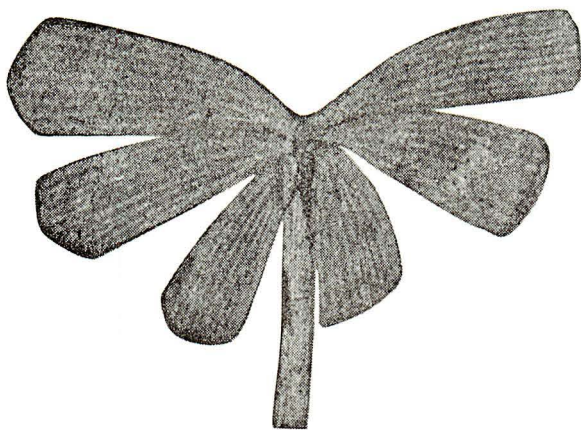


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Fossil on the cover is the six leaves in a whorl of *Trizygia oblongifolia*
(GERM. & KAULF.) ASAMA from the Maiya formation (*Parafusulina* zone),
Maiya, N. E. Japan.

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648. FUNCTIONAL MORPHOLOGY OF *OTOSCAPHITES PUERCULUS*
(JIMBO), AN UPPER CRETACEOUS AMMONITE*

KAZUSHIGE TANABE

Department of Geology, Kyushu University, Fukuoka 812

白亜紀後期アンモナイト *Otoscaphtes puerculus* (JIMBO) の機能形態学的研究：北海道中軸北部達布地域のチューロニアン (*Inoceramus hobetsensis* 帯) から連続的に採集された 16 サンプルに、南樺太内淵地域および北海道中部の大夕張地域産の 8 サンプルを加えた計 24 サンプル、約 150 個体の *Otoscaphtes puerculus* について正中断面、横断面での詳細な形態解析を行なうとともに、保存のよい数個体について実際に体積を測定し、近似的に殻の浮力を算出した。その結果、殻口に顕著なラベットの存在する成年殻のフラグモコーンの直径および 5.5π 以降の全回転角に対するラ環の半径のアロメトリーの成長比は、時間的に増加するが、逆に正常巻きに補正した住房の長さは 1.6π から 1.2π に減少することがわかった。また半径に対する隔壁および腹壁の厚さのアロメトリーの成長比についても時間的に浮力の増大したことを示す。浮力計算の結果、下位層準の標本ではフラグモコーンに水が入らない状態でも、全体の比重は水より大きくなるが、上位層準の標本ではフラグモコーンに約 30~47% 水を入れた状態で殻の比重は水と等しくなる。これらの事実から本種は上述の形態変化に伴って成年時の生活様式を底生から浮遊ないし遊泳性に変えたものと思われる。また下位層準のサンプルでは、ラ環のほどける約 1π 前 (約 7.5π) 付近から腹壁および隔壁の厚さが急に厚くなるから、個体発生前中に生活様式を遊泳・浮遊性から底生に変えたことが推定される。 棚部一成

Introduction and Acknowledgements

Shelled cephalopods are suitable material for the study of functional morphology, because of their diverse morphology and complicated organization.

Since MOSELEY's (1838) mathematical analyses of cephalopod shells, studies of the functional morphology of ammonites have been carried out by many paleontologists. Noteworthy examples of such studies are calculation of buoyancy and reconstruction of mode of life of the different shell type ammonites by TRUEMAN (1941) and experiments on relative streamlining using the plaster models of ammonites by KUMMEL and LLOYD (1955).

More recently, RAUP (1965, 1967), RAUP

and CHAMBERLAIN (1967) and CHAMBERLAIN (1969) analysed the fundamental morphology of ammonites using an analogue computer and simulation models. REYMENT (1956, 1973), HEPTONSTALL (1970), MUTVEI and REYMENT (1973) and RAUP (1973) discussed the nekroplanktic problem based on flotation experiments using modern *Nautilus* and models of ammonites. WESTERMANN (1971) discussed the functional significance of many characters of ammonites at the ordinal level.

Moreover, studies of modern *Nautilus* and *Sepia* by BIDDER (1962), COLLINS and MINTON (1967) and DENTON and GILPIN-BROWN (1961, 1963, 1966, 1973), have given a lot of important information for the study on the functional morphology of fossil cephalopods.

* Received Nov. 9, 1974: read Jan. 12, 1974 at Fukuoka.

As a result of these studies, many aspects of the functional significance of ammonites have become clear. However, most of the previous studies were mainly based on small collection, and little has been done on the functional evolution at the population level.

I have been working on the functional evolution of some species of the Upper Cretaceous scaphitoid ammonites under the supervision of Professor Tatsuro MATSUMOTO of Kyushu University.

In this study, I make a biometrical morphologic analyses of *Otoscaphtes puerculus* (JIMBO) on the basis of 24 samples, collected from south Sakhalin and Hokkaido, considering the functional morphology and evolution of the species.

Acknowledgements: Here I express my sincere gratitude to Professor Tatsuro MATSUMOTO for his valuable suggestions and critical reading of my manuscript. I am indebted to Professor Richard A. REYMENT of the University of Uppsala, Professor David M. RAUP of the University of Rochester, Associate Professor Itaru HAYAMI of the University of Tokyo and Dr. Hiromichi HIRANO of Kyushu University for their careful review of the manuscript and numerous instructive suggestions about the functional morphology of ammonites. I also express my sincere gratitude to Associate Professor Kame-toshi KANMERA and Dr. Tomowo OZAWA of Kyushu University and to Dr. Ikuwo OBATA of the National Science Museum, who have given me much instructive advice about my research, to Professor Tetsuro HANAI of the University of Tokyo for permission to examine the collections in the University Museum.

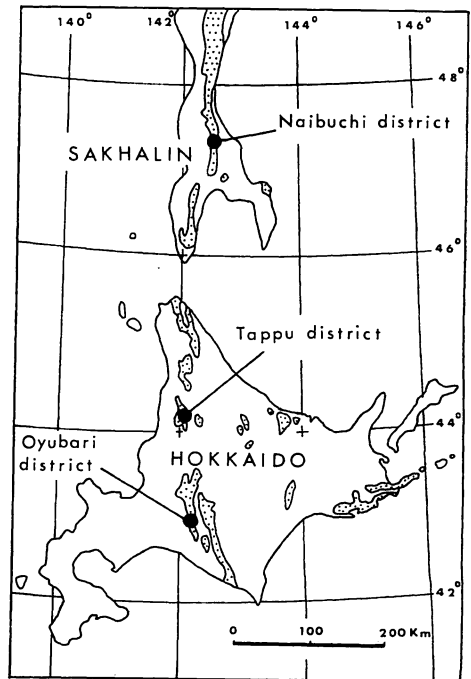
Material

Systematic position of Otoscaphtes puerculus: Occurrences of scaphitoid

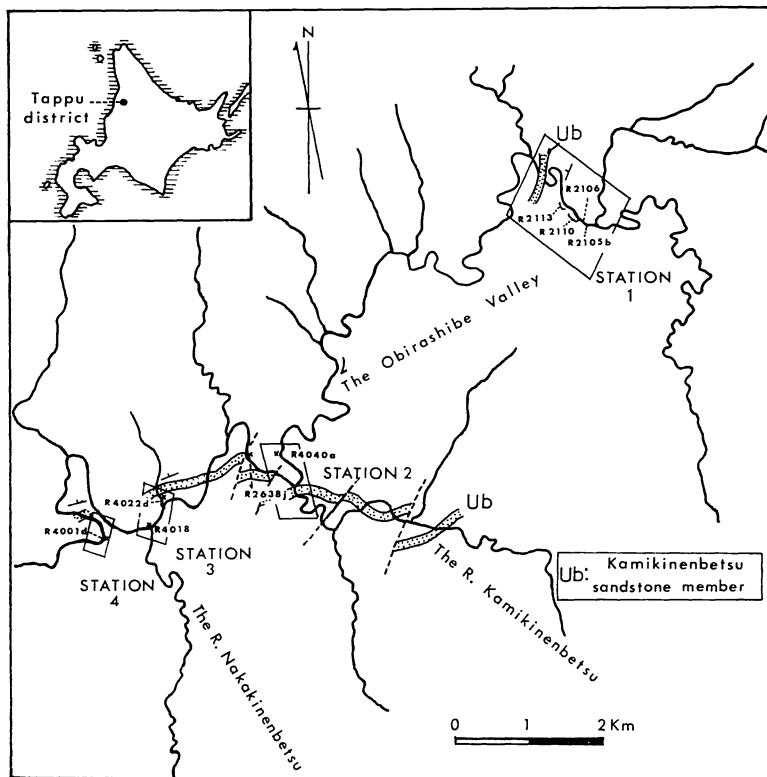
ammonites from Japan and its adjacent areas are, in general, limited to the Turonian and Coniacian. They often occur abundantly in the silty sediments of the Saku formation of the Middle Yezo Group (MATSUMOTO and OKADA, 1973). YABE (1927) called the biofacies characterized by *Scaphites* and *Otoscaphtes* the *Yezoites* Beds.

Otoscaphtes puerculus (JIMBO), discussing in this paper, is rather small in size for the Scaphitidae; it is characterized by a moderately evolute shell with a pair of long lappets.

Originally, JIMBO (1894, p. 37, pl. 5, fig. 4a, b) described the present species as *Scaphites puerculus* JIMBO from the Pankemoyubari River, a left tributary of the Yubari River, Yubari district of central Hokkaido.



Text-fig. 1. Map showing the Cretaceous outcrops and the areas studied.



Text-fig. 2. Map showing the fossil localities in the Tappu district.

YABE (1910) summarized the scaphitoid ammonites from Hokkaido and described some species. In that study, he established the genus *Yezoites* and included this species in it.

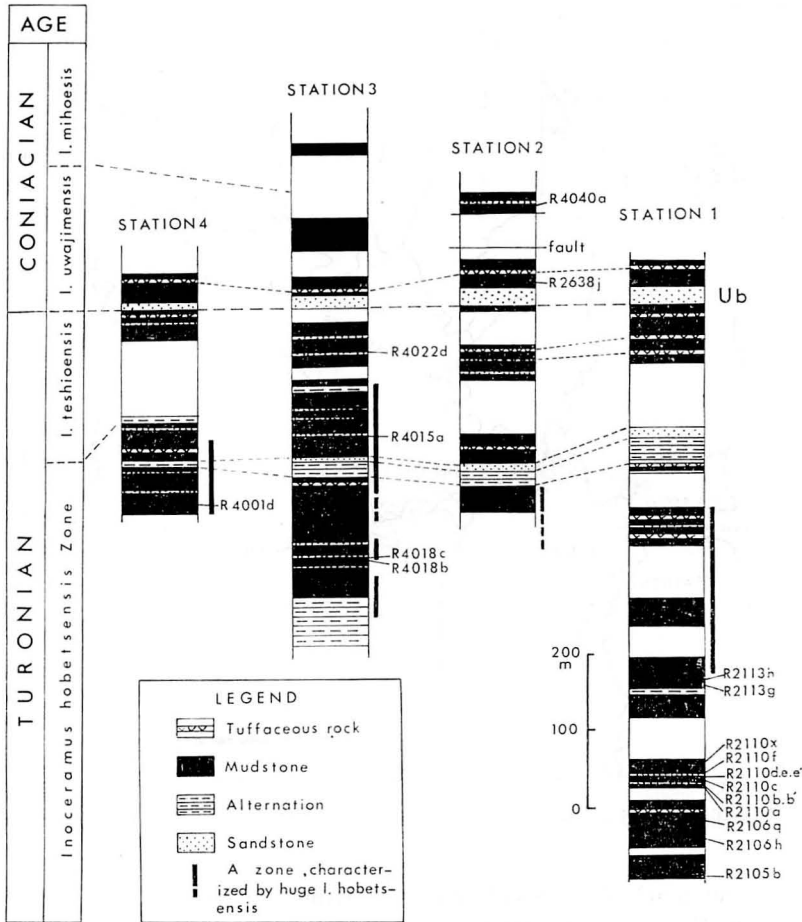
Subsequently, WRIGHT (1953) pointed out that *Yezoites planus* of YABE (1910) is a true *Scaphites*. He judged YABE's (1910) *Yezoites* as invalid and proposed the genus *Otoscaphtes* for the group of moderately evolute shells with a prominent constriction and a pair of long lateral lappets on their apertural margin; he included *Scaphites puerculus* in *Otoscaphtes*.

According to YABE (1910), the present species occurs abundantly in the Turonian and Coniacian of Japan, but I doubt

whether the present species ranges into the Coniacian, because the range in growth patterns of the Coniacian specimens is different from that of the Turonian ones. Furthermore, the Coniacian specimen has much smaller protoconch and nepionic sizes than the Turonian one. The Turonian samples remain constant ranges of nepionic and protoconch sizes throughout the sequence of the areas studied.

At present, I refrain from deciding whether these differences are intra-specific or interspecific, because insufficient Coniacian samples are at my disposal for this problem.

In this paper, I treat only the Turonian samples for the above mentioned reasons.



Text-fig. 3. Stratigraphic position of each sample from the Tappu district.

These samples were collected from the Naibuchi district, south Sakhalin, the Tappu district, northern central Hokkaido and the Oyubari district, central Hokkaido (Text-fig. 1).

Sampling method: Each sample, studied in this paper, is composed of several specimens collected from a single calcareous nodule. The stratigraphic position of each sample from the Tappu district is expressed by the thickness measured from the initial horizon of the earliest appearance of the present species. Many specimens of *Inoceramus* (s. str.) *hobets-*

ensis NAGAO and MATSUMOTO are associated with every sample. In some cases, other heteromorphs such as *Nipponites* and *Scalarites* are associated with the present species.

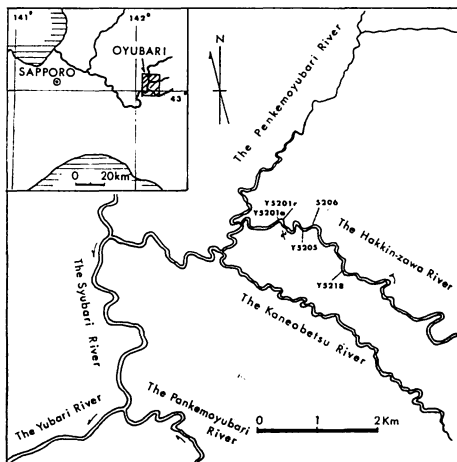
According to MATSUMOTO's (1959) biostratigraphic division of the Upper Cretaceous in Japan, *I.* (s. str.) *hobetsensis* is a zonal index of the Upper lower Gylia-kian (approximately Middle Turonian). Accordingly, the stratigraphic position of each sample is considered as being approximately within the Middle Turonian.

Samples: I used 24 samples in the present study. Among them, 3 samples were collected from the Naibuchi district, namely N315d and 317d near the confluence of the Naibuchi River and the Ichinosawa River and N320 in the upper stream about 3 km apart from the confluence. These samples were collected by MATSUMOTO in 1937. The detailed localities are illustrated in MATSUMOTO (1942).

I used 16 samples from the Tappu district. The fossil localities and their stratigraphic positions are summarized in Text-figs. 2, 3. 11 samples except R2110b', R2110e', R4018b, R4001d and R4022d were collected by T. MATSUMOTO, T. MURAMOTO, H. OKADA, H. HIRANO and me in 1971. The rest of the samples were collected by H. HIRANO and me in 1973.

TANAKA (1963) lithologically subdivided the Turonian in the district into several members. But, according to my field observations, the lateral changes of the lithofacies are rather great.

Accordingly, I used a zone as a key



Text-fig. 4. Map showing the fossil localities in the Oyubari district (adapted from MATSUMOTO's unpublished data).

bed, characterized by large specimens of *I.* (s. str.) *hobetsensis* and *I.* (s. str.) *iburiensis* NAGAO and MATSUMOTO, as well as certain beds of tuffaceous rocks and Ub member (TANAKA's Kamikinenbetsu sandstone member) (see Text-fig. 3).

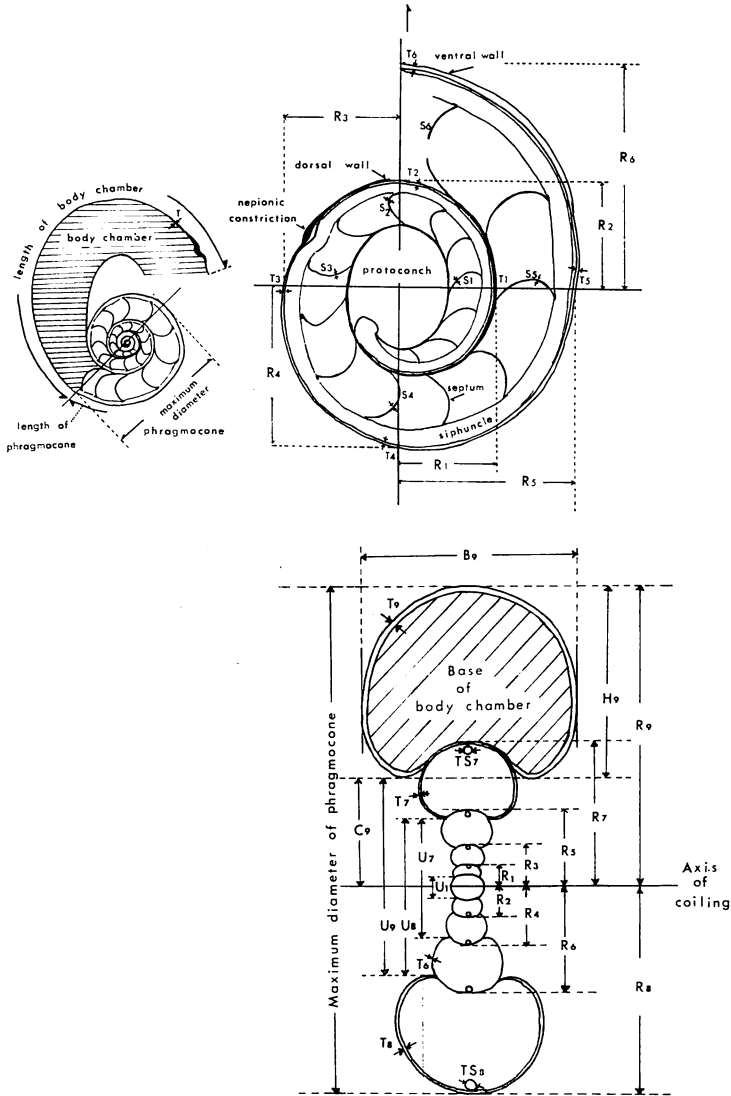
I also used 5 samples from the Oyubari district. These samples were collected from the lower course of the Hakkinzawa River, a tributary of the Yubari River, by T. MATSUMOTO in 1973 (Text-fig. 4). Incidentally, a Middle Turonian *Collignoniceras woollgari* (MANTELL) was collected from loc. Y5206d.

Methods of study

Generally speaking, adult shells form the main part of each sample. In the adult specimens, the body chamber, including a pair of long lateral lappets, is commonly in a good state of preservation as well as phragmocone. This fact implies that the present species is suitable material for the morphologic analysis.

I prepared the data for the morphologic analysis by measuring the median dorsoventral and the cross sections. Moreover, with respect to some favorably preserved adult specimens, I calculated the volume of the body chamber and the phragmocone after having separated them at the base of the body chamber.

Morphologic analysis: Regarding the adult specimens, the coiling of the whorls becomes loose from about $8-9\pi$ during the ontogeny. However, the coiling pattern belongs to planispiral growth. In order to analyse the fundamental morphology biometrically, I tried to polish each specimen carefully along the dorsoventral plane. When the siphuncular tube extended over one whorl at least on the cutting plane, I regarded the specimen as having been cut precisely along the median dorsoventral plane.



Text-fig. 5. Basic morphology, orientation and measurements in median and cross sections of scaphitoid ammonites.

As to the samples, R2110b' and R2110e', I also performed the morphologic analysis along the cross section. Each specimen was cut at the base of the body chamber.

The basic morphology, orientation and measurements on both sections of the present species are diagrammatically

shown in Text-fig. 5.

Each character was measured with a micrometer attached to a binocular microscope with magnification of 60 and 100 times. I also used a Wild microscope and a wide-view projector for sketching the magnified outline. The spiral length

of walls was measured with a curvimeter. The measured value of each character is the average of two measurements.

Volumometry: The volumetry of the body chamber and the phragmocone was done on 6 specimens of R2110a and 2 specimens of R4018b. We are able to cube the volume of the solid (V_m) by the following formula.

$$V_m = W_m - W'_m,$$

where W_m is the weight of the solid and W'_m is the immersed weight. An automatic balance of accuracy, 1 mg, was used for determining the weight.

