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The ostracod carapace on the cover is an adult specimen of *Manawa konishii* NOHARA (Suborder Palaeocopina, Family Punciidae) from the East China Sea. (photo by K. ABE, x190)

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769. NOTES ON THE SO-CALLED *INOCERAMUS JAPONICUS* (BIVALVIA) FROM THE UPPER CRETACEOUS OF JAPAN*

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Abstract. In this paper, *Inoceramus japonicus* Nagao et Matsumoto, 1940 is discriminated into *I. (Platyceramus) higoensis* sp. nov., *I. (Pl.) japonicus hokkaidoensis* subsp. nov., and *I. (Pl.) japonicus japonicus*, which approximately correspond to forma α, β and γ of the original description, respectively. And *I. (Pl.) higoensis* is subdivided into *I. (Pl.) higoensis higoensis* and *I. (Pl.) higoensis* subsp.

At first I mention the procedures of the specific and the subspecific discrimination at population level. Some selected characters are biometrically and statistically examined by means of the Student's *t*-test, the rejection ellipse, 75 percent rule and analysis of the relative growth. Then I give the specific and subspecific definition of the above taxa, comparing them with already known species. Finally I discuss the phylogenetic relationships of the concerned species and subspecies.

Introduction

Inoceramus japonicus Nagao et Matsumoto, 1940, is a good index of the Upper Santonian of Japan. Before that date the specific name, without defintion, was used tentatively by Sasa (1932), for the specimens from the Kunitan Formation of the Kuji Group, Northeast Japan. Nagao and Matsumoto (1940) examined many specimens from various localities of Japan and South Saghalien and recognized three forms in the species, denominating them as forma α, β and γ. Subsequently the succession of the species and its relationship with *I. ezoensis* Yokoyama from the Santonian of Japan were discussed by Matsumoto (1959). Matsumoto and Ueda in Ueda (1962) designated Sasa's specimen (Nagao and Matsumoto, 1940, pl. 9, fig. 1; Matsumoto and Ueda, 1962, pl. 24, fig. 1a, b; present paper, Pl. 41, Fig. 1) as the lectotype. This was forma γ of Nagao and Matsumoto.

On the other hand, the present species resembles closely the widespread species *I. undulatoplicatus* Römer, as has been already pointed out by Nagao and Matsumoto (1940), who suggested the possibility of the specific identity. Matsumoto and Ueda in Ueda (1962, p. 166) mentioned the reason of holding the specific name *I. japonicus* and furthermore proposed a problem as follows, "We expect that the statistic studies of the numerous specimens from selected provinces in the future might reveal that the variations overlap between the Japanese and Texas or European provinces and that the distinction on the average be rather subspecific. Until that the specific name *I. japonicus* is to be kept. The difference in the geological age between *I. japonicus* and *I. undulatoplicatus* can not also be overlooked. Whether the immediate ancestor is common or not is, therefore, another question to be settled."

The purpose of the present investigation is to work out the above mentioned problem by

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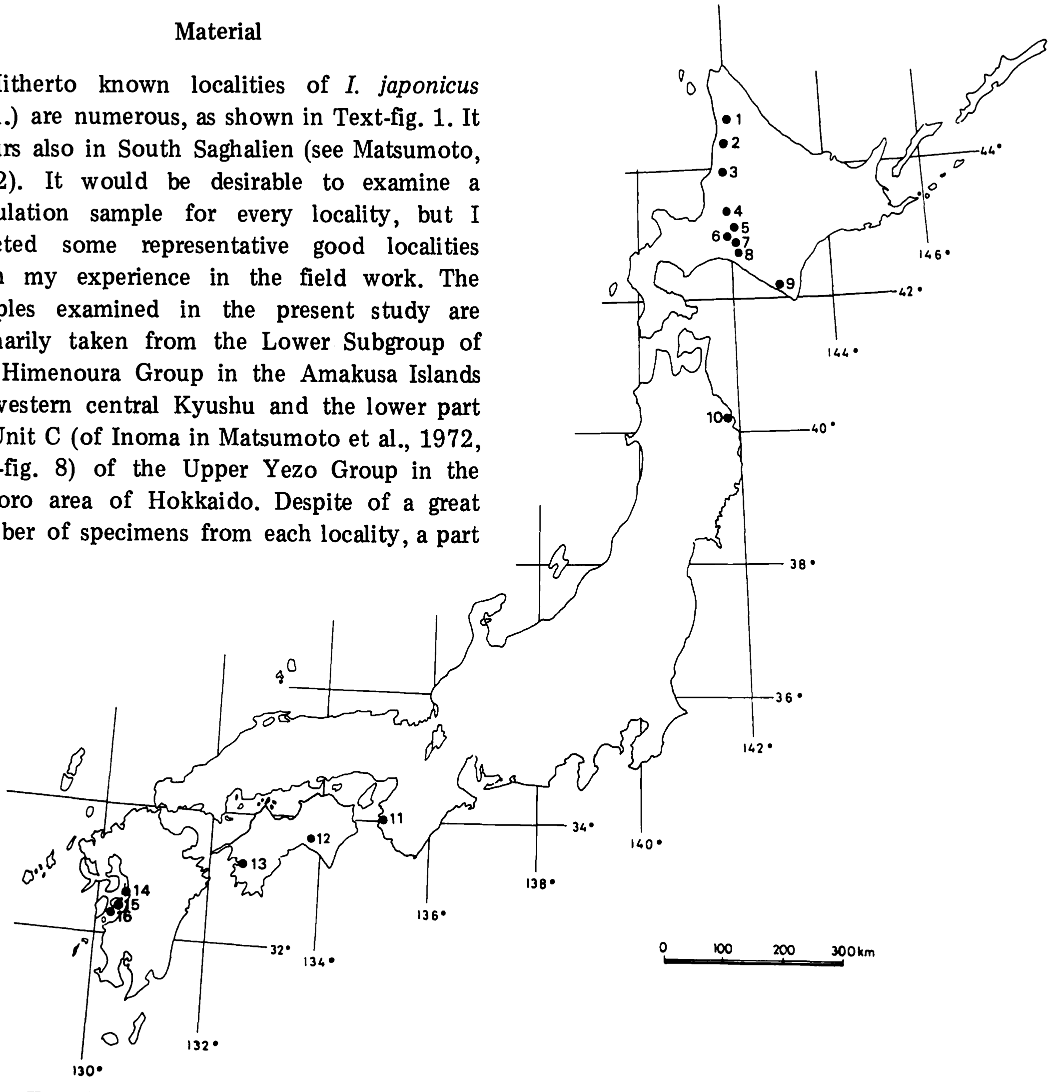
means of statistical methods of suitable samples collected by myself and others.

Although I have not yet dealt with enough samples of "*I. undulatoplicatus*" from the Texas and the European provinces, I report a result of my study on the samples of "*I. japonicus*" from selected areas of the Japanese province.

Material

Hitherto known localities of *I. japonicus* (s. l.) are numerous, as shown in Text-fig. 1. It occurs also in South Saghalien (see Matsumoto, 1942). It would be desirable to examine a population sample for every locality, but I selected some representative good localities from my experience in the field work. The samples examined in the present study are primarily taken from the Lower Subgroup of the Himenoura Group in the Amakusa Islands of western central Kyushu and the lower part of Unit C (of Inoma in Matsumoto et al., 1972, text-fig. 8) of the Upper Yezo Group in the Haboro area of Hokkaido. Despite of a great number of specimens from each locality, a part of them is available for measurements. Others are unsuitable for measurements due to more or less insufficient preservation or too small size for the standard dimension. The sample sizes for the selected characters are shown respectively in Table 1.

In addition to the above, as subsidiary material, samples from Uto Peninsula, Kunitan,



Text-fig. 1. Map showing the locations of *Inoceramus* (*Platyceramus*) *japonicus* and *I.* (*Pl.*) *higoensis*.

1: Abeshinai, 2: Haboro, 3: Obira, 4: Mikasa, 5: Yubari, Oyubari, 6: Hobetsu, 7: Tomiuchi, 8: Furenai, 9: Urakawa, 10: Kuji, 11: Aridagawa, 12: Kajisako, 13: Uwajima, 14: Uto, 15: Amakusa, 16: Shishijima.

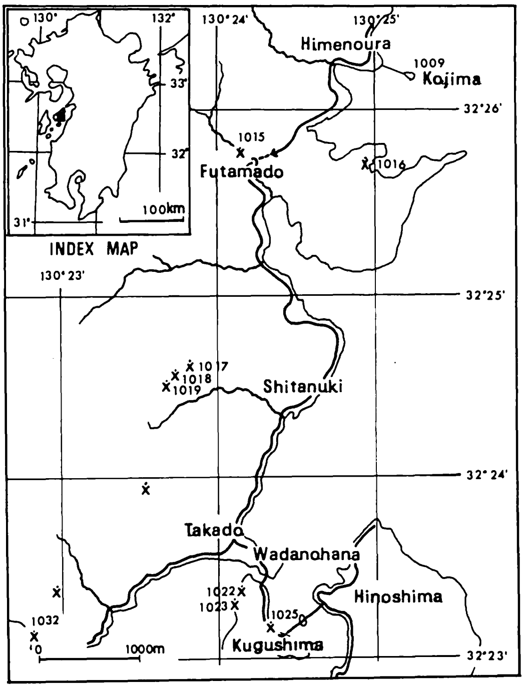
Table 1. Sample size for selected characters.

character		α	$h/l_{H=90mm}$	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$	rejection ellipse	relative growth	total number	
A	Kugushima	11	8	8	7	7	7	12	16	28
	Kojima								12	
B		7	6	5	5	5	5	9	9	

Tomiuchi, Kikume-zawa, Chikubetsu (Panke-zawa), Sankei (SK62), Nakahobetsu (Inasato 1), Kajisako and Kawakami (South Saghalien) are also examined. They consist of only a few specimens for each locality and insufficient for statistics, but used for some observation and measurements.

The examined specimens are probably allochthonous, but the distance between their habitat and place of burial is presumed to have been short, because they are often preserved as closed, articulated valves or little damaged and because it is hardly considered that large individuals more than 150 mm in shell height were transported for a long distance from the habitat to the embedded place where clay and silt deposited under a quiet condition.

The field work in Hokkaido was made together with Prof. Matsumoto, and the specimens of *Inoceramus* were all provided through the kindness of him.



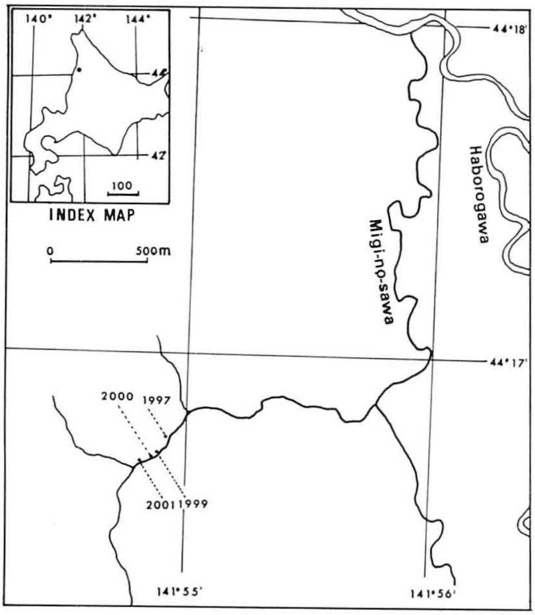
Text-fig. 2. Locality map of the Himenoura area.

Sample guide

Sample A-1 (see Text-fig. 2) Locality: HI 1023, on the western beach about 80 m southwestward from the mole, Kugushima, an islet of Amakusa Islands, administratively Ryugatake-machi, Amakusa-gun, Kumamoto Prefecture. Long. 130°24′08″E, Lat. 32°23′23″N (see topographic map, Takado Quad., 1:25000). Str. position: Upper part of the Middle Member, Lower Formation, Lower Subgroup, Himenoura Group (L-1-3 of Tashiro, 1976; K549, Lower part of I-d of Ueda, 1962). Mode of occurrence: Common in black shale about 40 cm in thickness, often with inarticulated valves disposed parallel to startification and somewhat crushed; together with *Eupachydiscus haradai* (Jimbo), *Protexanites (Anatexanites)* cf. *fukazawai* (Yabe et Shimizu), *Gaudryceras denseplicatum* (Jimbo), *Polyptychoceras obstrictum* (Jimbo), *P. haradanum* (Yokoyama). In addition, *Nucula* (s. s.) *amanoi* Tashiro, *N. (Leionucula) formosa* (Nagao), *N. (L.) nagaoi* Tashiro, *Acila (Trancacila) hokkaidoensis* (Nagao), *Glycymeris amakusensis* Nagao, *Naonavis sachalinensis* (Schmidt), *Apiotrigonia minor* (Yabe et Nagao), *Solemya augusticaudata* Nagao and *Sphenoceramus naumanni* (Yokoyama) are commonly associated.

Sample A-2 (see Text-fig. 2) Locality: HI 1009, on the northern shore of Kojima, near Himenoura, Himedo-machi, Amakusa-gun. Long. 130°26′12″E, Lat. 32°26′12″N (see topographic map, Himenoura Quad., 1:25000). Str. position: Lower part of the Middle Formation, Lower Subgroup, Himenoura Group (K26, 27, Lower part of II Formation of Ueda, 1962). Mode of occurrence: Abundant in a black shale layer of about 100 cm in thickness; commonly inarticulated valves of large individuals more than 150 mm in shell height, buried parallel to stratification and secondarily crushed; together with *Neophylloceras* cf. *ramosum* (Meek), *Hauericeras (Gardeniceras) angustum*, *Eupachydiscus haradai*, *Gaudryceras denseplicatum*, *Polyptychoceras obstrictum*, *P. haradanum*, *Nucula* (s. s.) *amanoi*, *N. (Leionucula) formosa*, *Ezonuculana mactraeformis* (Nagao), *Nanonavis sachalinenesis*, *Electroma shiranuiensis* Tashiro, *Parvamussium cowperi yubarense* (Yabe et Nagao), *Miltha* (s.l.) *amakusensis* Tashiro, *Inoceramus (Endocostea)* cf. *balticus toyajoanus* Nagao et Matsumoto and *Sphenoceramus* cf. *nagaoi* (Matsumoto et Ueda).

Sample B (see Text-fig. 3) Localities: Hb1997-2001, Migi-no-sawa, a tributary of the River Haboro at about 100 m—400 m downstream from the crossing of road and stream, Haboromachi, Tomamae-gun, Hokkaido; Long. 141° 53′48″E ~ 141°53′55″E, Lat. 44°16′40″N ~ 44°16′40″N (see topographic map, Horobetsuyama Quad., 1:25000). Str. position: Unit C, Upper Yezo Group of the Haboro Area, Santonian (see Matsumoto and Inoma, 1972, p. 189; text-fig. 8). Mode of occurrence: Common in calcareous nodules, generally well preserved; closed valves with well preserved test including a pearly layer; associated with *Gaudryceras tenuiliratum* Yabe, *Hauericeras (Gardeniceras) angustum*, *Menuites pusillus* Matsumoto, *Kitchnites (Neopuzosia) haboroensis* Matsumoto et Inoma, *K. (N.) ishikawai* (Jimbo), *Polyptychoceras (Subptychoceras) yubarense* (Yabe), *Damesites sugata* (Forbes) and *Sphenoceramus naumanni* (Yokohama).



Text-fig. 3. Locality map of the Haboro area.

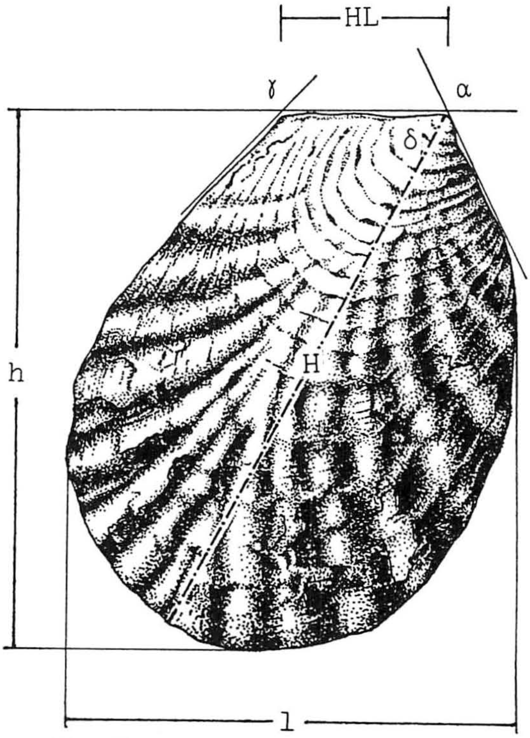
Sample. C (see Sasa, 1932 and Matsumoto and Ueda, 1962).

For the localities record of subsidiary specimens see the item of description and Text-fig. 1.

Method of analysis

Each of the samples examined in this study does not always represent one fossil population in a strict sense, but it has been obtained from one and the same stratigraphic unit within a limited area.

The following characters are statistically



Text-fig. 4. Basic morphology for measurements.

examined. The allometric characters are compared at a certain growth stage.

1. Anterior-hinge angle (α): angle between anterodorsal margin and hinge-line.
2. Obliquity of shell (δ): angle between hinge-line and line of H (H: maximum dimension from umbo to ventral extremity).
3. Number of divergent ribs. The anterior (Ra) and the posterior (Rp) ones respectively.
4. Simple ratio of shell height (h) to shell length (l) [h/l].
5. Simple ratio of shell height to shell length at the growth stage of 90 mm in H [$h/l_{H=90mm}$].
6. Simple ratio of length of hinge-line (HL) to shell height [HL/h].
7. Simple ratio of length of hinge-line to shell

Table 2. Measurements of sample A (Himenoura). linear dimension in mm.

specimen	valve	h	l	H	HL	α	δ	Ra , Rb
JG.H2701	R	36.3	32.0	39.0	16.9	120°	51°	– , –
JG.H2702	R	28.1	29.3	31.9	14.6	123°	44°	4 , 2
JG.H2708	R	49.9	47.0	52.6	21.8	111°	50°	5 , 2
JG.H2709	L	84.6	72.3	90.1	35.5	110°	53°	7 , 5
JG.H2712	R	94.3	67.3	100.0	26.3	110°	70°	13 , 12
JG.H2713	R	115.4	79.4	119.3	33.1	107°	73°	14 , 13
JG.H2719	L	184.3	145.1	195.3	45.1	117°	75°	13 , 10
JG.H2720	R	195.9	156.0	215.0	49.3	115°	70°	11 , 10
JG.H2727	L	139.4	112.0	144.0	30.5	122°	69°	13 , 9
JG.H2736	R	177.3	141.2	188.0	47.0	110°	70°	11 , 9
JG.H2737	L	205.2	167.2	216.5	47.0	116°	73°	14 , 14

specimen	valve	h/l	$h/l_{H=90mm}$	HL/h	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
JG.H2701	R	1.13	–	0.47	–	–	–
JG.H2702	R	0.96	–	0.52	–	–	–
JG.H2708	R	1.06	–	0.44	–	–	–
JG.H2709	L	1.17	1.17	0.42	–	–	–
JG.H2712	R	1.40	1.20	0.28	0.30	0.28	2.1445
JG.H2713	R	1.45	1.18	0.29	0.38	0.29	3.4874
JG.H2719	L	1.27	1.28	0.24	0.30	0.18	2.7475
JG.H2720	R	1.26	1.30	0.25	0.36	0.14	3.0777
JG.H2727	L	1.24	1.16	0.22	0.31	0.18	3.0777
JG.H2736	R	1.26	1.27	0.27	0.40	0.14	2.6051
JG.H2737	L	1.23	1.23	0.23	0.29	0.22	2.7475

reference :
h : shell height
l : shell length
H : dimension from umbo to ventral extremity
HL : hinge-line
α : angle between hinge-line and anterior margin
δ : angle between hinge-line and H
Ra : number of anterior rib
Rb : number of posterior rib
L : left valve
R : right valve

h/l : simple ratio of h to l
$h/l_{H=90mm}$: simple ratio of h to l at the growth stage of 90mm in H
HL/h : simple ratio of HL to h
$HL/h_{H=90mm}$: simple ratio of HL to l at the growth stage of 90mm in H
$R.D._{H=90mm}$: rib density at the growth stage of 90mm in H
$\tan\delta_{H=90mm}$: tangent of angle δ at the growth stage of 90mm in H

height at the growth stage of 90 mm in H [HL/$h_{H=90mm}$].

8. Divergent rib density (R.D.) at the growth stage of 90 mm in H [$R.D._{H=90mm}$].

9. Tangent of obliquity at the growth stage of 90 mm in H [$\tan\delta_{H=90mm}$].

10. Relative growth of shell height and shell length [$l=\beta h^{\alpha}$].

The basic morphology for measurements is shown in Text-fig. 4. Calipars of JIS standard, 200 mm in measurable extent and 1/20 mm in accuracy, and contact goniometer were used for measurements of length and angle respectively. Measurements were made three times for the same part, and the mean values are shown. From the above numerical characters, the standard deviation and Pearson's coefficient of variation were calculated. The results of statistics were analysed by the following procedures.

1. Evaluation of the difference between the means of a pair of samples by the method of the Student's *t*-test.

2. Examination by the method of the rejection ellipse.

Table 3. Numerical characters of Sample A (Himenoura).

	α	$h/l_{H=90mm}$	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
N	11	8	8	7	7
m	114.6	1.224	0.345	0.204	2.84106
s	5.44	0.0542	0.0480	0.0608	0.425860
v	4.75	4.43	13.91	29.80	14.99

N : sample size, *m* : mean value, *s* : standard deviation, *v* : Pearson's coefficient of variation

Table 4. Measurements of sample B (Haboro). linear dimension in mm.

specimen	valve	h	l	H	HL	α	δ	Ra , Rb
JG.H0115	L	100.0	98.6	119.3	44.8	116°	50°	8 , 8
JG.H0179	L	145.0	160.0	172.3	74.1	101°	54°	6 , 5
JG.H2738	R	85.6	77.7	90.5	31.4	110°	52°	7 , 3
JG.H2739	R	108.3	91.8	110.4	46.8	110°	65°	10 , 4
JG.H2740	R	121.3	106.8	131.4	—	105°	60°	9 , —
JG.H2741	L	46.8	44.9	49.0	22.1	106°	47°	6 , —
JG.H2742	R	102.1	103.7	121.5	52.6	111°	52°	10 , 7

specimen	valve	H/l	$h/l_{H=90mm}$	HL/h	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
JG.H0115	L	1.01	1.05	0.45	0.51	0.15	1.4281
JG.H0179	L	0.91	0.95	0.51	0.56	0.09	1.1504
JG.H2738	R	1.10	1.02	0.37	0.48	0.14	1.1504
JG.H2739	R	1.18	1.13	0.43	0.49	0.12	1.5399
JG.H2740	R	1.14	1.11	—	—	—	—
JG.H2741	L	1.04	—	0.47	—	—	—
JG.H2742	R	0.98	1.13	0.52	0.55	0.18	1.4281

3. Examination of the average relative growth.
   (1) Analysis of slope of a pair of reduced major axes.
   (2) Evaluation of intercept of a pair of reduced major axes.

4. For other characters inadequate for measurements and numerical analysis, for instance, the marginal outline of shell, the curvature of divergent ribs and other feature of surface ornamentations, I examined by the traditional method of observation for a number of specimens.

5. Examination in term of 75 percent rule for subspecific discrimination.

For the detail, refer to Hayami (1969), Hayami and Matsukuma (1971) and Noda (1975).

Results of analysis

The samples A, B and C are the representatives for the forma α, β and γ of *I. japonicus* respectively. The results of measurements are shown in Tables 2, 4 and 6, and their statistics are in Tables 3 and 5. The sample C consists of two specimens, one of which is the lectotype.

1. Correlation between the simple ratio h/l at the growth stage of 90 mm in H and the simple ratio HL/h at the same growth stage. — Plotting the ratio h/l in ordinate and the ratio HL/h in abscissa, the rejection ellipses of the samples A and B are shown in Text-fig. 5a in accordance with Table 7a. As is demonstrated in Text-fig. 5a, the rejection ellipses of the two samples drawn at 68 percent confidence level scarcely overlap each other. Due to the small size of samples and the large variation, the ellipses are

Table 5. Numerical characters of sample B (Haboro).

	α	$h/l_{H=90mm}$	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
N	7	6 (5)	5	5	5
m	109.7	1.065 (1.056)	0.518	0.136	1.33938
s	6.32	0.0720 (0.0767)	0.0356	0.0336	0.198445
v	5.76	6.76 (7.26)	6.87	24.71	14.82

( ) : figures of $h/l_{H=90mm}$ used for rejection ellipse
For others see the reference of Table 3.

Table 6. Measurements of Sample C (Kuji).

specimen	valve	h	l	H	HL	α	δ	Ra, Rp
UMUT-MM6524 [= I-1013]	L, R	100.5	113.2	133.4	59.3	106°	50°	9, 5

specimen	valve	H/l	$H/l_{H=90mm}$	HL/h	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
UMUT-MM6524 [= I-1013]	L, R	0.89	0.83	0.59	0.68	0.12	1.1106

Table 7a. Data of rejection ellipse (h/l, HL/h).

sample	X	Y	θ	λa	λb
A	0.345	1.224	116°29′	20.3mm	18.5mm
B	0.518	1.056	98°14′	42.8mm	18.4mm

X : mean of simple ratio of HL/h at the growth stage of 90mm in H
Y : mean of simple ratio of h/l at the growth stage of 90mm in H
θ : inclination of long axis
λa : length of long axis
λb : length of short axis

Table 7b. Data of rejection ellipse (tanδ, R.D.).

sample	X	Y	θ	λa	λb
A	0.204	2.841	91°18′	33.9mm	24.5mm
B	0.136	1.339	49°14′	22.8mm	14.6mm

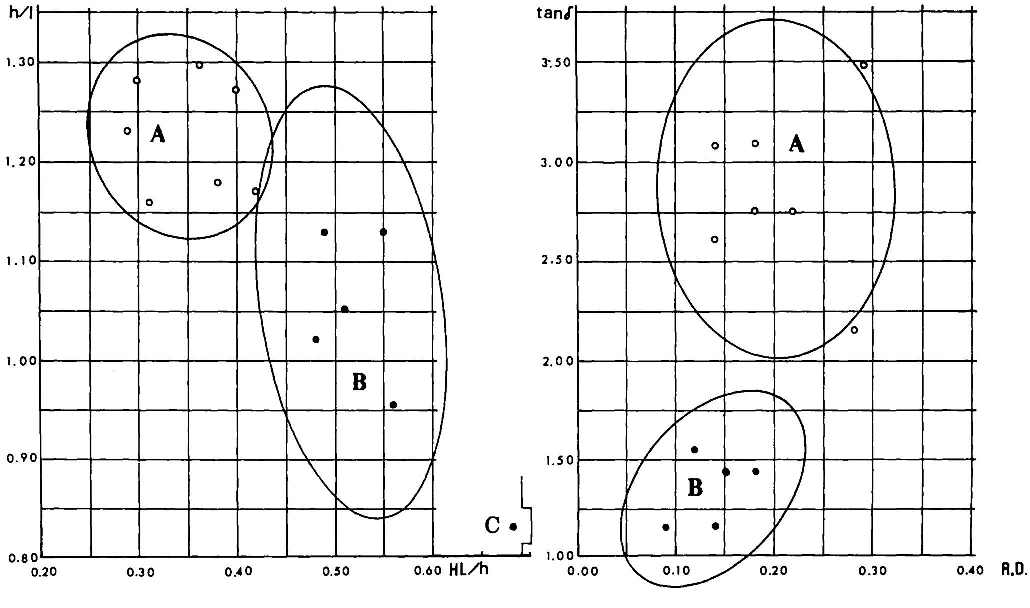
X : mean of divergent rib density at the growth stage of 90mm in H
Y : mean of tanδ at the growth stage of 90mm in H
For others see reference of Table 7a.

encircled on a large scale, but the dots of the two samples are not mixed with each other on both of the ordinate and the abscissa.

2. Correlation between the tangent δ at the growth stage of 90 mm in H and the divergent rib density at the same growth stage. — Plotting the value of tanδ in ordinate and the rib density in abscissa, the rejection ellipses of the two samples are shown in Text-fig. 5b according to Table 7b. As is evident from Text-fig. 5b, the ellipses at 68 percent confidence level of the two samples are clearly separated. But the dots of divergent ribs are overlapping in abscissa.

3. Result of Student's *t*-test. — As is shown in Table 8, the results of *F*-test for selected characters, i.e. anterior-hinge angle α, simple ratio $h/l_{H=90mm}$, simple ratio $HL/h_{H=90mm}$, $R.D._{H=90mm}$ and $\tan\delta_{H=90mm}$ are not significant in a pair of samples A and B. Thus, for the Student's *t*-test, the Welch's method is not adopted.

The results of the Student's *t*-test for the selected characters are shown in Table 9A, B, C, D and E respectively. In the characters of h/l and HL/h, the *t*-values are all significant at 5 percent significant limit, and these characters



Text-fig. 5a. Rejection ellipse showing at 68 percent confidence level (h/l, HL/h).
5b. (tanδ, R. D.). A: *I. (Pl.) higoensis*, B: *I. (Pl.) japonicus hokkaidoensis*, C: *I. (Pl.) japonicus japonicus.*

Table 8. *F*-test for selected characters between samples A and B.

	α	$h/l_{H=90mm}$	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
F-value	1.4704	2.0026	1.8180	3.2745	4.6053

Table 9. Student's *t*-test for selected characters.

9A

		A	B	C
α	A		1.7516	1.1616
	B	—		0.2516
	C	—	—	

9B

		A	B	C
$h/l_{H=90mm}$	A		4.7173	6.8536
	B	○		3.0217
	C	○	○	

9C

		A	B	C
$HL/h_{H=90mm}$	A		6.9587	6.5780
	B	○		4.1542
	C	○	○	

9D

		A	B	C
$R.D._{H=90mm}$	A		2.2764	1.2923
	B	○		0.1087
	C	—	—	

9E

		A	B	C
$\tan\delta_{H=90mm}$	A		6.3888	3.8009
	B	○		1.0524
	C	○	—	

○ : significant — : not significant

show small values in Pearson's coefficient of variation. This fact is remarkable for infraspecific distinction.

As is clear in Tables 3 and 5, the divergent rib density and tanδ show considerably wide variations, but the *t*-values of those characters are yet both significant in a pair of samples A and B, also significant in tanδ of sample A and C. These are notable for morphologic distinction too. The *t*-values between a pair of samples A and C, B and C, are not significant in rib density, and that between samples B and C, not significant either in tanδ.

4. Analysis of the relative growth. — For samples A and B an average relative growth and for sample C an individual relative growth are drawn in Text-fig. 6, because sample C consists of a single specimen, for measurements.

As is evident from Text-fig. 6, in the relative growth of l and h, the reduced major axis of every sample is monophasic without critical point. The relative growth of bivalvia, however, generally show abrupt change at a certain growth stage in various characters.

