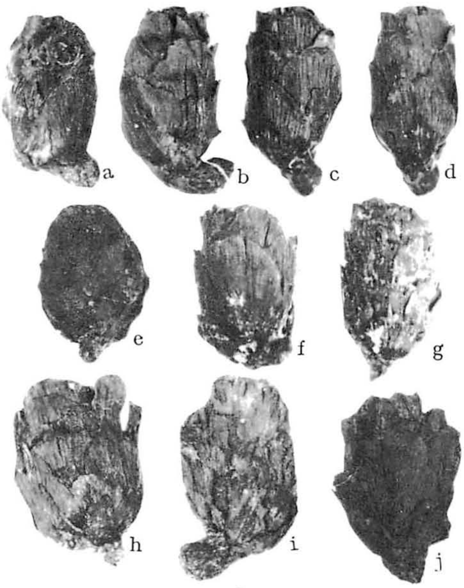
4a—g. Cones, x1.5; Loc. no. 4b, Kanamori, Hanaizumi-machi, Nishi-iwai-gun, Iwate Prefecture, Third peat of Hanaizumi Formation.

5a—e. Cone-scales x1.5; Loc. no. 4b, Kanamori, Hanaizumi-machi, Nishi-iwai-gun, Iwate Prefecture, Third peat of Hanaizumi Formation.

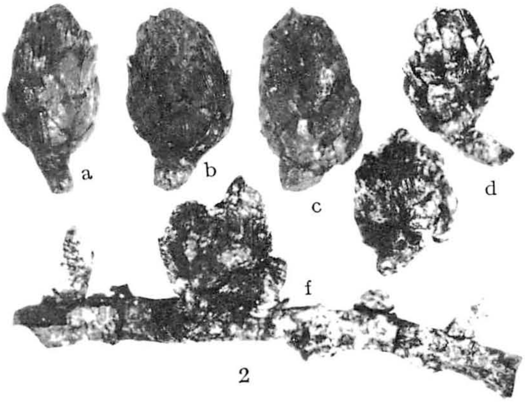
6a—o. Cones with various shapes, x1.0; Loc. no. 4b, Kanamori, Hanaizumi-machi, Nishi-iwai-gun, Iwate Prefecture, Third peat of Hanaizumi Formation; g, k—o outer parts somewhat destroyed.

7a—j. Cones, a—g x1.0, h—j x 1.5; Loc. no. 4c, Kanamori, Hanaizumi-machi, Nishi-iwai-gun, Iwate Prefecture, Fourth peat of Hanaizumi Formation; h—j enlarged figures of f, b and a.

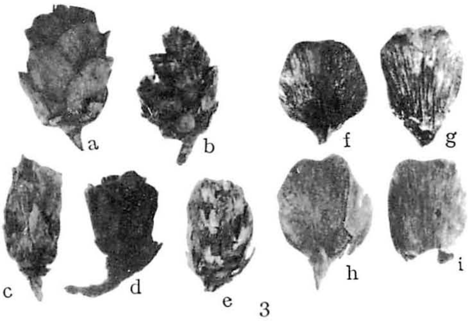
8a—r. Cones, a—k x1.0, l—r x1.5; Loc. no. 4a, Kanamori, Hanaizumi-machi, Nishi-iwai-gun, Iwate Prefecture, Second peat of Hanaizumi Formation; j shows transversed section, l—o somewhat destoyed in outer parts, b lacking upper part.