Abbreviations: The following abbreviations are applied in the present paper.

For fundamental morphology

R : Radius from the axis of coiling
(from the centre of the protoconch)

U : Umbilical diameter

B : Breadth of whorl

H : Height of whorl

C : Half length of umbilical diameter

W : Whorl expansion rate $(R_n/R_{n-1})^2$

D : Distance of generating curve
from the axis of coiling (R/C)

T : Thickness of ventral wall

S : Thickness of septum

For biometry

N : Number of specimens in a sample

O.R. : Observed range

\bar{X} : Arithmetic mean

V : Coefficient of variability $(100_s/\bar{X})$

s : Standard deviation

$\sigma_{\bar{x}}$: Standard error of the mean

P : Probability level

ν : Degrees of freedom

$\bar{X} \pm t_{0.05} \sigma_{\bar{x}}$: 95% confidence interval
of the sample mean

α : Growth ratio

β : Initial growth index

r : Correlation coefficient

$\sigma_{\bar{\alpha}}$: Standard error of the mean of
growth ratio

Repository: All the specimens, except for the Naibuchi samples of the University of Tokyo, are stored in the type collection of the Department of Geology, Faculty of Science, Kyushu University with registered numbers beginning with the prefix GK. H.

Morphologic analyses

Individual relative growth

Growth of radius: It has long been known that the growth of the whorl of cephalopod shells displays a logarithmic spiral (THOMPSON, 1917; HUXLEY, 1932).

OBATA (1959, 1960, 1964, 1965, 1967) investigated the allometry of such Upper Cretaceous ammonites as *Reesidites minimus* (HAYASAKA and FUKADA), *Desmophyllites diphyloides* (FORBES), *Damesites damesi* (JIMBO), *Phyllopachyceras ezoense* (YOKOYAMA), *Neophylloceras subramosum* SPATH, *Neopuzosia ishikawai* (JIMBO) and *Gaudryceras tenuiliratum* YABE.

In these papers, he realized that the growth of the radius in each species can be plotted on a semi-logarithmic graph with high degrees of correlation as a function of polar coordinates. Moreover, he pointed out that the growth pattern is constant in each species.

Recently HIRANO (1975a, b) has studied the ontogeny of some species of Upper Cretaceous *Gaudryceras* from the viewpoint of population paleontology. According to him, each species can be divided into several growth phases. He showed that the growth ratio in each growth phase is nearly constant within a species and that the variability is relatively small.

We can determine the growth ratio of the radius to the total rotation angle by using the least squares method. The equation is expressed as follows (THOMPSON, 1917; HUXLEY, 1932; OBATA, 1959, 1960, 1967).

$$\log R = \alpha\theta + c \text{ or } R = (\log c) \cdot \theta^\alpha,$$

where θ is the total rotation angle and c is a constant ($\log c$ is the initial growth index).

If rearranged with $e^c \rightarrow a$, the equation can be rewritten as follows:

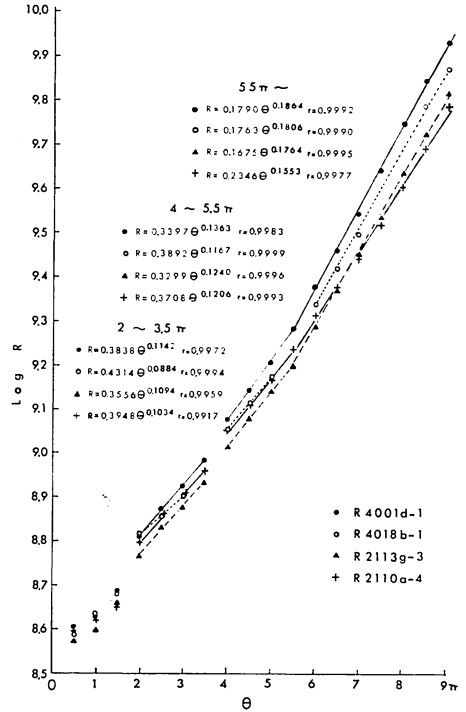
$$R = a \cdot e^{\alpha\theta}.$$

In each growth stage, the spiral angle (w) between a tangent touching the generating curve at a point and a straight line connecting the centre of coiling and a point, can be obtained by the following formula (OBATA, 1960, 1961).

$$w = \tan^{-1} 1/\alpha \quad \therefore w < 90^\circ.$$

In the case of the present species, the growth pattern of the radius exhibits the existence of 4 growth phases, that is, the 1st ($0 \sim 1.5\pi$), the 2nd ($2 \sim 3.5\pi$), the 3rd ($4 \sim 5.5\pi$) and the 4th ($5.5\pi \sim$) stages during the ontogeny, as shown in Text-fig. 6 and Table 1.

A pronounced gap in growth can be recognized between the 1st and the 2nd stages in every specimen. This gap corresponds to the nepionic (first) constric-



Text-fig. 6. Phylogenetic changes of growth of radius to total rotation angle. Each specimen shows nearly the same value of the growth ratio of the sample mean.

Table 1. Growth ratio of radius to total rotation angle at the 2nd to the 4th stages for each sample.

Sample	2nd stage (2 ~ 3.5π)				3rd stage (4 ~ 5.5π)				4th stage (5.5π ~)				
	N	$X \pm 1.96\sigma_x$	s	O. R.	N	$X \pm 1.96\sigma_x$	s	O. R.	N	$X \pm 1.96\sigma_x$	s	O. R.	
Naituchi d.	N317d	10	0.1002 ± 0.0127	0.0186	0.0352 - 0.1267	9	0.1170 ± 0.0118	0.0152	0.0877 - 0.1407	7	0.1576 ± 0.0103	0.0111	0.1449 - 0.1718
	N315d	2	0.1060 ± 0.0089	0.0134	0.1050 - 0.1069	3	0.1244 ± 0.0331	0.0134	0.1144 - 0.1397	3	0.1549 ± 0.0430	0.0174	0.1361 - 0.1705
	N320	5	0.0973 ± 0.0147	0.0119	0.0835 - 0.1118	4	0.1143 ± 0.0143	0.0089	0.1029 - 0.1249	3	0.1640 ± 0.0090	0.0090	0.1582 - 0.1744
	R2105b	2	0.1005 ± 0.0620	0.0070	0.0955 - 0.1054	2	0.1279 ± 0.0572	0.0063	0.1233 - 0.1324	1	0.1546	—	—
districti	R2110a	31	0.1026 ± 0.0039	0.0107	0.0786 - 0.1295	27	0.1243 ± 0.0058	0.0145	0.1059 - 0.1498	29	0.1610 ± 0.0055	0.0145	0.1322 - 0.1848
	R2110b	2	0.0917 ± 0.0407	0.0045	0.0885 - 0.0949	2	0.1183 ± 0.0839	0.0094	0.1116 - 0.1249	2	0.1663 ± 0.0419	0.0047	0.1630 - 0.1696
	R2110c	10	0.1043 ± 0.0095	0.0132	0.0903 - 0.1189	10	0.1145 ± 0.0085	0.0121	0.0919 - 0.1372	10	0.1597 ± 0.0086	0.0120	0.1386 - 0.1809
	R2110d	6	0.1021 ± 0.0111	0.0095	0.0897 - 0.1135	6	0.1208 ± 0.0105	0.0092	0.1091 - 0.1340	6	0.1603 ± 0.0136	0.0144	0.1490 - 0.1753
	R2110f	5	0.1074 ± 0.0178	0.0144	0.0922 - 0.1301	4	0.1128 ± 0.0156	0.0097	0.0988 - 0.1202	4	0.1601 ± 0.0095	0.0130	0.1532 - 0.1675
	R2110x	18	0.1029 ± 0.0038	0.0075	0.0891 - 0.1180	18	0.1268 ± 0.0049	0.0097	0.1101 - 0.1474	18	0.1618 ± 0.0055	0.0110	0.1337 - 0.1815
Tappu	R2113g	5	0.0999 ± 0.0130	0.0106	0.0900 - 0.1131	4	0.1192 ± 0.0124	0.0077	0.1101 - 0.1270	2	0.1773 ± 0.0102	0.0012	0.1764 - 0.1781
	R2113h	4	0.1012 ± 0.0105	0.0066	0.0915 - 0.1025	4	0.1255 ± 0.0089	0.0056	0.1182 - 0.1311	4	0.1753 ± 0.0127	0.0079	0.1697 - 0.1827
	R4018b	3	0.0879 ± 0.0370	0.0149	0.0728 - 0.1025	2	0.1184 ± 0.0203	0.0023	0.1167 - 0.1200	4	0.1798 ± 0.0150	0.0094	0.1708 - 0.1925
	R4001d	7	0.1085 ± 0.0250	0.0102	0.0988 - 0.1265	6	0.1311 ± 0.0121	0.0166	0.1111 - 0.1420	7	0.1818 ± 0.0117	0.0128	0.1630 - 0.1966
Yubert d.	Y5218b	9	0.0955 ± 0.0040	0.0061	0.0891 - 0.1068	9	0.1123 ± 0.0097	0.0126	0.1086 - 0.1402	9	0.1631 ± 0.0058	0.0076	0.1458 - 0.1738
	Y5201r	8	0.1063 ± 0.0132	0.0158	0.0872 - 0.1390	8	0.1328 ± 0.0102	0.0123	0.1078 - 0.1459	8	0.1676 ± 0.0125	0.0150	0.1359 - 0.1819

tion. The size of the nepionic stage of the present species indicates a constant range of 720~890 μ in each sample and is not changed with time. The coefficient of variability of each sample is small (V=2~6). The small gap in growth between the 2nd and the 3rd stages is probably referred to the nepionic constriction, because the range of the gap is nearly the same with that between the 1st and the 2nd stages. The growth

ratio of the 3rd stage is somewhat greater than that of the 2nd stage.

In order to realize the differences of growth ratio between the 2nd and the 3rd stages and also between the 3rd and the 4th stages quantitatively, I performed the biometrical examinations on three samples.

The results of the chi-square tests are as follows.

The 2nd stage

N 317d: $\chi^2=0.48 \ll 3.84 = \chi^2_{0.05}(\nu=1)$, $P \gg 0.05$, non-significant

R2110a: $\chi^2=0.39 \ll 7.82 = \chi^2_{0.05}(\nu=3)$, " , "

R2110x: $\chi^2=1.38 \ll 5.99 = \chi^2_{0.05}(\nu=2)$, " , "

The 3rd stage

N 317d: $\chi^2=0.52 \ll 3.84 = \chi^2_{0.05}(\nu=1)$, $P \gg 0.05$, non-significant

R2110a: $\chi^2=1.07 \ll 5.99 = \chi^2_{0.05}(\nu=2)$, " , "

R2110x: $\chi^2=1.38 \ll 5.99 =$ " , " , "

The 4th stage

R2110a: $\chi^2=2.48 \ll 3.84 = \chi^2_{0.05}(\nu=1)$, $P \gg 0.05$, non-significant

R2110x: $\chi^2=1.38 \ll 5.99 = \chi^2_{0.05}(\nu=2)$, " , "

The results of the chi-square tests indicate that the null hypothesis of normal distribution of populations is not rejected for the character.

Next, I examined the differences of the variances between the two growth stages

(F-test). The F-test, or variance ratio is given by the following formula.

$$F = s_1^2 / s_2^2$$

$$\because s_1 > s_2, \nu_1 = N_1 - 1, \nu_2 = N_2 - 1.$$

The results of the F-test are as follows.

Between the 2nd and the 3rd stages,

N 317d: $F=1.84 \ll 3.39 = F_{(\nu=9,8)}$, $P \gg 0.05$, non-significant

R2110a: $F=1.84 \ll 2.37 = F_{(\nu=26,30)}$, $P \gg 0.01$, "

R2110x: $F=1.68 \ll 2.31 = F_{(\nu=17,17)}$, $P \gg 0.05$, "

Between the 3rd and the 4th stages,

R2110a: $F=1.00 \ll 1.90 = F_{(\nu=28,26)}$, $P \gg 0.05$, non-significant

R2110x: $F=1.29 \ll 2.31 = F_{(\nu=17,17)}$, " , "

The results of the F-test indicate that the differences of the variances between the two growth stages is not significant with 95% or 99% confidence.

The difference of the mean between the two samples can be determined by the following well-known formula (Student's t-test).

$$t = \frac{(\bar{X}_1 - \bar{X}_2) \sqrt{\frac{N_1 \cdot N_2}{N_1 + N_2}}}{\sqrt{\frac{(N_1 - 1) \cdot s_1^2 + (N_2 - 1) \cdot s_2^2}{N_1 + N_2 - 2}}},$$

$$\nu = N_1 + N_2 - 2.$$

Using this formula, I calculated that value in each sample.

Between the 2nd and the 3rd stages,

N 317d: $|t|=2.14 \gg 2.11=t_{0.05}(\nu=17)$, $P \ll 0.05$, significant

R2110a: $|t|=6.56 \gg 2.00=t_{0.05}(\nu=56)$, " , "

R2110x: $|t|=8.28 \gg 2.04=t_{0.05}(\nu=34)$, " , "

Between the 3rd and the 4th stages,

R2110a: $|t|=9.47 \gg 2.00=t_{0.05}(\nu=54)$, $P \ll 0.05$, significant

R2110x: $|t|=10.15 \gg 2.04=t_{0.05}(\nu=34)$, " , "

The results of the t -tests show that significant differences in the growth ratio exist between the 2nd and the 3rd stages and between the 3rd and the 4th stages with 95% confidence.

The growth ratio of the 3rd stage is nearly constant over time, but that of the 4th stage gradually increases with time. In every sample, the difference in the

growth ratio between the 3rd and the 4th stages is greater than that between the 2nd and the 3rd stages.

The spiral angle of the 4th stage decreases with time in accordance with the increase of the growth ratio as shown in Table 2. The variability in each sample is extremely small.

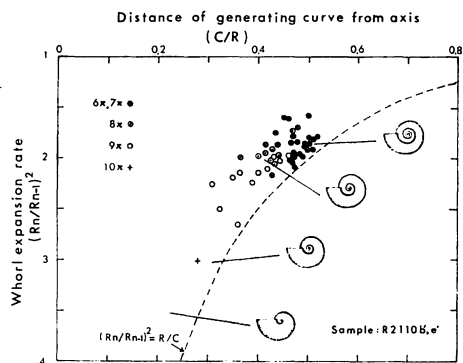
Table 2. Measurements of spiral angle of the 4th stage of *Otoscaphtes puerculus* (JIMBO) (in degrees).

Sample	N	$\bar{X} \pm t_{0.05} \sigma_{\bar{x}}$	V	s	O. R.
R2105b	1	83.55	/	/	83.55
R2110a	29	83.28 \pm 0.23	0.72	0.60	82.30–84.48
R2110b	2	83.07 \pm 1.71	0.23	0.19	82.93–83.20
R2110c	16	83.59 \pm 0.28	0.63	0.13	82.46–84.21
R2110d	5	83.24 \pm 0.61	0.58	0.49	82.69–83.78
R2110f	4	83.32 \pm 0.38	0.29	0.24	83.01–83.60
R2110x	18	83.25 \pm 0.22	0.55	0.45	82.44–84.41
R2113g	2	82.61 \pm 0.51	0.07	0.06	82.57–82.65
R2113h	4	82.70 \pm 0.53	0.40	0.33	82.39–83.03
R4018b	4	82.51 \pm 0.62	0.47	0.39	81.98–82.88
R4001d	7	82.42 \pm 0.49	0.64	0.53	81.89–83.20

RAUP (1965, 1967) developed the method of morphologic analysis of coiled ammonites using two simple parameters, the whorl expansion rate and the distance of generating curve from the axis of coiling (Text-fig. 5). Using this approach, I examined the ontogeny of R2110b' and R2110e'. The results are shown in Text-fig. 7. During the ontogeny, the present species displays the increase of whorl expansion rate and the decrease of dis-

tance of the generating curve from the axis of coiling.

Growth of whorl height, breadth and umbilical diameter: From the results of growth of radius, the present species can be divided into two main growth stages, $0 \sim 5.5\pi$ and $5.5\pi \sim$, as a whole. In the present study, I examined the growth of whorl height, breadth and umbilical diameter to shell diameter by means of the reduced major axis method (KERMACK



Text-fig. 7. Ontogenetic changes of morphology, expressed by distance of generating curve from axis and whorl expansion rate. Scale models are adopted from RAUP (1967).

and HALDANE, 1950). The results are summarized in Table 3. A pronounced critical point of growth is observed at

the point of 5.5π in every specimen (Text-fig. 8). The growth pattern expressed by these characters is almost harmonious with that of the radius.

HAYAMI and MATSUKUMA (1970) proposed a method of approximate discrimination of allometry using the reduced major axis. According to them, the range of isometry is represented by the following interval with 95% confidence (small sample method).

$$1 - \frac{t_{0.05} s_{\alpha}}{\sqrt{N}} \leq \bar{\alpha} \leq 1 + \frac{t_{0.05} s_{\alpha}}{\sqrt{N}},$$

where $\bar{\alpha}$ and s_{α} are the mean and the standard deviation of the growth ratio. Using this method, I tried to discriminate the allometry of the present species. The results are appended in Table 3. As to the growth of whorl height and breadth to shell diameter of every specimen,

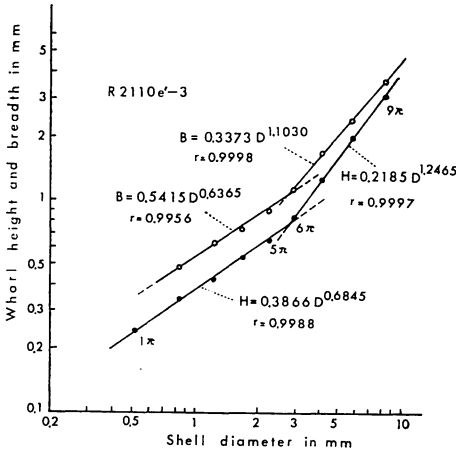
Table 3. Ontogenetic allometry of *Otoscaphtes puerculus* (JIMBO), calculated along the cross section.

Early stage (0~5.5π)

	Sample	N	$\bar{\alpha} \pm t_{0.05} s_{\alpha}$	s_{α}	O. R.	Allometry
H to D	R2110b'	5	0.8209 ± 0.1122	0.09	0.6616–0.8850	negative
	R2110e'	5	0.7436 ± 0.1188	0.10	0.6138–0.8435	"
B to D	R2110b'	5	0.6431 ± 0.0744	0.06	0.5798–0.7229	"
	R2110e'	6	0.7037 ± 0.0848	0.08	0.5740–0.7807	"
U to D	R2110b'	5	1.3264 ± 0.1688	0.14	1.2129–1.5523	positive
	R2110e'	6	1.3589 ± 0.2545	0.24	1.0045–1.6623	"

Later stage (5.5π~)

	Sample	N	$\bar{\alpha} \pm t_{0.05} s_{\alpha}$	s_{α}	O. R.	Allometry
H to D	R2110b'	5	1.2423 ± 0.1824	0.15	1.0158–1.4216	positive
	R2110e'	6	1.1856 ± 0.0452	0.04	1.1364–1.2465	"
B to D	R2110b'	5	1.1419 ± 0.1035	0.08	1.0624–1.2723	"
	R2110e'	6	1.0870 ± 0.0500	0.05	1.0260–1.1511	"
U to D	R2110b'	5	0.8002 ± 0.1466	0.15	0.6778–0.9904	negative
	R2110e'	5	0.7714 ± 0.0763	0.07	0.7010–0.8351	"



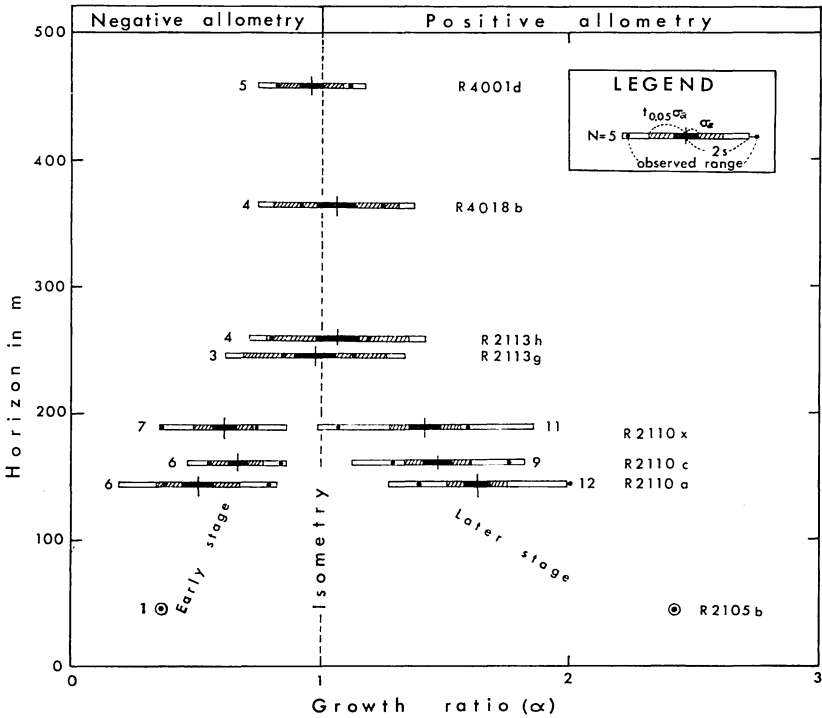
Text-fig. 8. Ontogenetic allometry of whorl height (H) and breadth (B) to shell diameter of R 2110e'-3.

the growth ratio changes from negative allometry to positive allometry during the ontogeny.