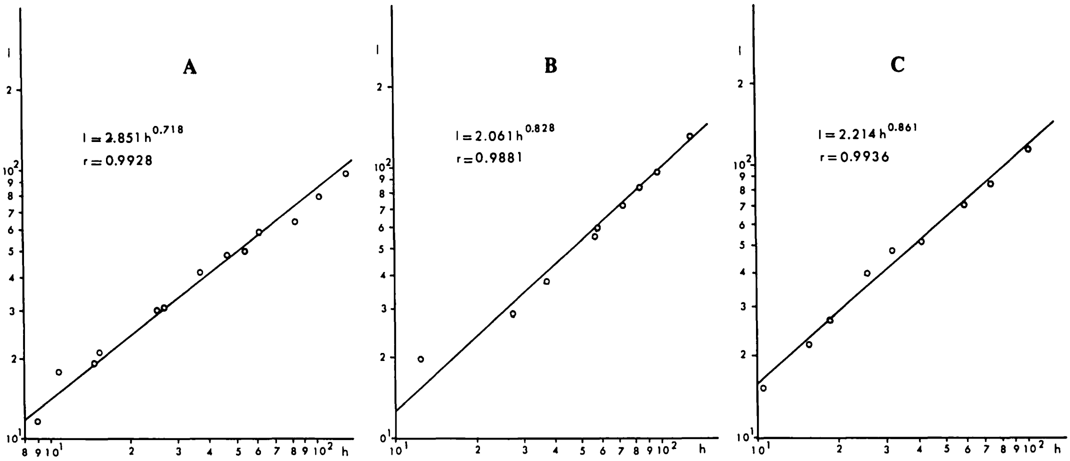
Although there may be some problems to compare the average relative growth with the individual relative growth, depending on the data of Table 10, the results of analysis for the slope of reduced major axes of each sample are shown in Table 11.

K-value (see Hayami and Matsukuma, 1971) of two pairs between A and B, and A and C are 2.26 and 2.68, respectively, which are higher than 1.96 and indicate significant differences at 95 percent confidence level, although the value between B and C does not indicate a significant difference.

For the difference of Y intercept of the reduced major axis (which shows insignificant value in slope) the *K*-value is 9.02 which is significant at 95 percent confidence level.

5. Result of evaluation for the 75 percent rule. — The 75 percent rule is applied for the selected characters in a pair of samples A and B. The results are shown in Table 12.

As is clearly shown in Table 12, the coefficient of difference for the simple ratio $HL/h_{H=90mm}$ between samples A and B is 2.07 which is more than 1.28 the conventional level of the 75 percent rule for the subspecific distinction, and also it shows a significant value in tanδ. It is slightly less than significant limit 1.28 in the simple ratio h/l. The anterior-hinge angle α and the rib density are not significant.



Text-fig. 6. Reduced major axis of h to l (in mm) for each sample. A: averaged relative growth of sample A, B: averaged relative growth of sample B, C: individual relative growth of sample C (UMUT. MM6524).

Table 10. Data of analysis of allometry.

sample	α	β	$\log\beta$	$\bar{h}$	$\bar{l}$	r	σ	N
A	0.718	2.851	0.455	48.2	43.5	0.9928	0.0238	13
B	0.828	2.061	0.314	66.1	64.3	0.9881	0.0424	9
C	0.861	2.241	0.345	42.4	54.1	0.9936	0.0325	(9)

α : growth index (slope of the reduced major axis), β : Y intercept, $\bar{h}$: mean of shell height,
$\bar{l}$: mean of shell length, r : correlation coefficient, σ : standard error, N : sample size
sample C : showing individual relative growth, parenthesized number : growth stages.

Table 11. Significance test for the difference of slopes between a pair of reduced major axes.

	A	B	C
A		*2.26	*2.68
B	○		0.62
C	○	—	

* : significant, ○ : significant,
— : not significant

Sepcific and subspecific distinction

Nagao and Matsumoto (1940) discriminated three forms in a species of *I. japonicus*, that is, forma α, β and γ, and Matsumoto and Ueda in Ueda (1962) suggested that the statistical examination is necessary to elucidate the variation in a species and the relationship with allied species from other provinces.

The Student's t-test is an effective method for the examination of the difference by means of the biometrical characters in infraspecific discrimination, and also the K-test is applicable for the above characters. The former is more reliable than the latter for small samples but the latter is effective only for large samples.

Table 12. Coefficient of difference for the selected characters of a pair of samples A and B.

	α	$h/l_{H=90mm}$	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
C.D.	0.42	1.26	*2.07	0.72	*2.40

C.D. : coefficient of difference, * : significant

Table 13. Data of approximate determination of infraspecific category.

		Sample A						Sample B						Sample C					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Sample A	*t*-test							—	○	○	○	○		—	○	○	—	○	
	K-test												○						○
	75% rule							—	△	○	—	○							
Sample B	*t*-test													—	○	○	—	—	
	K-test																		○
	75% rule																		

1 : α, 2 : $h/l_{H=90mm}$, 3 : $HL/h_{H=90mm}$, 4 : $R.D._{H=90mm}$, 5 : $\tan\delta_{H=90mm}$,
6 : $l=\beta^{\alpha}$, ○ : significant, △ : less significant, — : not significant

The 75 percent rule is a conventional method for the subspecific distinction in terms of the biometrical characters, and it is not affected by sample size as the Student's *t*-test. The result of the Student's *t*-test does not always agree with that of the 75 percent rule as has been already remarked by Hayami (see Hayami, 1969, p. 86).

The short cut method is very effective for the characters which are unsuitable for numerical examination, for example, the surface ornamentation and presence or absence of a certain character. But in the present study, the short cut method is not applied (see Noda, 1975, p. 247).

The results of the above examination are quite adequate for the taxonomic distinction of the infraspecific category. They are summarized in Table 13.

In Table 13, both the simple ratios h/l and HL/h show significant values in the Student's *t*-test for the samples examined and the two characters show small values in the Pearson's coefficient of variation. The patterns of relative growth between h and l show significant value in *K* for slope and intercept of the reduced major axes. These facts must be sufficient for morphologic distinction.

A serious question, however, arises. As Nagao and Matsumoto (1940) have recorded, the specimens of forma α are rarely found in Hokkaido and South Saghalien where those of forma β are common. It is biologically unreasonable to discriminate subspecifically various forms in a species obtained from synchronous deposits of one and the same area.

As is clear from the Tables 11 and 13, sample A, the representative of forma α, is very distinct from other two samples. Especially the fact that the difference of slope of the reduced major axis is significant in *K*-value in pair of other samples respectively indicates that the forma α should belong to a different lineage from that of two other samples. The former is most probably discriminated specifically from the latter.

Nagao and Matsumoto (1940) made *I. japonicus* forma α relate to *I. incertus* var. *yubarensis*, whereas Matsumoto (1959) mentioned the relationship between *I. japonicus* and *I. ezoensis*. Furthermore, I obtained subsequently more useful data for the consideration of phylogeny from the same localities in Southwest Japan.

From the fact mentioned above, I consider that it is reasonable and natural to divide the so-called *I. japonicus* into two independent species and two subspecies of *I. japonicus* itself as will be described below. They correspond approximately to forma α, β and γ of Nagao and Matsumoto (1940).

Subgeneric assignment

Nagao and Matsumoto (1940) included *I. japonicus* in the group of *I. ezoensis*, since they avoided to use the subgeneric names which were under a confused condition at that date.

Heinz (1932) proposed to use the subgeneric names *Platyceramus* and *Cladoceramus*, but they were both *nomen nudum* in accordance with the International Code of Zoological Nomenclature, because he gave no diagnosis of the two subgemera and no designation of the type-species of *Platyceramus*. Heinz (1932) designated *I. michaeli* Heinz (= *I. digitatus* Schlüter, 1911, revised to *I. undulatoplicatus michaeli* by Seitz, 1961, non *I. digitatus* Sowerby, 1877) as the type-species of *Cladoceramus*.

Seitz (1961) gave the diagnosis of *Platyceramus* and *Cladoceramus* and designated *I. mantelli* d'Mercy (Barrois), as the type-species of *Platyceramus*. Consequently the subgeneric names have obtained the availability and validity since that date, as Matsumoto, Noda and Kozai (1982) already mentioned. Thus, the author name for these defined subgeneric names is Seitz, 1961.

Seitz ascribed *I. ezoensis* and *I. ezoensis vanuxemiformis* (revised to *I. cycloides vanuxemiformis* by Seitz) to *Platyceramus* and *I. japonicus* to *Cladoceramus*.

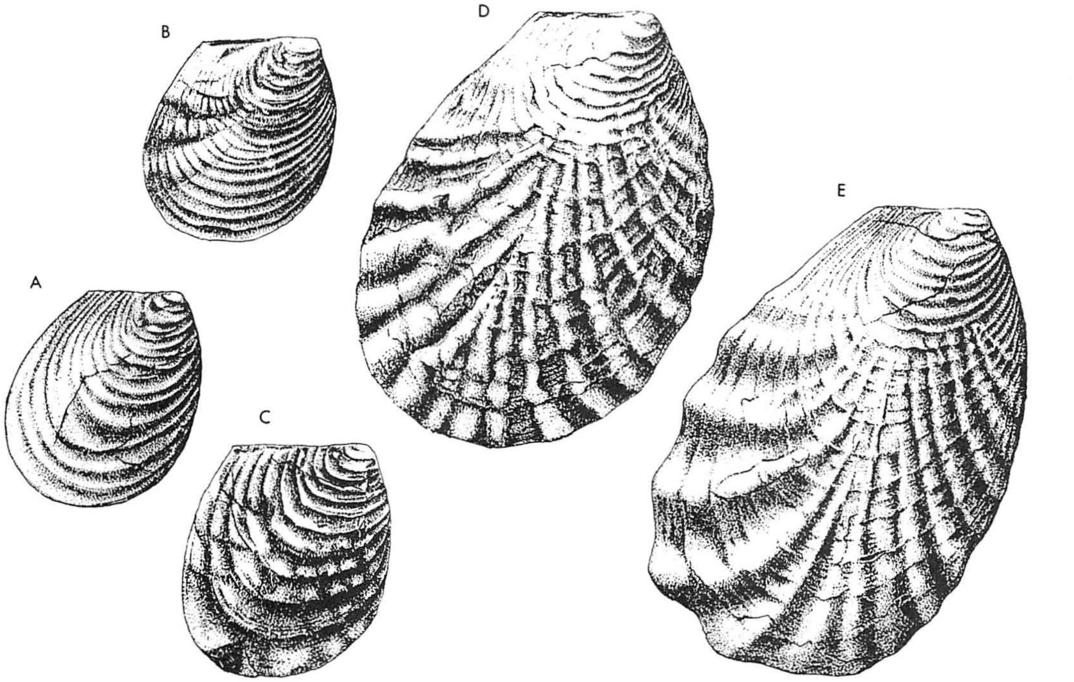
Notwithstanding the validity obtained since Seitz's revision, Vokes (1967) wrongly regarded these name as being invalid, and Cox (1969) inadequately recorded *Platyceramus* as junior synonym of subgenus *Inoceramus* and *Cladoceramus* as that of genus *Sphenoceramus*.

I should support Seitz's revisions for the following reasons. *Platyceramus* must be separated from subgenus *Inoceramus*, because the former is equivalve but the latter is inequivalve. This character is one of the fundamental characters for the subgeneric or generic distinction.

Sphenoceramus is clearly discriminated from *Cladoceramus* in that the posterior wing is distinctly demarcated from the main part of shell in the former, but gradually flattened without sharp boundary in the latter, among other points. In Seitz's (1961) concept, the distinction between *Platyceramus* and *Cladoceramus* is quite delicate. They are similar to each other in the marginal outline, shell convexity and curvature of concentric ornaments. The divergent ribs are commonly undeveloped or less prominent, if present, than concentric ones in *Platyceramus*, whereas the divergent ribs are said to be predominant in *Cladoceramus*. But in the case of the intermediate form linking them, the subgeneric assignment to either of them would be difficult.

I have assigned all the species belonging to the group of *I. naumanni* to *Sphenoceramus*, regardless of the presence or absence of divergent ribs. Likewise, the species of *Sphenoceramus* from Europe have been assigned to the same genus, regardless of the presence or absence of radial ribs. Thus the presence or absence of divergent ribs is not so important as a generic or subgeneric criterion.

The specimens illustrated in Text-fig. 7, taken from the same bed (Sample A-1), probably represent a certain population. It is impossible to discriminate one from another not only subgenerically but also specifically at population level. From the above discussion, the distinction of the two subgenera by the degree of develop-



Text-fig. 7. Variation of surface ornamentation in *Inoceramus* (*Platyceramus*) *higoensis* sp. nov. The specimens illustrated were taken from a single bed of Loc. HI1023.
A: concentric ribs only, B: special form with posterior divergent ribs only, C: weak divergent ribs developed, D: typical form, E: "michaeli type" with less numerous and strongly curved posterior ribs. A, B and C may be immature. A, B: natural size, C, D and E: ×0.75.

ment of divergent ribs is unnatural and unreasonable. It is better to unite the two nominal subgenera.

It is desirable to adopt *Platyceramus*, which has clearly page priority over *Cladoceramus*, in accordance with Article 24, (a), Advice 24A of I.C.Z.N.

Palaeontological description

Family Inoceramidae Giebel, 1852

Genus *Inoceramus* Sowerby, 1814

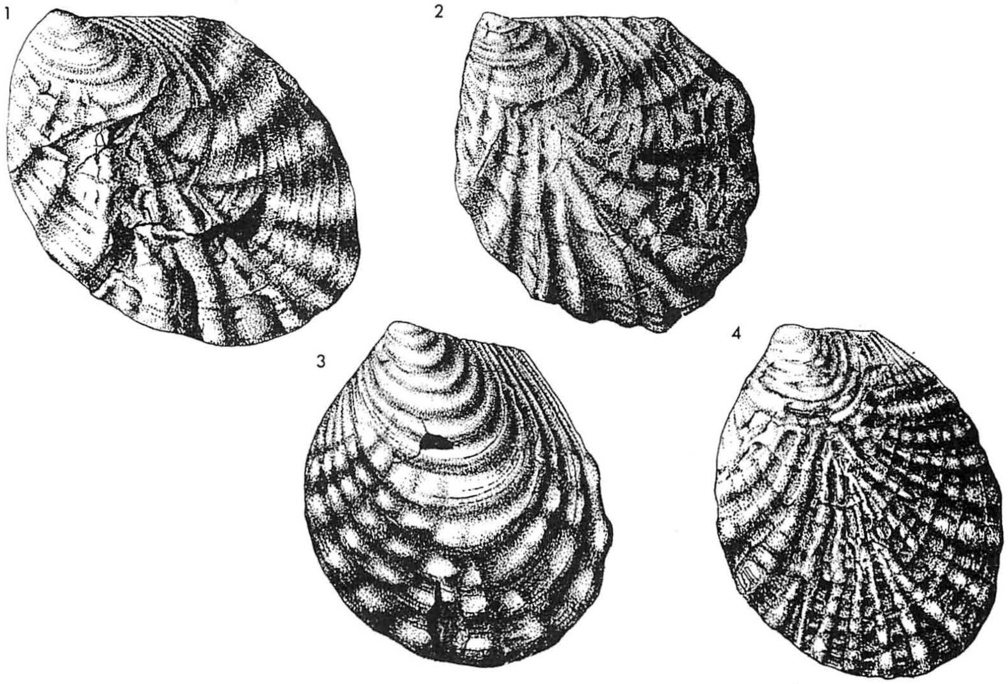
Subgenus *Platyceramus* Seitz, 1961

Inoceramus (Platyceramus) japonicus Nagao et Matsumoto

Lectotype:—The specimen figured by Nagao and Matsumoto (1940, pl. 9, fig. 1: reillustrated in this paper, Pl. 1, Fig. 1), was designated by Matsumoto and Ueda (1962), from Kunitan, Kuji City, Iwate Prefecture, Kunitan Formation of the Kuji Group, collected by Yasuo Sasa and kept at University Museum of the University of Tokyo (UMUT.MM6524 = TK.I-1013).

Specific characters.—Shell equivalve, fairly large in size. Umbo small, subterminal and slightly prominent but not incurved. Shell convexity gentle and uniform, anterior part comparatively steep, posterior one gradually flattened, passing into a wing-like area. Marginal outline considerably variable as described below.

Surface ornamentation consisting of concentric and divergent sculptures; the former are numerous, fine and low minor concentric rings and major concentric ribs in combination, the concentric ribs regular in size, intensity and distance. Divergent sculpture composed of



Text-fig. 8. Illustration of Forma α, β and γ of so-called *I. japonicus* Nagao et Matsumoto (1940). 1: forma γ = *I.* (*Pl.*) *japonicus japonicus* Nagao et Matsumoto, 2, 3: forma β = *I.* (*Pl.*) *japonicus hokkaidoensis* subsp. nov. showing the variation of marginal outline and surface ornamentation, 4: forma α = *I.* (*Pl.*) *higoensis* sp. nov. 1: ×0.4, 2: ×0.3, 3: ×0.6, 4: ×0.5.

Table 14. Ontogenetic change of obliquity in *I.* (*Pl.*) *japonicus japonicus.*

growth stage / specimen	H=10mm	20mm	30mm	40mm	50mm	60mm	70mm	90mm	110mm	140mm	170mm
UMUT.MM6524	56°	53°	52°	52°	52°	52°	51°	50°	49°	47°	44°

round-headed ribs separated by concave interspaces which are as wide as the ribs; the divergent ribs appearing in a more or less late growth stage, those of the posterior half of the valve commonly developing later and often less numerous than the anterior ones. Nodulous elevations developed at the intersection of the concentric and divergent ribs.

The present species is, herein, subdivided into two subspecies as follows:

Inoceramus (Platyceramus) japonicus japonicus Nagao et Matsumoto

Pl. 41, Fig. 1; Text-fig. 8A

1940. *Inoceramus japonicus* (Sasa MS) Nagao et Matsumoto, *Jour. Fac. Sci., Hokkaido Imp. Univ., [4]*, vol. 6, no. 1, p. 24—28, pl. 9, fig. 1.

1959. *Inoceramus japonicus*: Matsumoto, *Mem. Fac. Sci., Kyushu Univ., [D]*, vol. 9, no. 2, p. 86, pl. 11, fig. f.

1962. *Inoceramus japonicus*: Matsumoto and Ueda in Ueda, *Mem. Fac. Sci., Kyushu Univ., [D]*, vol. 12, no. 2, p. 165, pl. 24, fig. 1.

1975. *Inoceramus (Cataceramus) japonicus*: Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 57, pars.

Material:—UMUT.MM6524 [= TK.I-1013] and UMUT.MM6924 [= TK.I-1011] from the type locality.

Subspecific diagnosis.—Very oblique, with the obliquity gradually increasing with growth and the growth axis convex anteriorly as shown in Table 14. Much elongated from the umbo to the postero-ventral extremity. Antero-dorsal margin convex, postero-ventral margin rather broadly rounded in juvenile stage and more narrowly curved with growth; the posterior one widely rounded passing into nearly straight postero-dorsal margin. Hinge-line long, about a half of shell length, forming an obtuse angle of about 140° with the postero-dorsal margin.

Remarks.—The present subspecies corresponds to forma γ of Nagao and Matsumoto (1940).

Inoceramus (Platyceramus) japonicus hokkaidoensis subsp. nov.

Pl. 41, Fig. 2; Pl. 42, Figs. 1—3;
Pl. 43, Figs. 1—3; Text-fig. 8B, C.

1940. *Inoceramus japonicas* (Sasa MS) Nagao et Matsumoto, *Jour, Fac. Sci., Hokkaido Imp. Univ., [4]*, vol. 6, no. 1, p. 24—28, pl. 7, fig. 2, pl. figs. 2—4.

1969. *Inoceramus japonicus*: Katto, *Geology of Kochi Prefecture*. p. 132, fig. 97 (in Japanese).

1975. *Inoceramus (Cataceramus) japonicus*: Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 57, pars.

1976. *Inoceramus japonicus*: Noda and Matsumoto, *Atlas of Japanese fossils*. no. 45—268, Cr. 34, fig. 2 (in Japanese).

1978. *Inoceramus (Cladoceramus?) japonicus*: Matsumoto and Haraguchi, *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 110, p. 317, listed.

1982. *Inoceramus (Platyceramus) japonicus*: Matsumoto, Noda and Kozai, *Palaeont. Soc. Japan, Special Papers*, no. 25, p. 62, pl. 10, fig. 6.

Types.—Holotype: MC510621 from Loc. IK8015, upper reaches of Kikume-zawa, a tributary of the River Ikushumbetsu, near the Lake Katsura-zawa, Ikushumbetsu area, Mikasa City, Hokkaido (coll. Kikuo Muramoto). Str. position: Upper part of Member IIId, Upper Yezo Group (for the stratigraphic sequence see Matsumoto, 1965, text-fig. 4). Paratypes: JG.H2805, 2806 and 2807, not far from the type locality (coll. Noda, Matsumoto and Takahashi). JG.H0115, 0176 and 2738 from Loc. Hb1997; JG.H2739, 2740 from Loc. Hb2000. JG.H2741 from Loc. Hb2001; Migino-sawa, a tributary of the River Haboro, Haboro-machi, Tomamae-gun, Hokkaido. Str. position: Unit C of Upper Yezo Group (in Inoma's sense, see Matsumoto et al., 1972) (coll. Noda, Matsumoto and Takahashi, 1977); GK.H10027 from Loc. H2 of Matsumoto (T1006g of Tanabe) a road cutting on the left bank near Tomiuchi Bridge, Hobetsu-machi, Yufutsu-gun, Hokkaido (coll. Tanabe and Hirano, 1975). Str. position: upper part of Upper Yezo Group (see Matsumoto, 1942); GK.H10079 from Panke-zawa, a tributary of the Riber Chikubetsu, Tomamae-gun (coll. Ueda). Str. position: lower part of D Formation of Ueda et al. (1962), Upper Yezo Group; GK.H10105 from Loc. SK62, upper reaches of the River Haboro, Sankei area, Tomamae-gun (coll. Tanaka). Str. position: lower part of Unit F (= Unit U5 of Yamaguchi and Matsuno, 1963), Upper Yezo Group.

Material.—The type specimens cited above are concerned with description and measurements.

Subspecific diagnosis.—Shell nearly as high as long, moderately oblique, with constant obliquity through all the growth stages and an almost straight growth axis as shown in Table 15. Antero-dorsal margin long and straight or slightly concave, the anterior one broadly curved passing gradually into the widely rounded ventral one. Postero-ventral margin moderately rounded; posterior margin gently arcuate forming a very obtuse angle of about 135°—150° with the hinge-line, which is fairly long, more than two fifths of shell length. In the general aspect, the marginal outline is fan-shaped.

The surface ornamentation as for specific diagnosis, the divergent ribs are of variable intensity among individuals, on some individuals

Table 15. Ontogenetic change of obliquity in *I. (Pl.) japonicus hokkaidoensis.*

growth stage specimen	H=10mm	20mm	30mm	40mm	50mm	60mm	70mm	90mm	110mm	140mm
JGH2738	50°	50°	51°	51°	50°	51°	51°	52°		
JGH2739	60°	60°	60°	61°	61°	61°	60°	60°	60°	
JGH2743	50°	50°	50°							
GK.H10027	57°	57°	60°	59°	60°	60°	61°	59°	61°	61°

anterior divergent ribs much more numerous than posterior ones which are widely undulated and strongly curved posteriorly as on the specimen of JG.H2806.

Remarks.—The present subspecies corresponds to forma β of Nagao and Matsumoto (1940), and is readily distinguishable from *I. (Pl.) japonicus japonicus* in its straight antro-dorsal margin and straight growth axis bisecting the anterior-hinge angle. In these respects, the present subspecies is somewhat similar to *I. (Pl.) undulatoplicatus* Römer, but careful comparison is needed (see next chapter).

Occurrence.—

1. Abeshinai area of Nakagawa-machi, Nakagawa-gun (Teshio), Hokkaido. Str. position: Unit IIId of Upper Yezo Group.
2. Migi-no-sawa, upper reaches of River Haboro (see types JG.H0115, 0176, 2738—2741).
3. Panke-zawa, Chikubetsu area (see paratype GK.H10079).
4. Kikume-zawa, Ikushumbetsu area (see holotype and paratypes JG.H2805—2807).
5. Oyubari area. A cliff along the railway at Kashima-sennen, Y1001d2, at the entrance of Pankehorokayuparo-zawa and Y1559a and Y1561 of Omaki-zawa, Yubari City, Hokkaido. Str. position: upper part of Member IIId, Upper Yezo Group (see Matsumoto and Haraguchi, 1978).
6. H2268, A cliff about 200 m downstream of Nakahobetsu Bridge, Inasato I, Hobetsu-machi, Yufutsu-gun, Hokkaido. Str. position: upper part of Upper Yezo Group.
7. A cliff near the Tomiuchi Bridge, Hobetsu-machi (see paratype GK.H10027).
8. West of Frenai, Saru-gun, Hokkaido. Str. position: upper part of Upper Yezo Group (near the key bed of tuff), (coll. Kido and H. Matsumoto).
9. Urakawa area, Urakawa-gun, Hokkaido. Str. position: Unit U1 of Kanie (1966) (probably its upper part, see Matsumoto and Kanie, 1979), of Upper Yezo Group.

Inoceramus (Platyceramus) higoensis sp. nov.

Pl. 44, Figs. 1, 2; Pl. 45, Figs. 1, 2;
Pl. 46, Figs. 1—6; Text-figs. 4, 7A—E and 8D.

1940. *Inoceramus japonicus* (Sasa MS) Nagao et Matsumoto, *Jour. Fac. Sci., Hokkaido Imp. Univ., [4]*, vol. 6, no. 1, p. 24—28, pl. 5, fig. 2; pl. 6, figs. 2, 3; pl. 9, fig. 2.

1962. *Inoceramus japonicus*: Matsumoto and Ueda, *Mem. Fac. Sci., Kyushu Univ., [D]*, vol. 12, no. 2, p. 165, pl. 22, fig. 4.

1975. *Inoceramus (Cataceramus) japonicus*: Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 57, pars.

1976. *Inoceramus japonicus*: Noda and Matsumoto, *Atlas of Japanese fossils.* no. 45—268, Cr. 34, fig. 1 (in Japanese).

1982. *Inoceramus (Platyceramus) japonicus*: Matsumoto, Noda and Kozai, *Palaeont. Soc. Japan, Special Papers*, no. 25, p. 62, pl. 11, figs. 1, 2.

Types.—Holotype: JG.H2727 from Loc. HI 1009, a northern shore of Kojima, Himedo-machi, Amakusa-gun, Kumamoto Prefecture; Str. position: lower part of Middle Formation, Lower Subgroup, Himenoura Group. Paratypes: JG.H2701, 2702, 2708, 2709, 2712 and 2713 from Loc. HI1023, a western beach of Kugushima, Ryugatake-machi, Amakusa-gun; Str. position: upper part of Middle Member, Lower Subgroup, Himenoura Group. JG.H2719, 2720, 2736, 2737, 2745 and 2746 from the type locality. OES41001, 14047 and 14103 from the upper reaches of the River Kajisako, Monobe area, Kami-gun, Kochi Prefecture, Shikoku; Str. position: upper part of the Kajisako Formation. HK7134 from Kawakami, South Saghalien; Str. position: precisely unknown. HK7232 from Wakkawen, Nakagawa-machi, Nakagawa-gun, Hokkaido; Str. position: Unit IIId of Upper Yezo Group.

Diagnosis.—Shell equivalve of moderate size or considerably large. Umbo subterminal. Convexity of valve gentle and uniform, anterior part comparatively steep, posterior one gradually flattened, passing into a wing-like area, postero-ventral portion more or less flattened. Longer than high in juvenile stage, becoming gradually higher with growth and much higher than long at the adult stage. Obliquity not conspicuous, decreasing with growth as shown in Table 16, with the growth axis concave anteriorly. Antero-dorsal margin slightly convex, the anterior one long and broadly arcuate, passing into the moderately rounded ventral one; the broadly arcuate posterior one continuing to the long and broadly rounded postero-dorsal one, forming an obtuse angle of about 115°—130° with the hinge-line. Hinge-line rather short, about a half of shell length at an early stage, becoming gradually smaller in simple ratio to shell length, less than one third of shell length at the adult stage. In the general aspect, the marginal outline fan-shaped in the young shell and high oval in the adult one.

Surface ornamentation consisting of concentric and divergent sculptures; the former are numerous, fine and low minor concentric rings and major concentric ribs in combination. The concentric ribs regularly increasing in size, strength and distance, before the appearance of the divergent sculpture, round-headed and separated by concave interspaces as wide as the ribs. Divergent ribs appearing in a more or less late stage of growth; those of the posterior half of valve commonly developed later than the anterior ones. Anterior divergent ribs frequently bifurcate and inserted; posterior ones less numerous and stronger than the anterior ones, widely undulated and strongly curved posteriorly. Occasionally some of the posterior ribs tend to be united near the margin. On the later part of the shell where the divergent ribs predominate, the concentric ribs are weakened but the minor rings and growth lines are distinct. When the divergent ribs are as strong as the concentric ribs, the numerous nodulous elevations at the intersection.

Remarks.—The present species corresponds to forma α of Nagao and Matsumoto (1940). The high elliptical outline, a shorter hinge-line, less obliquity and smaller posterior-hinge angle enable us to distinguish this species from *I. (Pl.) japonicus* emended above.

Table 16. Ontogenetic change of obliquity in *I. (Pl.) higoensis.*

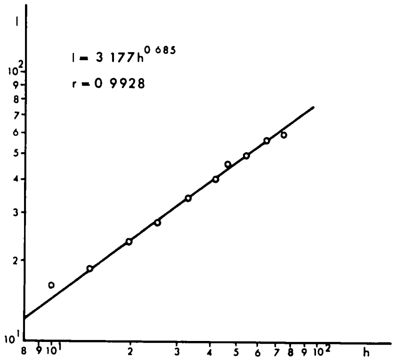
growth stage specimen	H-10mm	20mm	30mm	40mm	50mm	60mm	70mm	90mm	110mm	140mm	170mm	200mm
JGH2701	48°	58°	61°	63°								
JGH2702	51°	54°	56°									
JGH2708	47°	50°	52°	53°								
JGH2712	42°	43°	46°	53°	56°	59°	63°	65°				
JGH2713	44°	50°	54°	57°	61°	67°	71°	74°	73°			
JGH2720	44°	47°	54°	57°	60°	63°	66°	72°	72°	71°	70°	
JGH2736	50°	52°	55°	56°	58°	62°	64°	69°	67°	70°	70°	70°
JGH2737	50°	54°	58°	62°	65°	67°	68°	70°	74°	74°	75°	73°

Table 17. Measurements of *I.* (*Pl.*) *higoensis* subsp. linear dimension in mm.

specimen	valve	h	l	H	HL	α	δ	Ra, Rp	
HK7134	RV	75.2	59.1	82.0	25.0	114°	63°	8, 6	
HK7232	RV	75.0	59.9	81.7	25.0	117°	63°	9, 6	
HK7252	RV	79.5	65.0±	88.0±					imcomplete
HK5931	RV	65.5	61.2	78.0	25.5				

specimen	h/l	$h/l_{H=90mm}$	HL/h	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$
HK7134	1.27	—	0.33	—	—	—
HK7232	1.25	—	0.33	—	—	—
HK7252	1.22±	—	0.36±	—	—	—
HK5931	1.07	—	0.39	—	—	—

The species included two forms; one is represented by the specimens from Southwest Japan, for example, the sample A in the present study, and the other is a form from Hokkaido and Saghalien, for example, the specimens figured by Nagao and Matsumoto, 1940, pl. 5, fig. 2; pl. 6, fig. 2; pl. 9, fig. 2. The former is characterized by less conspicuous umbo and comparatively crowded divergent ribs, whereas the latter by a much projecting umbo beyond the hing-line and coarser divergent ribs. The measurements of the latter are shown in Table 17 and the relative growth between l and h is demonstrated in Text-fig. 9. For the slope of the



Text-fig. 9. Reduced major axis of h to l for *Inoceramus (Platyceramus) higoensis* subsp. (HK7134).