a
b
c
d
e
f
g
h
i
j

1


a
b
c
d
f

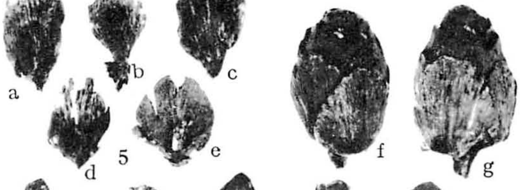
2


a
b
f
g
c
d
e
h
i

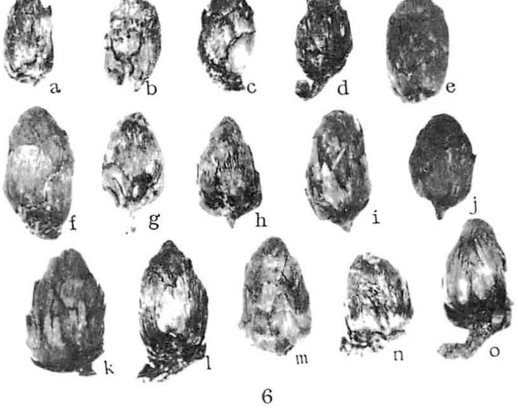
3


a
b
c
d
e

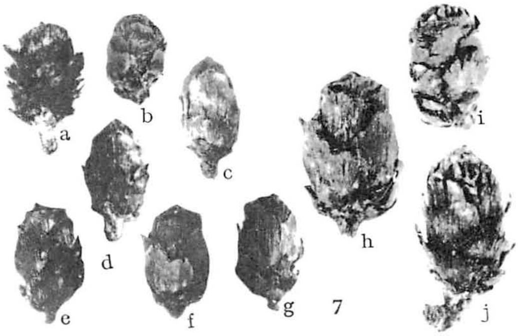
4


a
b
c
d
e
f
g

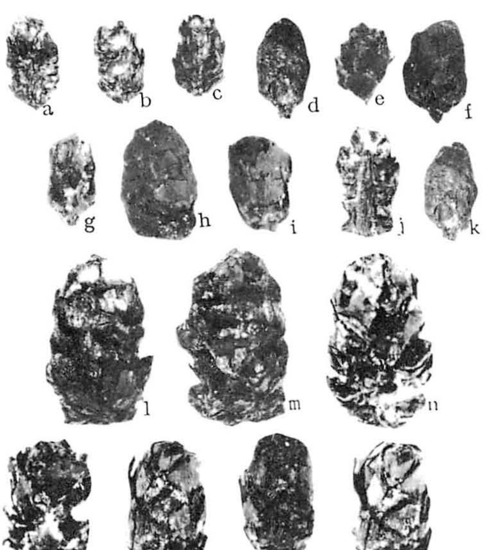
5


a
b
c
d
e
f
g
h
i
j
k
l
m
n
o

6


a
b
c
d
e
f
g
h
i
j

7


a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r

8

Quaternary deposits in the Oshima Peninsula, Hokkaido. *Mem. Hist. Mus. Hokkaido*, no. 9, p. 15—21 (in Japanese with English abstract).

——, Mino, N., Yamada, G. and Nakata, M. (1978): On the plant fossils from Quaternary deposits in Oshima Peninsula, Hokkaido, II. *Ann. Rep. Hist. Mus. Hokkaido*, no. 6, p. 13—20 (in Japanese with English abstract).

Yoshida, T., Ito, S. and Suzuki, K. (1969): Quaternary chronology along the middle and lower courses of the Abukuma River in the southern part of the Tohoku District, Japan. *Monogr. Assoc. Geol. Collab. Japan*, no. 15, p. 99—125 (in Japanese with English abstract).

——and Suzuki, K. (1981): On the Quaternary strata in the southern piedomont area of Mt. Bandai, Fukushima Prefecture, Japan. *Ann. Rep. Synthetic Study, Fukushima Univ., The Nature of Lake Inawashiro*, no. 2, p. 15—26 (in Japanese with English abstract).

——, Ito, S., Shirase, M., Hori-uchi, T., Manabe, K., Suzuki, K., Takeuti, S., Nonaka, T., Nirei, Y. and Nirei, N. (1981): On the Quaternary strata and plant fossil assemblages in the central Abukuma Mountains, with special reference to changes of vegetation in the southern Tohoku District during the Last Glacial Age. *The Quaternary Research*, vol. 20, no. 3, p. 143—163 (in Japanese with English abstract).