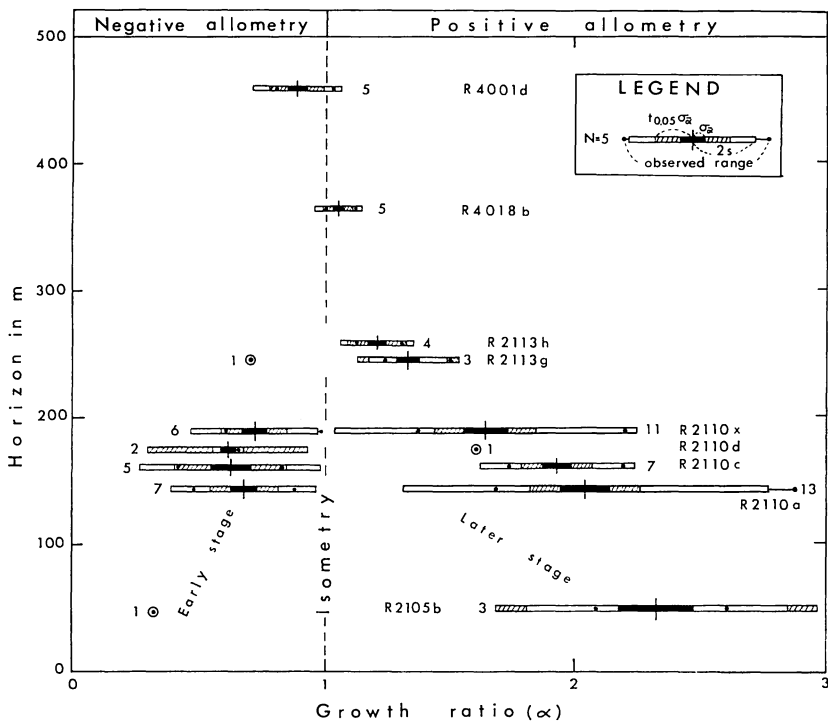
On the contrary, that of umbilical diameter against shell diameter changes from positive allometry to negative allometry.

Consequently, the growth pattern in terms of the above-mentioned three characters represents the fundamental morphology of the present species.

Growth of septal and ventral wall thickness: In the next step, I tried to investigate the growth of septal and ventral wall thickness to radius using the reduced major axis method again. The chronological changes in the growth ratio of both characters are illustrated in Text-figs. 9-10. Furthermore, the ontogenetic



Text-fig. 9. Changes in growth ratio of the reduced major axis of septal thickness to radius in samples from the Tappu district.



Text-fig. 10. Changes in growth ratio of the reduced major axis of ventral wall thickness to radius in samples from the Tappu district.

allometry of some specimens from different horizons is exemplified in Text-fig. 11. The results indicate that a plain critical point exists in the samples from the lower horizon (R2105b~R2113g).

In these samples, the growth ratio changes from negative allometry to positive allometry at about the 7.5π stage. However, the growth ratio of the later stage (from 7.5π) gradually decreased with time, and R4018b and R4001d indicate isometry or slight negative allometry. At the stage of $8.5\sim 9\pi$, the whorl of the present species begins to be loosely coiled, therefore, the growth of the ventral wall thickness is expressed not by the ratio of thickness to the diameter but that of thickness to the spiral length of ventral wall. The growth pattern is exemplified

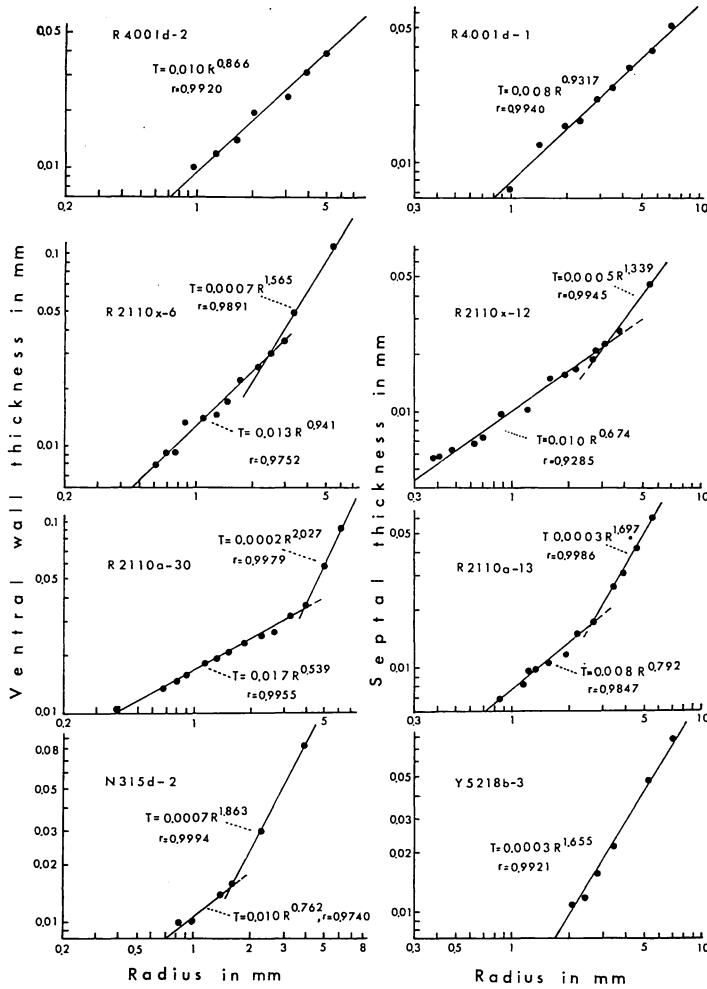
in Text-fig. 12. The thickness continues to increase until the point far apart from the centre of coiling and finally it decreases abruptly to this side of the apertural constriction. The thickness indicates the maximum value at the apertural constriction.

Relative variation

The present species has a conspicuous constriction and a pair of long lateral lappets on its apertural margin. As ARKELL (1957) pointed out, the shell having these characters may be considered as adult.

In the next part of the study, I examined the relative variation of the present species.

Maximum diameter of phragmocone:
In order to ascertain the variation of



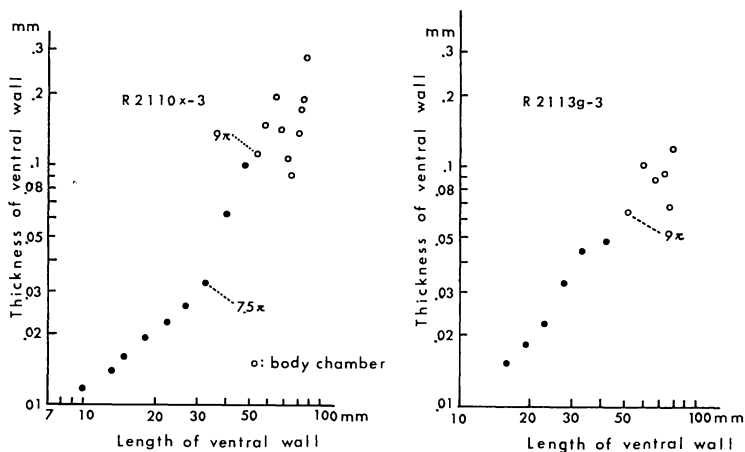
Text-fig. 11. Ontogenetic allometry of ventral wall and septal thickness to radius of selected specimens.

size of the phragmocone quantitatively, $\bar{X} \pm t_{0.05} \sigma_{\bar{x}}$, V, s and O.R. were calculated in each sample. The results are summarized in Table 4. The maximum diameter of the phragmocone increased rapidly with time.

Spiral length of body chamber: In the first place, the spiral length of the ventral and dorsal walls were separately calculated for each adult specimen from the Tappu district. For specimens hav-

ing nearly the same value of the sample mean, the reconstituted length of the body chamber was estimated. As the reconstituted lengths are almost the same between the ventral and dorsal walls, I have shown the length of the ventral wall in the examples (Text-fig. 13). The spiral length is gradually shortened about 0.4π from R2106h (ca. 1.63π) to R4018b (ca. 1.20π).

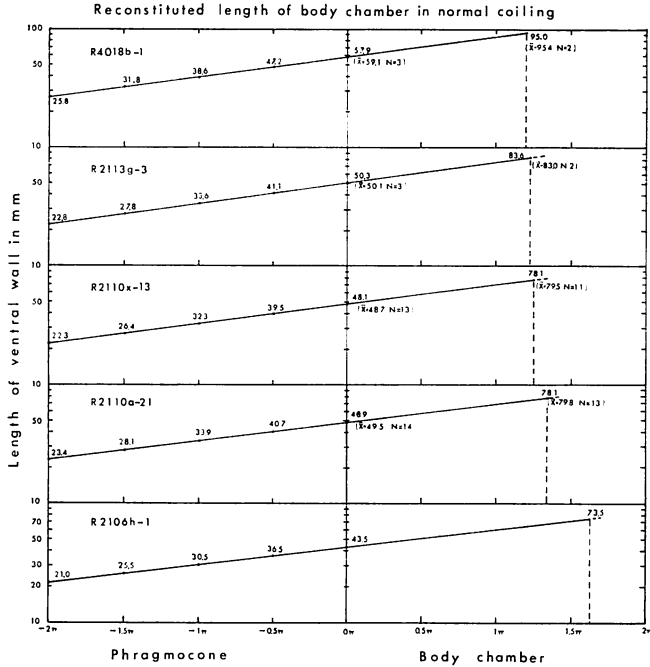
TRUEMAN (1941) estimated the length



Text-fig. 12. Ontogenetic changes of ventral wall thickness to spiral length of ventral wall of R 2110x-3 and R 2113g-3.

Table 4. Measurements of maximum diameter of phragmocone in adult specimens of *Otoscaphtes puerculus* (JIMBO) (in μ).

Sample	N	$\bar{X} \pm t_{0.05} \sigma_{\bar{x}}$	V	s	O. R.
N317d	3	7302.33 \pm 775.83	4.28	312.35	6944— 7517
N315d	2	9072.00 \pm 6670.69	8.18	742.46	8547— 9597
R2105b	1	8642	/	/	8642
R2106h	3	8565.59 \pm 1477.16	6.94	594.61	8077— 9228
R2106q	1	9420	/	/	9420
R2110a	31	9377.16 \pm 186.08	5.41	507.37	8353—10396
R2110b	3	8598.92 \pm 2219.59	10.39	893.46	8025— 9628
R2110c	14	9397.14 \pm 462.07	8.52	800.43	8408—10747
R2110d	6	9485.34 \pm 672.67	6.76	640.88	8973—10650
R2110f	2	8973.50 \pm 5216.19	6.74	580.55	8563— 9778
R2110x	19	9655.14 \pm 335.81	7.22	696.70	8730—10948
R2113g	4	10247.61 \pm 464.28	2.85	291.81	9874—10588
R2113h	4	10813.79 \pm 957.81	5.57	602.02	10147—11591
R4018b	5	11761.20 \pm 1038.49	7.11	836.52	10817—12882
R4022d	1	14342	/	/	14342
Y5218b	7	8539.29 \pm 498.42	6.31	538.91	7893— 9315
Y5205	1	9515	/	/	9615
Y5201r	6	9423.17 \pm 625.45	6.32	595.89	8556— 9985
Y5201a	1	11537	/	/	11537



Text-fig. 13. Changes of reconstituted length of body chamber in normal coiling. Each specimen shows nearly the same value of the sample mean.

of the body chamber on about 81 species of ammonites. According to his data, almost every ammonites has a body chamber longer than 1π . In the present species from the upper horizon, the body chamber is relatively short.

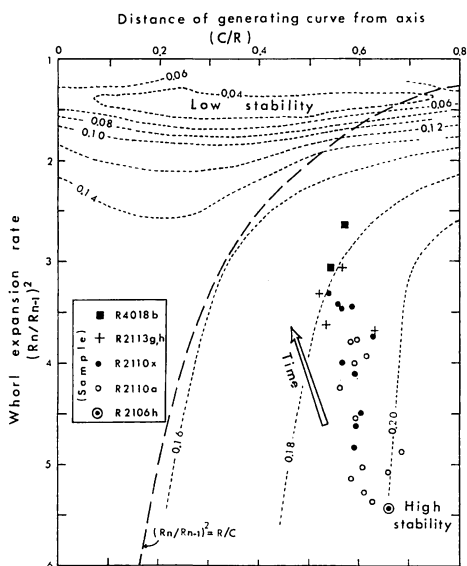
Shape of the adult shells: COBBAN (1951) and WIEDMANN (1965) made clear the trends of evolution of the scaphitoid ammonites above the species level. According to them, the shape at the adult stage gradually changed from abnormal to normal coiling with time in accordance with the increase in rate of the overlapping of whorls.

In the present species, the same pattern can be expected. To realize the chronological change of the shape at the adult stage, I examined the two characters, W and D for each specimen from the

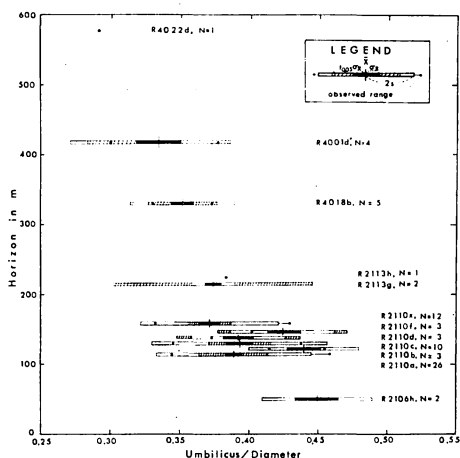
Tappu district. The results are shown in Text-fig. 14. As might well be expected, the change is similar to those of *Worthoceras* and some stocks of *Scaphites* studied by WIEDMANN (1965).

Umbilical diameter: KUMMEL and LLOYD (1955) and RAUP (1967) pointed out that the rate of overlapping of whorl is an important character in considering the stability and the relative streamlining of the shell in the floating and the swimming positions. RAUP (1967) realized that an evolute shell has generally a longer body chamber than an involute shell.

Subsequently, I examined the ratio of umbilical diameter to shell diameter for each adult specimen from the Tappu district. The chronological change of the ratio is illustrated in Text-fig. 15.



Text-fig. 14. Phylogenetic changes of morphology and stability index in adult specimens from the Tappu district. Stability index is adopted from RAUP (1967).



Text-fig. 15. Changes of ratio of umbilical diameter to shell diameter in adult specimens from the Tappu district.

The present species gradually changed from moderately evolute (40-50%) to moderately involute (ca. 30%) with time. The results can be applied to RAUP's (1967) generalization.

Number of septa and volutions: The number of septa for each adult specimen is nearly constant (40~57) and not so changeable with time. The coefficient of variability ranges from 4 to 8. The number of volutions of the phragmocone for each adult specimen is also constant (7.83~9.69π) with time and the coefficient of variability is relatively small value (V=2~6).

Functional considerations

Buoyancy of an empty shell: Here I consider the buoyancy of the present species on the ground of analyses of the individual relative growth and the relative variation.

The maximum diameter of the phragmocone in each adult specimen from the Tappu and the Oyubari districts rapidly increases with time. Furthermore, the growth ratio of septal and ventral wall thickness to radius of the later stage (from ca. 7.5π) gradually decreases from positive allometry to isometry or slight negative allometry. The growth ratio of these two characters at the stage for the samples from the lower horizon (R2105b~R2110x) is much smaller than those of normally coiled ammonites, as realized by TRUEMAN (1941) and WESTERMANN (1971). The growth pattern of whorls of the present species implies the increase of the area of cross section with time.

As THOMPSON (1917) pointed out, the volume of the body (V_b) increases in direct proportion to cube of the length (L), as represented by the following formula.

$$V_b = k \cdot L^3,$$

where k is a constant.

Consequently, the growth pattern of the present species suggests an increase of buoyancy of the shell with time.

To test this, I calculated approximately the buoyancy of some well-preserved specimens of R2110a and R4018b. There are three methods for estimating the buoyancy of ammonoid shells.

TRUEMAN (1941) calculated the buoyancy of *Promicroceras marstonense* SPATH, a Lower Jurassic ammonite after having measured the internal volume of camera and body chamber and the volume of shell material.

MOSELEY (1838), TRUEMAN (1941), RAUP and CHAMBERLAIN (1967) used simple equations for calculating the buoyancy of cephalopod shells. However, these equations may not be applied directly to actual specimens, because they were obtained from idealized models.

REYMENT (1973) and RAUP (1973) made floatational experiments using modern *Nautilus* shells and models of ammonoid shells. As REYMENT (1973) mentioned, this method is the most useful for studying the buoyancy of shells. But very well-preserved shells, completely separated from the host rock and if the camerae are not empty, the time-consuming technique of serial sectioning and modelling must be resorted to this method.

Unfortunately, it is difficult to separate completely the shell material from the host rock for the specimens at my disposal.

To calculate the buoyancy of the shell, the internal volume of camera and body chamber and the volume of shell material are required. We can calculate the volume of phragmocone and body chamber including the shell material. If we assume the present species to be a cone with a circular cross section, the base of the cone can be computed from length of the cone.

The approximate length of the cone (L) is expressed by the following formula.

$$L=1/2 \text{ (total spiral lengths of ventral and dorsal walls).}$$

The volume of the shell material (V_s) is represented by the following formula.

$$V_s=1/3 L \cdot (S-S'),$$

where S is the base of the cone, including the shell material, and S' is the internal area of the base. The wall thickness at the base is expressed by the maximum thickness of each specimen at the apertural constriction.

According to RAUP (1973), the proportion of flooding necessary to sink an empty shell (F_s) is expressed by the following formula.

$$F_s=[\rho_w \cdot (V_t - V_b) - \rho_s \cdot V_s] / \rho_w \cdot V_p,$$

where V_t is total volume of water displaced by a shell plus animal, V_b is volume of animal, assumed to be equivalent to that of body chamber, V_s is volume of shell material, V_p is volume of camerae, ρ_w is the density of water and ρ_s is the density of shell material. ρ_s is assumed to be 2.62 (REYMENT; 1958, 1973) and 1.00 is used for ρ_w .

Using this formula, I calculated the buoyancy index (F_s) for each specimen. The results are summarized in Table 5. Additionally, the data of two species of *Nautilus* and 6 species of ammonites, studied by HEPTONSTALL (1970) and RAUP (1973) are appended in Table 5.

TRUEMAN (1941) weighed several septa of such Jurassic ammonites as *Promicroceras marstonense* SPATH, *Dactylioceras commune* (SOWERBY) and *Ludwigia baylei* BUCKMAN. The proportion of the weight of septa is about 2~6% of the total shell weight for each species.

HEPTONSTALL (1970) calculated the correction value of F_s after the reconstruction of the soft parts. The correction value is about 0.10~0.25, subtracted from the value of an empty shell (Table 5).

Table 5. Calculated buoyancy index (F_s) (the proportion of flooding necessary to sink an empty shell). ** Data from RAUP (1973), *** Data from HEPTONSTALL (1970), V_p : Volume of phragmocone V_b : Volume of body chamber, V_s : Volume of shell material.