Explanation of Plate 41

Fig. 1. *Inoceramus* (*Platyceramus*) *japonicus japonicus* Nagao et Matsumoto. natural size. UMUT-MM6524 [= TK.I-1-13], lectotype. Kunitan, Kuji, Iwate Prefecture, Kunitan Formation, Kuji Group (coll. Y. Sasa).

Fig. 2. *Inoceramus* (*Platyceramus*) *japonicus hokkaidoensis* subsp. nov. x0.5. MC.520621, holotype. Loc. IK8015, Kikume-zawa, Ikushumbetsu area, Mikasa City, Hokkaido. Upper part of IIId, Upper Yezo Group (coll. K. Muramoto).

UMUT: University Museum, University of Tokyo
MC: Muramoto Collection

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reduced major axis to that of the sample A, the *K*-value is 0.897 which is less than 1.96 at the 5 percent significant limit but the position (Y intercept) is significant (K=5.38). The two forms are geographically separated from each other, the subspecific discrimination, therefore, would be possible. But I reserve, at present, to give a subspecific name because of the insufficient record of occurrence for the latter. Sample A-1 is variable both in the intensity and in the appearing stage of divergent ribs, as demonstrated in Text-fig. 7. Some specimens, e.g. JG.H2708, have scarcely discernible divergent ribs, whereas the specimens JG.H2712 and 2713 have predominant ones regardless of early growth stage, and these specimens occurred together in the same mudstone bed. Due to the small size of sample, the evaluation of population sample by the statistical method is impossible. Sample A-1, however, probably represents one population, because they are linked with various grades of intermediate ornaments. A specimen JG.H2719 (Pl. 45, Fig. 2), shows peculiar ornaments, with fewer and more strongly curved posterior divergent ribs. There are, however, some intermediate forms linking the typical form (see Pls. 44—46 and Table 2).

Occurrence.—

1. Loc. HI1008, a cliff of the sea shore at Motogama, Himedo-machi, Amakusa-gun, Kumamoto Pref.; Loc. HI1009 (= K25 by Ueda, 1962), the type locality; Loc. HI1015 (= K39 by Ueda, 1962), the back of the school (now abandoned), Hongo, Himedo-machi. Str. position: lower part of Middle Formation, Lower Subgroup, Himenoura Group.
2. Loc. HI1016, a cliff of road side at Washinosu, Himedo-machi; Locs. HI1017, 1018 and 1019, the road cutting along the mountain path from Shitanuki, Ryugatake-machi, Amakusa-gun; Locs. HI1022, 1023 and 1024, the western beach of Kugushima, Ryugatake-machi. Str. position: upper part of Middle Member, Lower Formation, Lower Subgroup, Himenoura Group.
3. Loc. HS103, Mojirobana, Hirano, Higashimachi (Shishijima), Izumi-gun, Kagoshima Pref.; Loc. HS108, eastern shore of Shishijima, Higashimachi. Str. position: upper part of Lower Formation, Lower Subgroup, Himenoura Group (Yamamoto and Hayami, 1971).
4. Oda and the other localities found in the Uto Peninsula, which seem to be referred to upper part of Lower Formation, Lower Subgroup, Himenoura Group.
5. Loc. M31, a right bank of the River Kajisako, about 100 m upstream from the artificial lake; Kajisako, Monobe-mura, Kami-gun, Kochi Pref., Shikoku. Str. position: Upper mudstone Member of Kajisako Formation (Matsumoto, Noda and Kozai, 1982, p. 63).
6. Loc. U129' (by Tanabe, 1972), Kawauchi, Uwajima City, Ehime Pref., Shikoku. Str. position: upper part of Upper Member, Furushiroyama Formation, Uwajima Group.
7. A cliff on the right bank of Hobetsu River, Nakahobetsu (Inasato I), Hobetsu-machi, Yufutsu-gun, Hokkaido. Str. position: upper part of Upper Yezo Group (Nagao and Matsumoto, 1940).
8. Wakkawen, Nakagawa-gun, Hokkaido. Str. position: Unit IIId of Upper Yezo Group (precisely unknown).
9. Kawakami, South Saghalien (in the Japanese place name, the Russian name unknown). Str. position: precisely unknown.

Comparison with allied species

Inoceramus (Platyceramus) japonicus and *I. (Pl.) higoensis* resemble a wide-spread species *I. (Pl.) undulatoplicatus* Römer in many features, as Nagao and Matsumoto (1940) have already pointed out. Stephenson (1950) also recognized the resemblance between *I. undulatoplicatus* and *I. japonicus* but mentioned that the Japanese species has much coarser divergent ribs than the Euramerican species. Subsequently Matsumoto and Ueda (1962) remarked the distinction between the two species and suggested the necessity of the statistic study for identificaiton or discrimination between them.

The measurements of the specimens of the allied species are shown in Table 18. The data have been measured on an actual specimen

Table 18. Measurements of specimens of *I. (Pl.) undulatoplicatus*. linear dimension in mm.

specimen	valve	h	l	H	HL	α	δ	Ra , Rp
Bo3, Seitz	R	86.4	90.0	110.0	48.8	84°	46°	7 , 6
S207WB, Seitz	R	147.2	124.8	166.1	45.7	85°	55°	8 , 7
Hg49, Seitz	L	323.6	265.7	346.5	114.2	100°	60°	14 , 9
no. 211, Sornay	L	289.8	217.7	300.9	63.9	104°	67°	13 , 11
no. 229A, Sornay	L	176.0	179.2	213.6	98.6+	93°	45°	9 , 6
GK.H9202	L	95.4	101.4	110+	59.6	79°	55°	9 , 6
UT-30564, Young	L	188.0	141.2	214.8	74.4	99°	59°	10 , ?
UT-30691, Young	R	188.0	146.0	207.6	70±	89°	57°	15 , 8
UT-30719, Young	R	211.6	182.0	238.4	—	95°	46°	6 , 10

specimen	valve	h/l	$h/l_{H=90mm}$	$HL/h_{H=90mm}$	$R.D._{H=90mm}$	$\tan\delta_{H=90mm}$	species
Bo3, Seitz	R	0.96	1.14	0.45	0.13	1.7321	*I. undulatoplicatus undulatoplicatus*
S207WB, Seitz	R	1.18	1.09	0.54	0.13	1.4281	*I. undulatoplicatus undulatoplicatus*
Hg49, Seitz	L	1.22	1.00	0.61	0.12	1.1917	*I. undulatoplicatus* subsp.
no. 211, Sornay	L	1.33	1.03	0.46	0.17	1.1917	*I.* aff. *undulatoplicatus michaeli*
no. 229A, Sornay	L	0.98	0.90	0.52+	0.13	1.0724	*I. japonicus mammillatus*
GK.H9202	L	0.94	0.96	0.64	0.14	1.3270	*I. undulatoplicatus undulatoplicatus*
UT-30564, Young	L	1.33	0.92	0.58	0.08	1.1106	*I. undulatoplicatus*
UT-30691, Young	R	1.29	1.33	0.53	0.17	1.5398	*I. undulatoplicatus*
UT-30719, Young	R	1.16	0.78	—	0.17	1.0355	*I. undulatoplicatus*

GK.H9209 from the Austin Chalk, Texas, and photographs of other specimens from Texas (Young, 1963) and Madagascar (Sornay, 1964, 1969). It is, however, unable to examine a sufficient number of extra Japanese specimens to know the extent of variation.

Plotting the above data in the rejction ellipse of Text-fig. 5, they are mostly encricled in the domain of Sample B, as demonstrated in Text-fig. 10. From the above examination, it is understood that *I. (Pl.) undulatoplicatus* and other allied species are well agreeable with *I. (Pl.) japonicus hokkaidoensis* subsp. nov. in the numerical characters, but there are some disagreeable points in unmeasurable characters. For example, the European specimens of *I. (Pl.) undulatoplicatus* described by Seitz (1961) are of rhomboidal outline with a subangular or

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Explanation of Plate 42

Fig. 1. *Inoceramus* (*Platyceramus*) *japonicus hokkaidoensis* subsp. nov. natural size. JG.H2739, paratype. Loc. Hb2001, Migi-no-sawa, a tributary of the River Haboro, Tomamae-gun, Hokkaido. Unit C of the Upper Yezo Group (coll. M. Noda, T. Matsumoto and T. Takahashi).

Fig. 2. *Inoceramus* (*Pl.*) *japonicus hokkaidoensis* subsp. nov. natural size. JG.H2741, paratype. Loc. Hb2002, near the Loc. Hb2001 (coll. ditto).

Fig. 3. *Inoceramus* (*Pl.*) *japonicus hokkaidoensis* subsp. nov. natural size. GK.H10027, paratype, Loc. H2[= T1006g by Tanabe], a left bank of the River Mukawa, near Tomiuchi Bridge, Hobetsu-Machi, Yufutsu-gun, Hokkaido. IIId Formation of the Upper Yezo Group (coll. K. Tanabe and H. Hirano).

JG: Jonan Geological Association

GK: Kyushu University

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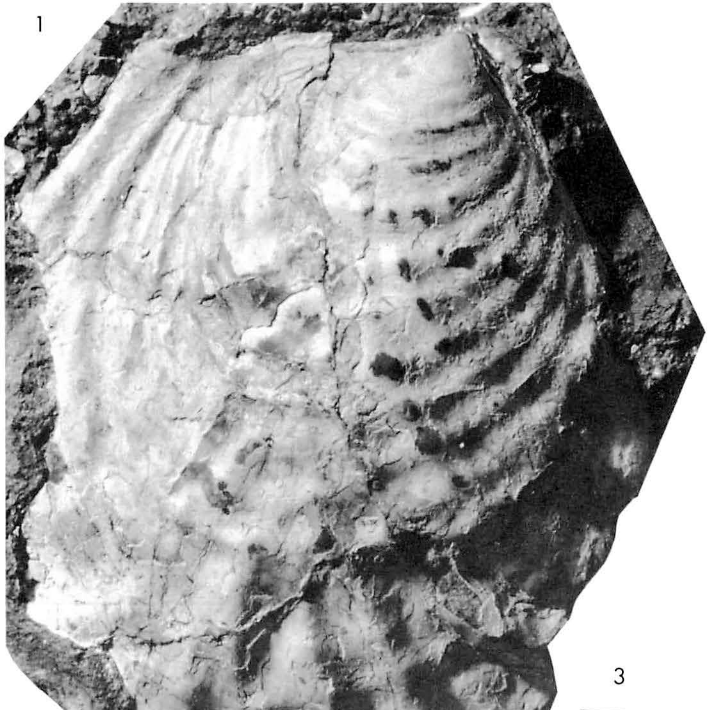

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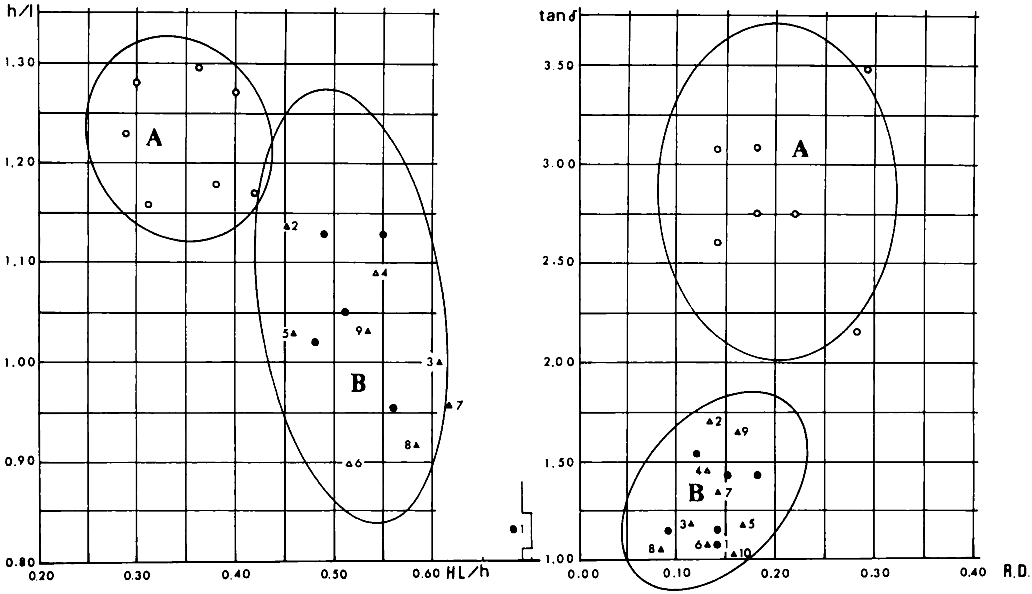

Text-fig. 10. Some allied species plotted in the rejection ellipses of Text-fig. 5a and b. 1: UMUT.MM6524, 2: Bo. 3, 3: Hg49, 4: S207WB, 5: no.211, 6: no.229A, 7: GK.H9202, 8: UT-30564, 9: UT-30691, 10: UT-30719. ○: *I. (Pl.) higoensis*, ●: *I. (Pl.) japonicus hokkaidoensis*, △: foreign allied species. A: rejection ellipse of *I. (Pl.) higoensis*, B: rejection ellipse of *I. (Pl.) japonicus hokkaidoensis.*

narrowly rounded ventral margin, whereas *I. (Pl.) japonicus hokkaidoensis* is fan-shaped. As to the American specimens, the distinction has already been remarked by Stephenson (1950), Seitz (1961) and Matsumoto (in Matsumoto and Haraguchi, 1978).

Inoceramus michaeli Heinz, 1932 (= *I. digitatus* Schlüter, 1877; *I. undulatoplicatus* var. *michaeli* Heinz, 1928; non *I. digitatus* Sowerby, 1829) somewhat resembles the specimens JG.H 2719 and JG.H2807 in that the posterior divergent ribs are much coarser, stronger and more acutely bent than the anterior ones. Heinz (1932) discriminated specifically *I. michaeli* from *I. undulatoplicatus* as an independent species, but Seitz (1961) treated it as a subspecies of *I. undulatoplicatus.*

In this study, the specimens of sample A, illustrated in Text-fig. 7 and Pls. 44—46, show a considerable variation in the divergent sculpture, in which the ornament of the pecuriar form (Text-fig. 7E; Pl. 45, Fig. 2) would be regarded as the "*michaeli* type". The specimens of Text-fig. 7 (sample A-1) and Pls. 44 and 45 (sample A-2) came from a single bed respectively. Thus, it is unreasonable to discriminate subspecifically the specimens with this type of ornament.

On the ground of population concept, they are linked one with another by intermediate forms. I consider, therefore, this kind of difference in divergent ribs is within the scope of variation in a single species *I. (Pl.) higoensis*. The specimens called *I. (Pl.)* aff. *undulatoplicatus* var. *michaeli* from the Middle Santonian of southwestern Madagascar (Somay, 1964, p. 174, fig. 6, 7) also resemble *I. (Pl.) higoensis*, but the former is distinguished from the latter in the marginal outline with a small anterior-hinge angle and its straight antero-dorsal margin.

A specimen JG.H2807 from Kikume-zawa, is also "*michaeli* type". Although it was found from a shaly bed about 20 m upper stream from the type locality of *I. (Pl.) japonicus hokkaidoensis*, it can be also included within the variation of a subspecies of *I. (Pl.) japonicus hokkaidoensis*, because the various grades of ornament linking the typical form to "*michaeli* type" are found in the specimens collected from this and adjacent areas (JG.H2805, 2806, 2807a, 2807b, MC510621, HK7239a, 7239b, 7240 and TK.I-1019).

I. japonicus mammillatus Sornay (1969, p. 218, figs. 10, 11) was established on a single specimen (no. 229A) from the Middle or Upper Santonian of southwestern Madagascar. Sornay remarked the resemblance between this subspecies and the forma α of *I. (Pl.) japonicus* [= *I. (Pl.) higoensis* sp. nov. in this paper]. But judging from his illustration, its longer hinge-line, smaller anterior-hinge angle and larger obliquity with a straight growth axis enable us to distinguish it from *I. (Pl.) higoensis* and *I. (Pl.) japonicus japonicus.* In these respects, that specimen (229A) is rather comparable with *I. (Pl.) japonicus hokkaidoensis* but clearly distinguished from the latter in its more prominent umbo, slightly concave antero-dorsal margin and smaller anterior-hinge angle.

I. japonicus var. *antsohaensis* Sornay (1964, p. 172, figs. 4, 5), from the Santonian of southwestern Madagascar, may belong to a different stock of species, because its outline is much elongated antero-posteriorly.

I. diversus Stoliczka (1871, p. 407, pl. 27, fig. 6), from the Trichinopoly Group of Anapaudy, southern India is clearly discriminated from the group of *I. (Pl.) japonicus* as have been already mentioned by Nagao and Matsumoto (1940, p. 27).

A specimen from the Lower Santonian of northwestern Germany was compared by Seitz (1961, p. 109, pl. 7, fig. 3) with *I. (Pl.) japonicus.* According to his illustration, it could be comparable with *I. (Pl.) higoensis* in the development of surface ornamentations at earlier stage of growth and the ontogenetic change of obliquity but is clearly discriminated from *I. (Pl.) higoensis* in the straight antero-dorsal margin, smaller anterior-hinge angle and longer hinge-line. Anyhow, Seitz's specimen is not identical with any subspecies of *I. (Pl.) japonicus* and *I. (Pl.) higoensis.* In addition, the stratigraphic position of the German specimen is geologically older than that of the Japanese specimens.

Biostratigraphically *I. (Pl.) undulatoplicatus* characterizes the Lower Santonian (Seitz, 1967 and many other authors), whereas *I. (Pl.) japonicus* and *I. (Pl.) higoensis* represent a particular zone of the Upper Santonian of Japan (Matsumoto, 1978 in Matsumoto and Haraguchi).

To sum up, *I. (Pl.) japonicus* and *I. (Pl.) higoensis* is distinguished from *I. (Pl.) undulatoplicatus.* Seitz (1961, 1967) and Sornay (1964, 1969) have already recognized *I. japonicus* as distinguishable from *I. undulatoplicatus* on their own reasoning.

Phylogenetic relationships

Inoceramus (Platyceramus) japonicus and *I. (Pl.) higoensis* occur characteristically in the

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Explanation of Plate 43

Fig. 1. *Inoceramus (Platyceramus) japonicus hokkaidoensis* subsp. nov. x0.8 GK.H10105, paratype. Loc. SK62, upper reaches of the River Haboro, Sankei area, Tomamae-gun, Hokkaido. Lower part of Unit F of the Upper Yezo Group (coll. K. Tanaka).

Fig. 2. *Inoceramus (Pl.) japonicus hokkaidoensis* subsp. nov. x0.6. GK.H10079, Panke-sawa, a tributary of the River Chikubetsu, Tomamae-gun. Lower part of IIId Formation, Upper Yezo Group (coll. Y. Ueda).

Fig. 3. *Inoceramus (Pl.) japonicus hokkaidoensis* subsp. nov. natural size. JG.H2738, paratype. Loc. Hb1998, Migi-no-sawa, Haboro. Unit C of the Upper Yezo Group (coll. M. Noda, T. Matsumomto and T. Takahashi).

NODA: *Inoceramus japonicus*

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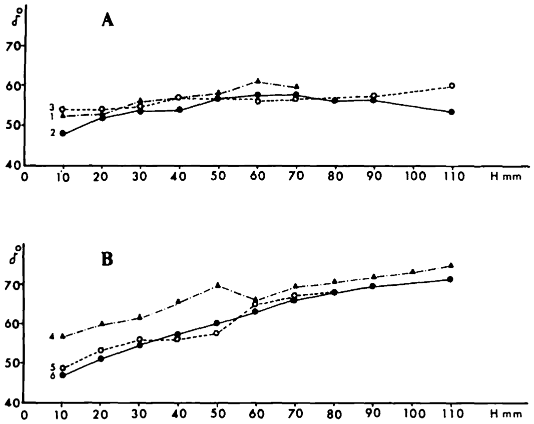
Upper Santonian in Japan, being effective zonal indices. Nagao and Matsumoto (1940) remarked that *I. japonicus* evidently belongs to the stock represented by *I. ezoensis* Yokoyama and that there is no essential difference between *I. incertus* var. *yubarensis* Nagao et Matsumoto and *I. japonicus* forma α.

I. ezoensis occurs in the Lower to Upper Santonian of Japan. Its range, therefore, overlaps with that of *I. (Pl.) japonicus* in the later half.



Text-fig. 11. Ontogenetic change of obliquity of *I.* (*Pl.*) *japonicus* and its allied species. 1: *I.* (*Pl.*) *ezoensis*, 2: *I.* (*Pl.*) *japonicus japonicus*, 3: *I.* (*Pl.*) *japonicus hokkaidoensis*, 4: *I.* (*Pl.*) *yubarensis*, 5: *I.* (*Pl.*) sp. aff. *I.* (*Pl.*) *yubarensis* (JG.H2706), 6: *I.* (*Pl.*) *higoensis*.

The immature shell of *I. (Pl.) japonicus* before the appearance of divergent ribs is scarcely distinguishable from that of *I. (Pl.) ezoensis*.

I. (Pl.) higoensis is nearly contemporary with *I. (Pl.) japonicus*, because it defined a zone in Southwest Japan above the Zone of *I. (Pl.) amakusensis* does so in northern Japan. *I. (Pl.) higoensis* is closely similar to *I. (Pl.) yubarensis* (independent species since Matsumoto and Noda, 1968, p. 320), from the Coniacian of Hokkaido, in the shell-form, including the comparatively smaller anteriorly concave growth axis. The concentric major ribs are, however, much lower and less distinct in the later than those on the umbonal half of the former. In this connexion, there is an undescribed form which is provisionally called *I. (Pl.)* sp. aff. *I. (Pl.) yubarensis*, from the Lower Santonian part of the Himenoura Group (Noda Coll., JG.H2706, see Text-fig. 12). It resembles *I. (Pl.) yubarensis* but differs in surface ornamentation. Namely its major concentric ribs are more distinct and regularly increased in intensity and distance (or coarseness). It has no divergent ribs, but otherwise it is very close to *I. (Pl.) higoensis*. Although the available material is yet insufficient, this may represent a transitional form from *I. (Pl.) yubarensis* to *I. (Pl.) higoensis*.

From the above facts, as well as the onto-

Table 19. Data of the relative growth (reduced major axis of h and l) of *I. (Pl.) japonicus* and its allied species.

species	α	β	logβ	r	σ	N
A	0.947	1.104	0.043	0.9943	0.0320	10
B	0.714	2.698	0.431	0.9973	0.0166	10
C	0.833	1.841	0.265	0.9983	0.0146	11
D	0.718	2.851	0.455	0.9928	0.0238	13
E	0.828	2.061	0.314	0.9881	0.0424	9
F	0.861	2.241	0.345	0.9936	0.0325	9

A : *I.* (*Pl.*) *yubarensis*, B : *I.* (*Pl.*) sp. aff. *I.* (*Pl.*) *yubarensis*, C : *I.* (*Pl.*) *ezoensis*, D : *I.* (*Pl.*) *higoensis*, E : *I.* (*Pl.*) *japonicus japonicus*, F : *I.* (*Pl.*) *japonicus hokkaidoensis*.

genetic change of obliquity as shown in Text-figs. 11A and B, the presumed phylogenetic relationships of *I. (Pl.) japonicus*, *I. (Pl.) higoensis* and their ancestral species are shown in Text-fig. 12.

The specimens HK5931 and HK7257 (Nagao and Matsumoto, 1940, pl. 5, fig. 2; pl. 6, fig. 3 respectively) from Nakahobetsu, Hokkaido are of both with weak divergent ribs, which would be presumed a transitional form linking *I.* sp. aff. *I. (Pl.) yubarensis* to *I. (Pl.) higoensis*.

It is evident that *I. (Pl.) japonicus* is intimately related to *I. (Pl.) ezoensis* whereas *I. (Pl.) higoensis* to *I. (Pl.) yubarensis* by way of *I.* sp. aff. *I. (Pl.) yubarensis* and transitional form of the specimens HK5931 and 7252. Tables 19 and 20 are very useful to compare their phylogenetic relationships. The stratigraphic occurrences of these species support the above consideration.

For comparison, I would like to give some remarks on the lineage of *I. (Pl.) undulatoplicatus*. Woods (1912b) connected *I. undulatoplicatus* with the flat form of *I. inconstans* Woods based on the resemblance of surface ornamentation in the young shell. He regarded *I. (Pl.) undulatoplicatus* as a descendant of *I. inconstans* or a closely related species. There is, however, no connecing form between them, as he mentioned. *I. inconstants* described by Woods (1912a) shows a considerable extent of variation and the extremely long range from the Lower Turonian to the Upper Campanian. It is not a homogeneous species. Seitz (1967, p. 93) revised the species, which belongs evidently to a stock different from the group of

Table 20. K-test for the slopes between a pair of *I.* (*Pl.*) *japonicus* and its allied species.

species	A	B	C	D	E	F
A		6.47	3.24	5.98	2.24	1.89
B	○		5.38	0.14	2.51	4.03
C	○	○		4.14	0.11	0.79
D	○	—	○		2.68	2.26
E	○	○	—	○		0.62
F	—	○	—	○	—	

A : *I.* (*Pl.*) *yubarensis*, B : *I.* (*Pl.*) sp. aff. *I.* (*Pl.*) *yubarensis*, C : *I.* (*Pl.*) *ezoensis*, D : *I.* (*Pl.*) *higoensis*, E : *I.* (*Pl.*) *japonicus hokkaidoensis*, F : *I.* (*Pl.*) *japonicus japonicus*.
○ : significant, — : not significant.

Explanation of Plate 44

Fig. 1. *Inoceramus (Platyceramus) higoensis* sp. nov. natural size. JG.H2727, holotype. Loc. HI1009, a northern shore of Kojima, Himedo-machi, Amakusa-gun, Kumamoto Prefecture. Lower part of the Middle Formation, Lower Subgroup, Himenoura Group (coll. M. Noda).

Fig. 2. *Inoceramus* (*Pl.*) *higoensis* sp. nov. x0.75, plaster cast of the external mould of the holotype.

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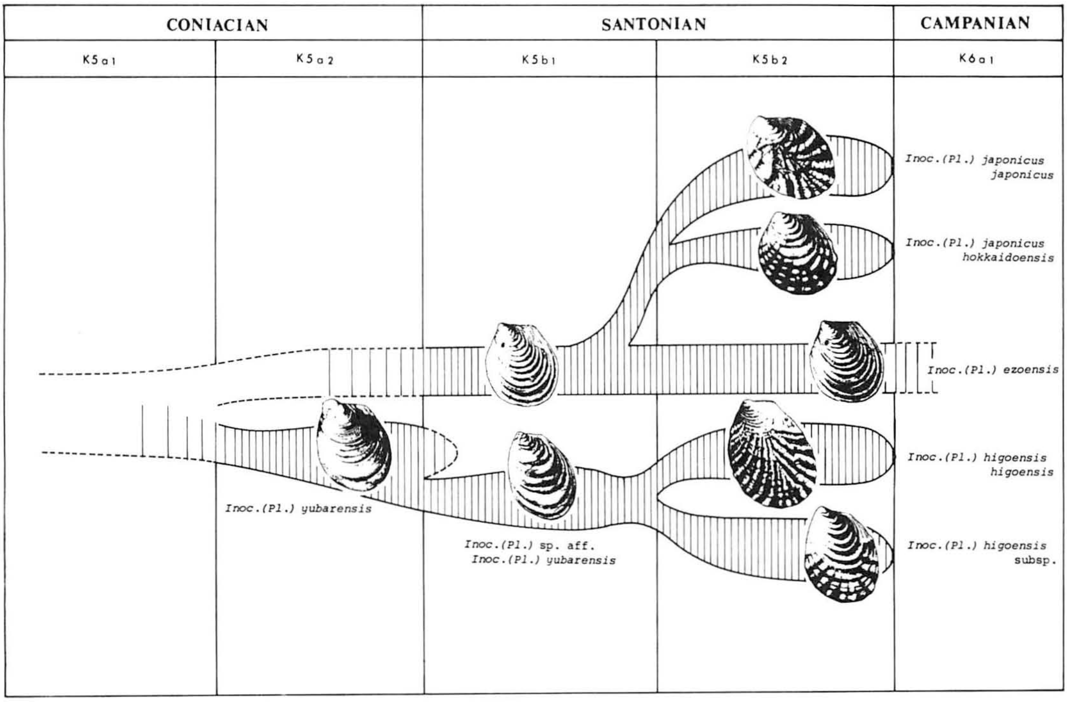

Text-fig. 12. Diagram showing the phylogeny of *I.* (*Pl.*) *japonicus* and its allied species.

I. (Pl.) japonicus and the revised species occurs in the lower part of the Middle Coniacian of Euramerica as Kauffman (1975, 1976 and 1977) has stated.

Judging from the precise description of Seitz (1961), *I. (Cladoceramus) undulatoplicatus* is closely similar to *I. (Pl.) rhomboides* Seitz in shell-form. There is, furthermore, a form called *I. (Pl.) rhomboides heinei* Seitz [= *I. cycloides* var. *undulata* Heine, 1929 (non Mantell)], which is essentially similar to *I. (Pl.) rhomboides rhomboides* of Seitz in the shell-form and the concentric ornamentation but has weak divergent ribs. This is at least morphologically a transitional form between *I. (Pl.) rhomboides* and *I. (Cl.) undulatoplicatus*, although I would not repeat here my comments on the subspecific classification of Seitz.

According to Seitz (1961, also 1967, p. 144), *I. (Pl.) rhomboides rhomboides* ranges from the Lower Santonian to the Lower Campanian, as *I. (Pl.) cycloides* Wegner does. *I. (Cl.) undulatoplicatus*, including subspp. *undulatoplicatus michaeli* and subsp. indet, are restricted to the Lower Santonian and *I. (Pl.) rhomboides heinei* occurs also in the Lower Santonian. *I. (Pl.) cycloides wegneri* Böhm, which is closely similar to *I. (Pl.) cycloides cycloides* in the shell-form and the concentric ornaments but has rather weak divergent ribs in more or less late growth stages, occurs also in the Lower Santonian of Germany.