Hara 原, Higashiyama 東山, Kanamori 金森, Kamiza 神座, Kori 桑折, Kumoba 雲場, Nakano-iri 中ノ入, Negishi 根岸, Ogawa 小川, Ookawa 大川, Ootai 大平, Ozaki 尾崎, Saru-uchi 猿内, Sunagawa 砂川, Takatori 高取, Wakamiya 若宮, Yosumizawa 四隅沢

東北日本の更新統産 *Larix* 属化石ーとくに最終氷期後半における *Larix* 属の分布：東北日本の更新統から産した *Larix* 属の毬果と長枝の化石の形態的特徴を検討した。それらは2つの現生種（*Larix kaempferi* (Lamb.) Carr. と *L. kamtschatica* (Rupr.) Carr.）と *L.* cf. *kaempferi* (Lamb.) Carr. に同定あるいは比較される。2つの種に同定された化石はすべて最終氷期の地層から得られた。ただ1つの *L.* cf. *kaempferi* (Lamb.) Carr. に比較される化石が前期あるいは中期の更新世の地層から得られている。*L. kamtschatica* (Rupr.) Carr. と *L. kaempferi* (Lamb.) Carr. の地理的分布範囲は，現在よりも最終氷期後半の時期においては，たがいにより接近していたことが指摘される。 鈴木 敬治

Explanation of Plate 9

Figs. 1—13. Fossil remains of *Larix kaempferi* (Lamb.) Carr.

1a—c. Cone, x1.0; Loc. no. 5, Ogawa, Shinchi-mura, Sohma-gun, Fukushima Prefecture, Fifth terrace deposits; a oblique view, b lateral view, c apical part.

2a—c. Cone, x1.0; Loc. no. 6b, Negishi, Kori-machi, Date-gun, Fukushima Prefecture, Upper Part of Fujita Formation; a—c lateral views from different angles.

3. Cone, x1.0; Loc. no. 6a, Negishi, Kori-machi, Date-gun, Fukushima Prefecture, Lower part of Fujita Formation.

4a—c. a, b lateral views of cone, c long shoot, x1.0; Loc. no. 7a, South of Kori Station, Kori-machi, Date-gun, Fukushima Prefecture, Upper part of Fujita Formation.

5a—c. a, b lateral views of cone (Outer part of cone somewhat destroyed), c cone-axis, x1.0; Loc. no. 12, Sunagawa, Inawashiro-machi, Yama-gun, Fukushima Prefecture, Sunagawa Formation.

6a—c. a—c lateral views of cones (Outer part of cones more or less destroyed), x1.0; Loc. no. 13, Nakano-iri, Konan-machi, Koriyama-City, Fukushima Prefecture, Konan Formation.

7. Cone lacking apical part, x2.0; Loc. no. 14, Ookawa River, Bange-machi, Kawanuma-gun, Fukushima Prefecture, Peat bed overlaid by Holocene gravel.

8a—c. Long shoots with short shoots, x1.0; Loc. no. 11, Saru-uchi, Takine-machi, Tamura-gun, Fukushima Prefecture, Upper part of Saru-uchi II Formation.

9a, b. Cones, x1.0; Loc. no. 10, Hara, Katabira-machi, Koriyama City, Fukushima Prefecture, Lower part of Ootsuki Formation.

10a—e. Cones, a—c x1.0, d, e x1.5; Loc. No. 9, 500 m north of Kamiza, Motomiya-machi, Adachi-gun, Fukushima Prefecture, Lower part of Ootsuki Formation.

11a, b. Cone-scales, x1.0; Loc. no. 9, 500 m north of Kamiza, Motomiya-machi, Adachi-gun, Fukushima Prefecture, Lower part of Ootsuki Formation; a outer side, b inner side.

12. Cones, x1.0; Loc. no. 15, Cliff of Kuboma River, Minamikaruizawa, Karuizawa City, Nagano Prefecture, Silt bed overlying Kumoba punice flow; middle one lacking apical and basal parts.

13. Cones, x1.0; Loc. no. 16, Ozaki, Egota, Nerima-ku, Tokyo Prefecture, Ekota Formation; middle one lacking apical part.