Specimen	V_p	V_b	V_s	$V_s \cdot V_p + V_b$	$V_b V_p$	F_s
R2110a—1	0.18 cc	0.41 cc	0.149 cc	0.202	2.28	-0.345
—2	0.18	0.45	0.236	0.273	2.50	-1.129
—3	0.19	0.48	0.148	0.181	2.53	-0.246
—4	0.18	0.51	0.246	0.277	2.83	-1.377
—5	0.14	0.45	0.169	0.223	3.21	-0.957
—6	0.22	0.51	0.226	0.236	2.32	-0.651
R4018b—1	0.39	0.74	0.127	0.101	1.90	+0.472
—2	0.42	0.76	0.181	0.133	1.81	+0.302
<i>Promicroceras marstonense</i>				0.089	2.80	+0.423** +0.338***
<i>Dactylioceras commune</i>				0.075	3.30	+0.458** +0.223***
<i>Ludwigia baylei</i>				0.081	2.36	+0.540** +0.520***
<i>Chondroceras</i> sp.				0.089	2.00	+0.545** +0.464***
<i>Asteroceras smithi</i>				0.123	2.00	+0.346** +0.264***
<i>Liparoceras subcrenatum</i>				0.036	7.50	+0.507** +0.248***
<i>Nautilus pompilius</i>				0.100	3.60	+0.206**
<i>Nautilus macromphalus</i>						+0.08~0.14***

Every specimen of R2110a indicates a negative value of F_s . Even if we take the effect of the phragmocone into consideration, it would be difficult to float these specimens in sea water.

On the contrary, two specimens of R4018b could have floated easily under the non-flooding condition. Their value of F_s is nearly the same as those of normally coiled ammonites, listed in Table 5. Furthermore, the two specimens could be more buoyant than *Nautilus pompilius* LINNÉ and *N. macromphalus* SOWERBY.

Streamlining: Experimental studies on the relative streamlining of ammonites were made by KUMMEL and LLOYD (1955). They measured the drag force acting on the plaster models of ammonites in a current of water. From the results of their experiments, they concluded the evolute shell forms tend to be less stream-

lined than the involute and highly ornamented forms.

As to the present species, the surface ornament (rib and tubercle) of the body chamber became weaker in accordance with the increase in rate of overlapping of whorls (see Plate 10). From this evidence, it may be inferred that the present species became more streamlined with time. But in order to study the relative streamling of the present species quantitatively, further detailed analysis of the surface ornament is needed as well as hydrostatic experiments.

Preliminary consideration on the functional evolution: Here I consider the functional evolution of the present species. The study on the individual relative growth and the relative variation indicates that the present species evolved rapidly.

The results of the buoyancy calculations suggest that the mode of life at the adult stage changed from benthic to nekto planktic.

RAUP (1967) and RAUP and CHAMBERLAIN (1967) developed graphically the relation between shell morphology and the stability in the floating position, based on computer analysis of the simulation models. According to them, the stability index is expressed by the distance between the centre of gravity and that of buoyancy, divided by the shell diameter.

The chronological change in stability is shown in Text-fig. 14. The stability of the adult specimens gradually decreased for the samples from the Tappu district.

REYMENT (1973) pointed out that a decrease of the stability is not favorable for maintaining the vertical position. As the stability index of the present species is relatively high, it may be postulated that the present species could not swim as quick as the normally coiled ammonites.

It may also be suggested that the present species from the lower horizon (R2105b to R2110x) changed its mode of life from nekto planktic to benthic during ontogeny. The growth of septal and ventral wall thickness to radius at the early stage ($0 \sim \text{ca. } 7.5\pi$) of these samples is negatively allometric as well as those of normally coiled ammonites by TRUEMAN (1941) and WESTERMANN (1971).

Unfortunately, I could not calculate the buoyancy of any young specimen, because of ill-preservation of body chamber.

For considering the function of ammonites, such characters as the siphuncular tube, the septal suture and the shape of the apertural margin are also important as well as the characters discussed in the present paper. It is absolutely necessary

for a precise discussion of the functional morphology of ammonites to analyse these characters quantitatively.

The functional evolution of the present species is tentatively summarized in Text-fig. 16.

Conclusions

Otoscaaphites puerculus (JIMBO) is a Turonian ammonite which is locally distributed in Japan and Sakhalin.


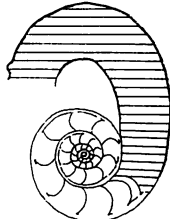
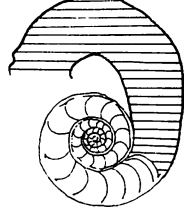
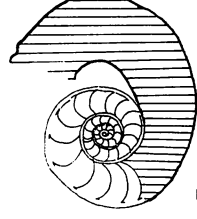
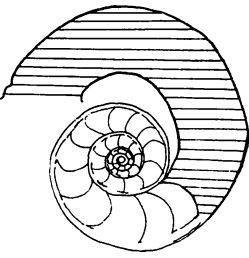
On the grounds of biometrical and hydrostatic treatment of about 150 individuals belonging to 24 samples which were collected from the Middle Turonian in south Sakhalin (Naibuchi district), northern central Hokkaido (Tappu district) and central Hokkaido (Oyubari district), the following functional significance has been made clear.

The analyses of individual relative growth and relative variation indicate that the present species evolved rapidly in accordance with the increase of internal volume of the phragmocone, the decrease in volume of shell material and the shortening of the body chamber in the adult stage.

The approximate calculation of a buoyancy index (the proportion of flooding necessary to sink an empty shell) suggests that the mode of life at the adult stage changed from benthic to nekto planktic during the course of evolution.

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Age	The trend of evolution in <i>Otoscaphtes puerculus</i>	Phragmocone			Volume of body cham.	Length of body cham.	Stability index	Buoyancy index	Mode of life
		Size in micron	Volume	Weight of septum					
MIDDLE TURONIAN Zone <i>Inoceramus</i> <i>hobetsensis</i>	 R2106h-1	8077 - 9228 (N=3)				ca. 1.63π (N=1)	0.20 (N=1)		
	 R2110a-2	8353 - 10396 (N=31)	0.14 - 0.27 _{cc} (N=6)		0.41 - 0.51 _{cc} (N=6)	ca. 1.35π (N=14)	high 0.19 - 0.20 (N=12)		
	 R2110x-1	8730 - 10948 (N=19)	rapidly increased	rapidly increased	gradually decreased	gradually increased	ca. 1.25π (N=11)	0.18 - 0.19 (N=10)	
	 R2113g-3	9874 - 10588 (N=4)	increased	increased	decreased	increased	ca. 1.22π (N=2)	low 0.18 (N=4)	
	 R4018b-2	10817 - 12822 (N=5)	↑	↑	↑	↑	ca. 1.20π (N=2)	0.17 - 0.18 (N=2)	
									Benthic → Nektoplanktic

Text-fig. 16. Functional evolution of *Otoscaphtes puerculus* (JIMBO) (Fundamental data based on the samples from the Tappu district).

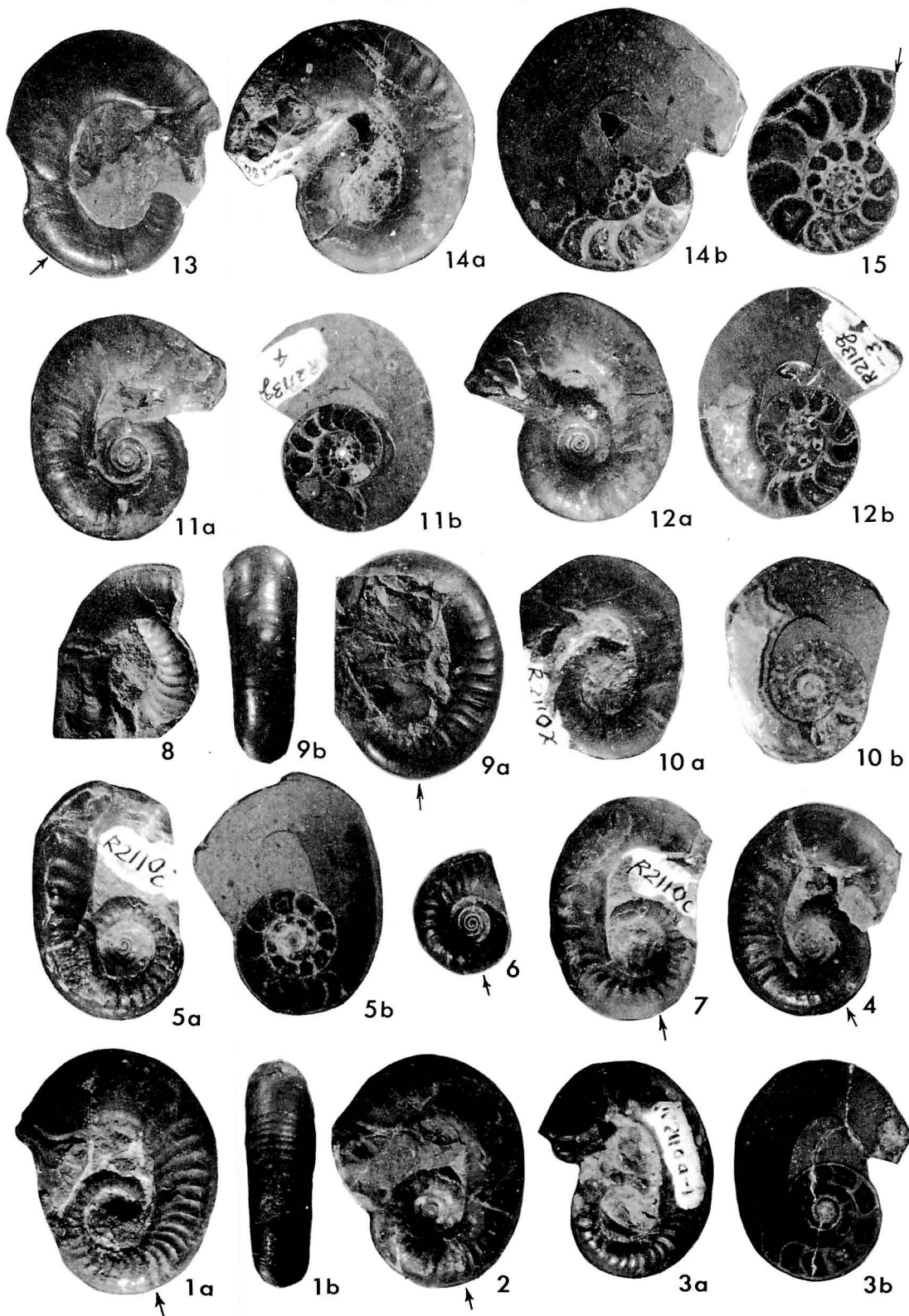
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Explanation of Plate 10

Otoscaphtes puerculus (JIMBO)..... (All ×2)

Arrow points to the base of body chamber

- Fig. 1. Lateral (a) and ventral views of GK. H. 5709, R 2110a.
- Fig. 2. Lateral view of GK. H. 5710, sample ditto.
- Fig. 3. Lateral view (a) and median section (b) of GK. H. 5711, sample ditto.
- Fig. 4. Lateral view of GK. H. 5712, R 2110b.
- Fig. 5. Lateral view (a) and median section (b) of GK. H. 5713, R 2110c.
- Fig. 6. Lateral view of GK. H. 5714, R 2110d, immature shell.
- Fig. 7. Lateral view of GK. H. 5715, R 2110c.
- Fig. 8. Apertural part of GK. H. 5716, R 2110x.
- Fig. 9. Lateral (a) and ventral (b) views of GK. H. 5717, sample ditto.
- Fig. 10. Lateral view (a) and median section (b) of GK. H. 5718, sample ditto.
- Fig. 11. Lateral view (a) and median section (b) of GK. H. 5719, R 2113g.
- Fig. 12. Lateral view (a) and median section (b) of GK. H. 5720, sample ditto.
- Fig. 13. Lateral view of GK. H. 5721, R 2113h.
- Fig. 14. Lateral view (a) and median section (b) of GK. H. 5722, R 4018b.
- Fig. 15. Median section of GK. H. 5723, R 4001d.



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Hakkinzawa	白金沢	Obirashibe	小平薬
Ichinosawa	一ノ沢	Oyubari	大夕張
Kamikinenbetsu	上記念別	Tappu	達布
Naibuchi	内淵		

Explanation of Plate 11

Otoscaphtes puerculus (JIMBO).....(All ×10)

Figs. 1-6. Median sections showing early stage.

Figs. 7-9. Cross sections cut parallel to base of body chamber.

Fig. 1. GK. H. 5724, R 2110x.

Fig. 2. GK. H. 5725, sample ditto.

Fig. 3. GK. H. 5726, sample ditto.

Fig. 4. GK. H. 5727, R 2110c.

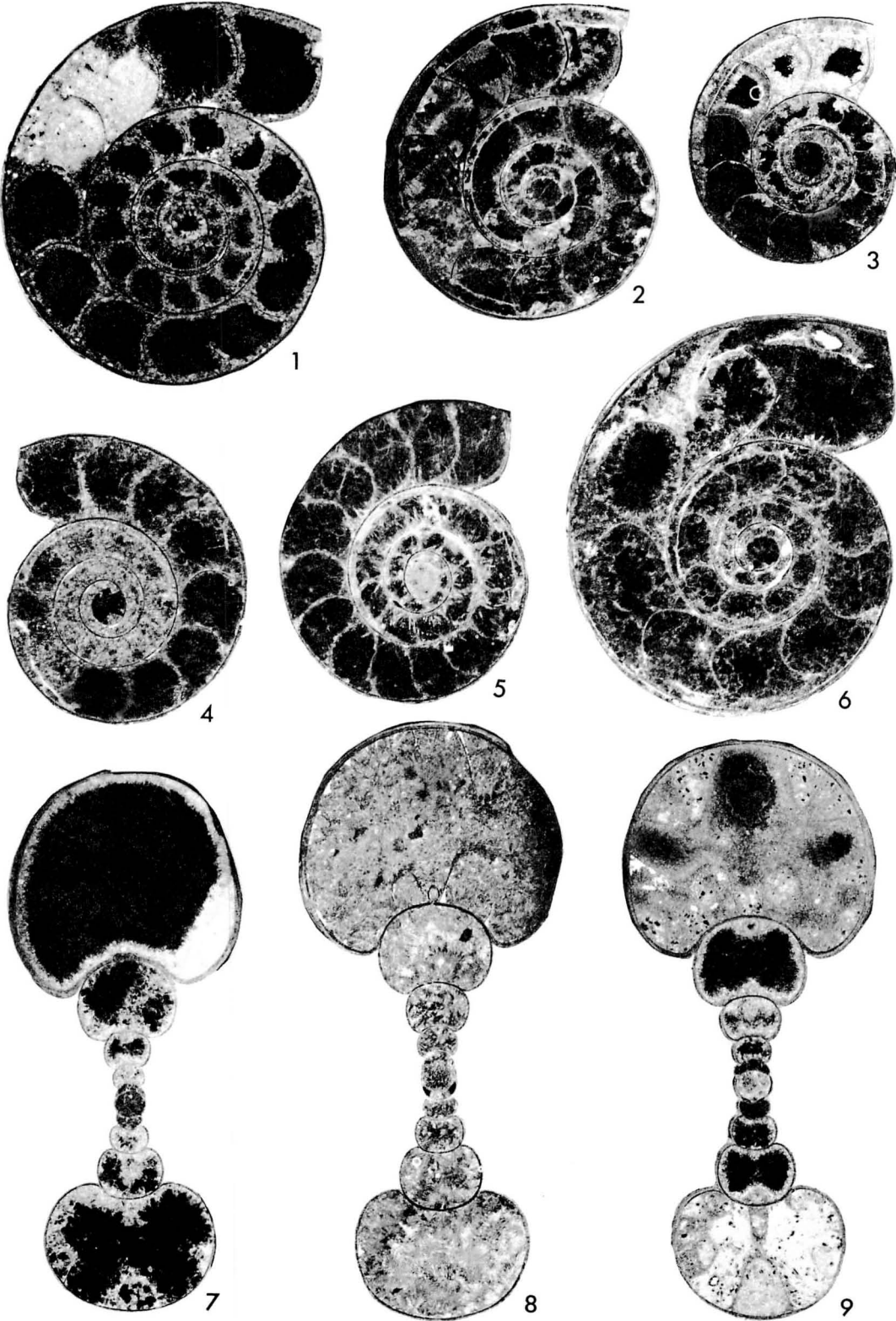
Fig. 5. GK. H. 5728, R 2110f.

Fig. 6. GK. H. 5729, R 2110d.

Fig. 7. GK. H. 5730, R 2110b'.

Fig. 8. GK. H. 5731, R 2110e'.

Fig. 9. GK. H. 5732, R 2110b'.



649. *IKEBEEA*, EINE NEUE GATTUNG DER PENNATEN
BACILLARIACEEN AUS DEM NEOGEN JAPANS*

SEIICHI KOMURA

Japan Petroleum Exploration Co., Ltd. (JAPEx)

日本新第三系産羽状目珪藻新属 *Ikebeea*: 天北地域に分布する増幌層・声間層・遠別層から *Fragilarioideae* 科にぞくする表記珪藻新属を5新種とともに記載し、その層位学的分布と生息環境について二・三論じる。本属は棍棒状の外形を有し、末端結節・1列の周辺トゲ・1-3列の条線列の存在を特徴とし、*Clavicula* PANTOCSEK に近縁である。属名は石油資源開発(株)常務取締役池辺稜博士にちなむ。 小村 精一

Einleitung

Während den Forschungen an einer Anzahl von Diatomeenfossilien, die in den Schichten der nördlichsten japanischen Inseln eingeschlossen sind, um damit für die Erdölforschung einen biostratigraphischen Standard festzustellen, habe ich einige zu keiner bisher festgelegten Gattung gehörigen Formen gefunden. Diejenigen Fossilien, welche unter diesen Namen hier angeführt werden sollen, tragen, wie *Opephora* PETIT und ähnliche, die zur Apikalachse symmetrische und zur Transapikalachse unsymmetrische Schale ohne Quersepten und Zwischenbänder, dagegen haben sie nicht die aus Punktstreifen bestehende Ornamentur sondern die mit eine Reihe von marginalen Stachelreihen umfassende Struktur und ein Paar von Endknoten.

Der weitverbreitete Individuenreichtum dieses Organismus in den gesammelten Proben gestattet es, ihre Beobachtungen durch Rasterelektronenmikroskop (SEM) zu machen. Dabei wird bestätigt, daß

* Received Nov. 15, 1974; read Oct. 19, 1974 at Nagoya.

bei der hier genannten Gattung keinerlei Spaltenstrukturen, wie Pinnularien- oder Kanalaraphe, an der Schalenoberfläche vorhanden sind. Aus diesen Gründen möchte ich die besondere Gattung proponieren.

Das Ziel dieser Arbeit ist es, eine neue Gattung der pennaten Bacillariaceen mit fünf neuen Arten taxonomisch zu beschreiben sowie ihre phylogenetische Gehörigkeit und Ansiedlung kurz zu diskutieren.

Sowohl Holotypen als Paratypoide der neubeschriebenen Formen werden im Technical Institute, Japan Petroleum Exploration Co. (JAPEx) in Hamura in Tokio, aufbewahrt.

Fundort und Material

Das für diese Arbeit verwendete Material stammt aus vier isolierten Aufschlüssen im Nord-Tenpoku Gebiet, wie folgt:

Km-3519. Bläulich-grauer bis gelblich-weißer, aschenreicher, unreiner Kieselgur der Koitai-Schichten. Breitengrad 45°23'36" N, Längengrad 141°41'22" E

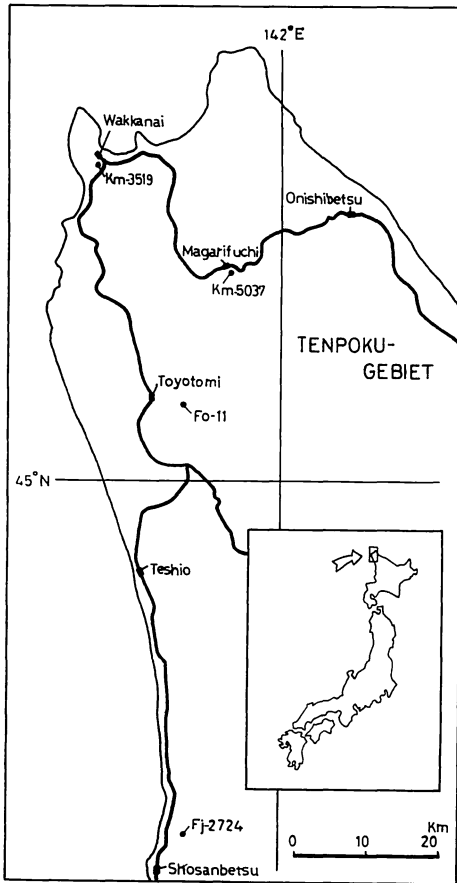


Abb. 1. Lage der Fundpunkte.

bei der Volksschule Wakkanai-Minami in der Stadt Wakkanai. Oberstmiozän (vgl. MINATO et al., 1965, S. 258; OSANAI, 1954).