It should be noted that as to the subdivision of a stage, there is some discrepancy between Germany and Japan. For example, the Santonian is tripartite into the Lower, the Middle and the Upper substages in Germany, whereas it is bipartite into the Lower and the Upper in Japan. The Campanian is bipartite in Germany but tripartite in Japan.

From the resemblance in early ontogeny, linking by transitional or intermediate forms and their stratigraphic levels, the above discussed species are undoubtedly closely related to one another, which have been derived from some common ancestral species of *I. (Platyceramus)*.

The relationships of the above mentioned species in Europe are analogous with those of the species and subspecies in Japan and the parallel evolution is recognized between Europe and Japan with some time lag in the development of divergent ribs.

This conclusion comfirms the opinion of Matsumoto (in Matsumoto and Haraguchi, 1978, p. 317) which was concisely and preliminarily given in his discussion of biostratigraphy.

Evidently *I. undulatoplicatus* should be assigned to the subgenus *Platyceramus*, since its close ally *I. rhomboides* is a typical *Platyceramus*. *Caldoceramus* is, thus, unnecessary, as has been recently pointed out by Matsumoto et al. (1982, p. 63).

Conclusion

1. By means of the statistic examination as well as normal observation, it has been elucidated that two independent species and two subspecies are distinguished in the so-called *I. japonicus* Nagao et Matsumoto, i.e. *I. (Pl.) higoensis* sp. nov., *I. (Pl.) japonicus hokkaidoensis* subsp. nov. and *I. (Pl.) japonicus japonicus* Nagao et Matsumoto, which approximately correspond to forma α, β and γ of Nagao and Matsumoto (1940) respectively.

2. On all sorts of available evidence discussed in this paper, *I. (Pl.) japonicus* is discriminated specifically from *I. (Pl.) undulatoplicatus* Römer which seemingly resembles *I. (Pl.) japonicus hokkaidoensis* in some biometric characters.

3. In a sample of *I. (Pl.) japonicus* taken from the same bed, some specimens have peculiar posterior divergent ribs of the "*michaeli type*". They occur together with typical specimens and linked by intermediate forms. They should be regarded as a variation within a species or subspecies.

4. From the resemblance in immature shell and partly overlapping stratigraphic occurrence, *I. (Pl.) japonicus* is probably a derivative from *I. (Pl.) ezoensis* and *I. (Pl.) higoensis* may be descendant of *I. (Pl.)* aff. *I. (Pl.) yubarensis* (a specimen JG.H2706) or *I. (Pl.) yubarensis*. On the other hand, *I. (Pl.) undulatoplicatus* probably descended from *I. (Pl.) cycloides* by way of *I. (Pl.) rhomboides*. These relationships are an example of parallel evolution with some time lag in developing divergent ribs. The development of divergent ribs is a convergence of the two lineages in *Platyceramus*.

5. *Platyceramus* and *Cladoceramus* obtained the validity since Seitz's revision (1961). However, the subgeneric distinction between them is very difficult in view of the presence of linking intermediate forms and impossible at population level. It is desirable to adopt *Platyceramus* which has the page priority over *Cladoceramus*.

Acknowledgements

I am deeply indebted to Emeritus Professor Tatsuro Matsumoto of Kyushu University for his cordial guidance, useful advice and a critical reading of the typescript. I wish to thank Dr. Masayuki Tashiro, Messrs. Kikuo Muramoto and Takemi Takahashi for their help in the field works and Dr. Kazushige Tanabe and Messrs. Kikuo Muramoto, Takeshi Kozai, Kenji

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Explanation of Plate 45

Fig. 1. *Inoceramus (Platyceramus) higoensis* sp. nov. x0.75. JG.H2720, paratype, plaster cast of external mould. Loc. HI1009 (coll. M. Noda).

Fig. 2. *Inoceramus (Pl.) higoensis* sp. nov. x0.75, JG.H2719, paratype. Loc. 1009. Showing an ornament of the "*michaeli* type" (coll. M. Tashiro).

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Sanada and Yoshimitsu Haraguchi for their generosity of offering some valuable specimens for this study. I am also indebted to Prof. Makoto Kato and Prof. Toshimasa Tanai of Hokkaido University and Dr. Itaru Hayami of University Museum of University of Tokyo for their kindness to let me study certain type specimens of Nagao and Matsumoto (1940). I am also indebted Messrs. Seiya Kimura and Katsuhiko Mukunashi of Oita Educational Center for making program and computer time available for this study. A part of the financial expenditure was defrayed from the Shimonaka Commemorative Foundation (1978, 1980).

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Explanation of Plate 46

Fig. 1-6. *Inoceramus* (*Platyceramus*) *higoensis* sp. nov. all natural size. 1. JG.H2701; 2. JG.H2702; 3. JG.H2708; 4. JG.H2709; 5. JG.H2712 and 6. JG.H2713, paratypes. Loc. HI1023, a western shore of Kugushima, Ryugatake-machi, Amakusa-gun, Kumamoto Prefecture. Upper part of the Middle Member, Lower Formation, Lower Subgroup, Himenoura Group (coll. M. Noda).

NODA: *Inoceramus japonicus*

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Abeshinai 安平志内，Amakusa 天草，Asahikawa 旭川，Chikubetsu 築別，Frenai 振内，Furushiroyama 古城山，Haboro 羽幌，Higashi-machi 東町，Himedo-machi 姫戸町，Himenoura 姫浦，Hirano 平野，Hobetsu 穂別，Hongo 本郷，Horobetsuyama 幌別山，Ikushumbetsu 幾春別，Inasato 稲里，Izumi-gun 出水郡，Kajisako 楮佐古，Kami-gun 香美郡，Katsura-zawa 桂沢，Kawakami 川上，Kawauchi 河内，Kikume-zawa 菊面沢，Kojima 小島，Kugushima 椚島，Kuji-Kudi 久慈，Kunitan 国丹，Migi-no-sawa 右の沢，Mikasa 三笠，Minamioita 南大分，Mojirobana モジロ鼻，Monobe-mura 物部村，Motogama 元釜，Nagashima 長島，Nakagawa-gun 中川郡，Nakahobetsu 中穂別，Oda 網田，Omaki-zawa 大巻沢，Oyubari 大夕張，Pankehorokayuparo-zawa パンケホロカユーパロ沢，Panke-sawa パンケ沢，Ryugatake-machi 竜ヶ岳町，Sankei 三渓，Saru-gun 沙流郡，Shirahama 白浜，Shishijima 獅子島，Shitanuki 下貫，Teshio 天塩，Tomamae-gun 苫前郡，Tomiuchi 冨内，Uto 宇土，Urakawa 浦河，Uwajima 宇和島，Wakkawen ワッカエン，Washinosu 鷲の巣，Yezo 蝦夷，Yubari 夕張，Yufutsu-gun 勇払郡

日本上部白亜系より産するいわゆる *Inoceramus japonicus* Nagao et Matsumoto について：日本のサントニアン階上部に特徴的に産するいわゆる *Inoceramus japonicus* について従来の研究方法に加えて，それぞれの産地のものにつき統計的に検討した結果，2つの独立した種と，それぞれの種が2つの亜種に区別されることが確認された。すなわち，*I.* (*Pl.*) *higoensis* sp. nov., *I.* (*Pl.*) *higoensis* subsp., *I.* (*Pl.*) *japonicus hokkaidoensis* subsp. nov., *I.* (*Pl.*) *japonicus japonicus* Nagao et Matsumoto で，これらのうち亜種を含めて *I.* (*Pl.*) *higoensis* は Nagao and Matsumoto (1940) が forma α としたもの，その他はそれぞれ forma β, γ としたものにほぼ相当する。本論では個体群の立場から種または亜種の区別をした過程を述べ，それぞれの特徴について記載し，外国産の近似種と比較した。また，統計の結果や相対成長の解析ならびに産出層準に基づいてその系統を考察した。さらに，亜属の帰属について論及し，*Cladoceramus* とされていたものを改めて *Platyceramus* とした。　野田雅之

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770. CRETACEOUS NAUTILOIDS FROM HOKKAIDO—III PART 3. SOME NAUTILOIDS FROM THE CAMPANIAN OF SOYA, NORTHERN HOKKAIDO*

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Abstract. This is Part III of a monograph of the Cretaceous Nautiloids from Hokkaido being published in series. It contains the descriptions of the three species from the Campanian strata exposed on the northwestern coast of Cape Soya (Text-fig. 1). The first is a new species of *Eutrephoceras*, which is allied to *E. kobayashi* Matsumoto and *E. pseudobouchardianum* (Spengler) but its siphuncle is central instead of subventral or subdorsal. Its whorl is broader and more inflated than *E. tawaense* Furuichi or *E. balchistanense* (Spengler). The second is a new species of *Cymatoceras*, which resembles *C. cenomanense* (Schlüter) but its suture is not so sinuous as in that species. The third is a new species of *Anglonautilus*, which is distinguished from *A. undulatus* (Sowerby) in its much weaker ribs and the development of a shallow ventral groove on its body-chamber. The group of strata in the studied area is subdivided into 8 members, A to G in ascending order, of which A to D are the Middle Campanian and E to G the Upper Campanian. The first species occurs in C and D, the second in F and the third probably in C. They are all of shallow open sea facies.

Introduction

One of us (T. Miyauchi) has been engaged in collecting the natural history material from northern Hokkaido to enrich the knowledge of botany, malacology and palaeontology. The other of us (T. Matsumoto) was invited to Wakkanai to cooperate with him in the palaeontological study. There are several nautiloid specimens among fairly numerous fossils collected from the Cretaceous of the Soya area, which are being studied by us. This paper gives a result of our study on the nautiloids.

Note on Stratigraphy

Before going into the palaeontological descriptions, we should give a note on the Cretaceous stratigraphy of the Soya area. Cape Soya, which now belongs administratively to the eastern part of the City of Wakkanai, consists primarily of Cretaceous and Tertiary strata, besides small bodies of basaltic rock and Quaternary terrace

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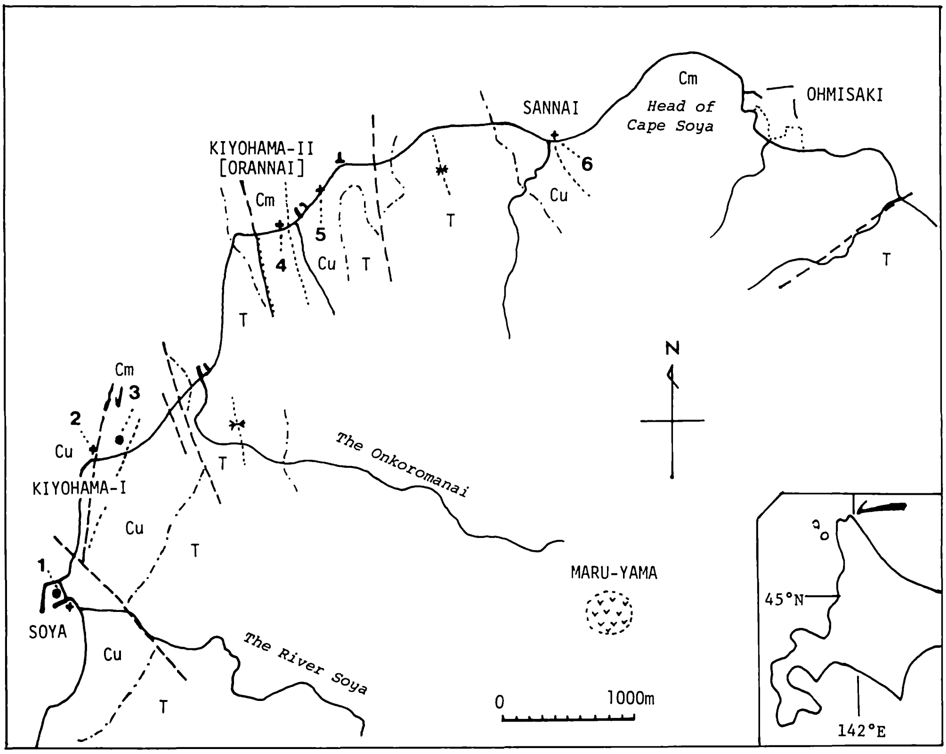
deposits at several levels. As shown in the published geological maps (Osanai *et al.*, 1959; Matsumoto and Obara, 1971), the Cretaceous strata are overlain by the Tertiary (Miocene) Magaribuchi Formation with an unconformity of a considerable time gap. The strata of the Cretaceous and the Tertiary are both folded and faulted, showing generally parallel structures.

The Cretaceous strata exposed on the eastern coast of Cape Soya range in age from Upper Albian (?) to Campanian, showing fairly complex geological structures (Matsumoto and Miyauchi *in* Matsumoto, 1982). Those exposed in the northernmost part and the western coastal area of the cape are mostly referred to the Campanian. They show rather gentle inclinations, but there is repetition or omission of strata by the faults of N-S and NW-SE trends (Text-fig. 1). The Maastrichtian is lacking in the coastal area but a part of it crops out in the central hilly area between Koishi and Magaribuchi, where Tertiary strata occupy a wider area.

The exposures of the strata in the western coastal area are insufficient on the land side, but there is a wave cut bench off the coast. That bench is usually submarine, but at the time of the lowest tide (twice a year) some parts of the bench are accessible for us to examine the constituting strata and to collect the contained fossils. There was, furthermore, a reconstruction of the fishery harbour of Soya in 1973, when one of us (T. Miyauchi) had an opportunity to observe the temporarily exposed (otherwise submarine) strata at the excavated place, and we collected fossils from the excavated rock masses brought to the coast.

In addition to the large scale excavation at the Soya harbor, small scale dredgings of



Text-fig. 1. Geological outline map of the northwestern part of Cape Soya.
Cm: Middle Campanian, Cu: Upper Campanian, T: Tertiary, v: basalt ●: fossil locality (in situ), +: *ditto* (floated), 1—6: localities of the Cretaceous nautiloid, ⊥: Landing place of Rinzo Mamiya. Inset at the lower right corner the index map.

submarine rock floor are in operation more frequently along the coast-line for the passage of small fishery boats. Fossils can be hunted from the dredged rock fragments.

Through these procedures of field work, the biostratigraphical sequence in the northwestern coastal area of Cape Soya has been made clear as follows in ascending order:

A. Medium- to coarse-grained, cross-bedded sandstone, exposed at the southeastern corner of Ohmisaki (e.g. near the Primary School). *Sphenoceramus schmidti* (Michael) occurs in certain layers.

B. Mudstone, with subordinate sandstone, typically exposed at the head of the cape, characterized by *S. schmidti*, *Gigantocapulus giganteus* (Schmidt), *Canadoceras kossmati* Matsumoto etc., occurring mostly in the contained clacareous nodules.

C. Silty fine-grained sandstone or fine-sandy siltstone. In the contained calcareous nodules, drifted pieces of vegetable matter are accumulated along with some well preserved molluscan fossils. This unit is called the "*Fukiyose* Beds" [*Fukiyose* in Japanese means drifted together] in our field work for convenience' sake. There are at least four beds which contain such nodules. This unit constitutes the wave cut bench off the coast of Kiyohama-I [=Dai-ichi Kiyohama] and also a part of the one off the western coast of Kiyohama-II [= Dai-ni Kiyohama] [= "Orannai"]. The characteristic species are *Canadoceras mysticum* Matsumoto, *C.* sp. nov. (small form), *C. multicostatum*, *Baculites* aff. *B. chicoensis* Trask, *Eutrephoceras soyaense* sp. nov. and probably also *Anglonautilus mamiyai* sp. nov. (both described below), among many others *S. schmidti* occurs in the lower part of this unit.

D. Silty fine-grained sandstone to fine-sandy siltstone, often bioturbated. Some of the contained nodules are prolific. In addition to the ammonite species which are common with those from units B and C, there are *Pseudophyllites* sp. *Desmophyllites* sp. and *Pachydiscus* sp. and probably *E. soyaense*. The fossiles from this unit exposed between Kiyohama-I and Soya are often distorted because of the deformation along a fault of N-S trend.

E. Green silty fine-grained sandstone with partly sandy siltstone. It contains a characteristic heteromorph ammonite, *Schlueterella* sp. nov. aff. *S. pseudoarmata* (Schlüter). In addition, *Diplomoceras notable* Whiteaves, *Parasolenoceras* sp. nov., *Baculites inornatus* Meek, *Pachydiscus* sp. nov. aff. *P. neevesi* Whiteaves and *Canadoceras multicostatum* (large form) are here. *Metaplaceaticeras subtilistriatum* is found rarely. Also *Cymatoceras honmai* sp. nov. (to be described below) is probably from this unit.

The beds of Unit E were recognized below Unit F during the large scale excavation (in 1973) to reconstruct the fishery harbour of Soya and have traced elsewhere along with F.

F. Dark grey silty sandstone or sandy siltstone containing rather sporadically remains of *Metaplacenticeras subtilistriatum* (Jimbo) and also very rarely *Hoplitoplacenticeras* sp. In addition to the Soya harbour excavation, this unit is exposed in the coastal belt (partly off-shore and partly on-land areas) south of the harbour and also on a shoal about 150 m off the coast of Kiyohama-II.

G. Sandy siltstone with some interbeds or lentils of sandstone. Fossils are rare, but for scattered occurrences of *Desmophyllites diphylloides* (Forbes), *Anapachydiscus fascicostatus* (Yabe), *Canadoceras multicostatum* and *Metaplacenticeras subtilistriatum*.

In the published geological map (Osanai

Explanation of Plate 47

Figs. 1, 2. *Eutrephoceras soyaense* sp. nov. . . . . Page 223
1. MNH. 8240606 (paratype), ventral (a) and lateral (b) views, x1.
2. MNH. 8240505 (paratype), lateral (a) and frontal (b) views, x1.

1a

2a

1b

2b

et al., 1959), Units A and B are major part of the Ohmisaki Formation and the rest (including units C to G altogether) is indicated as the Orannai Formation. Based on the concept of cycle of sedimentaion, the above subdivided units should be grouped into two formations; the lower one (the Ohmisaki Formation in a revised sense) which begins from the sandstone of Unit A and ends at Unit D, and the upper one (the Orannai Formation emend.) consisting of Units E, F and G.

Biostratigraphically, the lower formation is assigned to the Zone of *Sphenoceramus schmidti-Canadoceras kossmati*, which represents Substage K6a2 on the Japanese scale (Matsumoto, 1977, fig. 1; 1978, table 7 *in* Moullade and Nairn, 1978), approximately Middle Campanian in terms of the international scale (indicated as Cm in Text-fig. 1). Units E, F and G are to be assigned to Substage K6a3, approximately Upper Campanian (Cu in Text-fig. 1). The latter can be called the Zone of *Metaplacenticeras subtilistriatum*.

The localities of the described nautiloids, 1 to 6, are indicated in Text-fig. 1. They are referred to some of the above explained units, as will be recorded under *Occurrence* in the palaeontological descriptions.

Acknowledgments:—We are grateful to Messrs. Hajime Honma, Kinji Takagawa, Terumasa Masuda and Toshio Saheki who kindly helped us in the field work and have provided some of their obtained specimens to the Collection of MNH for this study. Thanks are extended to Mr. Akio Tanabe of Wakkanai who generously supported our study and Dr. J. A. Jeletzky who kindly sent us replica of the two type specimens of Whiteaves with necessary information. As in preceding parts, Dr. Masayuki Noda and Miss Kazuko Hara continued to help us in preparing plates of photographs and typescripts.

Palaeontological Descriptions

Class Cephalopoda

Subclass Nautiloidea

Order Nautilida

Family Eutrephoceratidae Miller, 1951

To evaluate this family one of us has discussed at length in Part I (Matsumoto, 1983).

Genus *Eutrephoceras* Hyatt, 1894

Type species:—*Nautilus dekayi* Morton, 1834.

Remarks:—For the general account of this genus, readers may refer to Miller (1947), Kummel (1956, 1964) and Wiedmann (1960), with whom we are agreeable in many respects, but for a point. Namely, in accordance with the establishment of *Kummeloceras* Matsumoto, 1983, we are inclined to restrict *Eutrephoceras* to the group of species which have nearly linear or only slightly sinuous sutures and almost smooth surface of shell, with finely reticulate or lattice ornament on a young shell. *Eutrephoceras*, thus understood, is not the direct ancestor of the living *Nautilus* but interpreted as a rather reduced group derived from *Cenoceras*.

Judging from its rather globose shell-form, smooth shell-surface and simple septal sutures, we presume that species of *Eutrephoceras* were adapted themselves to certain environments of very shallow, wavy sea-waters. A fairly common occurrence of a species of *Eutrephoceras* in particular beds (i.e. the *Fukiyose* Beds of Unit C in the preceding chapter) seems to support this interpretation.

Eutrephoceras soyaense sp. nov.

Pl. 47, Figs. 1, 2; Pl. 48, Fig. 1

Material:—Holotype, MNH. 148, consisting of the inner septate whorl (A) and the posterior portion of the body-chamber (B) from loc. 5 of Text-fig. 1. Paratypes, MNH. 8240605, MNH. 8240606, MNH. 8232102, MNH. 8232013 and GK. H5932 from loc. 3 of Text-fig. 1. There is another comparable (with indication cf.) specimen, MNH. 82032904 from loc. 6.

Description:—The shell must have been moderately large, as suggested by type specimens

MNH. 148 and 82040606. The holotype and MNH. 82032103 are somewhat smaller, about 65 mm in diameter at the end of the phragmocone.

The whorl is rounded in cross-section, somewhat broader than high, being broadest in the lower part. The umbilicus is very narrow on the internal mould and embedded by callus when the shell is preserved.

The surface of the shell looks smooth. On the young shell with diameters below 20 mm, as represented by MNH. 82032102 and GK. H5932, fine reticulate ornament is discernible.

Septation is fairly dense, about 10 per half whorl. The suture-line is nearly linear, without perceptible ventral lobe (i.e., nearly straight on the venter), very broadly arcuate (i.e., very shallowly concave) on the flank, with an indistinct low saddle near the rounded umbilical shoulder, showing a short descending line to the umbilical margin.

The siphuncle is nearly central, i.e. at about the midst of the dorso-ventral median-line of a septum.

Comparison:—*E. soyaense* is fairly similar to *E. kobayashii* Matsumoto (1967, p. 164, pl. 3, fig. 1, text-figs. 1, 2), from Urakawa (south central Hokkaido) in having the subrounded whorl, with B/H somewhat over 1.0, and fairly frequent septa, but distinguished in its central, instead of subventral, position of the siphuncle and narrower umbilicus which is filled with callus.

E. soyaense somewhat resembles *E. tawaense* Furuichi (1982, p. 336, pl. 54, figs. 1—4; text-figs. 1—4), from the Upper Campanian of Shikoku, but the latter has a narrower whorl, with B/H less than 1.0. The siphuncle position is unknown in that species. Incidentally, *E. tawaense* seems to be very close to and could be identical with *E. balchistanense* (Spengler) (1910, p. 139) [= *Nautilus sublaevigatus* of Noetling, 1897, p. 69, pl. 19, figs. 1, 2; pl. 20, figs. 1, 2], from the Upper Cretaceous of Baluchistan.

With respect to the rouned venter, central siphuncle and frequent sutures, *E. soyaense* is similar to *E. sublaevigatum* (d'Orbigny, 1850) [= *Nautilus laevigatus* d'Orbigny, 1840, p. 84,

Measurements (in mm) of *Eutrephoceras soyaense*:

Specimen		Diameter	Umbilicus	Height	Breadth	B/H
MNH.	148A	67.0(1)	4.2(.06)	38.0(.57)	43.0(.64)	1.13
	148B	—	—	70.0	80.0	1.14
MNH.	8240505	67.0(1)	0	42.0(.63)	44.0(.66)	1.05
	82040606	—	—	64.0	67.0	1.05
	82032103	60.0	—	37.0(.62)	42.5(.71)	1.15
	82032102	20.0	0	14.0(.70)	15.4(.77)	1.10
GK.	H5932	35.0	0	22.0(.63)	27.0(.77)	1.22

Explanation of Plate 48

Fig. 1. *Eutrephoceras soyaense* sp. nov. . . . . Page 223
Holotype, MNH. 148, lateral (a) and ventral (b) views of the inner whorl, frontal view (c) of both the inner and the outer whorls, x 1.

Fig. 2. *Cymatoceras honmai* sp. nov. . . . . Page 225
MNH. 144 (holotype), two lateral (a, b) and frontal (c) views, x 1.

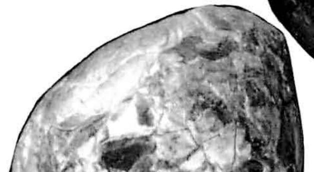
2 a

2 c

2b

1a

1c



1b

pl. 17, figs. 1–4], from the Albian of Europe, but the latter has a more inflated whorl, with a larger B/H (e.g. 1.21 in d'Orbigny's illustration). GK. H5932 has nearly the same B/H as *E. sublaevigatum*, but it is a poorly preserved small immature shell.

E. soyaense is likewise similar to *E. pseudobouchardianus* (Spengler, 1910) [= *N. bouchardianus* of Stoliczka, 1866, p. 203, pl. 92, figs. 4, 4a, which is the lectotype of *E. pseudobouchardianus* designated by Matsumoto (1967, p. 167)], from the Arriyalur Group of India, but the siphuncle is dorsocentral in the latter.

Occurrence:—The holotype was obtained by T. Miyauchi from one of the dredged blocks on the coast of Kiyohama-II at loc. 5 in Text-fig. 1. It came probably from Unit D. Most of the paratypes were obtained by H. Honma and T. Miyauchi from the wave cut terrace off the coast of Kiyohama-I at loc. 3 of Text-fig. 1. GK. H5932 was obtained by T. Matsumoto from the same locality. They came from the "*Fukiyose* Bed" of Unit C, uppermost part of the Zone of *Sphenoceramus schmidti*. A poorly preserved specimen of *E.* cf. *soyaense* was obtained at Sannai (loc. 6 in Text-fig. 1) in one of floated nodules. It may have come somewhere near the boundary of Cm and Cu in Text-fig. 1.

Family Cymatoceratidae Spath, 1927

One of us has given comprehensive remarks on this family in Part II (Matsumoto *in* Matsumoto and Muramoto, 1983).

Genus *Cymatoceras* Hyatt, 1884

In addition to *C. pacificus* Matsumoto et Muramoto, 1983, we are going to introduce herein another new species from the Campanian of Hokkaido.

Cymatoceras honmai sp. nov.

Pl. 48, Fig. 2; Pl. 49, Figs. 1, 2

Material:—Two specimens of different sizes, of which the smaller one, MNH. 144 is the holotype and the larger incomplete one, MNH. 146 is regarded as probably a part of the adult body-chamber of the same species.

Description:—The holotype is wholly septate and measured as follows (in mm):

D = 50.5, U = 5.6 (11% of D), H = 30.0,
B = 37.0; B/H = 1.23

It is an internal mould, without preserved test. It probably represents an immature stage.

The whorl is subtrapezoid in section, broader than high and broadest in the lower part, having high and nearly vertical umbilical walls, subangular umbilical shoulders, gently convex and convergent flanks, subrounded ventrolateral shoulders and a broadly arched or nearly flat venter. The umbilicus is deep and narrow, about 11 per cent of the shell diameter.

The surface of the internal mould looks smooth.

The siphuncle is dorsad from the center, being situated at the middle of the whorl-height. The septa are regularly and fairly densely disposed, numbering 19 per whorl. They show a very shallow and broad external lobe, a moderate sinuosity on the flank with an asymmetric, shallow lateral lobe, a low saddle at the umbilical shoulder and an umbilical lobe.

The larger specimen (MNH. 146), about 100 mm in breadth, is unseptate and probably represents a part of the body-chamber of an adult shell. It contains frequently septate inner whorls, which are unfortunately distorted and obliquely cut. The last septum is at about the whorl-height of 90 mm. The body-chamber is subquadrate in section, with rather flattened flanks and a very broad venter. The venter is broader and more flattened than that of the above described holotype. The apparent difference may be due to the secondary deformation. As only the inner layer of the shell is preserved, the so-called ribs are manifested indistinctly and rather irregularly. They are dense. Their backward curve is broad and shallow.

Comparison:—The holotype resembles one of the syntypes of *Cymatoceras cenomanense*

(Schlüter) (1876, p. 168, pl. 45, figs. 1, 2), from the Cenomanian of West Germany, in shell-form, position of siphuncle and septal density. There is, however, unnegligible difference in the sutural pattern. In that German specimen the lateral lobe is somewhat deeper than in ours and in addition there is a saddle at about the umbilical shoulder. Such a distinct saddle is lacking in the holotype of the present species.

Occurrence:—The holotype was obtained by H. Honma in 1981 from a pile of rock fragments dredged at loc. 2 of Text-fig. 1, off the western coast-line of Kiyohama-I. It is undeformed and its rock matrix is greenish dark grey, calcareous fine-sandy siltstone. Presumably it may have come from Unit E on the western side of the compact and coarse sandstone of Unit G which constitute the wave cut terrace for a long distance off the western end of Kiyohama-I.

The paratype was obtained by one of us (T. Miyauchi) from one of the blocks excavated from the bottom of the reconstructed harbour of Soya at loc. 1 in Text-fig. 1. It is certainly referable to Unit E (i.e. the Subzone of *Schlueterella* sp. nov.).

Genus *Anglonautilus* Spath, 1927

Type species:—*Nautilus undulatus* J. Sowerby, 1813.

Remarks:—We depend on Kummel (1956, p. 430), who has given a generic diagnosis on the basis of his observation of the topotype (Kummel, 1956, pl. 20, figs. 1, 2; text-fig. 1), from the Aptian of England. *A. undulatus* can be said to range up to the Cenomanian, since the specimens of Sharpe (1853, pl. 5, fig. 4) and Shimansky (1960) are referred to the same species. Two other Lower Cretaceous species have been regarded by Kummel as belonging to *Anglonautilus*, but no species later than the Cenomanian has been known.

The species described below is certainly referred to the same genus and thus the range of the genus is extended upward to the Campanian. One of us (Matsumoto) has noticed a poorly preserved specimen in the late Dr. Shingo Yehara's Collection (Tenri High School, 1981, p. 20), from the Upper Aptian of Miyako (?) (Northeast Japan), which may be referable to this genus. Another new species from the Cenomanian of Hokkaido has been recently described by Matsumoto and Takahashi (1982).

Anglonautilus mamiyai sp. nov.

Plate 50, Fig. 1

Material:—A single specimen, MNH. 147, that is the holotype by monotypy. The shell layer is preserved.