Figs. 14a—c. Cone remain of *Larix* cf. *kaempferi* (Lamb.) Carr. a x1.0, b, c enlarged figures, lateral views from different angles, x2.0; Loc. no. 17, Takatori, Nakano, Fukushima City, Fukushima Prefecture, Takada Formation.

Figs. 15, 18. *Larix kaempferi* (Lamb.) Carr. (extant) for comparison.

15. Cones and long shoot with cones attached to young tree cultivated in ground of Fukushima University, Matsukawa-machi, Fukushima City; x1.0.

18. Long shoots with cone and short shoots attached to tree growing wild in Mt. Yatsugadake, Nagano Prefecture; x1.0.

Figs. 16, 17. *Larix kamtschatica* (Rupr.) Carr. (extant) for comparison.

16. Cones attached to tree cultivated in Nopporo Park, Sappro City; x1.0.

17. Long shoots with cone and short shoots attached to tree cultivated in Nopporo Park, Sappro City; x1.0.


a
b
c
1
c
a
5
b
a
b
c
6
a
b
2
c
7
a
b
8
c
12
3
a
4
b
c
a
9
b
13
a
b
c
10
d
e
a
11
b
a
14
b
c
15
a
16
17
18

PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本古生物学会創立50周年記念式典・祝賀会

日本古生物学会創立50周年記念式典および祝賀会が1985年2月1日に国立科学博物館で開催された。

1) 開会の辞
2) 会長式辞
3) 来賓祝辞
4) 名誉会長挨拶　小林貞一
5) 創立時以来の会員に感謝状贈呈
6) 特別講演「模式標本にまつわる話」花井哲郎
7) 閉会の辞

記念祝賀会

日本古生物学会1985年会・総会

日本古生物学会年会・総会が1985年2月2日，3日に国立科学博物館および東京大学理学部を会場として開催された（参会者279名）。

海外学術集会出席報告

韓国古生物学会設立記念国際シンポジウム 1984, 10.8〜11, ソウル）........木村達明・浜田隆士
第6回国際パリノロジー会議（VI I·P·C)(1984, 8.26〜9.1, カルガリー）............高橋　清
第2回国際古植物学会議（2nd I·O·P·C)(1984, 8.18〜26, カルガリー・エドモントン）............ 棚井敏雅・木村達明・西田治文ほか13名
3rd Latinoamerican Palaeontological Congress (1984, 10.14〜22 メキシコ）........木村達明