Fo-11. Ebenda. Breite $45^{\circ}5'14''$ N, Länge $141^{\circ}19'17''$ E, etwa 3,8 Km südöstlich von Toyotomi. Oberstmiozän (vgl. MINATO et al., 1965, loc. cit.; NAGAO, 1960). Von Herrn N. FUJIOKA gesammelt.

Fj-2724. Grauer, aschenreicher, toniger Sandstein der Enbetsu-Schichten. Breite $44^{\circ}33'55''$ N, Länge $141^{\circ}49'19''$ E, eine Klippe am Südufer des Flusses Furenbetsugawa. Oberstmiozän (vgl. MINATO

et al., 1965, Loc. cit.; HATA, 1961). Von Herrn M. FUJITA angeboten.

Km-5037. Grauer, aschenreicher, sandiger Tonstein der Masuporo-Schichten. Breite $45^{\circ}15'39''$ N, Länge $141^{\circ}54'50''$ E, am Südufer des Uruyagawa-Flusses, zirka 1,1 Km östlich des Eisenbahnhofs Magarifuchi vor der Stadt ebenda. Mittelmiozän (vgl. MINATO et al., 1965, loc. cit.; TAKAHASHI & ISHIYAMA, 1968).

Für die optisch-mikroskopischen Untersuchungen des Materials wurden Streupräparate meistens mit der von KANAYA (1957, S. 42; 1959, S. 33) dargestellten Verfahrenstechnik genommen. Sauerbehandlungen wurden aber davon ausgenommen, stattdessen Dekantierung mehrere Male dazu hinzugefügt. Als Einbettungsmittel für Mikrofossilien wurde Pleurax verwendet.

Systematische Beschreibungen

Ordnung Pennatae SCHÜTT, 1896

Familie Fragilarioideae SCHÜTT, 1896

Subfamilie Fragilarieae SCHÜTT, 1896

Tribus Fragilariinae SCHÜTT, 1896

Gattung *Ikebea*, n. gen.

Gattungstypus: *Ikebea amphistriata*, n. sp.

Originale Beschreibung: Zellen in Gürtelansicht linear-keilförmig, zuweilen linear-rechteckig, in ventraler Gürtelbandsansicht ziemlich linear und dorsale Seite mit schwach konvexen Rändern, durch stark entwickelte Stachelkränze am Schalenrand zu dicht geschlossenen Bändern verbunden, in Transapikalschnitt flach elliptisch, ohne Septen oder Zwischenbänder; Schalen im Umriß keil- oder keulenförmig mit beiden Enden abgerundet, zur geraden Apikalebene

spiegel-symmetrisch, zur Transapikalebene heteropol und asymmetrisch, kurz vor dem Kopf- und Fußpol halsartig eingeschnürt; Schalendeckel flach gewölbt, mit zwei polaren und ohne zentralen Knoten; Schalenoberfläche mehr oder weniger gestreift, nicht punktiert, ohne keilartige Erhebungen; Pseudoraphe deutlich entwickelt, obgleich sie nicht vollkommen von Pol bis Pol läuft; keinerlei Raphe erscheinend, sogar bei Raster-Mikroskop.

Ableitung: Der Gattungsname wird nach Herrn Dr. Yutaka IKEBE, Vizepräsident unserer Gesellschaft, zum Andenken an seine Beiträge zur Erdölgeologie Japans und seine Ölexplorations-tätigkeit genannt.

Bemerkungen: Die Gattung zeigt starke Ähnlichkeit mit *Clavicula* PANTOCSEK, aber unterscheidet sich durch langgestreckte Streifung anstatt einiger Bändern von Punkten. Zu den Pennales stelle ich auch die Gattung aufgrund der bilateralen Eigenschaft von Schalen und Strukturanordnungen.

Schlüssel zum Bestimmen
der *Ikebea*-Arten

- I. Transapikalstreifen mit ein oder zwei Strahlen laufend; größte Schalenbreite der Mitte genähert liegend.
 - a. Streifen Pol bis Pol mit zwei Reihe durchlaufend.
 - 1. Schalen im Umriß robust, runde Randstacheln innerhalb des Schalenrandes stehend *I. robusta*
 - 2. Schalen im Umriß zart, elliptische Randstacheln am Schalenende stehend *I. amphistriata*
 - b. Streifen nicht in derartigen Weise laufend.
 - 1. Streifen in der Mitte reduziert.. *I. coronata*

- 2. Streifen in Nähe des Endes gegabelt *I. bifurcata*
- II. Transapikalstreifen mindestens im Teil mit drei Strahlen laufend, größte Schalenbreite dem Kopfpol genähert liegend *I. clavata*

Ikebea amphistriata, n. sp.

Taf. 12, Fig. 1-5; Abb. 2-5

Holotypus: Präparat Nr. JAPEX Km-5037(3)=10.4×84.6 (Fm 9928), Masuporo-Schichten, Mittelmiozän.

Paratypoide: Präparat Nr. JAPEX Km-5037(9)=12.9×79.4 (Fm 10241), Schichten ebenda, Mittelmiozän.

Präparat Nr. JAPEX Km-5037(9)=6.5×83.2 (Fm 10265), Schichten ebenda, Mittelmiozän.

Originale Beschreibung: Zellen in Gürtelansicht linear-keulenförmig, durch Stachelkränze am Schalenrand zu dicht geschlossnen Bändern verbunden; Zwischenbänder und Septa sowie Pseudo-septa fehlend; Schalen im Umriß

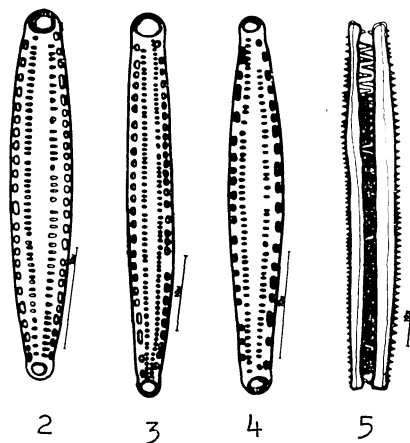


Abb. 2-5. *Ikebea amphistriata*, n. sp.
2: nach Holotypus (Taf. 12, Fig. 4).
3: nach Paratypoid (Taf. 12, Fig. 1).
4: nach Paratypoid (Taf. 12, Fig. 5).
5: nach Taf. 12, Fig. 2.

heteropol-keulenförmig bis etwa lanzettlich mit breit gerundeten Kopfpol und spitzer gerundetem Fußpol, unterhalb der Enden leicht eingeschnürt, größte Breite in Nähe der Mitte, aber mehr oder weniger oberhalb der Mitte genähert liegend, 37-49 μ lang, 5-6 μ breit; Schalenoberfläche schwach gewölbt; Endknoten deutlich, verhältnismäßig groß, oval oder elliptisch, in den beiden Polenfeldern vorhanden. Eine Reihe von zahlreichen Stacheln mit ovalen Querschnitt, am Schalenrande stehend, 7-10 in 10 μ ; Transapikalstreifen nicht punktiert, schmal und kurz, innerhalb der Stachelreihen und parallel zur Schalenrändern von Pol bis an den Pol langgestreckt durchlaufend; 14-16 in 10 μ ; Pseudoraphe deutlich, breit, lanzettlich, nach den Enden etwa verschmälert.

Ikebea robusta, n. sp.

Taf. 12, Fig. 6, 8; Abb. 6, 7

Holotypus: Präparat Nr. JAPEX Km-5037(1)=5.0×88.6 (Fm 9794), Masupor-Schichten, Mittelmiozän.

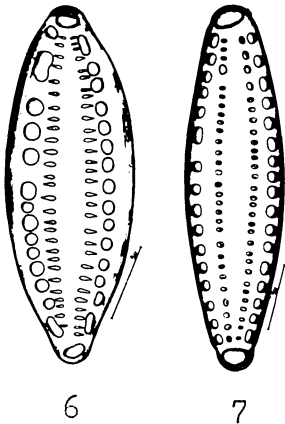


Abb. 6, 7. *Ikebea robusta*, n. sp.
6: nach Holotypus (Taf. 12, Fig. 6).
7: nach Paratypoid (Taf. 12, Fig. 8).

Paratypoide: Präparat Nr. JAPEX Km-5037(1)=5.3×87.5 (Fm 13403), Masupor-Schichten, Mittelmiozän.

Originale Beschreibung: Schalen im Umriß breit elliptisch-keulenförmig mit stark konvexen Seiten und kopfig gerundeten Enden, größte Breite wie bei der Typ-Art der Gattung in der Mitte genähert liegend, 23-38 μ lang, etwa 8 μ breit; Schalenoberfläche stark gewölbt, breit Mantel vorhanden; Endknoten deutlich, relativ klein, oval oder elliptisch, in den beiden Polenfeldern sich stellend; Eine Reihe von der zahlreichen, groben, warzenförmigen Stacheln mit gerundetem Querschnitt an der Basis, entfernt innerhalb des Seitenrandes einschließend, 5-9 in 10 μ ; Transapikalstreifen nicht punktiert, schmal und kurz, keilförmig nach Schalenrändern abfallend, leicht radial, innerhalb der Stachelreihen zwischen der Pseudoraphe und Stachelreihe gelegten, in einer bogenartigen Reihe von Pol bis an den Pol geordnet, 13-15 in 10 μ ; Pseudoraphe deutlich, sehr breit, lanzettlich, von der Mitte gegen die Enden gleichmäßig enger werdend.

Bemerkungen: Die Art ist mit Typ-Art, die eine grundsätzlich linzenähnliche Schalenform hat, zu vergleichen, mit dessen sie aber zufolge Vorhandensein von der viel konvexere, weit robustere Umriße und der mehr innen gelegten Stachelreihen, nicht verbunden werden kann.

Ikebea bifurcata, n. sp.

Taf. 12, Fig. 11-13; Abb. 8, 9

Holotypus: Präparat Nr. JAPEX Km-5037(8)=5.9×87.2 (Fm 10129), Masupor-Schichten, Mittelmiozän.

Paratypoide: Präparat Nr. JAPEX Km-5037(12)=8.5×86.0 (Fm 10454), Schichten ebenda, Mittelmiozän.

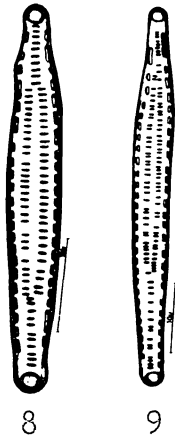


Abb. 8, 9. *Ikebea bifurcata*, n. sp.
8: nach Holotypus (Taf. 12, Fig. 12).
9: nach Paratypoid (Taf. 12, Fig. 13).

Präparat Nr. JAPEX Km-5037(8)=14.9 × 86.7 (Fm 10179), Schichten ebenda, Mittelmiozän.

Originale Beschreibung: Schalen schmal keulenförmig, größte Breite wie bei der vorigen Art in der Mitte genähert liegend, 42–54 μ lang, 5–6 μ breit; Knoten deutlich, kreisrund bis oval; Stacheln flach bis langlich-elliptisch in Querschnitt, 5–8 in 10 μ ; Transapikalstreifen nicht punktiert, klein, elliptisch oder keilförmig, in der Mitte in Ordnung zu Stachelreihe parallel und innen genähert verlaufend, zwei Reihen von Streifen gegen den Enden zu einander sich zu vereinigen konvergierend, 12–17 in 10 μ ; Pseudoraphe verhältnismäßig breit, aber gegen den Pol nicht nur weit enger werdend, sondern auch dort nicht reichend.

Bemerkungen: Die Art ist besonders im Umriß *I. amphistriata* ähnlich, aber unterscheidet sich davon durch die bis am Pol unreichenden Pseudoraphe und die gegabelten Transapikalstreifen.

Ikebea coronata, n. sp.

Taf. 12, Fig. 9, 10; Abb. 10, 11

Holotypus: Präparat Nr. JAPEX Km-5037(4)=14.5 × 79.4 (Fm 9944), Masupro-Schichten, Mittelmiozän.

Paratypoid: Präparat Nr. JAPEX Km-5037(10)=13.4 × 82.3 (Fm 10310), Schichten ebenda, Mittelmiozän.

Originale Beschreibung: Schalen linearkeilförmig, mit gerundeten Kopfpol und stumpfen Fußpol, von der größte Breite, die ganz dicht in der Mitte liegt, gegen die beiden Enden wenig an Breite abnehmend, in zu den Pol genäherten Teil transapikal eingeschnürt, 30–36 μ lang, 6 μ breit; Schalenoberfläche stark gewölbt; Endknoten deutlich, rundlich-oval oder kreisrund, aus der Schalenoberfläche sich abhebend; Stacheln rund bis flach-elliptisch in Querschnitt an der Basis, innen entfernt von und parallel zu Schalenrand laufend, 6–9 in 10 μ ; Transapikalstreifen nicht punktiert, klein, stabartig, innerhalb der Stachelreihe einem Kranze ähnlich in Ordnung, im Vergleich mit der vorliegende Art zu der Mitte reduziert, 8–13 in 10 μ ; zwei

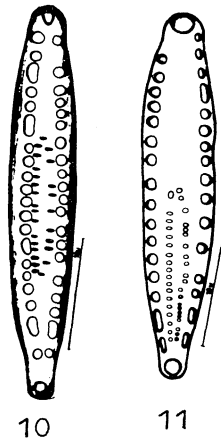


Abb. 10, 11. *Ikebea coronata*, n. sp.
10: nach Holotypus (Taf. 12, Fig. 10a–b).
11: nach Paratypoid (Taf. 12, Fig. 9a–b).

breite hyaline Felder zwischen dem Pol und der Streifenkränze bleibend; Pseudoraphe, die in der Mitte liegt, linsenartig, ein Drittel der Schalenlänge einnehmend.

Bemerkungen: Die Art ist durch die kranzartig geordneten Transapikalstreifen charakterisiert und kann dadurch von den übrigen *Ikebea*-Arten getrennt werden.

Ikebea clavata, n. sp.

Taf. 12, Fig. 14-16; Abb. 12-14

Holotypus: Präparat Nr. JAPEX Km-3519(10)=11.9×82.7 (Fm 8417), Koitoi-Schichten, Oberstmiozän.

Paratypoid: Präparat Nr. JAPEX Fj-2724(8)=11.4×95.0 (Fm 8069), Enbetsu-Schichten, Oberstmiozän.

Präparat Nr. JAPEX Fo-11(16)=16.5×92.0 (Fm 12054), Koitoi-Schichten, Oberstmiozän.

Originale Beschreibung: Zellen in Gürtelansicht linear-keulförmig, wie bei Typus von der Gattung durch stark

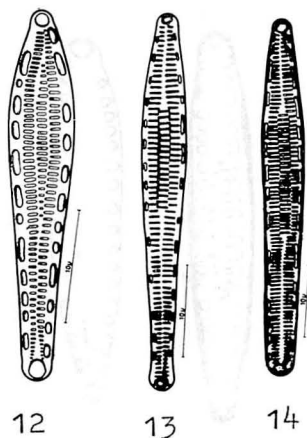


Abb. 12-14. *Ikebea clavata*, n. sp.
12: nach Holotypus (Taf. 12, Fig. 14).
13: nach Paratypoid (Taf. 12, Fig. 15).
14: nach Paratypoid (Taf. 12, Fig. 16).

entwikelte Stachelkränze am Schalenrand zu dicht geschlossenen Bändern verbunden; Zwischenbänder und Septen fehlend; Schalen im Umriß schlank-keulenförmig, größte Breite stets oberhalb der Mitte liegend, allmählich gegen die beiden Schalenpole verschmälert, in zu den Pol genäherten Teile mit schwach konkaven Rändern, 41-54 μ lang, 5-7 μ breit.

Bemerkungen: Die gegenwärtige, charakteristisch keulenförmige Art unterscheidet sich leicht von übrigen durch drei Reihen von Streifenlinie und die zu den Pol geschwundene Pseudoraphe. Sie tritt in oberem Teil an der Schichtenfolge Neogens von Tenpoku-Gebiet.

Diskussion

Es ist das Verdienst von F. HUSTEDT (1927-64), die bis heute allereingehendste Gesamtdarstellung und die klarste Systematikbildung der rezenten und fossilen Diatomeen gegeben zu haben. Manche Autoren haben infolgedessen wiederholt auf diese Arbeiten Bezug genommen (KANAYA & KOIZUMI, 1966; KOIZUMI, 1968; SCHRADER, 1969). Damit folge ich HUSTEDT als Grundlage des Gesichtspunktes zum Klassifikationssystem.

HUSTEDT (op. cit.), der als fundamentales Kriterium zur Gruppierung der Araphideae, einer raphenlosen Großeinheit der pennaten Diatomeen, Vorhandensein der Septen berücksichtigte und weiter von untergeordneter Bedeutung die transapikalen Rippen ansieht, zerlegte dieselbe Einheit in Diatominae und Fragilariinae. Der letztere Stamm, der sowohl das Fehlen oder den Mangel an Septenbildungen als das Fehlen der Transapikalrippen zeigt, enthält 18 Gattungen. Von diesen gibt es fünf Gattungen, die

zur Transapikalachse asymmetrisch sind: *Asterionella* HASSALL, *Synedrosphenia* PERAGALLO, *Podocystis* KÜTZING, *Sceptroneis* EHRENBERG, und *Opephora* PETIT. Die beiden ersten besitzen mit transapikalen Reihen zarter Punktstreifen oder gekammerter Rippen etwa ganze Valvarflächen (HUSTEDT, 1931-37, S. 240 u. 250), dadurch unterscheiden sie sich von *Ikebea*. Daß die dritte der genannten Gattungen nicht in verwandtschaftlichem Zusammenhang steht, erscheint beim ersten Blick auf die eigentümliche Gestalt und die areolierte Netzstruktur sehr deutlich zu sein. Als Meeresfossil bekannt scheinen nur die übrigen zwei Gattungen, *Sceptroneis* und *Opephora*, zu sein (vgl. HUSTEDT, op. cit.). Die erstere beschränkt, nach WORNARDT (1972, S. 53) und LOHMAN (1948, S. 183), ihre stratigraphische Verbreitung auf Mittelmiozän und die letztere nach WORNARDT (loc. cit.) auf Obermiozän bis Oberpliozän im Westküstengebiet der Vereinigten Staaten von Amerika, obwohl Vertreter der beiden Gattungen an den atlantischen Küsten und im Mittelmeergebiet bzw. durch ganz Europa, wenngleich durchweg selten und sehr vereinzelt, anzufinden sind, wie von HUSTEDT (1931-37, S. 130 u. 134) berichtet. Jedenfalls kommt es mir vor, daß eine große Menge von Vorkommen der Gattung *Sceptroneis* nur im Mittelmiozän, in welchem der Gattungstypus der *Ikebea*, d. h. *I. amphistriata* n. sp., im Tenpoku-Gebiet Japans auch sehr häufig auftritt, fortgesetzt ist. Keine der oben zitierten Gattungen trägt aber Endknoten und Stachelreihen wie bei der neuen Gattung *Ikebea*.

Die Gattung *Clavicula* PANTOCSEK, 1886, (fide KARSTEN, 1928, S. 267), deren Förderung aus dem Miozän Japans sowie aus der daran angrenzenden Sachalin-Insel der Sowjet-Union (SHESHUKOVA-PORETZKAJA, 1967, S. 246) dargestellt ist,

zeigt, daß sie in Beziehung auf Symmetrieverhältnis und Besitzen der beiden verdickten Endknoten mit *Ikebea* verwandtschaftlich nahe zusammenhängt. Sie hat nach SHESHUKOVA-PORETZKAJA (1967, loc. cit.) weitere stratigraphische Verbreitung im Obereozän Kazachstans und der Ukraine bis zum Neogen Sachalins.

Aus den oben diskutierten morphologischen Verhältnissen der neu propoziierten Gattung zu bisher dargestellten Formen mit ihren stratigraphischen Vorkommenszuständen geht hervor, daß die fragliche Gattung *Ikebea* die stammesgeschichtlichen Zusammenhänge zwischen *Sceptroneis* und *Clavicula* aufzeigt, obgleich von KARSTEN (1928, loc. cit.) die systematische Stellung dieser sonderbaren keulenförmigen Gattung für unsicher angenommen wurde.