Description:—At the preserved last part the shell is measured as follows in mm:

D = 95, H = 59(.62), B = ca 33 x 2 = 66(.69);
B/H = 1.12

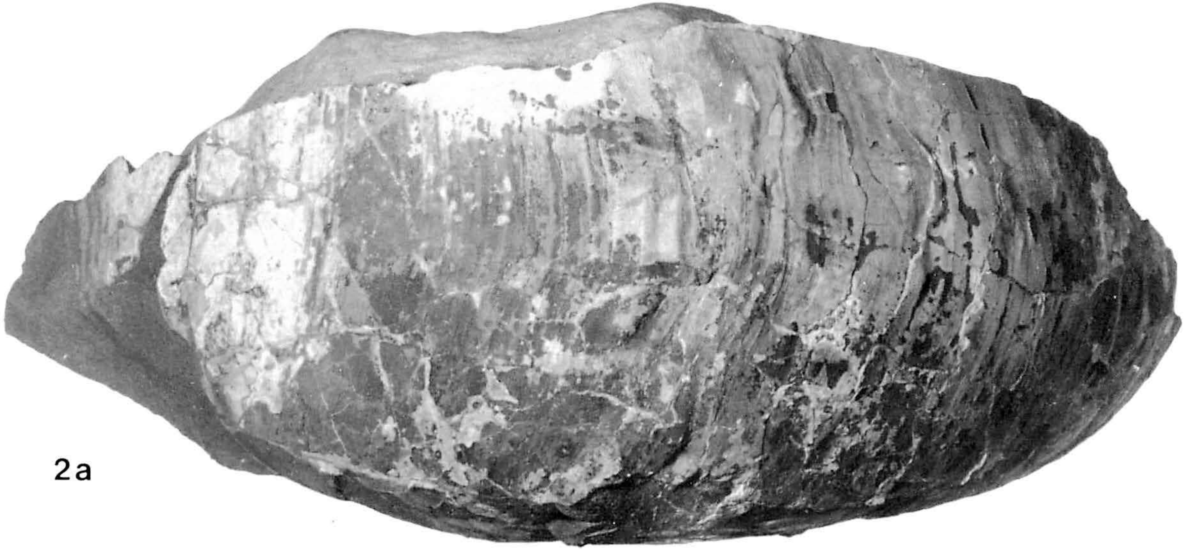
The last septum is at about 75 mm in diameter and the body-chamber is preserved for about 120° on the right side; its true length probably exceeds that amount to some extent. The left side is somewhat broken obliquely, so that a part of the inner whorl is favourably shown. For some reasons a part of the phragmocone is distorted for about a half volution (i.e. from −180° to −360° preceding to the last half whorl).

The body-chamber is subrounded-subquadrate

Explanation of Plate 49

Figs. 1, 2. *Cymatoceras honmai* sp. nov. . . . . Page 225
1. MNH. 144 (holotype), ventral view, x1.
2. MNH. 146, ventral (a) and lateral (b) views, x0.7.

1



2a

2b

in section, with gently inflated flanks, rounded ventrolateral parts and a broad venter with a shallow depression on the middle. It is broader than high, with B/H = 1.12. On the test of the outer whorl a fine longitudinal elevation is faintly discernible on the extension of the median line of the ventral depression. It cannot be called a keel and is not impressed on the internal mould. It may not be worth special consideration for a specific diagnosis.

On the septate whorl there is no ventral depression. The venter is broadly rounded in its late part but somewhat more narrowly arched in the next inner whorl. The umbilicus is nearly closed and surrounded by a steeply inclined wall.

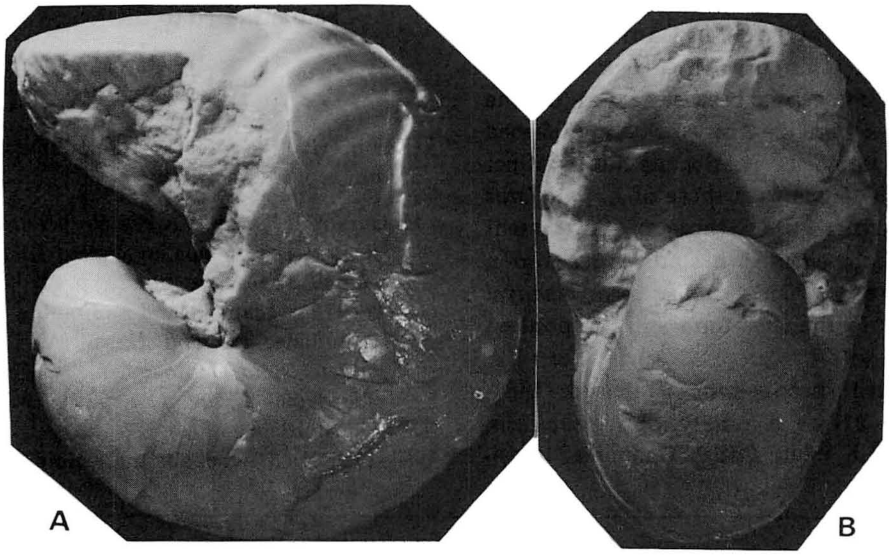
On the outer whorl there are low and broad, blunt undulations which are better manifested on the ventrolateral part. They show a considerably backward sinus on the venter. On the surface of the outer shell-layer fine growth-lines and periodic lirae are discernible.

On the surface of the shell of the next inner whorl, there are fine radial and longitudinal (i.e. spiral) lirae, forming a lattice pattern. The radial lirae show only very shallow and broad, backward curvature on crossing the venter.

The siphuncle is somewhat dorsad of the center, crossing septa at about the middle of the whorl-height. The septal suture is rather simple, showing a very shallow and broad external lobe and only a slight sinuosity on the side.

Etymology:—The locality is close to the historical landing place, where Rinzo Mamiya sailed off to Sakhalin in 1808 for a geodetic work. The species is dedicated to this pioneer geographer.

Comparison:—The holotype of the present species is fairly similar to the topotype of *Anglonautilus undulatus* (Sowerby), from the Lower Greensand of England, figured by Kummel (1956, pl. 20, figs. 1, 2; text-fig. 26) in the generally subquadrate whorl-section and the presence



Text-fig. 2. *Anglonautilus suciensis* (Whiteaves).
Replica of the lectotype, supplied to Kyushu University by courtesy of the Geological Survey of Canada. Lateral (A) and frontal (B) views, x0.8.

(Photos by M. Noda.)

of low and broad undulations. The undulations are more distinct and coarser and the suture shows a more pronounced lateral lobe in the latter. The former has more convex flanks than the flattened ones in the latter. The shallow ventral groove is characteristic of the former.

A. undulatus from the Cenomanian of the northern Caucasus, illustrated by Shimansky (1960, p. 244, pl. 3, fig. 1), is much larger and has less depressed whorl and stronger ribs than the holotype of the present species.

A smaller specimen figured by Sharpe (1853, p. 15, pl. 5, fig. 4a—c) under *N. undulatus*, from the Varians Zone (Cenomanian) of England, has likewise coarser, more distinct ribs than ours on the ventral part of the body-chamber. Its whorl is higher than broad than the above mentioned topotype, but this may be a variation. Anyhow, it has a distinctly more compressed whorl and more sinuous sutures than the holotype of the present species.

The illustrated syntype of *Nautilus suciensis* Whiteaves (1879, p. 97, pl. 11, fig. 1, 1a) (Text-fig. 2), from the Campanian Division A [= "Productive Coal Measures"] of Sucia Islands, which is designated here as the lectotype of that species, may be better referred to *Anglonautilus* rather than to *Cymatoceras*, because it has on the body-chamber fold-like ribs which are weakened toward the umbilicus. Its ribs are more distinct and more numerous than those of *A. undulatus* and still more so than those of the present species. Its body-chamber has no ventral groove, but otherwise it is fairly similar to *A. mamiyai* with respect to the shell-form and the position of siphuncle.

A specimen described by Whiteaves (1884, p. 197, pl. 21) as a variety of *N. suciensis*, from Skidegate Inlet, British Columbia, is evidently referred to *Cymatoceras*, and was called later *N. (C.) carlottensis* Whiteaves (1900, p. 269). It is similar to, if not identical with, *C. atlas* (Whiteaves, 1876). Its body-chamber has a ventral groove.

Occurrence:—This interesting specimen was found by a schoolboy with K. Takagawa in one of the calcareous nodules at loc. 4 of Text-fig. 1 on the sea-shore of Kiyohama-II [= "Orannai"] on the 12th April 1980, and then kindly presented to the MNH Collection. The lithology of its rock matrix (grey calcareous siltstone) and the mode of shell preservation, as well as other fossils, suggest its derivation from the upper part of Unit C.

Repositories

GK:	Geological Collections, Kyushu University, Fukuoka.
MNH:	Natural History Collection of Northern Hokkaido, c/o T. Miyauchi, Midori 6-Chome, Wakkanai. The Holotype with a MNH number is to be transferred to GK.

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(For brevity the references listed in Parts 1 and 2 are not repeated here.)

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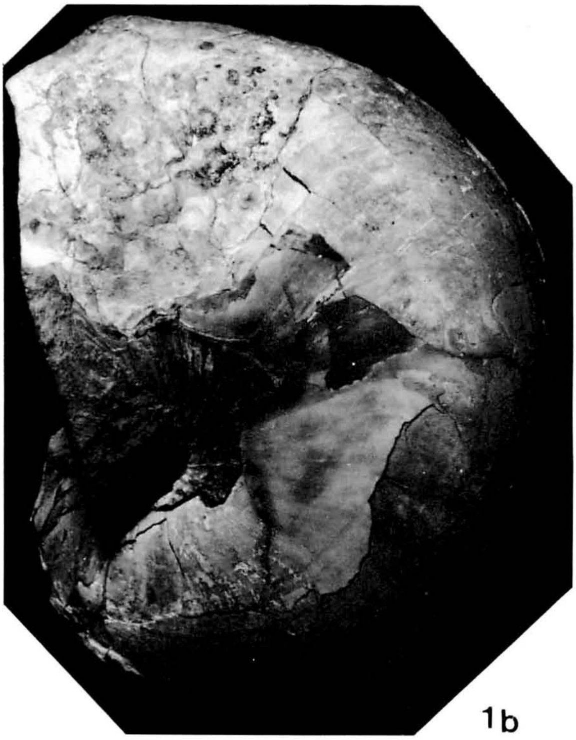
Explanation of Plate 50

Fig. 1. *Anglonautilus mamiyai* sp. nov. . . . . Page 226
MNH. 147 (holotype), ventral (a), two lateral (b, d) and frontal (c) views, x1.

Photos (Pls. 47—50) by courtesy of Dr. M. Noda.


1a


1b

1c

1d

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Kiyohama 清浜, Koishi 小石, Magaribuchi 曲淵, Maru-yama 丸山, Ohmisaki 大岬, Onkoromanai オンコロマナイ, Orannai 尾蘭内, Sannai 珊内, Soya 宗谷, Urakawa 浦河, Wakkanai 稚内

北海道産白亜紀オウムガイ類—III．その3。宗谷のカンパニアン産オウムガイ類：宗谷岬の北西海岸地帯には，カンパニアン中部（第1図 Cm）から上部（Cu）にわたる地層が露出する。この地層からオウムガイ類化石が若干産出した。これらを整理し3種を識別して，(1) *Eutrephoceras soyaense*, (2) *Cymatoceras honmai*, (3) *Anglonautilus mamiyai* と命名，新種として記載した。(1) は *E. kobayashii* や *E. pseudobouchardianum* に似るが，連室細管が中央に位置し，*E. tawaense* より螺環の幅が広い，(2) は *C. cenomanense* に似るが，縫合線の波打ちが弱い，(3) は *A. undulatus* に比し肋がはるかに弱く，住房の外面中央に浅い凹帯が発達する。なお当地の層序を下から A—G の部層に分け，A—D と E—G がそれぞれ堆積サイクルを示し，改訂した大岬層と尾蘭内層に当たり，各々の時代は Cm, Cu である。(1) は C, D, (2) は F, (3) はたぶん C 部層産である。いずれも外洋に面した浅海相とみなされる。

松本達郎・宮内敏哉

Trans. Proc. Palaeont. Soc. Japan, N. S., No. 132, pp. 230—252, December 30, 1983

771. PALYNOLOGICAL STUDY OF 200-METER CORE SAMPLES FROM LAKE BIWA, CENTRAL JAPAN

I: THE PALAEOVEGETATIONAL AND PALAEOCLIMATIC CHANGES DURING THE LAST 600,000 YEARS*

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Abstract. The samples of a 200-meter core obtained from the present bottom in Lake Biwa, Central Japan for the investigations of the palaeoclimatic and palaeovegetational changes in and around the lake during the last 600,000 years can be divided into 19 pollen zones from the view point of palynology. The palaeoclimatic change and the ages of glacial and interglacial stages display similarity to the palaeotemperature curve by oxygen isotope ratio determination from the Caribbean Sea. During the glacial stages or stadials, the typical vegetation thriving today in the Subpolar or Subalpine zone of Japan prevailed at the summit area and/or the montane area around Lake Biwa, and in the lowland around the lake, plants growing today in the Cool Temperate zone were distributed. In the interglacials and interstadials, the palaeovegetation in the higher area was characterized mainly by plants of the Cool Temperate zone and the present Temperate zone, and in the lowland, the palaeovegetation was composed mainly of broadleaved deciduous and evergreen trees growing in the Warm Temperate zone.

Introduction

The existence and character of several Quaternary glaciations are documented by the glacial geology, topography, palaeoclimatology, and palaeopedology in many countries. In Europe, during the cold part of the last glacial age (Dreimanis *et al.*, 1972), some 15,000 to 20,000 years before the present, an inland ice sheet covered the nothern part of the continent, and both mountain and piedmont glaciers covered the Alps. Almost the whole area between the southern border of the inland ice and the Alps was poor of forest; it was covered only with tundra or cold steppe vegetation.

In the Japanese Islands, however, crustal movements, volcanic activity, weathering, and erosion have dominated during this period. The Islands were not affected by an ice sheet or piedmont glaciers; there were only some small glaciers in a few high mountain areas such as the Japan Alps and Hidaka Mountain Chain. It therefore is difficult to depend on glacial geology and topography or palaeopedology to study the history of glaciation in this area. The detailed chronology of stadials and interstadials during the last glacial age is complex. So are correlations with earlier glaciations in

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Europe and North America. Therefore, if we do not want to lose ourselves in a terminology based on inaccurate correlations, it seems necessary to establish a stratigraphic nomenclature which is not primarily based on meager and inaccurate evidences in mountainous regions, but rather on sedimentary sequences in basins outside the glaciated regions. Extensive deposits from glacial and interglacial times can be studied in deep bore holes. Pollen analysis of the stratigraphic sequences in minute details during the last two million years can reveal a continuous record of the change of vegetation and climate in the non-glaciated area.

With this objective in mind, a project was proposed to study 200-m core sediments from Lake Biwa obtained in 1971 (Horie *et al.*, 1974). As a member of a research team the writer has been engaged in an intensive investigation of the palaeolimnological evidence of the subsurface deposits of the lake.

In this paper, a palynological record of the continuous 200-m core sediments, spanning the last about 600,000 years from Lake Biwa is presented, along with the vegetational and climatic interpretations of this record. A more detailed record from the core and the interpretation will be presented in the near future.

Acknowledgments

The palynological investigation reported herein was carried out during a stay (1975 to 1976) at the Limnological Research Center of the University of Minnesota, Minneapolis, Minnesota, the United States of America. I am greatly indebted to Prof. Herbert E. Wright Jr. of the Limnological Research Center for his kind advice and the helpful criticism of the manuscript. I am indeed grateful for the support and encouragement of Dr. Shoji Horie of the Institute of Palaeolimnology and Palaeoenvironment on Lake Biwa, Kyoto University and Dr. Teiichi Kobayashi, Prof. Emeritus of the University of Tokyo during this investigation. I wish to express my acknowledgment to Prof. Edward J. Cushing of the Department of Ecology, University of Minnesota, to Prof. W. A. Watts of the Botany Department, Trinity College, Dublin in Ireland, to Dr. C. R. Janssen of the Laboratory of Palaeobotany and Palynology, Utrecht, Netherlands, and to Dr. Hsin-Yi Ling of the Department of Geology, University of North Illinois for their useful discussion. I also acknowledge the help of Miss Kazuko Kaneda of the Kanazawa University. My investigation made possible through a Scientific Grant from the Ministry of Education, Japanese Government for ten years (1971 to 1980) and a help of the University of Minnesota, U.S.A.

Significance of research on deposits from Lake Biwa

Palaeomagnetic stratigraphy has provided a means of correlating continents and oceans over the world. With the advent of deep-sea research by DV Glomar Challenger and other oceanographic vessels, oceanographers and geologists have verified the probable existence of continental drift through work conducted on an international scale and thus established a new field of plate tectonics and neotectonics.

Recent studies of sediments in deep-sea cores (Hays *et al.*, 1969) and of loess deposits from central Europe (Kukla, 1970) indicate successive changes of palaeoclimate during the Quaternary period.

Our understanding of climatic change during the Quaternary period are based primarily on research on terrestrial and submarine deposits. However, the Quaternary system exposed on land is frequently represented by coarse-grained materials such as sand and gravel. This is true of Pleistocene deposits from the Japanese Islands but also in deposits from Europe. The pollen record, unfortunately, is not continuous in northern Europe, because, especially in the late and middle Pleistocene, deposits suitable for pollen preservation, like peat and clay, were principally formed during the interglacials and interstadials. Deposits from glacial times are not preserved even in areas located between the ice sheets. Coarse-grained materials such as sand and gravel are not suitable for pollen analysis. Furthermore, if the change of sea level is explained by glacial-eustatic theory, sea level should have been lower during the cold glacial and stadial times. Therefore, it is difficult to collect continuous samples in the Quaternary period, which is characterized by an alternation of warm and cold climatic times.

On the other hand, although sediments of both the cold and warm periods are complete in the deep-sea cores, we cannot evaluate changes in climate over short periods because of the extremely slow sedimentation rate.

On the basis of the above-mentioned considerations, the following conditions have to be satisfied if climatic changes can be investigated by means of palynological, geochemical and palaeomagnetic analyses:

a: the rate of sedimentation must be large,
b: the sediments must be entirely *fine-grained materials*, such as silt, clay, or gyttja, and
c: the sediments must be *continuous* since the early Pleistocene.

According to a few glacial-geological field works (Minato, 1972; Kobayashi, 1958; and Horie, 1961 etc.), several expansions of glaciers probably occurred in the Japanese Islands during the Wisconsin glacial age, those fluctuations being closely similar to the oscillation of the ice sheets in both Europe and North America. Late-Pleistocene climatic changes were probably synchronous throughout the Northern Hemisphere. In unglaciated areas, the bottom sediments of ancient lakes may cover the whole Pleistocene. Lake Biwa in Central Japan is such a lake (Horie, 1961 & 1962). The exact thickness of bottom deposits in the center of the lake is not known yet, but geological evidence indicates that the lake was formed in the latest Pliocene or earliest Pleistocene and has been in existence continuously. Furthermore, Lake Biwa is the third oldest lake in the world, after Lake Baikal and the Caspian and Aral Seas.

In addition, Lake Biwa is important for the following reasons:

a) A strikingly negative gravity anomaly exists in the northern part of Lake Biwa, amounting to —55 milligal. Isoanomaly lines almost coincide with the outline of coastal line of this lake (Tsuboi *et al.*, 1954; Abe *et al.*, 1974). Such gravity anomaly suggests us the existence of extremely thick (ca. 1,000 m class) lacustrine sediments.

b) A great number of endemic species of animals and plants is known in the lake. They differ markably from the biota of other parts of Japan.

c) Judging from the previous geological studies (Ikebe, 1933; Takaya, 1963; Hayashi, 1974), the Pliocene-Pleistocene and Pleistocene-Holocene boundaries exist in lake sediments that are preserved as the lacustrine terraces. This fact affords us the evidence of an ancient Lake Biwa that appeared in sometime during the Neogene.

A deep boring in such a lake having an extremely long limnetic history must yield valuable samples for palynological research. These samples contain a continuous record of the change in climate since the latest Pliocene or earliest Pleistocene. These results may be correlated with changes in climate during the Quarternary period already worked out in North America (Dreimanis *et al.*, 1972) and Europe. From those viewpoints it may be said that the long core is significant for the promotion of our knowledge in the Quaternary geology not only in the Japanese Islands but also in the other countries of the globe.

Topography

Lake Biwa, the largest lake in the Japanese Islands, is located northeast of Kyoto, Central Japan (approximately 35°13′10″ N. Lat. and 136°1′28″ E. Long.). As shown in the topographic map (Text-fig. 1), a lowland around Lake Biwa is named the Omi Basin. Wakasa and Ise Bays are located respectively in the northwest and southeast of the basin. The lake is situated just on the isthmus that seems to be the distorted portion of two arcs comprising Honshu Island.

The Nosaka Mountains (500—1,000 m) occur on the border between Fukui and Shiga prefectures of the north of this basin, the Ibuki

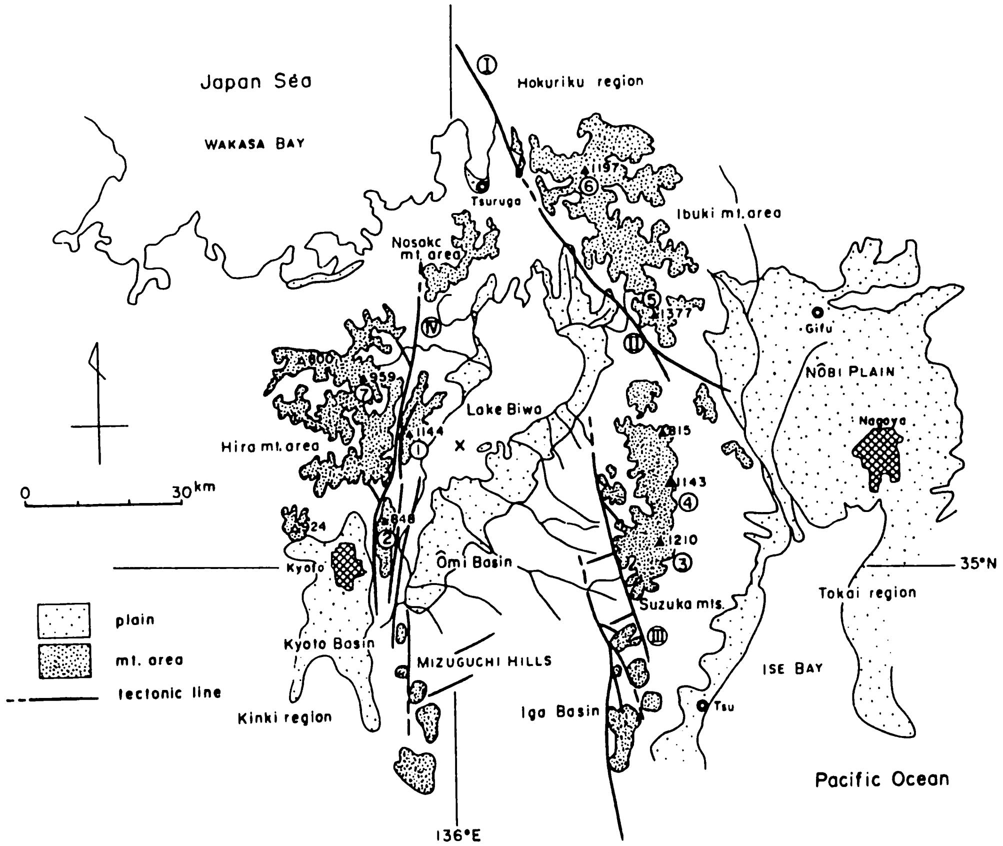
Mountains (500—1,300 m) on the border between Gifu and Shiga prefectures, the Suzuka Mountains (500—1,200 m) on the prefectural borders between Shiga and Mie or Gifu prefectures of the east of the basin, and Hira Mountains (500—1,200 m) and Mizuguchi Hills to the west and south of the lake.

Although the distance between the abovementioned mountain areas and the lake is very short (5—20 km), the difference of height between mountain and the lake is large (500—1,200 m). Rivers flowing into the lake, therefore, generally are fast.

An important topographical character around the lake is an existence of graben structure. In both the eastern and western sides of the lake, there are active faults with north-south trend (the Suzuka trend of Huzita, 1962).

Climate

Most of the Omi region under discussion is the central part of the Temperate zone, and the weather is controlled mainly by topography characterized by the large lake and the north-trending. mountains. In general, the weather of the northern half corresponds to that of the Hokuriku region, while the southern part to that of the Kinki region. At Otsu the mean annual temperature is about 14°C.



Text-fig. 1. Topographic map of the Lake Biwa area, Central Japan.
1: Mt. Hira, 2: Mt. Hiei, 3: Mt. Gozaisho, 4: Mt. Fujihara-dake, 5: Mt. Ibuki, 6: Mt. Mikuni-ga-dake, 7: Mt. Mikuni-dake, I: Kaburaki tectonic line, II: Yanagase tectonic line, III: Suzuka tectonic line, IV: Hira tectonic line, x: boring locality.

The weather system in summer is more or less controlled by the Bonin high atmospheric pressure. The mean July temperature of the area increases to about 24°C, and the precipitation decrease to about 150 mm. In spite of little precipitation the Omi basin is relatively humid because of higher evaporation rate from the large lake in its center. During this season a southerly wind prevails.

During the winter the weather is dominated by the Siberian high pressure. The average January temperature is about 2°C, and the precipitation in the same month is about 300 mm. Strong humid northwesterly or westerly winds prevail in the area, and snowfall is abundant in the northern part and mountainous areas.

Frost occurs first in early November. There are 200 non-frost days and 1,900 hours of sunshine per year. The basin is hidden in a mist for about 60 days as the result of much evaporation from the lake.

Vegetation

The vegetation around the lake is complicated, and due partly to the above climatic condition, and partly to the fact that the lake located near Kyoto, which was a capital of Japan for about 1,100 years, for a long time man has exacted a heavy toll on the natural vegetation by clearing forests for farming, by lumbering for ship-building, by cutting wood for charcoal, and by using timber for domestic purposes. The reconstruction of the vegtation around the lake, as in many other areas in the Japanese Islands and in other countries, poses serious difficulties. The original vegetation has been destroyed throughout the surroundings of Lake Biwa.

The vegetation around the lake belongs to the flora of the central part of the Temperate zone and is located near the northern limit of *Citrus* (orange) in the Japanese Islands. The vegetation is divided into two types, namely *Querco-Fagetea crenatae* and *Camellietea japonicae* types (Kobayashi *et al.*, 1974).

1) *Querco-Fagetea crenatae* region

The *Querco-Fagetea crenatae* region occurs around Mt. Hira and in the Ibuki and Suzuka Mountains. The flora of this type is found in areas higher than about 300 m above the sea level in the northern part and higher than 700 m in the southern part of this region.

In the neighborhood of the lake, this type is divided into eight natural communities. They are: *Lindero umbellatae-Fagetum crenatae*, *Querco-Clethretum barbinervis*, *Scrophulario-Aceretum shirasawae*, *Rumohreto-Eupteletum polyandrae*, *Zelkova serrata*, *Enkianthus cernuus forma rubens*, *Fagus crenata-Cryptomeria japonica* and *Hosta montana* communities. Among them, *Lindero umbellatae-Fagetum crenatae* is distributed at about 800 m in the Ibuki Mountains, and *Zelkova serrata* community occurs along a valley, with *Quercus acutissimo serratae* belonging to *Camellietea japonicae* region in the northern part of this region. *Fagus crenata-Cryptomeria japonica* community occurs around the summit area of Mt. Hira. The distribution of the other communities and assemblages is confined to local area in the region. Although *Cryptomeria japonica* does not mix with *Fagus crenata*, the former mixes with *Quercus cripula* or *Castanea crenata*. The *Lindero umbellatae-Fagetum crenatae* is scattered in the *Cryptomeria japonica* forest. *Abies firma-Illicium regiosum* community occurs on a very small scale together with *Larix leptolepis* about 750 m high on Mt. Hiei.

A substitutional vegetation of the *Querco-Fagetea crenatae* region is divided into *Fagus crenata-Quercus mongolica* var. *grosseserrata* community, *Castaneto-Quercetum crispulae*, *Cryptomeria japonica-Chamaecyparis obtusa* plantation, *Sasa* and *Miscanthus sinensis* communities in the Omi region. The *Fagus crenata-Quercus mongolica* var. *grosseserrata* community is substitutional vegetation of *Fagus crenata* forest. Around 700–800 m high in the Nosaka, Hira, Ibuki and Suzuka Mountains, the *Quercus crispula*, *Fagus japonica*, *Acer japonicum*, and *A. rufinerve* are distributed as high trees, *Parabezoin trilobum* of the above-mentioned community grows remarkably as scrub or small tree. *Castaneto-Quercetum cripulae* is distributed wide between *Fagus crenata-Quercus mongolica* var. *grosseserrata* community area and *Quercetum acutissima-serratae* area belonging to *Camellietea japonicae* region. A distributional lower limit of the *Castaneto-Quercetum crispulae* is distributed about 600 m above the sea level at the southern part of this region, and about 300 m at the northern part. *Sasa* or *Miscanthus sinensis* community scatters at the summit areas and ridges reaching to 1,000 m or more in altitude.

2) *Camellietea japonicae* region

The *Camellietea japonicae* region covers a wide area in the Omi basin. However, natural vegetation belonging to this type occupies very small areas. In this region, the natural forest of broadleaved evergreen trees is as follows: *Quercus glauca*, *Quercus myrstona-efolia*, *Bladhio-Shiietum cuspidatae*, *Aucuba japonica* var. *borealis-Quercus stenophylla* communities.

On the other hand, *Alnus japonica* and *Salix scrub* are found on a small scale along the lakeside or riverside in the northern part of this region.

A substitutional vegetation of the *Camellietea japonicae* region is divided into thirteen communities or assemblages as follows: *Quercetum acutissimo-serratae*, *Rhododendron-Pinetum azumanus*, *Rhododendron-Pinetum kinkianum*, *Sasa*-bamboo, *Bamboo* stand, *Miscanthus sinensis*, *Phragmites* communities, *Salix scrub* in riverside, *Thea sinesis* garden, *Mornus* garden, Paddy-field weed communities and *Pinus thunbergii* plantation. Among them, the *Pinus densiflora* forest occupies very wide areas. The forest is divided into *Rhododendron-Pinetum azumanum* and *Rhododendron-Pinetum kinkianum*. The latter assemblage is distributed in the southern part, and the former in the northern part. Roughly speaking, in the northern part of this region the *Quercetum acutissimo-serratae* is distributed wider and higher than the distributional area of the *Pinus densiflora* forest. This assemblage, however, is dotted with the *Pinus* forest in the southern part.

The true natural vegetation is very sparse around Lake Biwa, and most of it is found in the *Querco-Fagetea crenatae* region. The original vegetation is almost never found in the *Camellietea japonicae* region except forests composed of a several broadleaved evergreen trees around some shrines and temples and the *Zelkova serrata* community in the northern part.