特　別　講　演

Cythere 属（介形虫）の地理的分布と種分化 .... 池谷仙之
北太平洋東西両岸海域の現世底生有孔虫群とその深度分布 ....的場保望

50周年記念普及講演

人間と化石 ....小畠郁生
小さな小さな化石 ....斎藤常正
大きな動物を復元する ....長谷川善和
地学映画会　氷河時代の日本 ......亀井節夫ほか

個　人　講　演

完新世奈良盆地の花粉分析 ―稲作起源を探る― .... 小島夏彦・Barnes, G. L.
Xenoxylon の放射柔組織の細胞高について .... 山崎純夫・綱田幸司・朴　鉄洙
北海道産白亜紀花化石の構造と類縁 .... 西田治文・西田　誠
Dipteridaceae from the Upper Triassic Mine Group in Yamaguchi Prefecture, Japan (4) ....Naito, G.
韓国忠清南道忠南炭田，白雲寺（Baegunsa）層より *Lobatannularia* ほか二畳紀遺存植物の発見.................... 木村達明・金　鐘憲
銚子層群（下部白亜系）から産出した Cheirolepidiaceous conifer .... 木村達明・齋木健一・荒井恒子
銚子層群（下部白亜系）から産出した *Nilssonia* 類の表皮構造 ....大久保敦・木村達明
中北部九州，後期新生代の化石植物群，その2・安心院地域 ....長谷義隆・岩内明子
北日本の古第三紀ブナ科 (Fagaceae) 化石葉の再検討 ....棚井敏雅
植物系統論における問題点について ....浅間一男
東アジアのペルムトリアス紀古生物地理に関する2・3の問題 ....市川浩一郎
Cretaceous Corbulidae from Japan. Part II, *Caestocorbula* and *Nipponicorbula*. .Kozai, T.
Two new species of the Lower Cretaceous corbiculoid in Shikoku.................................... Tashiro, M. and Onishi, T.
On the *Plicatounio* (Cretaceous nonmarine bivalvia) from Korea ....梁　承栄
A note on an inoceramid species (Bivalvia) from the Lower Coniacian (Cretaceous) of Hokkaido......Matsumoto, T. and Noda, M.
A new species of *Inoceramus* (*Cordiceramus*) (Bivalvia) from the Upper Cretaceous of Hokkaido ....Noda, M.
北海道小平・大夕張地域上部白亜系の化石層序 .... 浅井明人・平野弘道・松本達郎
北海道達布地域の上部白亜系にみられる底生動物群集と古環境 ....前田晴良

白亜紀アンモナイト類数種の殻体形質の集団内変異 ......久門賢治・棚部一成

カニ類に捕食された白亜紀アンモナイト殻 ......蟹江康光・林　俊一

Barremian ammonites from the Ishido Formation, Japan ......Matsukawa, M.

Some gaudryceratid ammonites from the Campanian and Maastrichtian of Hokkaido ......Matsumoto, T.

異常巻きアンモナイト *Nipponites* の理論形態 ......岡本　隆

Akiyoshiceras, a new Carboniferous goniatite from the Akiyoshi Limestone Group ......Kyuma, Y. and Nishida, T.

Morphologic analysis of *Nautilus pompilius* from the Fiji Islands ......Tanabe, K., Hayasaka, S. and Oki, K.

Radiolarian assemblages and their relationship to the oceanic conditions in the Northeast Pacific ......Yamaguchi, M.

Nassellaria（放散虫）の内部構造と分類について ......竹村厚司

日本のジュラ系放散虫化石分帯 ......松岡　篤・八尾　昭

東京都五日市町付近の秩父帯より産する前期ジュラ紀放散虫 ......指田勝男・遠西敬二

Paleocene Radiolaria at Site 384, DSDP（予報） ......Nishimura, A.

Fusulinacean biostratigraphy of the Akasaka Limestone, Central Japan ......Kawai, K. and Ozawa, T.

Gradual evolution in some neoschwagerinid lineages from the Akasaka Limestone ......Ozawa, T. and Kawai, K.

帝釈石灰岩の *Parafusulina* 帯の紡錘虫について ......佐田公好・福多亮子

Tethys and peri-Gondwana faunal provinces of smaller Foraminifera in the Late Permian ......Okimura, Y. and Ishii, K.

栃木県葛生町秋山川上流における石灰岩より産する三畳紀コノドントについて ......佐藤良嗣・小久保珠実

関東山地南部，浦山層群より産出した二畳紀コノドント ......猪郷久治・久田健一郎

Miocene ostracoda from Mizunami, central Japan ......Yajima, M.

Plio-Pleistocene ostracoda from the Tsugaru Basin, North Honshu ......Tabuki, R.

八代海北部に分布する貝形虫 ......岩崎泰頴

Recent marine ostracodes from Korea ......崔　桂林

アマモ場のオストラコーダ その1—生息場所と殻形態の関係 ......神谷隆宏

潮間帯の底生二枚貝類の現世古生態学—愛媛県河原津海岸を例として—その1，生貝および遺骸集団の分布と産状 ......棚部一成・藤木　透・勝田　毅

同上—その2，分布と成長様式からみたクチバガイ（*Coecella chinensis*）とカガミガイ（*Phacosoma japonicum*）の生存戦略 ......勝田　毅