Die mittels des Raster-Mikroskopes hergestellte Aufnahme (Taf. 12, Fig. 7) zeigt eine Überfeinskulptur auf der Schalenunterfläche von *Ikebea amphistriata*. Diese besteht aus einer Reihe von winzigen dendritischen Schmalspalten, die sich senkrecht zum Schalenrande bis halbwegs zur Sagittallinie ausstrecken. Ihre systematische Bedeutung läßt sich nur aus diesen wenigen Aufnahmen nicht erklären. Fokussierung bei Raster-Mikroskopie ist von so zeitraubender Beschwerlichkeit, daß die Umstände ununtersucht geblieben sind. Damit wird es in Zukunft zu untersuchen sein, wie weit derartige Ultrastruktur nur variabel innerhalb der Individuen-Gruppe oder Artkonstant oder auch gar charakteristisch für die Gattung sein kann.

Es ist auch notwendig, die stratigraphische Bedeutung der vorliegenden Gattung zu berücksichtigen. Die im Mittelmiozän auftretenden Arten sind verhältnismäßig primitiv gestaltet, wie *Ikebea*

robusta n. sp. und *I. bifurcata* n. sp. Sie tragen die isolierten, gerundeten bis geflüchten Randstacheln und die etwas zerstreut geordneten, mindestens in einem Teil der Schalenlänge mit zwei Reihen laufenden Transapikalstreifen, sowie das im Vergleich zur Schalenbreite sehr breite Mittelfeld. Die aus dem Oberstmiozän beschriebene Art mit komplizierteren Zeichnungen, d. h. *Ikebea clavata* n. sp., erscheint dagegen entwickelter, weil ihre Randstacheln länglich miteinander verwachsen, ihre Transapikalstreifen in drei Reihe aufwachsen, und endlich ihre Pseudoraphe stattdessen zur Nähe der Pole reduziert ist. Mit dem Zeitverlauf gibt es da eine Tendenz zur Verwandlung in der Struktur der *Ikebea*-Formen; demnach dürfen ihre Evolutionslinie und Benützungswert zur Neogenstratigraphie bei künftigen Untersuchungen erklärt werden.

Es handelt sich vielleicht aus der Literatur von Diatomeen Japans und näherer Reiche um die Abbildungen, die nach SAWAMURA und YAMAGUCHI (1963, Taf. 1, Fig. 5) als "*Fragilaria* sp." und nach SHESHUKOVA-PORETZKAJA (1967, Taf. 39, Fig. 6a-b; Taf. 40, Fig. 5a-b) als "*Goniothecium tenue* Brun" veröffentlicht worden sind, da sie enge Ähnlichkeit mit *Ikebea*-Arten zu haben scheinen.

Die aus folgenden Formen bestehenden Diatomeenfloren umfassen die beiden Proben, aus den die hier beschriebenen Arten stammen:

1) aus dem Aufschluß von Koitoi-Schichten (Km-3519),

Denticula kamtschatica ZABELINA
Thalassiosira antiqua (GRUNOW)
 CLEVE
Thalassiosira decipiens (GRUNOW)
 JORGENSEN
Coscinodiscus stellaris ROPER
Thalassionema nitzschioides GRUNOW

2) aus dem Aufschluß von Masuporo-Schichten (Km-5037),

Denticula lauta BAILEY
Denticula nicobarica GRUNOW
Thalassionema nitzschioides GRUNOW
Mediaria splendida SHESHUKOVA-
 PORETZKAJA
Kisseleviella carina SHESHUKOVA-
 PORETZKAJA

Keine limnisch-brachischen Diatomeen wurden aus den vorliegenden beiden Proben gewonnen. Das zeigt vermutlich, daß alle *Ikebea*-Arten pelagisch-ozeanische Habitat haben können.

Danksagung

Es ist mir eine angenehme Pflicht, Herrn Dr. T. KANAYA, früherem außerordentlichen Professor an der Universität Tohoku, für die kritische Einsicht der Originalstücke zu danken.

Für Veröffentlichungserlaubnis der Arbeit bin ich Herrn Dr. Y. IKEBE, Vizepräsident von JAPEX, zu großem Danke verpflichtet. Die Arbeit durch Raster-Mikroskop wurde im Technology Research Center der Japan Oil Development Corporation durchgeführt. Ich danke Herrn Dr. Y. ISHIWADA, Vizedirektor, für die Möglichkeit, dies dort tun zu können, sowie auch Herrn K. SUZUKI und Herrn H. KAMAKURA für ihre hilfreichen Anleitungen bei der Bedienung.

Herrn Dr. K. SAWAMURA und Dr. O. FUKUTA am Geologischen Landesamt Japans in Tokio sowie Herrn Dr. T. ONITSUKA, Direktor der Oceania Petroleum Pty. Ltd., danke ich ebenso für die langjährigen Anregungen.

Ich danke endlich Herrn M. FUJITA und N. FUJIOKA, Geologen von JAPEX, für die freundliche Überlassung der Proben.

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(Die Schrift der russischen Literatur wird als Transkription gegeben.)

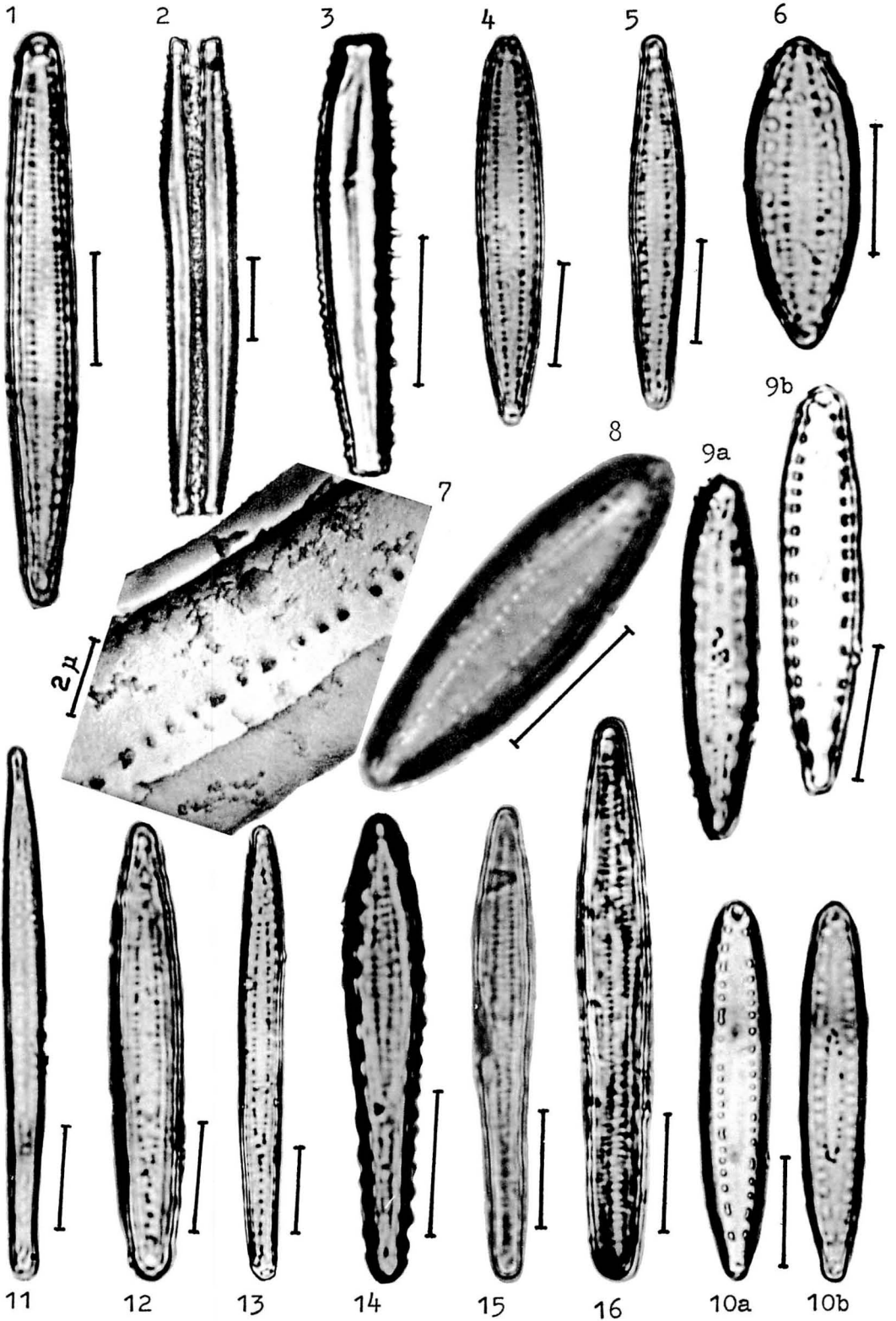
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Enbetsu	遺 別	Masuporo	増 幌
Furenbetsugawa	風蓮別川	Tenpoku	天 北
Hamura	羽 村	Toyotomi	豊 富
Koitoi	声 間	Uruyagawa	宇流谷川
Magarifuchi	曲 淵	Wakkanai	稚 内

Tafelerklärungen

(Vergrößerung: Jeder schwarze Stock entspricht einheitlich 10 Mikron ohne andersartiges Bezeichnen.)

- Fig. 1. *Ikebea amphistriata*, n. gen., n. sp.
Paratypoid. Präparat Nr. JAPEX Km-5037(9) = 6.5 × 83.2 (Fm 10265). Masuporo-Schichten. Mittelmiozän.
- Fig. 2. *Ikebea amphistriata*, n. gen., n. sp.
Gürtelansicht. Exemplar der zwei zelligen Kette. Präparat Nr. JAPEX Km-5037(3) = 8.0 × 86.5 (Fm 9915). Masuporo-Schichten. Mittelmiozän.
- Fig. 3. *Ikebea amphistriata*, n. gen., n. sp.
Gürtelansicht. Präparat Nr. JAPEX Km-5037(7) = 4.4 × 85.3 (Fm 10067). Masuporo-Schichten. Mittelmiozän.
- Fig. 4. *Ikebea amphistriata*, n. gen., n. sp.
Holotypus. Präparat Nr. JAPEX Km-5037(3) = 10.4 × 84.6 (Fm 9928). Masuporo-Schichten. Mittelmiozän.
- Fig. 5. *Ikebea amphistriata*, n. gen., n. sp.
Paratypoid. Präparat Nr. JAPEX Km-5037(9) = 12.0 × 79.4 (Fm 10241). Masuporo-Schichten. Mittelmiozän.
- Fig. 6. *Ikebea robusta*, n. sp.
Holotypus. Präparat Nr. JAPEX Km-5037(1) = 5.0 × 88.6 (Fm 9794). Masuporo-Schichten. Mittelmiozän.
- Fig. 7. *Ikebea amphistriata*, n. gen., n. sp.
Raster-elektronenmikroskopische Aufnahme. Exemplar der dendritischen Schmalspalten.
- Fig. 8. *Ikebea robusta*, n. sp.
Paratypoid. Präparat Nr. JAPEX Km-5037(1) = 14.7 × 91.3 (Fm 13404). Masuporo-Schichten. Mittelmiozän.
- Fig. 9. *Ikebea coronata*, n. sp.
Paratypoid. Präparat Nr. JAPEX Km-5037(10) = 13.4 × 82.3 (Fm 10311, 10310). Masuporo-Schichten. Mittelmiozän.
- Fig. 10. *Ikebea coronata*, n. sp.
Holotypus. Präparat Nr. JAPEX Km-5037(4) = 14.5 × 79.4 (Fm 9943, 9944). Masuporo-Schichten. Mittelmiozän.
- Fig. 11. *Ikebea bifurcata*, n. sp.
Paratypoid. Präparat Nr. JAPEX Km-5037(8) = 14.9 × 86.7 (Fm 10179). Masuporo-Schichten. Mittelmiozän.
- Fig. 12. *Ikebea bifurcata*, n. sp.
Holotypus. Präparat Nr. JAPEX Km-5037(8) = 5.9 × 87.2 (Fm 10129). Masuporo-Schichten. Mittelmiozän.
- Fig. 13. *Ikebea bifurcata*, n. sp.
Paratypoid. Präparat Nr. JAPEX Km-5037(12) = 8.5 × 86.0 (Fm 10454). Masuporo-Schichten. Mittelmiozän.
- Fig. 14. *Ikebea clavata*, n. sp.
Holotypus. Präparat Nr. JAPEX Km-3519(10) = 11.9 × 82.7 (Fm 8417). Koittoi-Schichten. Oberstmiozän.
- Fig. 15. *Ikebea clavata*, n. sp.
Paratypoid. Präparat Nr. JAPEX Fo-11(16) = 16.5 × 92.0 (Fm 12054). Koittoi-Schichten. Oberstmiozän.
- Fig. 16. *Ikebea clavata*, n. sp.
Paratypoid. Präparat Nr. JAPEX Fj-2724(8) = 11.4 × 95.0 (Fm 8069). Enbetsu-Schichten. Oberstmiozän.



650. ON TWO FOSSIL MOLLUSCAN SPECIES FROM THE
EOCENE OF THE BONIN ISLANDS*

YASUhide IWASAKI

Geological Institute, Faculty of Science, University of Tokyo,
Hongo, Tokyo 113, Japan

小笠原始新統産の貝化石2種について：小笠原諸島母島に分布する、始新統の含貨幣石砂岩及び粗粒でやや石灰質の堆積岩から産出する貝化石のうち、かつてミノガイ科ミノガイ属の二枚貝として記載され、左右不等殻であることを特徴としたメオトミノガイは、新たに検討を加えた絞歯の形状なども含めて、ウミギク科の種の形態的特徴に共通する点が多い。また殻の形態がヨーロッパ上部白亜系産の *Spondylus spinosus* (SOWERBY, 1812) に著しく類似することから、同様な機能形態を有し似たような環境に適応したと考えられるが、直接、系統的に結びつく資料はない。棲息時の形態を復元し再記載する。同時に採集されたアマオブネ科の1種と思われる巻貝については、始新統に特有の *Velates* よりもむしろ現存するカノコガイ類に近い形態が認められる。しかし現生の同類より大形であり、保存状態がよくないので属種名は確定していないが、現状を概略記載する。両種とも殻の内層に相当する殻石層は溶脱し、表面の方解石層のみ保存されているので、形質の一部が失われており、かつ見かけの殻は薄くなっている。

岩崎泰顕

Introduction

In July, 1969, the writer had an opportunity to visit and to make a short geological survey at Chichijima and Hahajima of the Bonin Islands (Ogasawara Islands) as a member of a scientific expedition organized jointly by the Ministry of Education and the Agency of Cultural Affairs, Japan, at the time of return of the Bonin and Volcano Islands to the Japanese territory.

Hahajima is located in the western Pacific Ocean 1,000 km south of Tokyo. This island has been well studied by Japanese paleontologists since YOSHIWARA (1901, 1902), YABE (1920) and HANZAWA (1925) reported the occurrence of Eocene nummulite and alveolinid forami-

nifers. Further investigations were unfortunately interrupted by World War II. The Bonin Islands were governed subsequently by the United States of America for over 20 years. During the post-war administration, Hahajima was an uninhabited island. Pathway networks and villages vanished into heavy bush in the island. Several fossiliferous outcrops that were previously reported, however, have been very well preserved. Some shelly fossils are exposed thoroughly at weathered surface of those outcrops and also in nearby blocks.

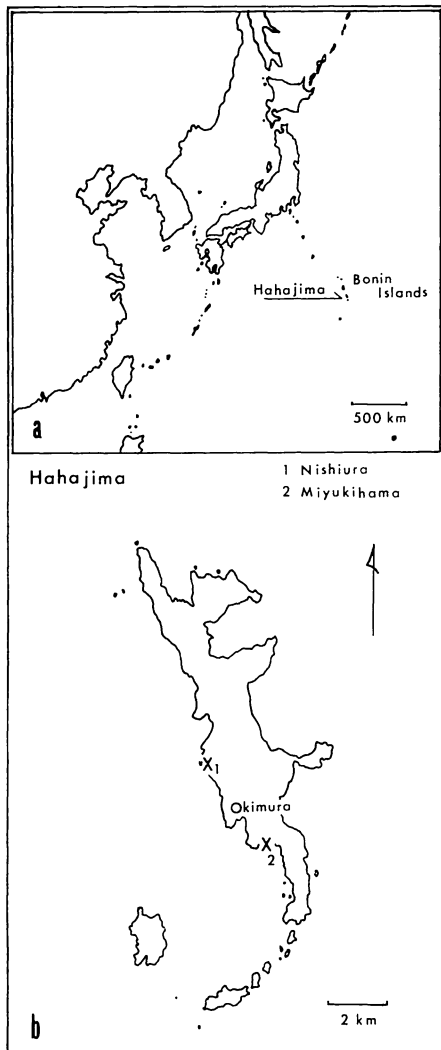
Abundant fossil samples obtained from the Eocene foraminifer-bearing rocks during the short excursion include a pectiniform bivalve species which was described by OYAMA (1943) as a peculiar limid (IWASAKI and AOSHIMA, 1970). This paper deals with the systematic,

* Received Feb. 5, 1975; read Jan. 17, 1973 at Sendai.

ecological and other significance of this species and the description of an associated neritid gastropod.

Geological outline

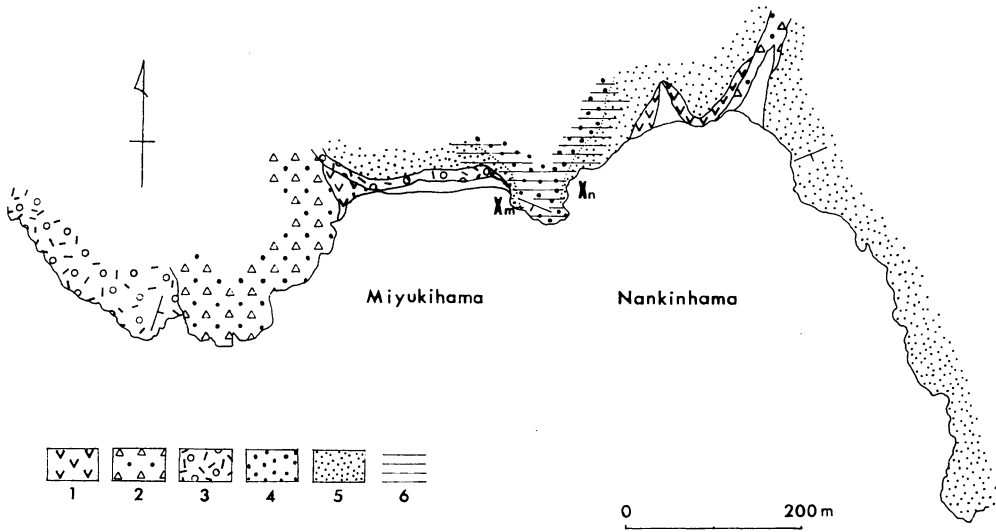
Hahajima (Hillsborough Island) is the main island, having an area of 21 km²,



Text-fig. 1. Map showing the location of Hahajima (a), and the location of Nishiura and Miyukihama (b).

of the Hahajima-retto (Hahajima group of YOSHIWARA (1902)) that occupy the southern part of the Bonin Islands, and that make up parts of ancient volcanoes once raised above sea level in the midst of the Pacific Ocean. Lava flows and various kinds of pyroclastic flow deposits predominate in the total stratigraphic succession. Sedimentary rocks are less in quantity and their distribution is restricted in the southern half of the island. Most of these sediments are tuffaceous and intercalated in thick pyroclastic layers. Fossil-bearing sandstone abuts on lavas and tuff breccia, and coquina limestone frequently thins out between two layers of volcanic ejecta, hence the lateral extension of a single sedimentary layer is usually traceable within a few kilometers. Layers dip gently, less than 20° in usual, southwestward in the southern area, and northwestward in the northern area. Thus Hahajima seems to be a part of western slope of a dissected volcano. Larger foraminifers such as *Nummulites boninensis* and *Alveolina javana boninensis* are contained in sandy sediments at Miyukihama (Cocanut Beach of HANZAWA (1947)), Nankinhama (Nanking Beach), and in limestone at Nishiura and several other localities (IWASAKI and AOSHIMA, 1970).