In this region, the snow line and forest line are about 4,300 m and 2,300—2,600 m above the present sea level respectively (Minato *et al.*, 1958).

Geology

Palaeolimnology is Pleistocene stratigraphy applied to lakes (Deevey, 1955), that is, it is lacustrine biogeography with a discussion of the problems of such ancient lakes as Lake Biwa. The writer will discuss at first the discontinuous distribution of biota in the lake sediments around the lake.

Judging from many stratigraphic and palaeontologic observations on ancient deposits around the lake (Ikebe, 1933, and Ishida *et al.*, 1969), it is presumed that the lake appeared in the latest Pliocene and has continued its existence ever since.

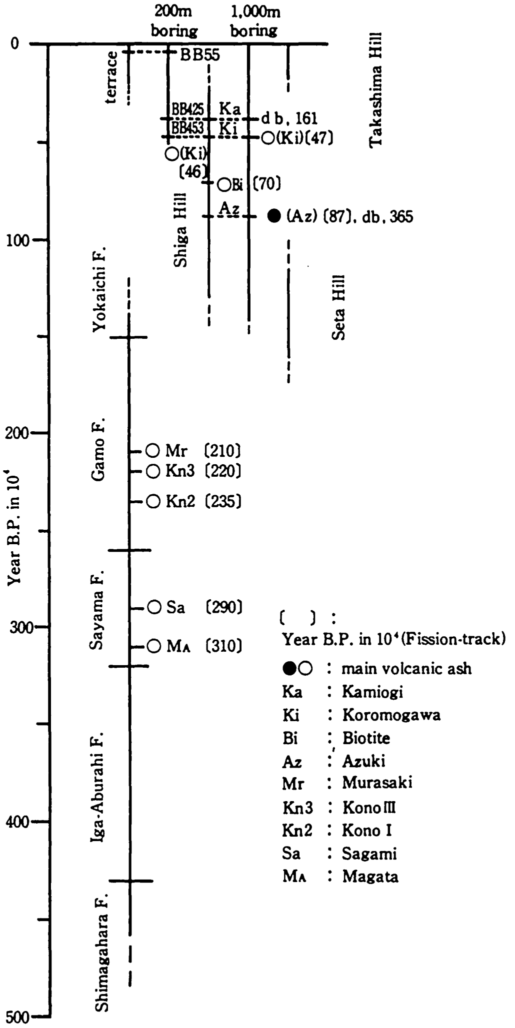
The Quaternary system in and around Lake Biwa has been roughly divided into the following three groups (Yokoyama *et al.*, 1974);

1) Plio-Pleistocene Kobiwako Group

This group occupies the Omi and Iga basins. It is 1,000 to 1,500 m in total thickness and is divided into six formations which are composed of lacustrine and fluvial deposits and yield many lacustrine fossil molluscs similar to those living in the present lake. Some mammal fossils such as *Stegodon orientalis* and *Elephas shigensis* are found in the Pleistocene deposits. The radiometric ages of 3.0 to 0.35 million years from minerals contained in the volcanic ash-layers of this group were obtained by means of the fission-track (Nishimura and Yokoyama, 1975). The absolute age of the basal part of this group is estimated to be 4.5 to 5.0 million years before the present.

2) Middle to Late Pleistocene Terrace Deposits

These deposits consist mainly of a single gravel layer. Fossil remains are scanty except



Text-fig. 2. Chronological correlation among the Quaternary deposits in and around Lake Biwa.

in a few localities. The thickness of these deposits is less than 20 m.

3) Holocene Deposits

These deposits are mostly fan and/or deltaic sediments deposited by the present rivers, and composed of sandy beds mixed with some clay and gravel. The thickness of these deposits is about 10 m.

Geomorphologically the base of the Lake Biwa basin has been regarded as the Neogene (?Miocene) peneplain which was subsided by down-warping accompanied by faulting. The connection between the lake and Japan Sea or Osaka Bay at that time may have been possible, for the peneplain was formed near sea level. The existence of such connection is supported by the occurrence of land-locked marine fishes and molluscs in the lake (Kuroda, 1948). Since then, the lake basin has continuously occupied an environment isolated by the surrounding barriers for more than two million years without any serious geological disturbance.

Tectonic lines stated already show recent activity and indicate that the crustal movement has continued during the Quaternary. The Omi, Iga, Kyoto, and Nara basins near the lake were formed along the Suzuka trend. These tectonic lines are very important in a discussion of the origin and the geological structures in and around the lake.

The center of downwarping of the Lake Biwa basin almost coincides with the center of the gravity anomaly. There is an argument among geophysicists whether such a peculiar gravity anomaly is caused mainly by the special structure of the earth's crust or mainly by thick lacustrine sediments, but if the latter is correct, we can expect the existence of extremely thick sediments, resulting from continuous sinking of the lake basin. This inference is supported by the geological evidence of a few recent long drilled cores in the eastern area of the Omi basin.

Palynological investigation

(a) Location of the Boring

A 200-m core used for the writer's investigation was collected from Lake Biwa in the water depth of 65 m at a location between the Okinoshima Island and Omi-maiko in Shiga Prefecture, during the autumn of 1971.

(b) Description of Core Samples

About one and half months after recovery, the long core was cut at 1 m length, and samples were taken at intervals of about 5 m for primary analyses. The core was then frozen and cut longitudinally. Samples used for geochemical analyses, palaeomagnetic, palaeontologic, mineralogical, granulometric, and radiometric dating analyses were taken always from a half of the core keep under frozen state. The other half of the core was divided for observation of lithofacies and volcanic ashes under the normal state after melting.

The core sediments mainly consist of soft homogeneous clay including at least 30 thin volcanic ash layers. The clay is generally blue in color when it is fresh, though it is grey or black at several horizons. The balck clay contains some plant fragments (Yokoyama *et al.*, 1974, 1975). Almost all grains of sediments are smaller than 44 microns in diameter, except either large plant fragments or volcanic materials.

No sedimentary structure can be observed by the naked eye.

The volcanic materials in the core samples are divided into two types, andesitic and trachytic. The former contains two pyroxenes, hornblende, and abundant volcanic glass. The latter is chiefly composed of orthorhombic pyroxene, hornblende, biotite, quartz, volcanic glass flakes, and small pumice grains and were derived from Quaternary volcanoes such as Dai-sen, Sanbe-yama, Ohe-takayama, etc., which occur 100—350 km west of Lake Biwa (Yokoyama, 1973).

About 50 smaples taken at intervals of about 5 m throughout the core were analyzed for palynological investigation.

The samples taken from the same horizons have been analyzed for chemical components, palaeomagnetism, particle size, clay mineralogy, and microfossils.

(c) Preparation for Pollen Analyses

Pollen grains in the sediments were concentrated with slight modifications (Fuji, 1963, 1965, 1973, 1974, 1975, 1976) of the method described by Faegri and Iversen (1964). Sediments containing coarse organic materials as moss, small leaves, and small shells were strained through a fine screen. As most sediments were predominantly silt and clay, they were left for 2 hours in hydrofluoric acid to remove the siliceous minerals. They were treated by standard acetolysis method. Pollen grains from most samples were stained with safranin, and were mounted in glycerine jelly. Throughout the present investigation one slide (size of covering glass area: 24 x 24 mm) was generally enough to obtain a pollen count of about 500.

(d) Method for Interpretation of Palaeovegetation and Climatic History

The writer depends upon pollen analyses for reconstructing a vegetation during a geological age. For the interpretation of pollen spectra obtained from the 200-m core sample the writer used two ways as (1) pollen spectra of the modern samples taken in and around Lake Biwa and from various localities of some climatic zones throughout the Japanese Islands (Wright *et al.*, 1967), and (2) the warmth index (month-degrees) (Fuji, 1965). According to the law of total effective temperature, the distribution of a plant is influenced more with the sum of mean day or month temperature than with the mean annual temperature. The total temperature is given by the formula:

$(e_m - p)$, where

e_m: mean month temperature

p: physiological zero point, which is shown generally to be by 5°C in the Japanese Islands

In the formula, if e_m is smaller than p, $(e_m - p)$ value is omitted from this formula.

The total temperature is generally called the "warmth index" (Kira *et al.*, 1958).

The relationship among the warmth index (month-degrees), major plants growing in the Japanese Islands, latitude, temperature and climatic zones is summarized. On the basis of the distribution of the warmth index of every plant, all of the arboreal genera found from the samples can be grouped into one of the following five groups: the Subpolar or Subalpine zone (warmth index month-degrees: 15°—55°), the Cool Temperate zone (45°—90°): the Cool Temperate zone — Temperate zone (55°—140°); the middle part of the Cool Temperate zone — Warm Temperate zone (70°—140°); and the southern part of the Temperate zone — the Subtropical zone (100°—180°).

(e) Construction of the Diagrams

Shown from the left to the right in pollen diagrams are sediment stratigraphy, lithofacies and depth of the core, spectrum number, C^{14} and fission-track dates, palaeomagnetic stratigraphy, summary diagram, pollen profiles of each taxon and assemblage zone. The pollen sum used on the pollen types concerned, on the local situation, and on the kind of deposit. The main pollen diagram is divided into two parts. The pollen diagram (2) shows all non-arboreal pollen (herbs), aquatic and marsh plants, and ferns, excluded from the pollen sum but calculated as a percentage over the pollen sum. Percentages in both diagrams are shown on two scales; the scale with 10 x exaggeration permits the accurate plotting of minor curves and minor fluctuations. The summary diagram is drawn to facilitate the discussion and interpretation of palaeovegetation and climatic history. This summary diagram is composed of changes of the ratio between total AP and total NAP, and of percentages of the Subpolar plants, Cool Temperate plants, Cool Temperate — Temperate plants, plants of the middle area of the Cool Temperate zone and of the Warm Temperate zone, and plants of the southern area of Temperate zone and of the Subtropical zone, calculated on the basis of the warmth index (month-degrees) as will be described in a later chapter. There follow the curves for boreal conifers.

(f) Remarks on Identification of Pollen Grains

Most of pollen grains from the core samples are found in the present Japanese Islands, and their descriptions can be found in the published references.

Some of the critical genera are discussed below.

1) *Abies*: In the Japanese Islands, six species belong to *Abies*. *A. Mariesii*, *A. Veichii*, *A. sachalinesis*, and *A. sachalinesis* var. *mayriana* grow in the Subpolar or Subalpine zone. *Abies homolepis* and *A. firma* grow in the Cool Temperate and Temperate zones. Pollen grains of latter two species, however, are not distinguished from other species of *Abies* from the view point of the shape of pollen grains.

2) *Picea*: Six species of *Picea* are found in the Islands. Although *Picea* is not classified into species on the basis of pollen morphology, *P. jezoensis* and *P. jezoensis* var. *hondoensis*, *P. glehnii*, *P. bicolor* var. *reflex*, and *P. bicolor* grow in the Subpolar of Subalpine zone, and *Picea polita* is found in the Cool Temperate zone (Yamazaki, 1951).

3) *Pinus*: Genus *Pinus* includes about six spcies. *Pinus pumila* and *P. pentaphylla* are found in the Subpolar or Subalpine zone, *P. koraiensis* grows in the Cool Temperate and Subpolar or Subalpine zones, and *P. densifora*, *P. himekomatsu*, and *P. thunbergii* grow in the Temperate and Warm Temperate zones. *Pinus*, however, is divided easily into two types by the pollen morphology: They are *P. haploxylon*-type and *P. diploxylon*-type. Species with five leaves belong to the former; they grow in the Subpolar or Subalpine zone at the present. The latter includes species with two leaves, such as *P. densiflora*, *P. himekomatsu*, and *P. thunbergii*.

4) Taxodiaceae: For genera belonging to Taxodiaceae, *Cryptomeria* and *Taxodium* grow in the Japanese Islands after the early Pleistocene. However, in the surroundings of Lake Biwa, the Plio-Pleistocene Kobiwako Group is distributed widely and yields pollen grains of *Metasequoia* and *Glyptostrobus*. Accordingly, these pollen grains are found sometimes as secondary (reworked) fossils in younger deposits. Pollen grains of *Metasequoia* and *Cryptomeria* are discriminated from other genera by grain size and shape of papilla. According to the measurement of modern species (Fuji, 1973), *Metasequoia*: 20 x 23 microns in width and length; *Cryptomeria japonica*: 30—33 x 34—38 microns; *Sequoia sempervirens*: 36—42 x 34—38 microns; *Glyptostrobus pensilis*: 26—28 x 30 — 33 microns; *Taxodium distichum*: 22—25 x 25—29 microns. The secondary pollen grains are not shown on the pollen diagram.

5) *Tsuga*: In the present-day Japanese Islands, *Tsuga diversifolia* is found in the Subalpine or Subpolar zone and *T. sieboldii* in the Cool Temperate zone and in the northern part of Temperate zone. They are not differentiated from other species.

6) *Betula*: Species such as *Betula ermani* is found in the Subpolar or Subalpine zone, and *B. platyphylla* in the Cool Temperate zone. Their pollen grains are not differentiated.

7) *Fagus*: In the present-day Japanese Islands, *Fagus* has two species, *F. crenata* and *F. japonica.* According to the wirter's observations: *Fagus crenata* measures 38—40 x 45—48 microns and can thus be distinguished from *F. japonica* which measures 29—32 x 33 microns. *F. crenata* grows in the Cool Temperate zone, and *F. japonica* is found in the middle part of the Cool Temperate and Temperate zones (Fuji, 1976; Fuji *et al.*, 1975).

8) *Quercus*: *Quercus* is divided into two subgenera, *Lepidobalanus* and *Cyclobalanopsis*, by its grain-size and morphology. An evergreen *Quercus* belongs to the latter, and deciduous *Quercus* to the former. Pollen grains of *Cyclobalanopsis* can be distinguished from those of the *Lepidobalanus* by a combination of features (Shimakura, 1973). As shown below, grains of *Cyclobalanopsis* are in general smaller than those of *Lepidobalanus.* The thickness of the pollen grain wall of both subgenera varies from 0.8 to 1.8 microns. The *Lepidobalanus* usually shows a somewhat thicker wall than *Cyclobalanopsis.* The wall in *Cyclobalanopsis*, however, is relatively thicker because of the small size of the grain. The costae in *Cyclobalanopsis* are generally heavier than those of *Lepidobalanus.* The shape of costae and colpi in *Cyclobalanopsis* differs from that of *Lepidobalanus.* The shape of costae and colpi in *Cyclobalanopsis* often shows a poroid area or a constriction (Bottema, 1974).

Cyclobalanopsis (evergreen *Quercus*)

Quercus acuta: 21—23 x 26—27 microns; *Quercus glauca*: 29—20 x 21—23; *Q. phillyraeoides*: 20—22 x 23—26;

Lepidobalanus (deciduous *Quercus*)

Quercus serrata: 22—23 x 24—28 microns; *Q. dentata*: 32—34 x 36—38; *Q. variablilis*: 29—30 x 31—33; *Q. acutissima*: 28—30 x 37—38.

Cyclobalanopsis occurs in the Temperate and Warm Temperate zones, and *Lepidobalanus* in the Cool Temperate zone and in the northern part of the Warm Temperate zone.

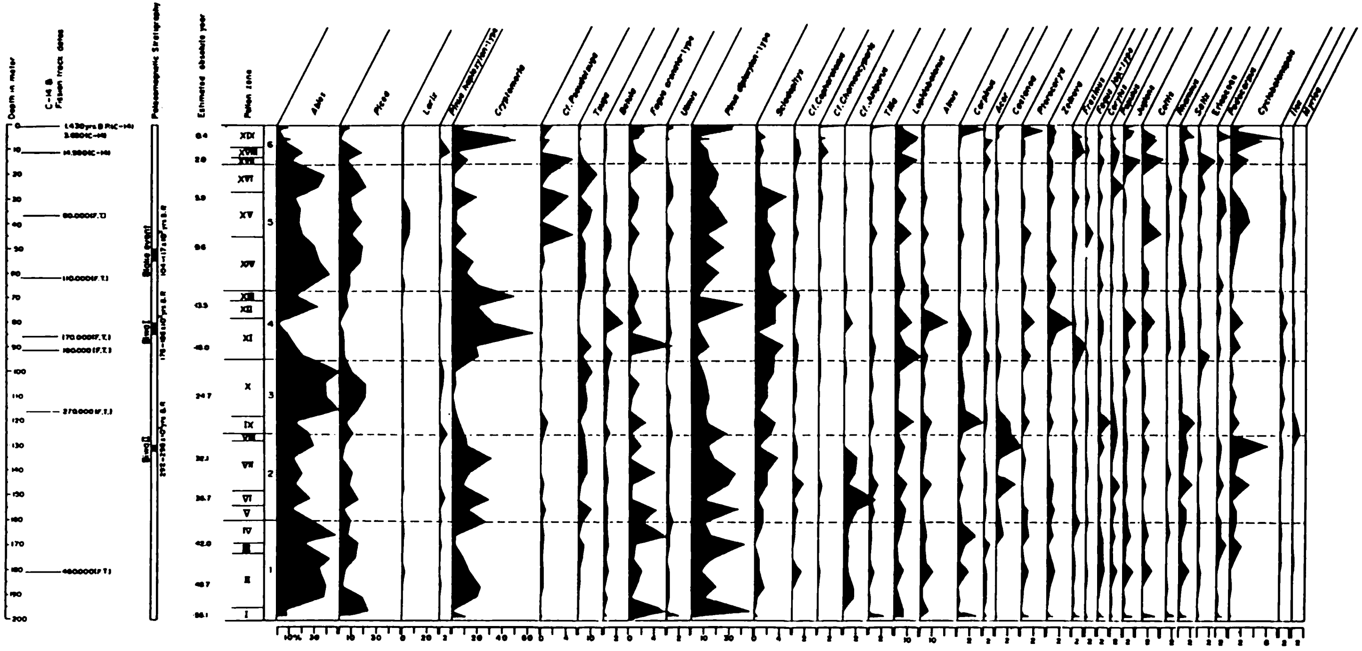
The use of the suffix "-type" after the name of a species or a genus implies that the fossil may belong to the named species or genus or to others of closely similar or identical morphology which have not been distinguished by the writer. Thus, *Pinus haploxylon*-type includes pollen grains of *Pinus* with five leaves such as *Pinus pumila*, *P. pentaphylla*, and *P. koraiensis.* This type is not divided into three above-mentioned species on the basis of pollen morphology. The use of "cf." as in cf. *Cepharotaxus* indicates that most of grains could be referred to this genus.

(g) Zoning of Pollen Assemblages, and Interpretation of Vegetation and Climatic History

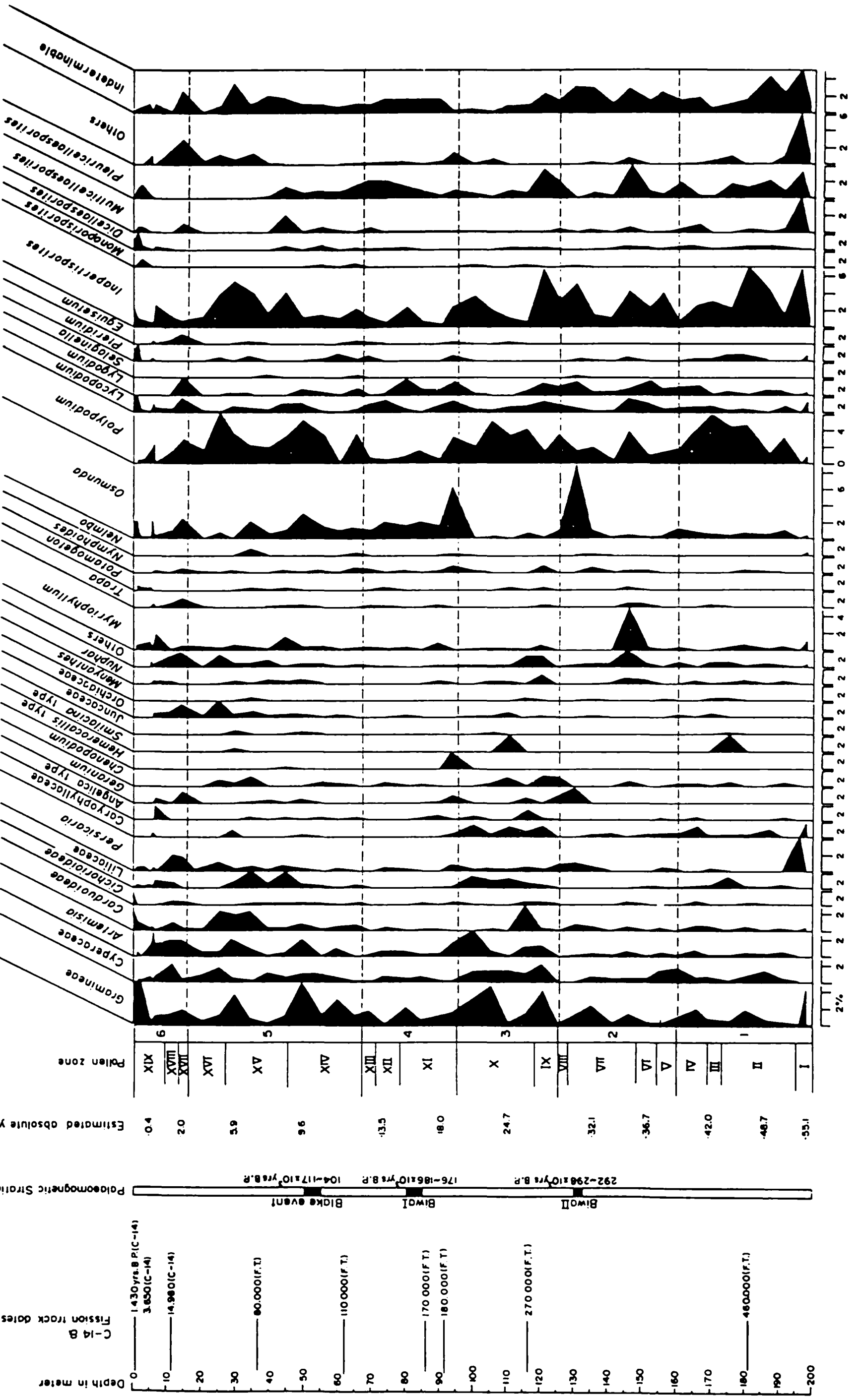
In order to facilitate descriptions and discussions of the pollen assemblages, the pollen diagrams are divided into 19 pollen zones based on distinct changes in pollen percentages (Fuji *et al.*, 1972). Changes in the ratio of Total AP to Total NAP can be established, but changes in the values of one or two pollen types may also lead to the establishment of pollen zones which have similar assemblages of pollen grains and spores. The writer has attempted to indicate them under the same letter code in order to facilitate comparisons.

ZONE I, depth 195—198 m: The pollen assemblage of this zone is defined by *Pinus diploxylon*-type (46%), *Picea* (24%), *Fagus crenata*-type (21%), and *Cryptomeria* (10%), and is characterized by a very high pollen percentage of plants thriving in the middle part of the Cool Temperate — Temperate zone. The mean annual temperature of the summit area and lowland at the time of this zone may have been higher than 5°C and 13°C respectively, and the humidity was probably more or less arid.

ZONE II, depth 173—195 m: This zone is characterized by large amounts of boreal conifers, especially *Abies* and *Picea*, and Cool Temperate — Temperate plants. The climate in the lakeside at that time may be compared with that in the middle part of the Cool Temperate zone. In the lowland areas, *Cryptomeria*, *Pinus diploxylon*-type, *Alnus*, *Fagus crenata*-type, *Carpinus*, *Zelkova*, *Juglands*, and *Lepidobalanus*



Text-fig. 3. Arboreal pollen diagram of samples at 5 meters interval from a 200-meter core.



Text-fig. 4. Non-arboreal pollen diagram of samples at 5-meter interval from a 200-meter core.

grew, and at the mountain sides *Abies*, *Tsuga*, and *Betula* grew. *Pinus pumila* and *Abies* may have prevailed in the summit area during the later part of this period.

ZONE III, depth 168–173 m: Although the pollen percentages of the boreal conifers are almost the same as in Zone II, the pollen values of broadleaved deciduous trees decrease, and plants of the Warm Temperate – Subtropical zones such as broadleaved evergreen trees and *Podocarpus* attain relatively higher values. The climate at that time may have been as warm as that of the present day and relatively arid.

ZONE IV, depth 160–168 m: This zone is characterized by an increase of plants of the Cool Temperate zone and of the Cool Temperate – Temperate zones, and by a decrease in plants of the middle part of the Cool Temperate – Temperate zones and of the southern Temperate – Subtropical zones. Judging from the pollen assemblages, the climate at that time may have been as cool as that in the southern part of the Cool Temperate zone and was probably wet as indicated by the large value of *Cryptomeria*.

ZONE V, depth 154–160 m: This zone is characterized by decreases in the Subpolar or Subalpine plants and in the Cool Temperate – Temperate plants, and by sharp increase in the middle Cool Temperate – Temperate plants. In the mountainous area, broadleaved deciduous trees, *Abies* (perhaps *A. firma*), *Picea* (perhaps *P. polita*), and at the lakeside, *Pinus densiflora* prevailed. There were also scattered *Cryptomeria*, *Zelkova*, *Juglans*, *Salix*, and *Alnus*. The climate may have been similar to that of the present day.

ZONE VI, depth 148–154 m: Relatively high percentages of the Subpolar or Subalpine plants and Cool Temperate – Temperate plants, and decreases in the percentage of the middle Cool Temperate – Temperate plants and the southern Temperate – Subtropical plants are the characteristic features of this zone. The climate of the lowland at the time represented by this zone may have been similar to that of the middle part of the Cool Temperate zone.

ZONE VII, depth 128–148 m: The main elements of this zone are *Pinus diploxylon*-type (28–34%), *Cryptomeria* (12–30%), and *Abies* (13–29%). This zone is characterized by boreal conifers which lasted for a time with only long small fluctuations in abundance. The climatic condition at that time was similar to that of the present day with temporarily cool periods.

ZONE VIII, depth 125–128 m: The pollen assemblage of this zone contains *Pinus diploxylon*-type (28%), *Abies* (25%), *Picea* (11%), and *Cryptomeria* (9%). The zone is notable for drastic increases in the Subpolar of Subalpine plants, and boreal conifers, and for decreases in the Cool Temperate – Temperate and southern Temperate – Subtropical plants. The climate during this time may have been similar to that of the middle part of the Cool Temperate zone, and was probably relative dry with the mean annual temperature of about 10° at the lakeside.

ZONE IX, depth 118–125 m: This zone is similar to zones V and VII. The climatic condition at that time may have been somewhat milder than that in the northern part of the Temperate zone. *Abies* (perhaps *A. homolepis*) and *Picea* prevailed with a little *Betula* (perhaps *B. platyphylla*) and *Fagus crenata*-type in the higher part of mountainous area. In the lowland area, the broadleaved trees, especially *Lepidobalanus*, and *Pinus densiflora* probably prevailed.

ZONE X, depth 95–118 m: This zone is characterized by a high concentration of boreal conifers, especially *Abies* (45%) and *Picea* (18%). The climate in the lowland at that time may have been as cold as that of the northern part of the Cool Temperate zone and dry, with a temporarily cooler interval during the middle of the period. On the other hand, in the mountainous areas, boreal conifers prevailed.

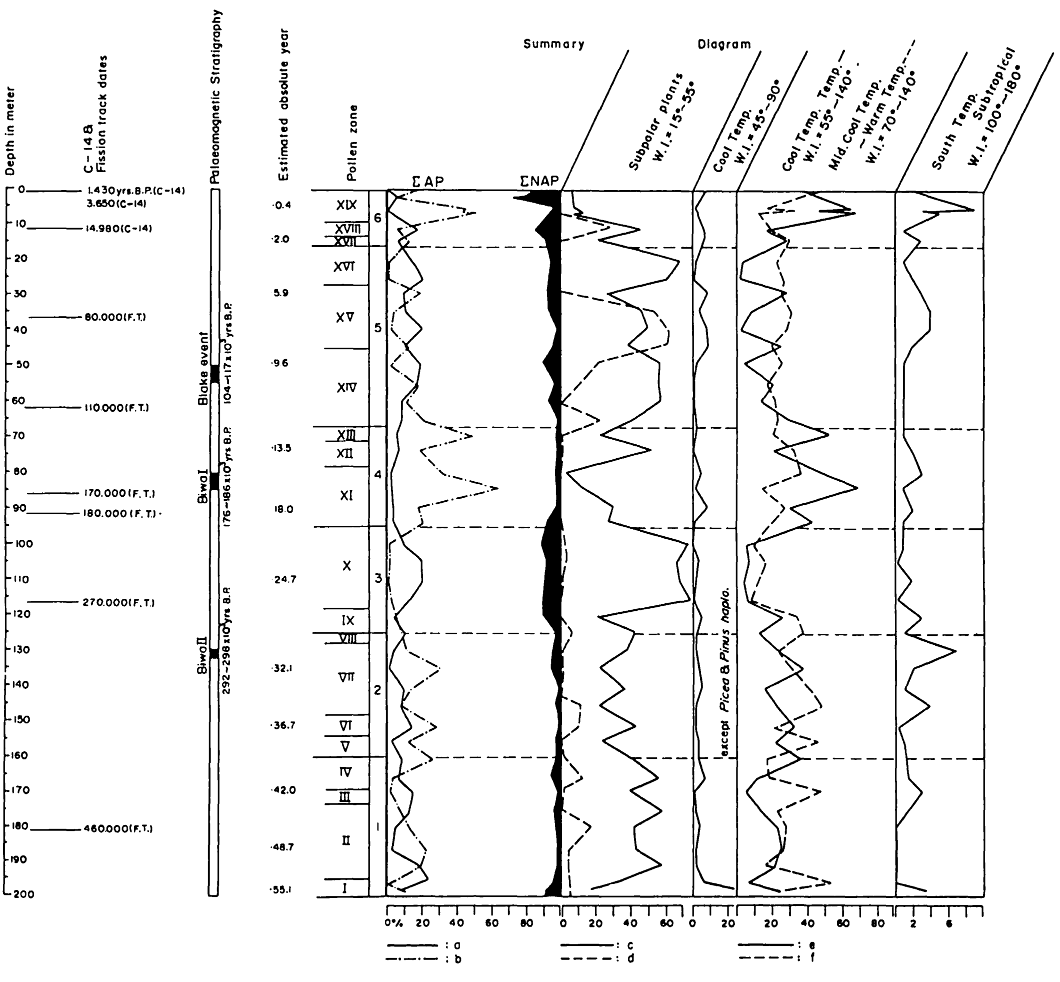
ZONE XI, depth 78–95 m: This zone is characterized by an increase in other plants than boreal conifers. The climate in the lakeside area may have corresponded to that of the northern part of the Temperate zone or of the southern part of the Cool Temperate zone, and wetter condition probably prevailed.

ZONE XII, depth 71–78 m: This zone is characterized by increases in boreal conifers and plants of the middle part of the Cool Temperate — Temperate zones. The climate in the lowland area around Lake Biwa may have been as cool as those of zones VI and VIII, but, on the other hand, *Pinus haploxylon*-type (here perhaps *P. koraiensis*), *Abies* (perhaps *A. homolepis*), and *Picea* (perhaps *P. polita*) presented in the mountainous area.