軟体動物 *Cyclina sinensis* の遺骸生産の長期観察 ......下山正一

カキの殻構造と生活様式の関係 ......鎮西清高

二枚貝殻中の古潮汐パターンの復元法 ..大野照文

日本産 *Volachlamys* の分類と進化（予察） ......速水　格

台湾省脊稜山脈産古第三系化石について ......菅野三郎・橋本　亘・林　朝棨

種子島，屋久島近海の腕足動物群集構造　郡司幸夫

新潟地域の新生代こけ虫化石 ......西澤康男

下北半島新第三系浜田層中のウニによる生痕化石 ......山口寿之・金沢謙一

Isocrinidae（ウミユリ）の形態と分布の地史的変化 ......大路樹生

喜界島に分布する更新統石灰岩産サンゴのウラン系列年代に関する新資料 ......大村明雄・辻　喜弘・大村一夫・桜本勇治

イシサンゴ骨格を用いた海洋の放射性炭素濃度測定 ......佐藤野広・今井敏夫・小西健二

イシサンゴ骨格の示す古水温　井口真仁・小西健二

小笠原海台産造礁性生物化石と石灰岩 ......小西健二・畠　周平・加瀬友喜・高山俊昭・井口真仁・小林和男・石井輝秋・仲　二郎ほか KH84—I 次航海乗船者

日本周辺の海山産石灰藻化石 ......小西健二

琉球層群に含まれる rhodoliths の特徴について ......井龍康文

Mortality of a Pleistocene solitary coral, *Fungiacyathus kikaiensis* (Yabe and Eguchi) ......Mori, K.

中新世の化石サンゴ礁 ......門田真人・末包鉄郎・浜田隆士・中山克己

沖縄県石垣島の現世造礁サンゴ類の群集構造 ......中森　亨・高橋達郎・木庭元晴

沼サンゴは自生？......山口寿之・北村久仁子・松島義章

模式地における鳥ノ巣石灰岩の岩相および化石相について ......狩野彰宏

Notes on the genera *Labechiella* and *Labechiellata* (Stromatoporoidea) ......Mori, K. and Kato, M.

Heterocorallia from the Akiyoshi Limestone, Southwest Japan, Part 2. Biostratigraphy and correlation................Sugiyama, T.

A new tremanotiform bellerophontacean from the Devonian Fukuji Formation .... Nishida, T. and Niko, S.

Mode of life of an open coiling gastropod *Semitubina sakoi*, n. sp. from the Silurian of Shikoku, Japan..................Kase, T.

南部北上山地の長岩層産腕足類 *Choristites*.... .... 田沢純一

飛騨山地福地の石炭紀腕足類 *Striatifera, Gigantoproductus* ....田沢純一・加藤　誠

A new Siluro-Devonian brachiopod fauna from Fukuji, Gifu Prefecture, Central Japan.... .... Ohno, T. and Hoe, G. D.

スピッツベルゲン島のペルム系中にみられた有関節腕足類の古生態 ....中村耕二

阿武隈山地相馬地域の下部石炭系真野層産出三葉虫 ....高泉幸浩・橋本一雄・小泉　斉

北九州芦屋層群から発見された絶滅歯鯨類アゴロフィウスの頭骨化石について .... 岡崎美彦・長谷川善和

台湾海峡の澎湖動物群について 大塚裕之・潘常武

Correlation of mammalian fossil bearing deposits, southeastern Arizona, U. S. A. .... Tomida, Y.

慶尚層群産恐竜化石について ....梁　承榮

兜岩産蛙化石について .... 野苅家宏・長谷川善和・岡部　静

Ichthyoliths from deep-sea sediments of Penrhyn Basin, Southwestern Pacific Ocean ....Nishimura, A.