HANZAWA (1925, 1947) summarized the stratigraphic succession of Hahajima. The coarse sandstone that exposes at the border ridge between Miyukihama and Nankinhama (Text-fig. 2) seems to correspond either to “#3 *Nummulites* tuff” or to “#5 *Nummulites-Discocyclina* tuff and agglomerate” of HANZAWA (1947). Also the tuffaceous coquina limestone at Nishiura seems to correspond to his “#7 *Eorupertia-Alveolina* tuff”. Accordingly, the coarse sandstone at Miyukihama and Nankinhama seems to be lower in horizon than the coquina



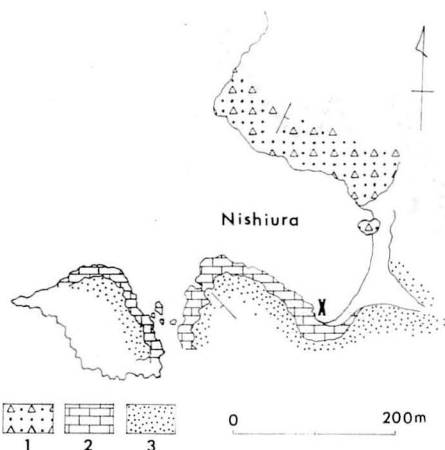
Text-fig. 2. Geological sketch map of Miyukihama and Nankinhama. 1. Andesite lava flow. 2. Volcanic breccia. 3. Tuff breccia. 4. Coarse-grained sandstone. 5. Medium-grained sandstone. 6. *Nummulites*-bearing part. X_m . Collecting locality of Miyukihama. X_n . Collecting locality of Nankinhama.

limestone at Nishiura. In the present field observation, however, no evidence that the former is lower than the latter is recognizable because abundant volcanic materials distributed between the two areas prevent the writer from a strict correlation of these two sedimentary layers. SAITO (1962) stated that no significant stratigraphic difference was estimated between those two layers on the basis of planktonic foraminiferal correlation. Thus, molluscan shells collected from Nankinhama, Miyukihama and Nishiura are nearly of the same geological age. Geological age of the layers is Rutetian (Middle Eocene) (HANZAWA, 1947; SAITO, 1962).

On the molluscan fossils

The sedimentary rocks of the Hahajima Eocene yield abundant foraminifers, but molluscan fossils are quite uncommon. Descriptions and remarks on the

foraminiferal fossils have been published by YABE (1921), HANZAWA (1947, 1950), SAITO (1962) *et al.* Studies on molluscan fossils from the Eocene of Hahajima have been done by YOSHIWARA (1902), YABE and HATAI (1939) and OYAMA (1943). YOSHIWARA (1902) first cited the occurrence of molluscan fossils. They are *Trochus* (?) sp., "*Nerita*" sp. that resembles *Velates schmidelianus*, *Nerita* sp., *Nalica* sp., *Vermetus* sp., *Voluta* sp., *Pecten* sp., *Ostrea* spp., *Cardium* sp., *Tapes* sp. and *Dentalium* sp. from the tuff of Nishiura probably corresponding to the tuffaceous coquina limestone of this article. Specimens of YOSHIWARA's collection can not be examined because they were lost. YABE and HATAI (1939) described a large naticoid gastropod as a new genus and new species, *Hahazimania hahazimensis*, based on three molds from the calcareous tuffite of Nishiura, probably the same rocks that YOSHIWARA's specimens came from.

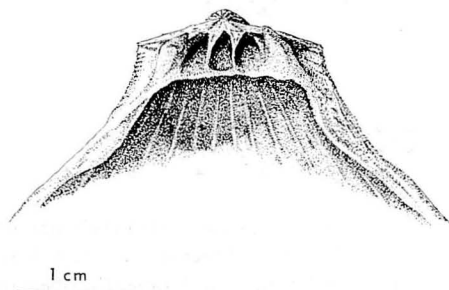


Text-fig. 3. Geological sketch map of Nishiura. 1. Alternation of andesite lava flow and tuff breccia. 2. Tuffaceous limestone. 3. Tuffaceous sandstone. X. Collecting locality of Nishiura.

OYAMA (1943) described *Lima* (*Meotolima*) *ogasawarana*, new subgenus and new species, based on a few specimens collected from Nishiura and Miyukihama. In the original description of the subgenus, it was noted that the left valve is larger than the right, and that the ligamental areas of two valves are different in size. OYAMA stated further that the inaequivalved configuration was a diagnostic feature of the subgenus.

The pectiniform specimens newly collected are identical with the types of *Lima* (*Meotolima*) *ogasawarana* in the shell outline, and may be conspecific with YOSHIWARA'S "*Pecten* sp.". Of ten specimens examined during the present study, nine are disarticulated valves and they are all damaged in the umbonal region. The other specimen is an inner mold of the dorsal part of a valve (Pl. 13, fig. 4), showing a nearly straight hinge line with three sockets and two stout teeth. A socket at the middle portion appears to be a resilium pit that is triangular in shape. Arrangement of the hinge line

is, therefore, formulated as $\frac{L10C01}{R01C10}$ by DALL'S system (DALL, 1913). This formula is the same as that of the spondylids. The linear arrangement of teeth and sockets and sturdiness of teeth also agree well with those of *Spondylus*. A restored hinge area of a left valve chiefly on the basis of the internal mold (specimen CM 8489) is shown in Text-fig. 4.



Text-fig. 4. Restored hinge part of left valve of *Spondylus* (*Meotolima*) *ogasawaranus* (OYAMA, 1943).

This species is considered most appropriately as belonging to the genus *Spondylus* instead of *Lima*. The unequal size of valves and ligamental areas between two valves is a quite common characteristic of the genus *Spondylus*, though it is very peculiar for the genus *Lima*. In comparison with common Recent spondylids, however, the present species differs from them in its nearly equal convexity of two valves and equally spaced and stout radial ribs. The surface of ribs is almost smooth except for three specimens having rows of tubercles and sparse punctations mainly on the ribs near the both marginal portions. This species is easily distinguished from other Cenozoic *Spondylus* species in the West Pacific, and has an external appearance closer to some pectinids than to spondylids. The only species morphologically comparable with the present one is *Spon-*

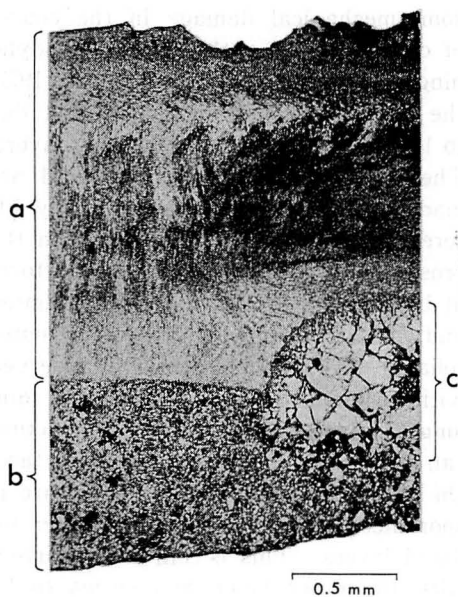
dylus spinosus (SOWERBY, 1812), which was originally described from the Upper Cretaceous Chalk of Great Britain. *S. spinosus* is a common species in the Upper Cretaceous molluscan faunas of West Europe, characterized by a pectiniform shell outline with 25 to 50 distinct radial ribs and by long spines found exclusively on the right (lower) valve. According to WOODS (1901), the shell morphology of the Cretaceous spondylid is variable especially in surface ornaments that vary considerably among individuals from different stratigraphic horizons. The present Eocene species seems to be closely allied to such individuals of the Cretaceous species having fewer radial ribs, though the shell convexity is generally weaker.

The specimens of this Eocene species apparently have no spines, but tubercles and punctations on some radial ribs may be the vestiges of some peculiar ornaments. Some right valves of the Cretaceous *S. spinosus* which have lost their spines in the course of fossilization display similar surface appearance to these tuberculate and punctate Eocene specimens. Thus, the three Eocene specimens are inferred to be right valves that most likely had long spines similar to those of the Cretaceous species in the living state. The true length and shape of spines which have existed on the right valve of the Eocene spondylids are unknown, but it is at least obvious that spines are fewer in number than in the Cretaceous species, and that they are distributed mainly on the ribs near the anterior and posterior peripheries.

The hinge of all specimens except for one inner mold are broken away. Such broken shells are also common in the Cretaceous species (WOODS, 1901; CARTER, 1972; Collections of Univ. Mus., Univ. Tokyo). This is partly due to

some mechanical damage in the course of disarticulation of the strong spondylid hinge, and partly because (CARTER, 1972) the umbonal area is chemically lost due to leaching of the aragonitic inner layers. The shells of the Eocene spondylid are made up of at least two structurally different layers that are recognized in the cross section of shells. The crystal form of both layers is calcitic, outer foliated and "inner" grained layers. The outer foliated layer is rather well preserved with original growth increments, and long tabulae of original foliated structure can be observed on the fractured surface. On the other hand, grained structure is sporadically found beneath the outer foliated layers. This is thin in comparison with the outer layer and seems to be composed of recrystallized calcite that replaced a part of aragonite layer without any ghost of original shell structure. The shells of common Recent spondylids are made up of three structural layers; the foliated, crossed-lamellar and inner crossed-lamellar structures of TAYLOR, KENNEDY and HALL (1969), or foliated, crossed-lamellar and complex structures of KOBAYASHI (1971), and consist of calcite and aragonite. The absence of aragonite layer in the Eocene shell seems to be due to alteration or leaching subsequent to burial. The shell layers originally occupied by aragonite and not recrystallized are almost thoroughly filled with sedimentary particles instead of remaining a vacant space. It is still problematic whether the shell of this species is essentially double layered or triple layered. The shell structure of the Eocene species does not coincide with that of the Recent limids, which consists of foliated, crossed-lamellar and complex crossed-lamellar structures (TAYLOR, KENNEDY and HALL, 1969).

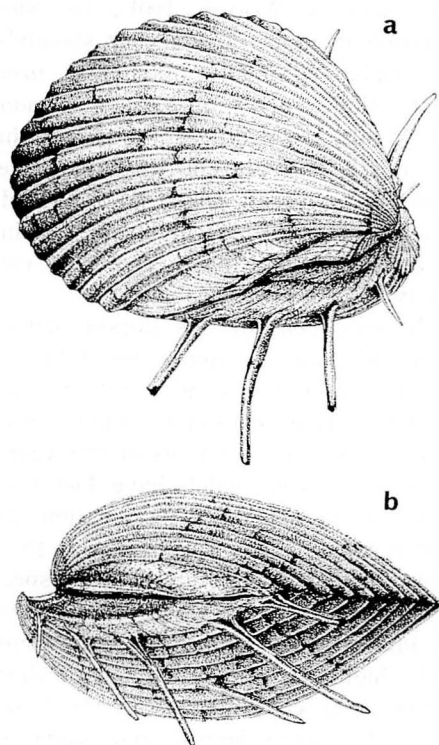
The Cretaceous *S. spinosus* is regarded



Text-fig. 5. Acetate replica of shell of *Spondylus (Meotolima) ogasawaranus* (OYAMA, 1943). A part of cross section along umbo (left) to ventral margin (right). a. Well preserved outer foliated layer. b. Grained calcite, a part of middle layer? c. Cavity filled with calcite, originally penetrated by boring animals.

as a dweller on soft bottom of chalky sediment without cementing to hard objects in the adult stage (CARTER, 1972). The spiny right valve is considered to lay downward, and the long spines prevent the shell, especially its commissure plane, from sinking into the soupy substrate (CARTER, 1972). This is an ecological adaptation different from other contemporaneous spondylids. The mode of life of the Eocene species is presumably similar to that of *S. spinosus*, because of the close resemblance in shell morphology. The environment in which the Eocene species acquired such living attitude is not a chalky basin but the submarine slope of a volcano, where debris of shell materials and fine tuff pos-

sibly accumulated in a way forming a bottom not unlike a chalky environment. The complete shell form of the Eocene *Spondylus (Meotolima) ogasawaranus* is thus restored on the basis of above discussed characteristics and of a simulation to *Spondylus spinosus* described and discussed by SOWERBY (1812), WOODS (1901) and CARTER (1972) (Text-fig. 6a, b).



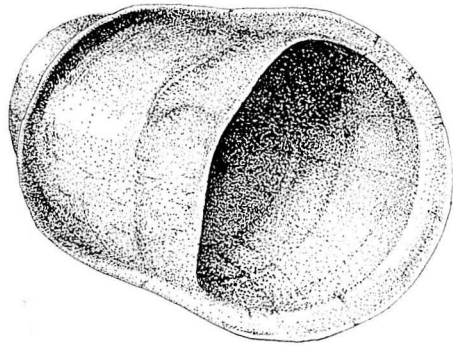
Text-fig. 6. Restored shell morphology of *Spondylus (Meotolima) ogasawaranus* (OYAMA, 1943). Oblique-posterior view (a), anterior view (b).

OYAMA (1943) originally noted that the left valve is larger than right valve probably on the basis of an articulated specimen; in the present article the large valve of OYAMA's specimen is regarded as right. This interpretation coincides with *S. spinosus* as well as the common tendency in other *Spondylus* species.

The type specimens (syntypes) of "*Lima ogasawarana*" were lost according to OYAMA, MIZUNO and SAKAMOTO (1960).

The second species to be described in this article is a large neritid gastropod. The single specimen at hand is not well preserved, shell material of the apertural side is dissolved away. The shell is characterized by its ovoid form and strong expansion of the body whorl. The outer lip of the aperture turns gently outward, and the inner lip which is lost in the present specimen seems to extend widely on the penultimate whorl forming a labial area, judging from remnants of the marginal flange surrounding the base. The feature of the labial area as restored in Text-fig. 7 somewhat resembles those of *Septaria* and *Dostia*. No umbilicus is observable. The present specimen has a thin test, less than 1 mm in thickness, so the appearance of shell is rather fragile if compared with common neritid species.

The Recent neritid shell is composed of three structural layers, namely outer prismatic layer of calcite, middle crossed-lamellar layer and inner complex crossed-lamellar layer of aragonite. According to BOGGILD (1930), species of *Neritina* have a very thin outer calcite layer in comparison with thick layer of species belonging to *Nerita* (s.l.). This thin outer layer is common to species of *Theodoxus*, *Clithon*, *Septaria* and *Dostia*. The test of the present specimen is all calcitic and seems to be made up of only a single layer. Although typical prismatic structure cannot be observed in this calcitic test owing to recrystallization, the thin shell seems to correspond to the outer layer, especially that of the *Neritina* group. Inner two layers of the shell consisting of aragonite, are most likely leached as in the same case with *Spondylus ogasawaranus*. Thickening of outer lip and feature of inner lip as well as



Text-fig. 7. Restored apertural side of "*Neritina*" sp.

dentition characterizing the neritid shell aperture cannot be observed owing to the replacement by sedimentary particles.

This specimen is in all probability not conspecific with YOSHIWARA's "*Nerita*" sp. which is allied to *Velates schmidelinus* (CHEMNITZ) because of the difference in the mode of coiling of spires. *Hahazimania hahazimensis* YABE and HATAI is a naticoid and is obviously different in shell morphology from the present species. The characteristics of this species are considered to be mostly allied to those of genus *Neritina* (s.l.) despite the shell size being much larger than common *Neritina* species.

Comparison with the molluscan species and assemblages of related area and stages

Fossil bearing Eocene formations are known from the Japanese Islands and several islands in the West Pacific surrounding the Bonin Islands. The Eocene molluscan fossils in the main islands of Japan are summarized by MIZUNO (1964a, b). The Takashiman and Okinoshiman stage faunas are the Eocene representatives of Kyushu, and they are predom-

inated by shallow embayment or inland sea inhabitants containing brackish water species. The other is the Lower Ishikarian fauna of Hokkaido, which is predominated also by shallow embayment species and by non-marine species. Remarkable differences in species association are recognizable between above cited Eocene faunas and the molluscan fossils in Hahajima, and seem to reflect differences in the living environment. Another molluscan assemblage is described from the Eocene Miyara formation of Ishigaki Island (MACNEIL, 1964). It is noticeable that among 17 species described, one gastropod species, *Ampullinopsis* cf. *A. hahazimensis* (= *Hahazimania hahazimensis*), is closely related to the species of the Hahajima Eocene according to MACNEIL (1964). Other species that were reported from the Miyara formation are not found in Hahajima. MACNEIL noted the faunal resemblance to the Eocene formations in Kyushu of the Japanese Islands rather than to elsewhere in the West Pacific. Paleogeologically, both the Ishigaki Island and Kyushu are located at the eastern marginal zone of the Asiatic continent, hence the living environment of the Miyara fauna may be more intimately related to those of the Takashiman and Okinoshiman stage faunas than to the oceanic island fauna of Hahajima.

Several islands in the West and the South Pacific are composed in part of the Eocene clastic sediments such as the Alutom formation of Guam (TRACEY *et al.*, 1964), the Hagman and Densinyama formations, the Matansa limestone of Saipan (CLOUD, SCHMIDT and BURKE, 1956), Wainimala Series and limestone in Viti Levu of Fiji (LADD, 1966). Although abundant occurrences of larger foraminifers have been emphasized, well preserved molluscan fossils have scarcely

been reported from these formations. Another Eocene molluscan fauna is reported from Tonga in the South Pacific (LADD, 1970). It occurs from tuffaceous limestone and is represented by small sized gastropods. No comparable species with the two Eocene species of Hahajima was reported. The geographical distribution of *Spondylus ogasawaranus* and "*Neritina*" sp. may be restricted to Hahajima and adjacent small areas.

There are few evidences to combine phylogenetically the Cretaceous *Spondylus spinosus* with the Eocene *S. ogasawaranus*. The former species seems to be endemic to the European region, and its extension in distribution to North America, or to East Asia has not been reported. There are, therefore, no areas where the distribution of both species overlaps. Stratigraphically younger *S. ogasawaranus* may not be a direct descendant of the European species, but be derived from a stock of sessile spondylids lived in the Pacific region of the Mesozoic, which is probably different from the *S. spinosus* stock, in a manner similar to *S. spinosus*. *S. ogasawaranus* may be, therefore, regarded as a good example of parallelism in adaptation.

A few Cretaceous spondylid species have been known in Japan. *Spondylus japonicus* from the Upper Cretaceous formation in Nagano, described by AMANO and MARUI (1958) is a large species with numerous fine radial ribs, and its morphology is more similar to some Recent sessile forms. *S. decoratus* NAGAO is another Cretaceous species (HAYAMI, 1956), and its shell morphology also resembles common Recent spondylids rather than *S. ogasawaranus*. Both Cretaceous species in Japan have no apparent morphological and inferred ecological relations to the Eocene species.

Description of species

Superfamily Pectinacea

RAFINESQUE, 1815

Family Spondylidae GRAY, 1826

Genus *Spondylus* LINNÉ, 1758Subgenus *Meotolima* OYAMA, 1943

Type species: *Lima* (*Meotolima*) *ogasawarana* OYAMA, 1943, (original designation).

Subgeneric diagnosis: Moderate sized spondylid. Pectiniform in outline with distinct radial ribs on shell surface. Nearly aequilateral, slightly inaequivalve. Right valve larger than left valve. Right valve has several spines formed mainly on ribs near anterior and posterior peripheries. Left valve has no spines. Two valves equal in convexity.

Remarks: Species of this subgenus seem to be kept on soft bottom sediments by spines of right (lower) valve in life position in the adult stage instead of cementation by right valve to hard substrate. *Meotolima* was proposed originally by OYAMA (1943) as a subgenus of *Lima* without description of the hinge teeth. The inaequivalve shells were emphasized as a diagnostic character of this subgenus. COX *et al.* in MOORE (1969) adopted OYAMA's proposal, and treated *Meotolima* as a subgenus of genus *Lima*. *Meotolima* is here assigned to a subgenus of the genus *Spondylus* because *Lima* *ogasawarana* of OYAMA has an isodont hinge as illustrated in Text-fig. 4. The diagnostic characters of the subgenus are redefined. The morphological characteristics of *Meotolima* have intimate relations to peculiar mode of life among spondylids. The shell morphology and inferred ecology of the *Meotolima* species are very similar to those of the

Upper Cretaceous *Spondylus spinosus* (SOWERBY, 1812) in Europe, although the application of this subgenus is tentatively restricted to the Eocene Pacific species.

Spondylus (*Meotolima*) *ogasawaranus*
(OYAMA, 1943)

Plate 13, figs. 1-7

Lima (*Meotolima*) *ogasawarana* OYAMA, 1943,
p. 36, 37, pl. 2, figs. 9, 10; pl. 14, fig. 7.

Lima (*Meotolima*) *ogasawarana* OYAMA : OYAMA, MIZUNO and SAKAMOTO, 1960, p. 124,
pl. 33, fig. 1.