ZONE XIII, depth 67—71 m: This zone is characterized by a markedly drastic increase in plants growing in the Cool Temperate — Temperate zones, particularly *Cryptomeria.* The climate was probably similar to that of the southern part of the Cool Temperate zone, and was clearly wetter.

ZONE XIV, depth 45—67 m: The main elements of the pollen assemblage of this zone are *Abies* (26—42%), *Pinus diploxylon*-type (21—26%), *Sarix* (24%), *Picea* (17%), and *Cryptomeria* (11—17%). The zone is marked by a drastic decline in plants thriving in the Cool Temperate zone, and by a strong increase in boreal conifers. The climate appeared to have deteriorated slightly during this time from cool condition at the beginning of the period to relatively cold and dry conditions at the middle and at the end of the period.

ZONE XV, depth 27—45 m: The climate



Text-fig. 5. Summary pollen diagram of the palynological analysis of a 200-meter core. a: *Picea*, b: *Cryptomeria*, c: boreal conifers, d: *Pinus haploxylon* + *Larix* (x 10), e: except *Tsuga*, f: except *Abies*.

during the early part of this period may have been similar to that of the northern part of the Temperate zone. In the late period, however, it became cooler and resembled that in the southern part of the Cool Temperate zone.

ZONE XVI, depth 16—27 m: During this period the climate deteriorated and, in the lakeside area, boreal conifers and broadleaved deciduous trees probably prevailed.

ZONE XVII, depth 13—16 m: This zone is characterized by a drastic decline in boreal conifers. Instead of boreal conifers, plants of the Cool Temperate — Temperate zones, particularly *Cryptomeria* (12%), and *Lepidobalanus* (16%) were relatively abundant. The climate at that time may have been correlated to that of the northern part of the Temperate zone or of the southern part of the Cool Temperate zone.

ZONE XVIII, depth 9—13 m: The climate at the time represented by this zone had been the coldest throughout the last 560,000 years, and was almost comparable to that of Zone X. In the summit and mountainous areas, *Pinus pumila*, *Abies* (perhaps *A. mariesii* or *A. veitchii*), and *Picea* prevailed. Boreal conifers such as *Abies homolepis*, *A. firma*, *Picea* (? *P. polita*), *Pinus koraiensis*, *Betula* (perhaps *B. platyphylla*) and other broadleaved trees were distributed in the lowlands around Lake Biwa.

ZONE XIX, depth 0—9 m: During the time represented by this zone, boreal conifers and the Cool Temperate plants decreased in abundance and were replaced by plants growing near the middle part of the Cool Temperate zone and in the southern part of the Temperate — Subtropical zones. At this time, *Lepidobalanus* (perhaps *Quercus crispula* and *Q. serrata*), *Acer*, *Cryptomeria japonica*, and *Chamaecyparis* prevailed in the mountainous area instead of *Abies*, *Larix*, and *Ulmus* as in the period represented by zone XVIII. On the other hand, *Lepidobalanus* as *Quercus acutissima* and *Cyclobalanopsis* as *Quercus glauca* were distributed widely with *Salix* and *Alnus* along the sides of the lake and rivers. The climate of this time may have been 1°—2°C warmer than and more humid than at the present (Fuji, 1976).

Comparison with previous palaeoclimatic analyses

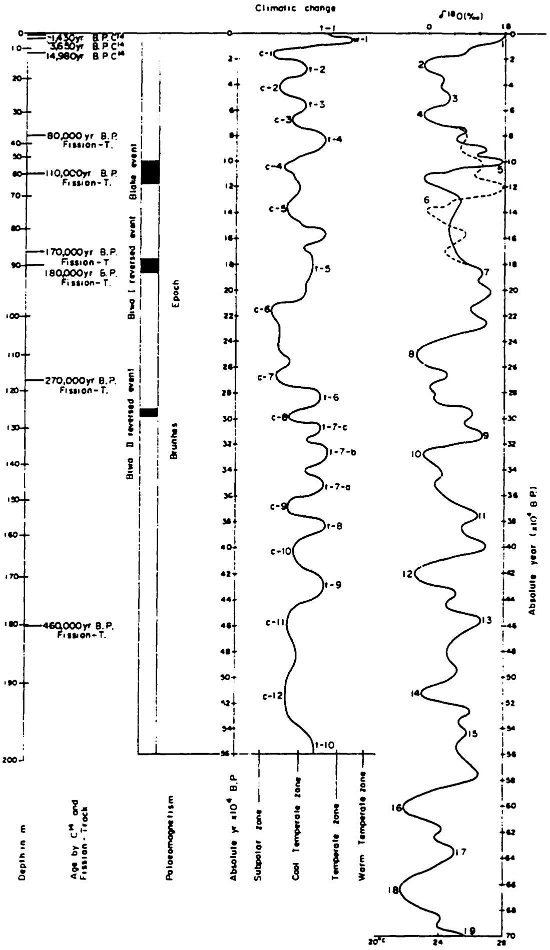
The age determination of the upper part of the core from Lake Biwa has been carried out by the C^{14} method (Horie *et al.*, 1971), and the other by the fission-track method (Nishimura *et al.*, 1975). The age of the lowermost horizon, about 200 m below the present lake bottom, is about 565,500 years, B.P. With the use of the age determination by C^{14} and fission-track methods, and palaeoclimate by the palynology, the writer determined preliminary the ages of the boundaries between glacial and interglacial times, and between stadial and interstadial times.

Same samples from the 200-m core analysed for the palynology, geochemistry and other micropalaeontology were studied from the viewpoint of palaeomagnetism (Kawai *et al.*, 1972). All samples are belonged to the Brunhes normal polarity epoch, the past 690,000 years, and the new three short reversed polarity events, called "B", "Biwa I", and "Biwa II" from the lake bottom, have been recognized in the core. Judging from a correlation between the palaeomagnetic results from Lake Biwa (Kawai *et al.*, 1972) and these from some deep-sea cores (Opdyke, 1972; Ninkovich *et al.*, 1966), the "B" reversed polarity event at a depth of 50 to 55 m in the core of Lake Biwa is correlated with the Blake event (Ninkovich *et al.*, 1966; Denham, *et al.*, 1975) which is estimated to have lasted from 117,000 to 104,000 years ago. Then the "Biwa I" event at a depth of 80.5 to 85 m and the "Biwa II" event at a depth of 130.0 to 132.5 m are estimated respectively to be from 176,000 to 186,000 years ago and from 292,000 to 289,000 years ago (Yaskawa, 1974). Accordingly, sedimentation at the 200-m-level must have begun from the early stage of Brunhes normal polarity epoch. Therefore, pollen analysis of this long core stated in this paper has produced a record for most of the Brunhes epoch.

The phases of vegetation development during the time not covered by the radiocarbon and fission-track age determinations need to be dated by the other methods. Geological studies from the surroundings of Lake Biwa unfortunately do not provide much evidence for such dating. So the changes in vegetation and associated climatic changes inferred from the palynological results offer the possibility for further dating. As there are no other palynological studies covering the 565,000 years time span represented by the Lake Biwa core, the writer correlated the pollen diagram from Lake Biwa with Emiliani's palaeotemperature curve (1966 & 1974) based on oxygen isotope analysis. Emiliani's study covers the last 700,000 years and shows fluctuations in more detail than palaeoclimatic curves from other deep-sea cores (for example: Hays *et al.*, 1969).

On the palaeoclimatic curve from Lake Biwa (Text-fig. 6) cold, warm, and temperate climatic periods are named as c-1, c-2,. . . , w-1, and t-1, t-2.

The t-10 period (temperate climatic period) is correlated with period no. 15 in Emiliani's curve, but if estimated age by Kanari *et al.* (1975) is correct, the end of t-10 period was slightly later than period no. 15. A short and relatively mild period separates the c-10 and c-12 periods. This mild period is correlated with a mild period between nos. 13 and 14 of the Emiliani's curve. According to the present writer's curve, the duration of the c-12 period was as long, and the climate was as cold as that of the c-11 period. Although there is a cold period shown by no. 14 in Emiliani's curve correlated with the c-12 period, this cold period was shorter and colder than the c-12 period. A temperate climatic period shown by an abbreviation t-9 may be correlated with period no. 13 in Emiliani's curve. The latter, however, is chronologically older by about 10,000 years than the former. Judging from the present analyses, the duration of the t-9 period is inferred to have been shorter than that of period no. 13. This inconsistancy may result from the long sampling interval (5 m) used in the Lake Biwa core. Shorter sampling intervals should be used in the future.



Text-fig. 6. Correlation diagram between the palaeoclimatic change in the Omi Basin and palaeotemperature curve based on oxygen-isotope ratio determination from the Caribbean Sea (Emiliani *et al.*, 1974).

The t-8 period is clearly correlated with period no. 11 of Emiliani's curve from the viewpoints of chronology and palaeoclimatology. Lack of exact agreement is again attributed to the long sampling interval in the Lake Biwa core. Climatic fluctuations during the periods from c-9 to c-7 are too indistinct to be correlated with Emiliani's curve. There are so many periods of mild climate that it is difficult for example, to decide which of these should be correlated with the Emiliani's no. 9. However, if it is assumed that the c-8 period is correlated with a cold period between the Emiliani's periods no. 8 and no. 9, the t-7-b subperiod in the present curve may be correlated with the Emiliani's no. 9. A mild climatic period shown by the abbreviation t-6 may be correlated with the cool period just before period no. 8 of Emiliani's curve. Judging from chronological and palaeoclimatic investigations, it is most probable that the cold c-7 and mild t-5 periods are correlated with periods no. 8 and no. 7 of Emiliani's curve respectively. According to the writer's analysis, the climatic condition during the time interval from period c-7 to period c-6 was continuously cold. A marked drastic climate amelioration is recognized in the time, about 210,000 years B.P., between period c-6 and period t-5. A similar climatic amelioration is occurred during the time interval from period no. 8 to period no. 7 of Emiliani's curve but this interval appears to correspond precisely to the time interval from period c-6 to period t-5 in absolute age. The mild t-5 period may be correlated with Emiliani's period no. 7, judging from the climatic fluctuations recorded.

Emiliani and Shackleton (1974) showed two tentative palaeotemperature curves for the period between the mild period no. 7 and cold no. 4. According to the present writer's curve, the climate during this time may have correspond more closely to the trend of the period line in Emiliani's curve, except in the period around about 120,000 years B.P.

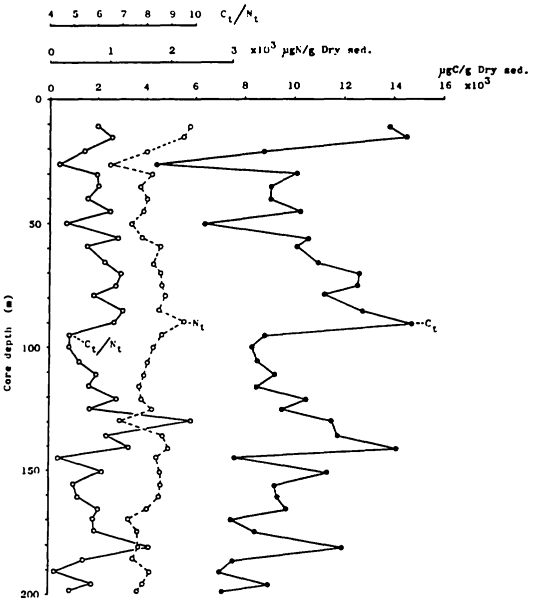
The c-3, t-3, c-1, and t-1 periods may be correlated with periods nos. 4, 3, 2 and 1 of Emiliani's curve, respectively.

In conclusion, judging from this detailed comparison there are a few differences between Emiliani's generalized temperature curve from the Caribbean Sea and the present writer's climatic curve from Lake Biwa, still there seems a general similarity between the curves.

Comparison with chemical, palaeomagnetic, and fossil diatom analyses

The samples examined for the contained microflora were also investigated from palaeomagnetic, chemical, granulometric, mineralogical, and fossil diatoms aspects.

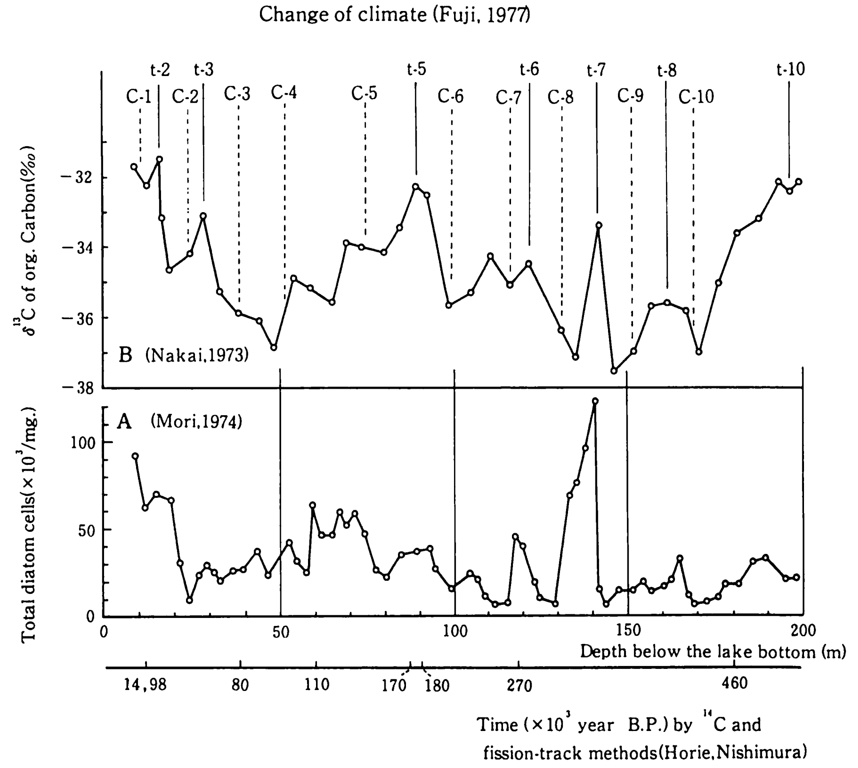
The contents of heavy metal irons in the samples are almost similar to those of soils in unpolluted areas. Ranges of determined values are as follows. As: 9—58 ppm, Cd: 0.24 ppm, Cu: 34—66 ppm, Mn: 620—5300 ppm, Pb: 18—43 ppm, Zn: 98—160 ppm. However, the fact that the highest peakes of Cd and Mn contents are observed at the depth of 130 m suggesting that some environmental change might have taken place at around the age of 300,000 years B.P. The four peaks also correspond to the minimum values of organic carbon/organic nitrogen ratio (Koyama *et al.*, 1973). The content of organic carbon varies similarly to that of the total carbon showing four remarkable peaks at 15 m, 90 m, 140 m warm periods which are recognized from the results of palynological analysis. According to vertical profiles of organic carbon and nitrogen content of the core samples, ranging 4.4—14.7 mgC/g of dry sediment and 1.0—2.3 mgN/g of dry sediment respectively, were found to be almost similar to that of size distribution of the fine-grained clastics. This suggests that the allochthonous materials must



Text-fig. 7. Vertical distribution of total carbon and nitrogen in the core sample from Lake Biwa (Koyama *et al.*, 1973).

contribute to the sedimentary organic materials in certain extent. This fact was supported by the low values of the C_{16} + C_{18}/C_{20} — C_{30} of dicarboxylic acids of the sediments, because C_{20} — C_{30} of the acids are mainly drived from the terrestrial plant wax, whereas C_{16} and C_{18} acids are main constituents of dicarboxylic acids in the autochthonous phytoplankton. The concentration of phaeopigment and carotenoids was determined to vary with intervals of the core depth. Vertical profiles of these plant pigments are almost similar with those of carbohydrate, amino acids and protein and lipid and with that of fossil diatoms. These facts suggest that the productivity of organic materials due to the photosynthetic activities of diatoms in this lake varied with time in the past time. In addition, vertical profiles of these organic materials and fossil diatoms were found to be quite similar with the change in the palaeotemperature around this lake, which was established on the basis of palynological analysis by the present writer.

The positive correlation between the total organic contents and $\delta^{13}C$ values can be found throughout the core samples. The isotopic composition of organic carbon becomes enriched in $\delta^{13}C$ with increase in the organic carbon contents. The isotopic variation in organic carbon in the core samples is undoubtedly controlled with a kinetic isotope effect due to the temperature at which plankton grew. In warmer climate, the production rate of organic materials such as plankton in the lake and their accumulation rate in the sediments are relatively higher, resulting in relatively higher $\delta^{13}C$ enrichment than those in a colder climate. The palaeoclimatic variation estimated by palynological investigation shows an excellent correlation with that by the $\delta^{13}C$ values. From

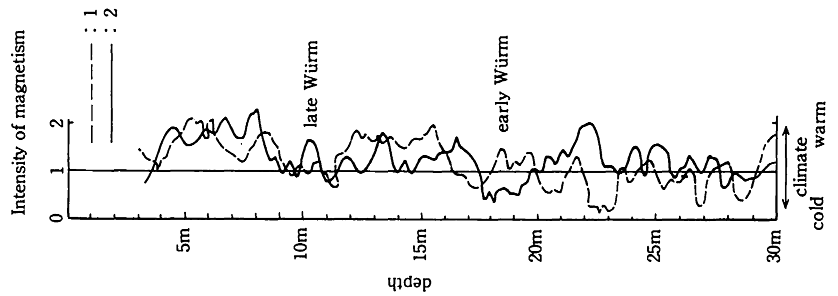


Text-fig. 8. Comparison among the change of climate (Fuji, 1977), $\delta^{13}C$ of organic Carbon and total diatom cells from the samples a 200-meter core in Lake Biwa.

this isotopic study, it can be concluded that three or four glacial and interglacial ages were repeated in the depositional history of Lake Biwa sediments during the past 600,000 years (Nakai, 1973).

On diatom fossils (Mori, 1975) the following are noticed. Two genera of *Melosira* and *Stephanodiscus*, which belong to discoid diatoms and are planktonic habitat, are observed abundantly through the core column. A diatom assemblage consisting mainly of *Melosira solida* and *Stephanodiscus carconensis*, which are observed in the lake at present, is found in a part of 75.0 m in core depth and above. And below that depth diatom assemblages differ remarkably from the viewpoint of a dominant species of diatom. It is possible to recognize five diatom zones in the core column based on the rise and fall in the abundance of *Melosira solida*. There are four periods in the core column when *M. solida* is yielded abundantly. Lake Biwa was under a temperate to warm climate in those peirods.

The palaeomagnetic study of the 200-m core reveals that there are three short reversed polarity events in the Brunhes normal plarity epoch (Kawai *et al.*, 1972). Comparison between the results of the magnetic reversals and of the palaeoclimate estimated by the palynological research is shown in Text-figs. 6 and 9. Viewed from the tentative conclusion on the palaeoclimate during the last 0.6 million years, the cold periods may be chronologically responded to the reversed polarity events. Although the reason remains unknown, when the polarity was reversal, it has not been solved yet in the present why the palaeoclimate was cold or cool (Kawai *et al.*, 1972). In addition, it is a very noticeable fact that some horizons were found in the core at which the variation of fossil diatom abundance and species was correlated with the event of oscillating geomagnetic field. The correlations are shown in the following Table 1. Among the correlations one at the Biwa event II was the most conspicuous. It can be con-



Text-fig. 9. Comparison between the change of palaeoclimate based on the pollen analyses and the intensity of palaeomagnetism in samples of a 200-meter core from Lake Biwa. 1: palaeoclimatic change based on pollen analyses; 2: intensity of palaeomagnetism.

Table 1. Relationship between geomagnetic events and variation of diatom assemblage from a 200-meter core.

Geomagnetic events	Microfloral change of diatom
B (Blake event)	Extinct horizon of *Melosira* cf. *juergensi*
C (Biwa event I)	Decrease horizon of *M.* cf. *juergensi*
C-D (weak magnetism)	Bl diatom subzone
D (Biwa evnet II)	Decrease horizon of *Melosira solida* & *M.* cf. *juergensi*

sidered that an oscillating geomagnetic field had some influence on the diatom fossils existence, though it might be indirect.

The scientific solution of these similarity is due to the detailed measurements and analyses and to the co-operation with the scientists of both geophysics and cosmophysics (Kind, 1969).

Conclusions

(1) Judging from the pollen analyses, the 200-m core samples of Lake Biwa can be divided into 19 pollen zones; Zones I, through XIX.

(2) The climatic curve and ages from Lake Biwa display similarity to the palaeotemperature curve (oxygen-isotope ratio determination) from the Caribbean Sea (Emiliani *et al*, 1974). In spite of differences in details and in interpretation of curves, general agreement exists in the major trends in the inferred climatic fluctuations of North America, and Europe.

(3) During the glacial stages or stadials, the typical vegetation thriving today in the Subpolar or Subalpine zone of Japan prevailed at the summit area and/or the montane area around Lake Biwa and, in the lowland around the lake, plants growing today in the Cool Temperate zone were distributed. In the interglacials and interstadials, the vegetation in the higher area was characterized mainly by plants of the Cool Temperate zone and the present Temperate zone, and in the lowland, the vegetation was composed mainly of broadleaved deciduous and evergreen trees growing in the Warm Temperate zone.

(4) The remarkable-human influence that is represented by cleaning forest for rice-cultivation and by cutting woods began about 3,000 years B.P. The influence is supported by the archaeological evidence around the lake.

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Lake Biwa 琵琶湖, Fujihara-dake 藤原岳, Fukui 福井, Gifu 岐阜, Gozaisho 御在所, Hidaka 日高, Hiei 比叡, Hira 比良, Hokuriku 北陸, Ibuki 伊吹, Iga 伊賀, Ise Bay 伊勢湾, Kaburaki 甲楽城, Kinki 近畿, Kyoto 京都, Mie 三重, Mikuni-ga-dake 三国ヶ岳, Mizuguchi 水口, Nara 奈良, Nosaka 野坂, Okinoshima 沖ノ島, Omi 近江, Osaka 大阪, Otsu 大津, Shiga 滋賀, Suzuka 鈴鹿, Wakasa 若狭, Yanagase 柳ヶ瀬

琵琶湖底200 mボーリング・サンプルの花粉学的研究 I：過去60万年間の古植生と古気候の変遷　日本における第四紀を通じての古植生の変遷とそれに基づく古気候の変化を究明して，世界における第四紀の気候変化の標準の1つにすることを目的として，1971年秋，琵琶湖の水深65 mの湖底から約200 mに及ぶボーリングを実施した。そして，殆んど完全に連続するコアを採集することに成功。このコア・サンプルは，研究の第一段階として，5 m間隔で採集され，花粉分析の視点から研究された。その結果，200 mコアは19の花粉帯に区分され，約60万年間に12回の寒冷期（氷期）と10回の温和期の存在したことが確認された。このような琵琶湖における気候変化の記録をカリブ海からの酸素同位体による古水温変化と比較すると，全般的にみてよく酷似する。なお，琵琶湖底からのサンプルは，有機化学，δ^{13}C，珪藻群集，フィッション・トラック法年代測定，及び古地磁気変の諸視点からも究明され，気候変化とそれらとの比較検討も併せて述べた。

藤　則雄

Trans. Proc. Palaeont. Soc. Japan, N. S., No. 132, pp.253—262, pls. 51—53, December 30, 1983

772. RADIOLARIANS IN MIDDLE JURASSIC SILICEOUS SHALE FROM KAMIASO, GIFU PREFECTURE, CENTRAL JAPAN*

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Abstract. Three new species of Radiolaria, *Pantanellium foveatum*, *Dictyomitrella*(?) *kamoensis* and *Pachyoncus kamiasoensis*, are described from the middle Jurassic siliceous shales in Kamiaso, Gifu Prefecture. These species together with other spumellarians and nassellarians characterize the *Dictyomitrella*(?) *kamoensis* — *Pantanellium foveatum* Assemblage, which is commonly found in the radiolarian assemblages recognized in the sedimentary complex of the Mino area, central Japan.

Introduction

The radiolarian micropaleontology and biostratigraphy have been rapidly advanced in this decade through the advent of new techniques in laboratory works. The results of developments have forced us to reappraise our ideas about stratigraphy and geologic history of central Japan. We have carried out an extensive field investigation in the Mino area, in the course of which we recognize three Jurassic radiolarian assemblages, i.e., (1) the *Mirifusus baileyi*, (2) the *Dictyomitrella* sp. A — *Pantanellium* sp. A, and (3) the *Unuma echinatus* Assemblages (Mizutani *et al.*, 1981; Kido *et al.*, 1982). Radiolarian species in the respective assemblage were reported in each type area by Mizutani (1981), Kido *et al.* (1982), and Mizutani and Koike (1982).

We describe in this paper three new species of radiolarians which represent the second assemblage of the above-mentioned three, and introduce the *Dictyomitrella*(?) *kamoensis* — *Pantanellium foveatum* Assemblage, discussing its biostratigraphic position in the Jurassic succession in the Mino area, central Japan.

Dr. E. A. Pessagno, Jr., University of Texas at Dallas, and Dr. K. Nakaseko, Osaka University, gave us many instructive suggestions on the Jurassic radiolarian biostratigraphy. Dr. A. Yao and Mr. T. Matsuoka of Osaka City University kindly informed us their biostratigraphic results in the Mino area. Dr. M. Adachi, Mr. I. Kawaguchi, and Mr. S. Kojima of Nagoya University showed us their micropaleontologic data discussing the litho- and biostratigraphy in their fields of central Japan. Dr. K. Shibata of Geological Survey of Japan who generously joined us in the study of the chronostratigraphy of the Jurassic formations, carried out the isotopic age determinations on our samples. We are much indebted to all of them, and would like to record our sincere appreciations for their kindness and encouragements.

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All the original data of the radiolarian fossils treated in this paper are stored in the Rad File, Department of Earth Sciences, Nagoya Univer-

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* Received November 1, 1982, read Oct. 17, 1982 at Tsu.

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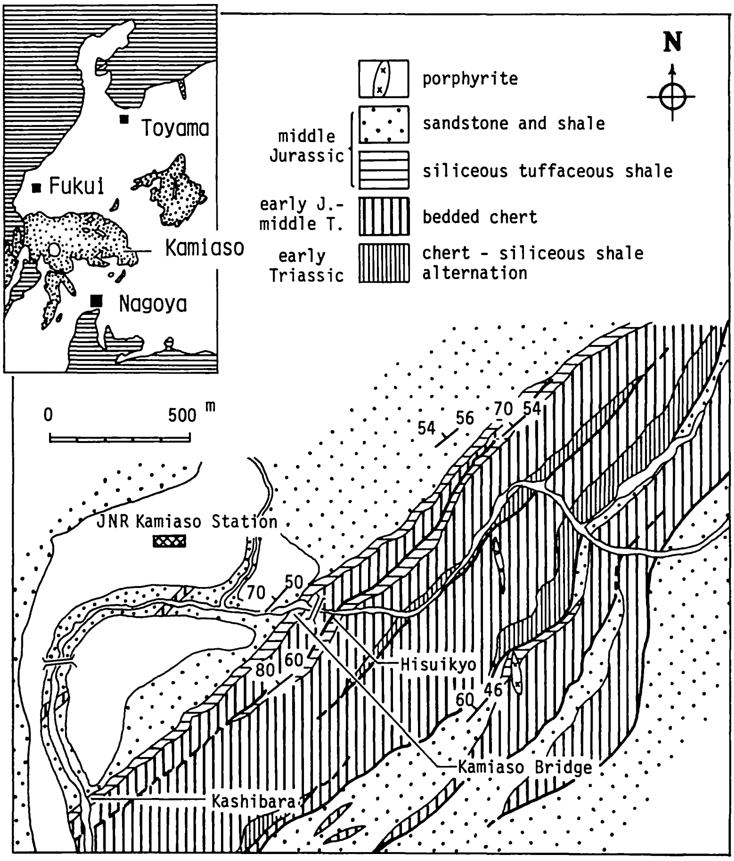
sity. The data are numbered, for example, as 22789/542, in which the numerator represents a sequential number of SEM negative film and the denominator indicates that of the rock specimen from which the radiolarian fossil was extracted.

Geologic setting

The Kamiaso area was geologically studied by Mizutani (1964), and subsequently by Adachi and Mizutani (1971), and recently by Kano (1979). Paleontologic researches have been performed by Koike *et al.* (1971), Igo and Koike (1975) and Igo (1979) on conodonts, and by Nakaseko and Nishimura (1979) and Matsuda and Isozaki (1982) on radiolarian fossils. Kido (1982) and Kido *et al.* (1982) also have carried out radiolarian biostratigraphic works for a continuous outcrop of siliceous shale and chert exposed along Hidagawa (Hida River). The studied area reported in this paper is composed mainly of chert, siliceous shale, black shale interbedded with turbidite and sandstone, trending approximately NE-SW (Text-fig. 1). Although these formations are apparently seen to be conformably overlain by successive beds with the thickness of the order of hundred meters, detailed mapping reveals that some of them occur repeatedly in places in much smaller scale. The duplicate and interleaved occurrence of a lithologic unit is also verified by the biostratigraphic study, which then confirms a close relationship between the lithostratigraphy and



Text-fig. 1. Geologic map of the Kamiaso area and sampling locations. The dotted area in the inset map shows the distribution of the Mesozoic-Paleozoic sedimentary complex of the Mino area, central Japan.

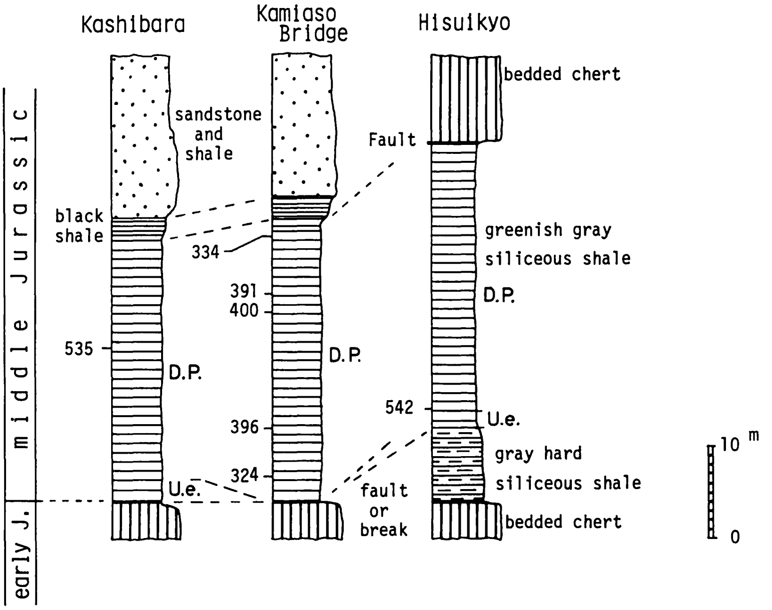
the chronostratigraphy.