下部伊賀層群産の骨組織中に保存されていた Osteocyte の化石 ....奥山茂美・福田芳生

古琵琶湖層群伊賀油日累層より産出した化石骨中の Osteocyte について..奥山茂美・福田芳生

遺跡出土ニホンジカの齢構成からみた狩猟圧の時代変化と歯の小型化について ......小池裕子

九州西方海底コアの解析，その1，底生有孔虫 .... 北里　洋

同上，その2，*Paralia sulcata* の分布と大陸沿岸水の消長 ....谷村好洋

同上，その3，石灰質ナンノプランクトン .... 大山直美

同上，その4，放散虫 ....酒井豊三郎

同上，その5，浮遊性有孔虫および酸素同位体比 ....大場忠道

日本海（隠岐堆）コアの解析，その1，有孔虫および石灰質ナンノプランクトン .... 加藤道雄・高山俊昭

同上，その2，縄文・弥生時代の海洋環境解析 .... 小泉　格

下北半島北東部の新第三系層序と中期中新世珪藻化石群集 ....山口寿之・小泉　格・伊藤谷生

珪藻群集による北西太平洋鮮新世以後の古環境変遷 ....小泉　格

An evolutionary trend of *Reticulofenestra* and its related taxa based on biometrical data....:......Nishida, S. and Taguchi, K.

現世ギイムノディニウム・グループ（渦鞭毛藻）の発芽孔の形態とアクリターナ ......松岡数充

Nannofossils from some marine mangaese nodules, especially on their age and growth rate ....Yahagi, H. and Nishida, S.

大磯丘陵・第四系二宮層群の底生有孔虫群集 .. .. 武藤朝子・山口寿之・北里　洋

太平洋新第三系微化石層序学の展開，その1，浮遊性有孔虫分帯による沖縄・島尻層群の地質構造解析 ....氏家　宏

同上，その2，中期中新世堆積間隙の古海洋学 .... 氏家　宏

A standard Late Cenozoic microbiostratigraphy in southern Okinawa-jima, Part 1. Calcareous nannoplankton zones and their correlation to the planktonic foraminiferal zones. ....Tanaka, Y. and Ujiié, H.

栃木県下の第三紀層の有孔虫化石について（予報）................................青島睦治

日本産 Elphidid 科底生有孔虫について..野村律夫

鹿児島湾の底生有孔虫群集―その2，湾中央部 .... 大木公彦

Inner structure of some species of *Globigerina* and its phylogenic meaning........Ikeda, T.

岩礁地海藻帯に生息する底生有孔虫群集にみられる地理的平行現象について ....北里　洋

西郷泥岩の *Lepidocyclina* 新産地 .... 茨木雅子・土　隆一

土佐清水からの大型有孔虫について .... 松丸国照・木村公志

波照間島の有孔虫生層序 ....松丸国照

宇和島市周辺に分布する白亜系の微化石相と岩相 ....岡村　真

Geologic events across the Cretaceous/Tertiary boundary and recognition of the boundary in eastern Hokkaido, Japan........Saito, T., Kaiho, K., Yamanoi, T. and Okada, H.

Foraminifera from the Cretaceous/Tertiary boundary interval in the Mokawaruppu River section in eastern Hokkaido, Japan..Kaiho, K.

“若手”の勉強会（夜間小集会）

世話人（安藤寿男・前田晴良・
阿部勝巳・森田利仁）

世話人挨拶および会の主旨説明

オストラコーダによる古生物学 ....阿部勝巳

Cladistic analysis とその応用例—脊椎動物を例として .... 平山　廉・久家直之・三枝春生・渡部真人

形態形成の数理モデルについて ....梅田民樹

古生物学におけるモデル化について—連鎖系としての生物学的構造— ....郡司幸夫・森田利仁

総合討論

New members approved by the Council Meeting held on June 23, 1984

Ordinary Members

Arai, Tsuneko; Hayakawa, Hiroshi; Hayano, Hisamitu; Itoh, Hideki; Kim, Jong Heon; Kojima, Fumitoshi; Komori, Kazuo; Manabe, Makoto; Nakagawa, Tohru; Nikaido, Akinobu; Ohkura, Mitsuko; Okada, Daiji; Saegusa, Haruo; Shibuya, Masamichi; Shiraishi, Tateo; Takayasu, Katsumi; Tanaka, Noriko

New members approved by the Council Meeting held on January 31, 1985

Ordinary Members

Endo, Kazuyoshi; Ezaki, Yoichi; Horiuchi, Tadashi; Kawaguchi, Shiro; Katsuta, Tsuyoshi; Kishida, Youjirou; Kikuchi, Hitosi; Kurimoto, Chikao; Suzuki, Akihiko; Takagi, Kyo; Takizawa, Kanemitsu; Tasaka, Kuniko; Tokumoto, Tadashi

Withdrawing Members

Akai, Kozue; Ito, Tomio; Kawakami, Toru; Kushima, Yasuo; Nakamichi, Osamu; Naruse, Takehiko; Ogose, Sunao; Shibata, Toyokichi; Shimakura, Misaburo; Shiraki, Takayoshi; Shuzui, Haruo; Takenaga, Shigeo; Tsuruta, Sayuri; Uchida, Nobuo; Yokoyama, Michiaki

Deceased Members

Hisamitsu, Masao; Nishida, Shoichi

Fellows

Eto, Tetsuto; Harada, Kenichi; Koike, Hiroko; Matsuda, Tetsuo; Mori, Shinobu; Okami, Kazuyoshi; Okazaki, Yoshihiko; Okazaki, Yoshio; Okumura, Yoshitsugu; Ohmura, Kazuo; Ohno, Terufumi; Samata, Tetsuro; Takeuti, Sadako

行事予定

	開催地	開催日	講演申込締切
第134回　例会	大阪市立大学	1985年6月15,16日	1985年4月15日
1986年　年会・総会	東北大学・他	1986年1月31日～2月2日	1985年11月30日

講演申込先：113 東京都文京区弥生 2-4-16　日本学会事務センター　日本古生物学会　行事係

○第134回例会ではシンポジウム「化石放散虫の分類・生層序・古生物地理--最近の研究成果より」が予定されている。

お知らせ

今春から常務委員および常務委員の役割分担が大幅に変更になりました。会務の円滑を期するため，1985-86年度の本会関係の連絡先を用務別に記しておきますのでよろしく御協力下さい。

○会費の払込→お送りしている振込用紙で日本学会事務センター
○会費に関する問合せ→会計係：木村達明（東京学芸大学地学教室）
○常務委員会への連絡一般→庶務係：小畠郁生（国立科学博物館分館）
○住所変更・入退会申込→日本学会事務センター内日本古生物学会
○報告紀事への投稿→なるべく書留便で日本学会事務センター内日本古生物学会編集係〔原稿の完全コピー1部と投稿カードを同封または別送して下さい。投稿にあたっては編集出版規約（No. 121）と原稿作成上のお願いを参照して下さい。報告紀事に関する問合せ・投稿カードの請求も上記にお願いします〕
○本会所蔵の図書閲覧の問合せ→速水　格（東京大学理学部地質学教室）〔No. 120 に外国誌の目録と利用案内を掲載してあります〕
○特別号に関する問合せ・購入申込→特別号編集委員会：柳田寿一（九州大学理学部地質学教室）（三和銀行福岡支店普通預金口座 12172；振替　福岡 19014）
○“化石”に関する問合せ・投稿・バックナンバー→化石編集部：高柳洋吉・石崎国熙（東北大学理学部地質学古生物学教室）
○各種の賞に関する問合せ・推薦依頼→賞の委員会幹事：速水　格（1985年度のみ）

○文部省科学研究費補助金（研究成果刊行費）による。

1985年4月25日　印　刷
1985年4月30日　発　行

ISSN 0031-0204
日本古生物学会報告・紀事
新篇 137号
2,500円

発行者　日本古生物学会
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）
（電話 03－815－1903）

編集者　猪郷久義・浜田隆士

印刷者　東京都練馬区豊玉北2ノ13
学術図書印刷株式会社　富田　潔
（電話 03－991－3754）

Transactions and Proceedings of the Palaeontological
Society of Japan

New Series No. 137 April 30, 1985

CONTENTS

TRANSACTIONS