Measured stratigraphic sections and biostratigraphic analyses reported by Kido (1982), Kido *et al.* (1982) and Matsuda and Isozaki (1982) along the exposures of the Hida River show the middle Jurassic siliceous shale to be underlain by middle Triassic to early Jurassic bedded chert, and overlain in turn by sandstone and shale totaling approximately 200 m in thickness (see Text-figs. 1 and 2). The middle Jurassic shale appears to cover the early Jurassic bedded chert; but because a minor bedding fault is found parallel to the lithologic boundary between them, and because minor intraformational folds are occasionally developed in the lowest part of the shale, the stratigraphic continuity cannot be ascertained; it is also presumable that there is a stratigraphic break between them.

Radiolarian Assemblage

In the Jurassic shale of this area, we recognized two radiolarian assemblages (Mizutani *et al.*, 1981; Kido *et al.*, 1982), the *Unuma echinatus* Assemblage and the *Dictyomitrella*(?) *kamoensis* —*Pantanellium foveatum* Assemblage, in which latter new species of radiolarian fossils described in this paper are much more commonly contained.

Kido (1982) and Kido *et al.* (1982) reported radiolarian species identified in each assemblage; among them, *Acanthocircus hexagonus* (Yao), *Acanthocircus suboblongus* (Yao), *Eucyrtidium*(?) *unumaensis* Yao, *Stichocapsa japonica* Yao, *Tricolocapsa* cf. *rüsti* Tan and *Tricolocapsa plicarum* Yao are common in both assemblages. The *Unuma echinatus* Assemblage of this area is characterized by concurrence of *Parasaturnalis* sp., *Unuma echinatus* Ichikawa and Yao, and *Cyrtocapsa mastoidea* Yao as described by Ichikawa and Yao (1976), Yao (1972, 1979) and Yao *et al.* (1980) in the Inuyama area, while the *Dictyomitrella*(?) *kamoensis* — *Pantanellium foveatum* Assemblage is characterized by the abundance of *Pantanellium foveatum* n. sp., *Pachyoncus kamiasoensis* n. sp. and



D.P. : Dictyomitrella(?) kamoensis - Pantanellium foveatum Assemblage Zone

U.e. : Unuma echinatus Assemblage Zone

Text-fig. 2. Measured stratigraphic sections and rock-specimen numbers at Kashibara, Kamiaso Bridge and Hisuikyo (see Text-fig. 1).

Dictyomitrella(?) *kamoensis* n. sp. These new species, however, do not always occur exclusively in the above-said assemblage, but they are occasionally found in the *Unuma echinatus* Assemblage. It is very likely that the *Unuma echinatus* Assemblage and the *Dictyomitrella*(?) *kamoensis* — *Pantanellium foveatum* Assemblage are inherently comprised in a fossil association occurring in a chronologically continuous formation.

As discussed by Mizutani and Koike (1982) and Shibata and Mizutani (1982), the *Unuma echinatus* Assemblage zone of Unuma, Gifu Prefecture, is probably of the Bajocian, which is equated with that of Kamiaso biostratigraphically as well as lithologically. The field investigation suggests that shale carrying radiolarian remains of the *Dictyomitrella*(?) *kamoensis* — *Pantanellium foveatum* Assemblage apparently conformably overlies siliceous shale of the *Unuma echinatus* Assemblage. In the Kamiaso area, *Ristola*(?) *turpicula* Pessagno and Whalen, described later, coexists with *Pantanellium foveatum* n. sp. and *Dictyomitrella*(?) *kamoensis* n. sp. in the siliceous shale. According to Pessagno and Whalen (1982), *Ristola*(?) *turpicula* is found in the late Bathonian sample of the Snowshoe Formation of Oregon. In Southwest Japan, regional correlation made by Yao *et al.* (1982) on the Triassic and the Jurassic formations demonstrates that the *Unuma echinatus* Assemblage zone is successively covered with the siliceous shale or mudstone carrying radiolarians of their *Lithocampe*(?) *nudata* Assemblage, which can be correlated to our *Dictyomitrella*(?) *kamoensis* —*Pantanellium foveatum* Assemblage.

All these data consistently indicate the siliceous shale of the *Unuma echinatus* Assemblage to be overlain successively by that of the *Dictyomitrella*(?) *kamoensis* — *Pantanellium foveatum* Assemblage in Southwest Japan. The stratigraphic sequence containing radiolarian fossils of these two assemblages probably ranges in age from the Bajocian to the Bathonian, or possibly to the Callovian.

We describe herein three new species of middle Jurassic radiolarians, two of which are marker species with distinctive morphologic characters, occurring commonly in Southwest Japan, and characterize the *Dictyomitrella*(?) *kamoensis* —*Pantanellium foveatum* Assemblage. *Pachyoncus kamiasoensis* n. sp. is regarded as a supplementary species in this assemblage, while *Ristola*(?) *turpicula* Pessagno and Whalen is dealt with as a key taxon for a biostratigraphic correlation in the Circum-Pacific radiolarian realm.

Systematic Description

Subclass Radiolarian Müller, 1858

Superorder Polycystida Ehrenberg, 1838, emend. Riedel, 1967

Order Spumellariina Ehrenberg, 1875

Genus *Pantanellium* Pessagno, 1977

Type species:—*Pantanellium riedeli* Pessagno, 1977, p. 78, pl. 6, figs. 5—11.

Pantanellium foveatum Mizutani and Kido, n. sp.

Pl. 51, Fig. 1a—1d, 2a—2c; Pl. 52, Fig. 1—3

Pantanellium sp. A Mizutani *et al.*, 1981, p. 197, fig. 2b.

Description:—Cortical shell spherical with large hexagonal and pentagonal pore frames (predominantly hexagonal). All pore frames have circular pits at pore frame vertices and have short flat secondary spines at bars between pore frame vertices. The presence of the pits mentioned above is much more distinctly manifested by the stereophotographs as shown in Plate 51, Figs. 1c and 1d. Bars of pore frames moderately thick along Y and three to four times thicker along Z (designations described herein are after Pessagno and Blome, 1980, p. 241, text-figure 5). Five pore frames visible along AA', while five pore frames also visible along BB'. Shorter polar spine about 3/4 length of longer one. Proximal 3/4 to 4/5 part of the shorter spine is triradiate in the axial section and its distal 1/4 to 1/5 circular in the same section, longitudinally composed of three moderately wide, flat-topped ridges about the same width along polar spine, alternating with three relatively wide grooves. The grooves become wider proximally. Longer polar spine with three flat-topped ridges about the same width as that of shorter spine. The ridges also alternate with three wide grooves longitudinally. First medullary shell with fragile hexagonal and pentagonal pore frames is connected with two triradiate primary radial beams and numerous thin secondary radial beams (Plate 52, Fig. 1).

Remarks:—*Pantanellium foveatum* n. sp. differs from all other species of *Pantanellium* by possessing diagnostic circular pits at all vertices of pore frames. *Pantanellium baileyi* Pessagno and Blome and *Pantanellium malheurense* Pessagno and Blome have flat secondary spines along bars between nodal points, but do not have any pits at pore frame vertices. Secondary spines of *Pantanellium foveatum* n. sp. are rather short. Some specimens have narrower ridges than the type specimen on both polar spines completely triradiate in axial section, but their cortical shell has similar structure (Pl. 52, Figs. 2 and 3). We assign these forms to *Pantanellium foveatum* n. sp., too.

Etymology:—Fovea (Latin, feminine) = pit.

Measurements:—System of measurement described below is based on that of Pessagno and Blome's description (1980, p. 241, text-figure 5).

AA'	A'S'	AS	BB'	cc'	dd'	(micron)
65	72	60	62	24	24	Holotype
70	80	60	65	24	22	Paratype
64	70	53	64	22	23	Average of 20 specimens
70	80	60	72	28	25	Maximum in 20 specimens
55	60	40	57	18	20	Minimum in 20 specimens

Type locality:—Kamiaso, Gifu Prefecture, central Japan.

Deposition:—Holotype (16395/535), paratype (12253/334).

Occurrence:—Mino area, central Japan. See Mizutani *et al.* (1981) p. 195, fig. 1. This species is also reported by Wakita (1982) from the northern part of the Mino area (pl. 7, figs. 1 and 2), and similar species is found by Owada and Saka (1982) in the Kanto Mountains (pl. 1, fig. 2). It is highly probable that this species is widespread in Southwest Japan.

Genus *Pachyoncus* Pessagno and Blome, 1980

Type species:—*Pachyoncus tumidus* Pessagno and Blome, 1980, p. 237, pl. 10, figs. 9, 16, 17, 19, 20, pl. 11, fig. 12.

Pachyoncus kamiasoensis Mizutani and Kido, n. sp.

Pl. 52, Fig. 4a–4d; Pl. 53, Fig. 1a–1c

Description:—Cortical shell subspherical or rather subcylindrical with large hexagonal and pentagonal pore frames. Four or five pore frames visible along AA', five pore frames visible along BB'. Pore frames have short, triradiate secondary spines or circular pits at pore frame vertices. Some secondary spines are connected with neighbouring secondary spines by thickening of bars between nodal points. Otherwise, bars have very short secondary spines between nodal points. These morphologic characters of this species can be observed in the stereophotographs as displayed in Plate 52, Figs. 4c and 4d, and in Plate 53, Figs. 1a and 1b. Bars of pore frames moderately thick along Y, three or four times thicker along Z. Both of polar spines quite wide proximally, triradiate in axial section. One polar spine shorter than the other. Both polar spines have three wide ridges alternating with three wide grooves.

Remarks:—*Pachyoncus kamiasoensis* n. sp. is closely related in form to *Pachyoncus crassus* Pessagno and Blome, which has short triradiate secondary spines connected with neighbouring secondary spines by thickening of bars, and circular pits at pore frame vertices. But *Pachyoncus kamiasoensis* differs from the latter in having

(i) bars of pore frames thicker along Z, and (ii) thicker polar spines.

Etymology: —*Pachyoncus kamiasoensis* is named for Kamiaso, its type locality.

Measurements:—

AA'	A'S'	AS	BB'	cc'	dd'	(micron)
70	100	90	70	32	34	Holotype
70	—	82	70	35	33	Paratype
66	104	90	77	34	32	Average of 12 specimens
75	120	100	90	40	40	Maximum in 12 specimens
55	95	60	70	30	30	Minimum in 12 specimens

Type locality:—Kamiaso, Gifu Prefecture, central Japan.

Deposition:—Holotype (22789/542), paratype (22785/324).

Occurrence:—Mino area, central Japan.

Order Nassellariina Ehrenberg, 1875

Genus *Dictyomitrella* Haeckel, 1887

Type species:—*Eucyrtidium articulatum* Ehrenberg, 1873, p. 226; 1875, pl. 11, figs. 2, 3 (subsequent designation by Campbell, 1954, p. D140).

Dictyomitrella(?) *kamoensis* Mizutani and Kido, n. sp.

Pl. 53, Figs. 2, 3, 4a—4b

"*Dictyomitrella*" sp. A; Mizutani *et al*., 1981, p. 197, fig. 2a.

Description:—Test conical to subcylindrical having six to nine segments. Cephalis dome-shaped without horn, and with or without small pores at the joint to thorax. Thorax truncate-conical with one row of pores at the joint to abdomen. Abdomen and post-abdominal chambers also truncate-conical, a few last chambers cylindrical in form, and increasing slightly in height and moderately in width. Abdomen and post-abdominal chambers separated by nodose circumferential ridges have each one row of paired pores just below and above the ridges, pores increasing in size toward distal segments. Ten to fifteen pores visible along circumferential ridges. Abdomen and post-abdominal chambers have tetragonally-arranged two rows of circular pits somewhat larger than neighbouring pores, pits and pores arranged trigonally.

Remarks:—We tentatively assign this species to genus *Dictyomitrella*, belonging to a conical or subcylindrical multicyrtid Nassellaria, which has circumferential ridges with each one row of pores below and above and has imperforate surface on medial part of post-abdominal segments. *Dictyomitrella*(?) *kamoensis* n. sp. is quite similar to *Canoptum*(?) sp. A of Pessagno and Whalen (1982, p. 125, pl. 7, figs. 14 and 16), but diagnostically differs from the latter by lacking inner layer of polygonal pore frames (Plate 53, Figs. 4a, b). *Dictyomitrella*(?) *kamoensis* n. sp. has a single layer of thick wall with smooth inner surface and two rows of circular

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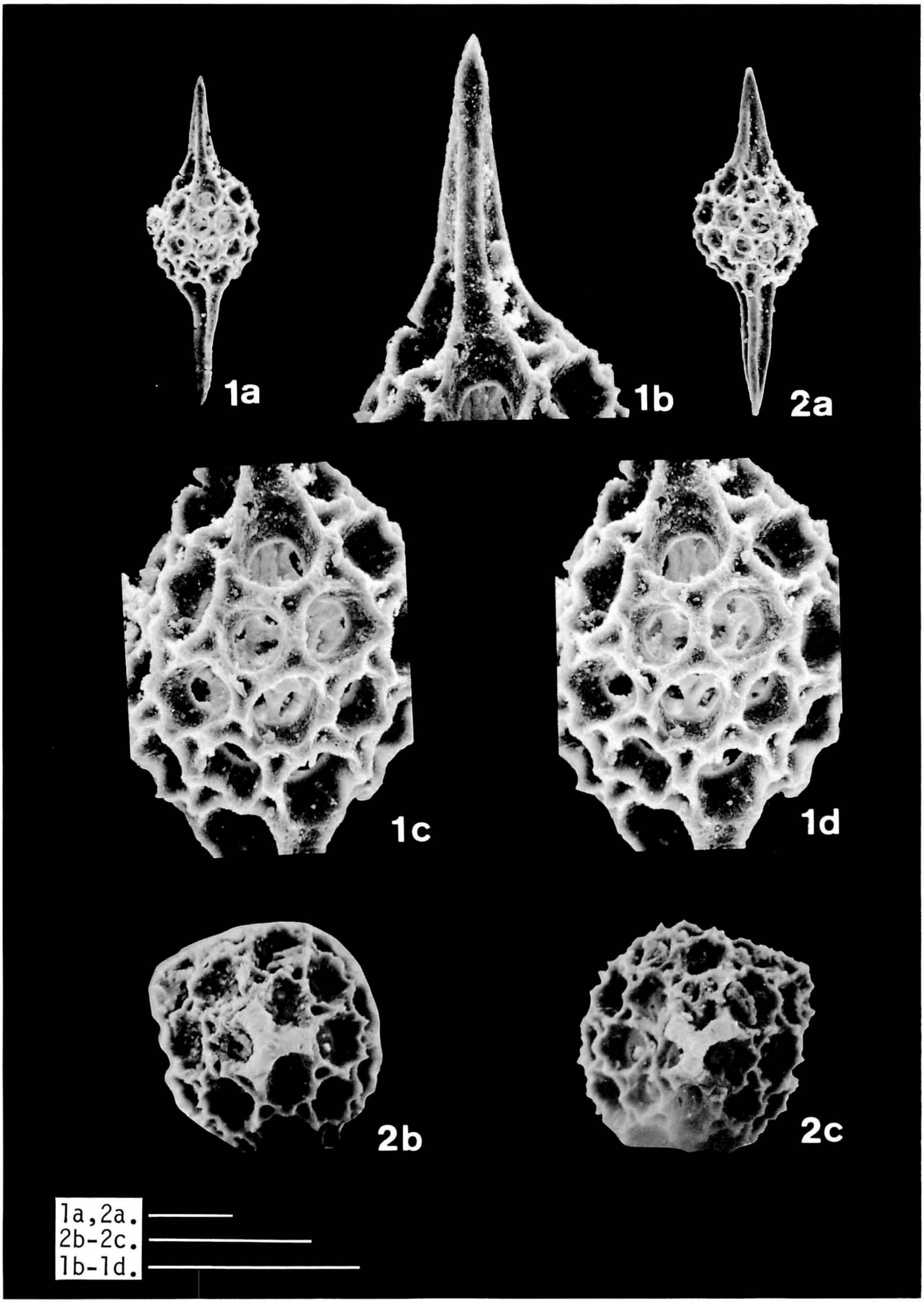
Explanation of Plate 51 (marker = 50 microns)

Figs. 1 and 2. *Pantanellium foveatum* Mizutani and Kido n. sp. (1a—1d, holotype; 2a—2c, paratype)

1a, 16395/535.
1b, 16398/535; upper part of fig. 1a.
1c, 16396/535. } stereophotographs of cortical shell of fig. 1a.
1d, 16397/535. }
2a, 12253/334.
2b, 12207/334; axial view of shorter spine of fig. 2a.
2c, 12206/334; axial view of longer spine of fig. 2a.


1a
1b
2a
1c
1d
2b
2c
1a,2a.
2b-2c.
1b-1d.

pits on outer surface. *Dictyomitrella*(?) *kamoensis* n. sp. differs from *Dictyomitrella* sp. A (De Wever *et al.*, 1979, p. 90, pl. 5, figs. 12, 16) by possessing one row of pores not only just below but also just above the nodoce circumferential ridges. It also differs from *Triassocampe* of Dumitrica *et al.* (1980) by having segments with the largest diameter in its lower part.

Etymology:—*Dictyomitrella*(?) *kamoensis* n. sp. is named for Kamo-gun, Gifu Prefecture, its type locality.

Measurements:—

Length	Width	(micron)
180	95	Holotype with 8 segments
160	90	Paratype with 7 segments
156	92	Average of 11 specimens with 7 segments
180	105	Maximum in 11 specimens with 7 segments
130	85	Minimum in 11 specimens with 7 segments

Type locality:—Kamiaso, Gifu Prefecture, central Japan.

Deposition:—Holotype (12675/396), paratype (11643/391).

Occurrence:—The present species occurs widely in the Mino area, central Japan. Hattori and Yoshimura (1982) reported this species from the Nanjo area (pl. 3, fig. 4), Kojima (1982) from Takayama (pl. 1, fig. 3), Wakita (1982) from the northern margin of the Mino area (pl. 1, fig. 6), and Yao *et al.* (1982) described the occurrence of similar species from Inuyama (pl. 3, fig. 21). Owada and Saka (1982) also reported this species from Kanto Mountains (pl. 1, fig. 14). All of these papers suggest the wide occurrence of *Dictyomitrella*(?) *kamoensis* in Southwest Japan.

Genus *Ristola* Pessagno and Whalen, 1982

Type species:—*Parvicingula*(?) *procera* Pessagno, 1977, p. 86, pl. 9, figs. 6—9.

Ristola(?) *turpicula* Pessagno and Whalen

Pl. 53, Fig. 5

Ristola(?) *turpicula* Pessagno and Whalen, 1982; pl. 11, figs. 8, 12, 13, 16, 20; pl. 13, figs. 11.

Description:—Apical portion of the test conical and termination blunted, lacking a horn. Except for the apical portion, the upper half of the post-abdominal chambers is cylindrical, whereas the remaining lower part of the test is slender fusiform. Circumferential ridge distinct in the medial and distal part of the test and is not well developed in the upper half. Post-abdominal chambers always have coarse pentagonal and hexagonal pore frames arranged in three rows. Length of the test 150 microns and width of the basal part 80 microns, comparatively smaller in size than those of Pessagno and Whalen's specimen. The present specimen, however, closely resembles what was described by Pessagno and Whalen, especially that of their paratype (plate 11, figure 12).

Deposition:—12214/334.

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Explanation of Plate 52 (marker = 50 microns)

Figs. 1—3. *Pantanellium foveatum* Mizutani and Kido n. sp.
1, 16400/334.
2, 16185/535.
3, 12765/400.

Figs. 4a—4d. *Pachyoncus kamiasoensis* Mizutani and Kido, n. sp. (4a—4d, holotype)
4a, 22789/542.
4b, 22792/542; lower part of fig. 4a.
4c, 22791/542. } stereophotographs of cortical shell of fig. 4a.
4d, 22790/542. }


1


2


3


4a


4b


4c


4d

1-4a.

4b-4c.

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Gifu 岐阜, Hisuikyo 飛水峡, Kamiaso 上麻生, Kamo 加茂, Kashibara 樫原, Mino 美濃

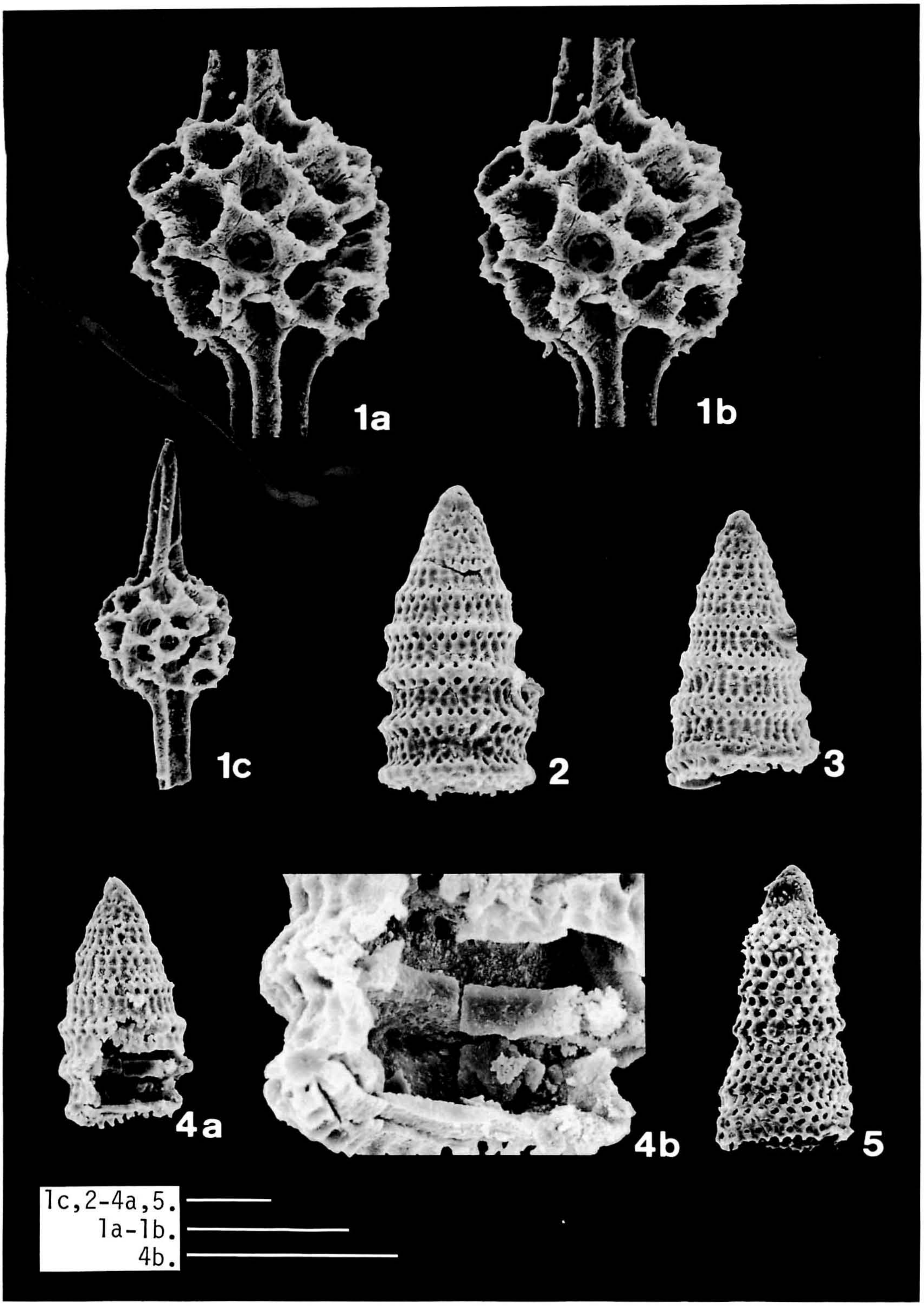
岐阜県上麻生の珪質頁岩中のジュラ紀中期放散虫：岐阜県加茂郡七宗町上麻生の飛驒川沿いに露出するチャート，珪質頁岩および砂岩・頁岩からなる三畳・ジュラ系を調査し，岩相層序学的に，また，生層序学的に検討した。このうち，珪質頁岩には *Unuma echinatus* 群集と *Dictyomitrella* (?) *kamoensis—Pantanellium foveatum* 群集の2放散虫群集が認められる。筆者らは，後者を代表する特徴種を選び，4種の放散虫（うち3種は新種）を記載した。このうち *Dictyomitrella* (?) *kamoensis* n. sp. と *Pantanellium foveatum* n. sp. は代表種であり，日本の各地にも広く産出する。*Pachyoncus kamiasoensis* n. sp. は上記の2種と共存するが，他の地域ではまだ報告されていない。この *Dictyomitrella* (?) *kamoensis—Pantanellium foveatum* 群集に含まれる *Ristola* (?) *turpicula* は，北米オレゴン州の Snowshoe 層 (Bathonian 上部) より産することが知られている。　水谷伸治郎・木戸　聡

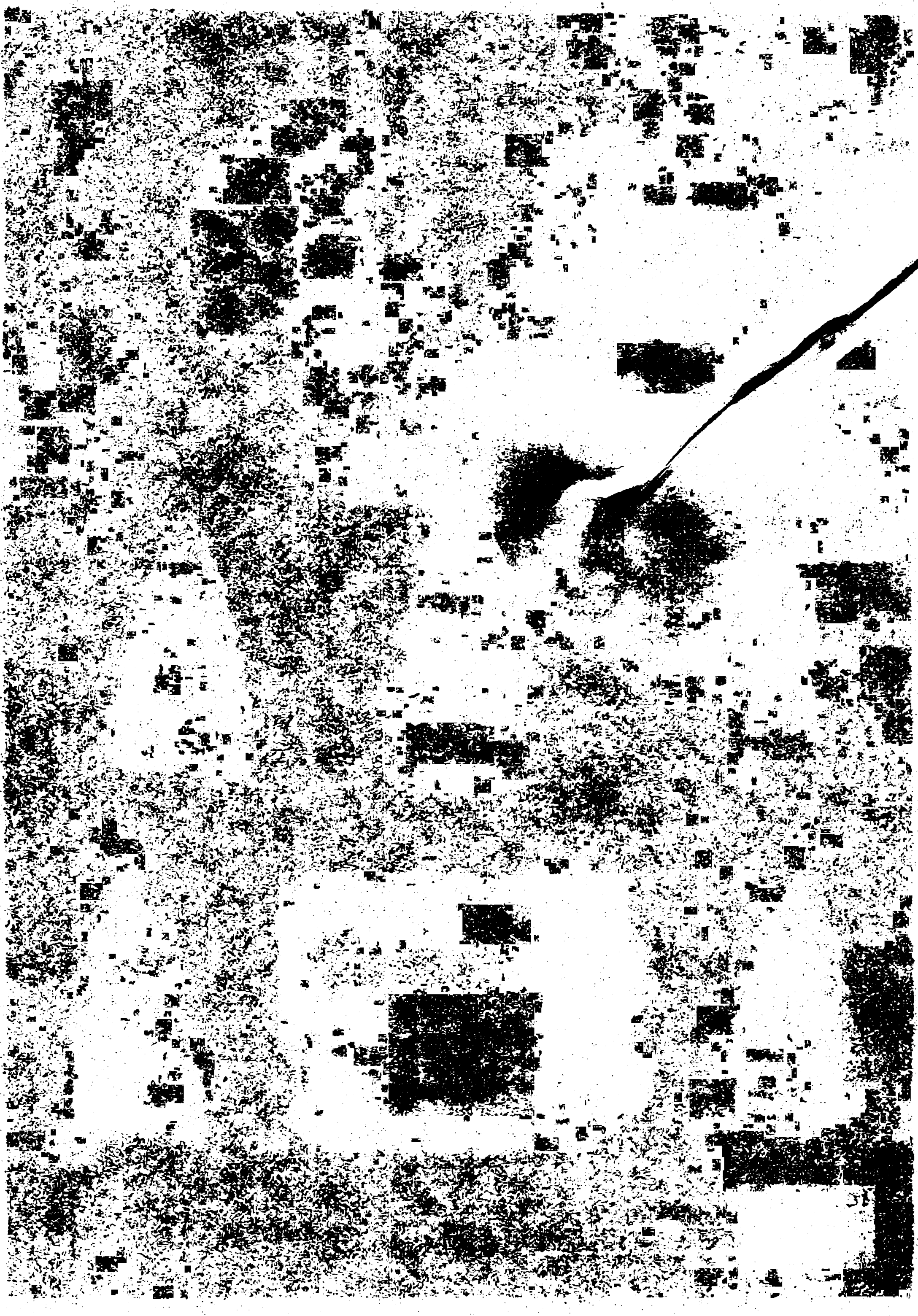
Explanation of Plate 53 (marker = 50 microns)

Fig. 1. *Pachyoncus kamiasoensis* Mizutani and Kido, n. sp. (1a—1c, paratype)
1a, 22786/324.
1b, 22787/324. } stereophotographs of cortical shell of fig. 1c.
1c, 22785/324.

Figs. 2—4. *Dictyomitrella*(?) *kamoensis* Mizutani and Kido, n. sp. (2, holotype; 3, paratype)
2, 12675/396.
3, 11643/391.
4a, 11670/391.
4b, 11671/391; lower part of fig. 4a.

Fig. 5. *Ristola*(?) *turpicula* Pessagno and Whalen.
5, 12214/334.


1a
1b
1c
2
3
4a
4b
5
1c,2-4a,5.
1a-1b.
4b.



PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本右生物学会第132回例会

日本古生物学会第132回例会が1983年10月23日に，熊本大学を会場として開催された（参会者51名）。

個人講演

舞鶴層群から産出したペルム紀放散虫 ..石賀裕明

高知県西部秩父累帯南帯における上部ジュラ系の放散虫化石層序 ....松岡　篤

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白亜紀 *Crassostrea* のコロニーについて...... .... 清田泰行

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秋吉石灰岩層群下部層の Schistocerataceae 超科アンモナイトについて ....久間裕子・西田民雄

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Dipteridaceae (Pteridophyta) from the Upper Triassic Mine Group in Yamaguchi Prefecture, Japan (1)...................Naito, G.

桃の木層産の *Sphenopteris* ....内藤源太郎

Paleovegetation and paleoclimate based on the pollen-analysis of Kurobe-gawa-fan Submerged Forest, central Japan ....Fuji, N. and Fujii, S.

南半球における *Nothofagus* 属の分布変遷.... .... 棚井敏雅

フウ属（マンサク科）化石の分類学的再検討，とくに *Liquidambar* 節について ....植村和彦

南部九州の後期中新世化石植物群 ......長谷義隆

日本古生物学会特別号の原稿募集

PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS, NUMBER 29 を 1985年度に刊行したく，その原稿を公募します。適当な原稿をお持ちの方は，次の事項に合わせて申込書を作成し，原稿の写しを添えて，〒812　福岡市東区箱崎　九州大学理学部地質学教室気付，日本古生物学会特別号編集委員会（代表者首藤次男）宛に申し込んで下さい。

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