Supplementary description: Shell moderate to small in size for the genus, suborbicular in outline, nearly aequilateral, inaequivalve. Dorsal end auriculate, and ventral margin broadly rounded. Umbo of right valve (lower valve) more prominent than that of left valve. Left umbo scarcely projects from the hinge line. Convexity of two valves nearly equal. Auricle small, neither byssal gape nor byssal notch found in adult shell. Weak auricular sulci observed anteriorly and posteriorly both in right and left valves. Shell surface ornamented with equally elevated and spaced distinct radial ribs. Ribs neither bipartite nor grooved. Number of ribs between 21 and 25, 23 and 24 of modal value. Rib profile triangular or rounded quadrate shaped. Interspace narrow. Growth lines visible only near ventral margin of adult shell. No ornamentation found on ribs except spines. Spines grow in most individuals on the ribs just adjacent to the anterior and posterior auricular sulci of right valve. Spines seem to be 2 or 3 in number on each rib. Actual length and feature of spines unknown. Other ribs rarely furnished by spines. No spines found on left valve. Hinge plate not so long, about

a half of shell length. Hinge teeth stout and 2 in number (Text-fig. 4) in each valve. Resilium large. Inner surface weakly grooved at middle and ventral part where thin inner shell layer remains unsolved (recrystallized by calcite). Grooves correspond to the rib elevation of outer surface. Adductor scar indis-

tinct. Inner ventral margin crenulated strongly. Two valves seem to close tightly at the ventral margin. Test moderately thick and may consist at least of two different structural layers, the outer calcite foliated layer, but inner layer either leached or recrystallized.

Measurements:

Specimen	Length	Height	Depth	Number of radial ribs	Apical angle	Valve	Locality
CM 8480	36.5 (mm)	37.4 (mm)	9.6 (mm)	23	90°	left	Nankinhama (Nanking Beach)
CM 8481	40.4	38.4+	9.4	24	97°	"	"
CM 8482	40.0	40.5	9.4	24	85°	right	"
CM 8483	34.7	36.5	10.3	24	86°	"	"
CM 8484	42.5	47.0	12.6	21	86°	left	"
CM 8485	40.0	42.0	12.0	24	93°	"	"
CM 8486	36.3	38.1	10.4	24	92°	right	Miyukihama (Cocoanut Beach)
CM 8487	28.4	28.6+	6.8?	22	89°	left	Nishiura
CM 8488	20.0+	25.2	6.0	23+	84°	right	"
*Type specimen	33 ca	36.2	15.3 (R+L?)	23	?	left+ right	" ?

* after OYAMA (1943)

Comparison: The species resembles *Spondylus spinosus* (SOWERBY, 1812) of the Upper Cretaceous (Turonian to Maastrichtian) in shell morphology, but is distinguishable by the smaller number of radial ribs. Surface sculpture and shell convexity are less variable compared with morphological variation of *S. spinosus* described by WOODS (1901). Most of adult shells do not exceed 50 mm in shell length, though some individuals of *S. spinosus* attain 70 mm.

No species of *Spondylus* other than sessile forms have been reported from the Paleogene formations in the Japanese Islands and the West Pacific.

Remarks: This species occurs from the coarse tuffaceous sandstone and tuff-

aceous limestone of Hahajima associated with *Nummulites boninensis* HANZAWA, 1947 and *Alveolina javana boninensis* HANZAWA, 1950. It is not common. The valves are disarticulated in most individuals, and are broken at the hinge or in the umbonal area. No articulated specimens were examined. All spines on the right valves are broken at their base, and their existence is only recognizable by scars marked on shell surface. Such broken valves show a pectinid appearance like *Aequipecten* or *Cryptopecten*, and are rather dissimilar to common Recent spondylids which are cemented by right valve to a hard substrate. This species seems to be endemic to the islands.

Occurrence and specimens: *Nummulites*-bearing coarse tuffaceous sandstone of Miyukihama (Cocoanut Beach), CM 8486, and Nankinhama (Nanking Beach), CM 8480-CM 8485, Okimura; *Alveolina*-bearing tuffaceous limestone of Nishiura, CM 8487-CM 8489, Okimura; both in Hahajima (Hillsborough Island), Ogasawara-mura, Tokyo-to.

These specimens are deposited in the Department of Geology and Palaeontology, University Museum, University of Tokyo.

Superfamily Neritacea RAFINESQUE, 1815

Family Neritidae RAFINESQUE, 1815

Genus *Neritina* LAMARCK, 1816

"*Neritina*" sp.

Plate 13, fig. 8; Text-fig. 7

Description: Shell very large for the genus. Ovoid in outline, but somewhat flattened at apertural surface. Test thin for common neritid species and seems to be fragile. Spire low, slightly protruding, so the right side (apertural side) almost flat. Body whorl expanded attaining about a half of shell diameter. Five spires observable. Aperture large. Its width nearly equal to height. Outer lip bent outward. Inner lip extends abaxially to the opposite end of aperture forming a labial area, and its margin seems to protrude making thin flange like that of *Septaria* species. No umbilicus. Dentition of aperture unknown, and apertural margin most likely smooth. Shell surface smooth. Surface pigmentation and operculum unknown.

Measurements: Maximum diameter, 50.0; shell height, 38.5; shell width, 33.4 (in mm).

Remarks: Only one specimen is at hand. The shell outline shows apparent neritid characteristics. It resembles somewhat pre-Cenozoic species of "*Naticopsis*" in overall shell outline, but the morphology of aperture seems to be different. Generic assignment of the species is based mostly on apertural configuration inclusive of morphology of outer and inner lips, that are restored from fragmental data (Text-fig. 7). Very thin test does not represent that of living state as stated in the chapter of discussion. Original thickness of test at its aperture is estimated to be more than 3 mm. The specimen is so large in size for genus *Neritina* that identification to the assigned genus is somewhat hesitant. This species differs from *Velates* species of the Eocene in the shell outline especially in the mode of coiling and sturdiness of test.

Occurrence and specimen: *Alveolina*-bearing tuffaceous limestone of Nishiura, Okimura, Hahajima (Hillsborough Island), Ogasawara-mura, Tokyo-to, CM 8490, stored in the Department of Geology and Palaeontology, University Museum, University of Tokyo.

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Explanation of Plate 13

(All figures in natural size unless otherwise stated)

- Figs. 1-7. *Spondylus (Meotolima) ogasawaranus* (OYAMA, 1943)
 1a, posterior view of 1b, right valve, CM 8483; 2, right valve, CM 8482; 3, interior view of right valve, CM 8488, $\times 2$; 4, inner mold, dorsal part of right valve, CM 8489; 5, left valve, CM 8480; 6a, anterior view of 6b, left valve, CM 8485; 7, interior view of left valve, CM 8487. 1, 2, 5, 6 from Nankinhama (Nanking Beach); 3, 4, 7 from Nishiura.
- Fig. 8. "*Neritina*" sp.
 8a, posterior view, 8b, apical view, CM 8490, from Nishiura.



1a



1b



2



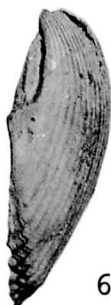
3



4



5



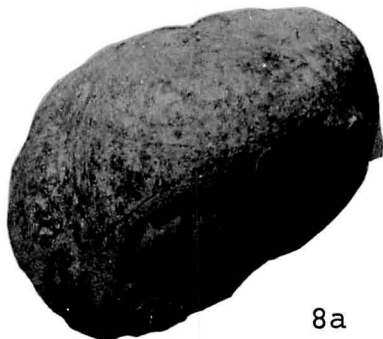
6a



6b



7



8a



8b

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Chichijima	父 島
Hahajima	母 島
Ishigaki	石 垣
Ishikari	石 符
Miyako	宮 古
Miyara	宮 良
Miyukihama	御 幸 浜

Nankinhama	南 京 浜
Nishiura	西 浦
Ogasawara	小 笠 原
Okimura	沖 村
Okinoshima	沖 ノ 島
Takashima	高 島

651. MISSISSIPPIAN CONODONTS FROM THE OMI LIMESTONE,
NIIGATA PREFECTURE, CENTRAL JAPAN

KOZO WATANABE

Noda Senior Highschool, Noda-City, Chiba 278

青海石灰岩産下部石炭系のコノドント：青海石灰岩の青海川沿いに分布する *Endothyra* 帯（長谷川，他，1969）から，世界的に分布する *Gnathodus bilineatus*-*G. commutatus*-*G. nodosus* を含むコノドント化石群を認めた。これらのコノドント化石群は，阿哲石灰岩名越層の *Gnathodus bilineatus*-*G. commutatus* 帯（KOIKE, 1967），秋吉石灰岩最下部層のコノドント化石群（Hisaharu IGO, 1973），さらに関東山地南東部三ツ沢産の *Gnathodus bilineatus*-*G. nodosus*-*G. commutatus* 化石群（Hisayoshi IGO & KOBAYASHI, 1974）等と同様な化石群集であり，青海石灰岩の *Endothyra* 帯の一部は，少くとも北米の Chesterian 中部，ヨーロッパの Viséan 上部に対比される。

渡辺 耕造

Introduction and acknowledgements

The *Endothyra* Zone established by HASEGAWA et al. (1969) in the Lowest Omi Limestone Group distributed in western part of Niigata Prefecture yields many conodont species which are widely recognized in the Lower Carboniferous. Carboniferous conodont faunas of Japan were described and illustrated from the Nagoe Formation of the Atetsu Limestone (KOIKE, 1967), Ohkubo area of the Lowest Akiyoshi Limestone (Hisaharu IGO, 1973) and Itsukaichi district of Western Tokyo (Hisayoshi IGO & KOBAYASHI, 1974).

The present paper deals with a conodont fauna from the *Endothyra* Zone of the Omi Limestone. The fauna recognized from this zone is closely similar to the above mentioned faunas. Namely, it is characterized by the occurrence of *Gnathodus bilineatus*, *G. nodosus* and *G. commutatus*, which were well known

* Received March 31, 1975; read Jan. 25, 1969 at Tokyo.

species recognized in the Upper Viséan of Europe or the Chesterian of North American Mississippian.

Deep thanks is expressed to Professors Mosaburo KANUMA and Professor Tatsuki KIMURA of Tokyo Gakugei University, Associate Professors Hisayoshi IGO of University of Tsukuba and Toshio KOIKE of Yokohama National University for their continuous encouragement and critical reading of this manuscript. Thanks are also due Associate Professor Atsushi ISHII and Mr. Hisaharu IGO of Tokyo Gakugei University and Mr. Fumio KOBAYASHI of Tokyo University of Education, for their kind advice and help in various ways.

**Remarks on the lowest part of
the Omi Limestone**

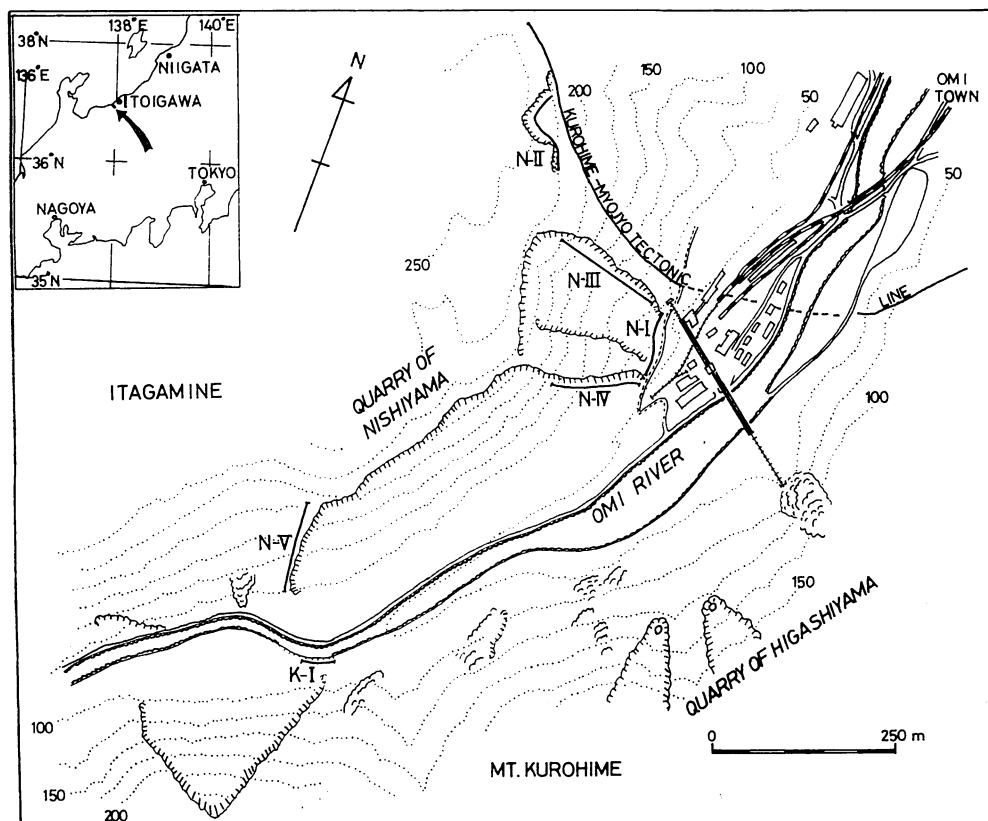
The Omi Limestone Group is distributed in a wide belt, trending northwest and southeast in the Nishikubiki County of Niigata Prefecture, Central Japan. The

lowest part of this limestone group was studied repeatedly by HAYASAKA (1924), KAWADA (1954), FUJITA (1958), SAKAGAMI (1962, 1963), IGO & KOIKE (1964), ROWETT & MINATO (1968), HASEGAWA et al. (1969) and WATANABE (1974).

Among the above, rather detailed geology and paleontology were contributed by KAWADA and FUJITA. Their lowest division was characterized by the *Millerella*-Coral-Brachiopod Zone, which was distributed in a narrow belt trending northwest and southeast along the Kurohime-Myojo Tectonic Line in the Itagamine district of the Omi Limestone. This zone was measured in thickness

about 250 m by KAWADA and 400 m by FUJITA.

On the basis of fusulinacean and endothyroid foraminiferas, the strata of the lower facies of the pre-Moscovian were subdivided into two zones by HASEGAWA et al. (1969), namely, the *Endothyra* Zone and the *Eostaffella-Millerella* Zone. According to the faunal distribution, they thought that the Carboniferous strata of the lower facies had formed an arcuated arrangement which was separated in distribution into the inner and the outer. As the result, HASEGAWA et al. proved more extensive distribution of the Lower Carboniferous than that of the previously



Text-fig. 1. Index map showing the locations of two sections for this conodont study.

published geologic maps. The thickness of the pre-Moscovian zones are about 150 m and 170 m, respectively.

Recently, in the lowest fusulinacean zone, WATANABE (1974) recognized the *Eostaffella kanmerai* Zone, however, the distribution and thickness of this zone are still open.

These zones are delimited at their base by pyroclastic rocks composed of basic tuffs and breccia tuffs. In the areas of calcareous sediments in the Inner Zone of Southwest Japan, the lowest part of the Carboniferous succession is well marked by pyroclastic rocks; such a succession is recognized in the Akiyoshi, Taishaku, and Atetsu areas, except the Omi area where underlying pyroclastic rocks are not so well developed owing probably to the interruption of the so-called Kurohime-Myojo Tectonic Line. Therefore, the pyroclastic rocks which were regarded by KAWADA (1954) as the base of the Omi Limestone were considered, according to FUJITA (1958), to be the intrusive dike formed along the thrust plane. Recently, HASEGAWA et al. (1969) surveyed widely for this limestone area and founded a good stratigraphic succession of the lower part at the Fukugaguchi point in the Kurohime district, where the pyroclastic rocks composed of basic tuffs were conformably overlain by the *Endothyra* Zone. The author believes that the pyroclastic rocks, though not whole, is not the basal part of the Lower Carboniferous limestone, because he found *Neoschwagerina* sp. from one of the lenses in them.

Concerning with faunal evidences, HAYASAKA (1924) once discriminated that the Omi fauna was very prolific in brachiopod and coral faunas including *Gigantoproductus edelburgensis* (PHILLIP), *Syringothyris cuspidatus* MARTIN and other species. And he stated that *Gigan-*

toproductus was from the uppermost part of the Lower Carboniferous or from the transitional zone between the Lower and Upper Carboniferous. According to IGO & KOIKE (1964), the above *Syringothyris cuspidatus*, which was said to be an indicator of the Tournaisian, is one of the characteristics of the Omi Limestone fauna.

FUJITA discussed that the coral fauna including *Lithostrotion somaense*, *Amygdalophyllum giganteum*, *Lonsdaleia floriformis* and *Axophyllum centrotrium* from his lowest zone (C₁) in the Itagamine, which were indicating the Upper Mississippian of North America or the Lower Namurian of Europe.

As to the bryozoan fauna SAKAGAMI (1962, 1963) described *Fenestella* cfr. *triserialis* URLICH, etc. *F. triserialis* was originally reported from Keokuk Group of the Middle Valmeyeran of North America and also reported from the Lower Carboniferous of U.S.S.R. He stated that the Omi bryozoan fauna was more related to the Russian fauna rather than the North American one.

IGO & KOIKE (1964) described the conodont fauna from the Omi Limestone consisting of the *Streptognathodus expansus*-*S. suberectus* faunule from the ammonite-bearing limestone which occurred in the *Millerella*-Coral-Brachiopod Zone. This faunule indicates the Lower Pennsylvanian or the Upper Namurian.

In the micro-biostratigraphical studies on the foraminiferal faunas of Chugoku region, Southwest Japan, OKIMURA (1966) discussed the geologic age and correlation of the lowest part of the Omi Limestone depending on the INAMURA's collection. The endothyrid-paleotextularid faunule and the *Eostaffella*-*Millerella* faunule were discriminated by him in the lowest part of the Omi Limestone. According to OKIMURA, these faunules were very

similar to the assemblages of the *Endostaffella delicata* Zone and the *Eostaffella* sp. A-*Millerella* sp. A Zone as well in the Chugoku region, and both zones were correlated to the Upper Valmeyeran and the Upper Chesterian or the Middle Viséan and the Lower Namurian.

HASEGAWA et al. (1969) mentioned the similarity of fossil assemblages and lithofacies of the Omi Limestone to the Ohkubo area of the Lowest Akiyoshi Limestone Group, though they have not referred to the geologic age of the *Endothyra* Zone of the Omi Limestone. The Ohkubo fauna consisting of smaller foraminiferas (OKIMURA, 1966), rugose corals (MINATO & KATO, 1963, OTA, 1968), brachiopods (YANAGIDA, 1965) and conodonts (Hisaharu IGO, 1973) seems to be divergent in the geologic age. However, they summarized that the geologic age of this fauna indicated the Viséan or the Upper Mississippian.

From above mentioned evidences, the geologic age of the lowest part of the Omi Limestone is the Lower to Upper Viséan or the Valmeyeran to Chesterian of North America.

Previous conodont studies

The first discovery of Carboniferous conodonts in Japan was made by IGO & KOIKE (1964) from the ammonite-bearing limestone which occurred from the *Millerella*-Coral-Brachiopod Zone of the Omi Limestone. They discriminated the following species *Streptognathodus expansus* IGO & KOIKE, *S. suberectus* DUNN, *Idiognathodus parvus* DUNN, *Idiognathoides noduliferus* (ELLISON & GRAVES), *I. convexus* (ELLISON & GRAVES), *I. opimus* (IGO & KOIKE), and many other species. This conodont fauna is very similar to those of *Idiognathodus parvus*-

Idiognathoides noduliferus Zone (K-II) of the Kodani Formation of the Atetsu Limestone (KOIKE, 1967) and *Streptognathodus expansus*-*S. suberectus* Zone of the Bird Spring Formation of Southern Nevada (DUNN, 1970). It was considered to be equivalent to the parts of G₁ and G₂, the goniatite zones of the European Namurian to Westphalian, or the Upper Morrowan of North America. In the present study, this conodont assemblage appears in the middle part of the Sections II, III, and IV.

Conodont fauna

As mentioned before, the *Endothyra* Zone in the Itagamine district established in the lowest subdivision of the Omi Limestone is restricted in distribution along the Omi river. This limestone is massive throughout and has no stratification. Accordingly, the author measured seven sections not only in vertical but also horizontal directions. More than 100 samples were collected from these sections. The vertical sections from N-I to N-V were measured in the Nishiyama quarry of the Denki-Kagaku Mine and the horizontal sections, N-I and K-I, in the Nishiyama and Higashiyama quarries of this mine (Text-fig. 1).

Fortunately, an excellently preserved conodont fauna was found from all sections. The vertical sections from N-II to N-V yield the Lower to Middle Pennsylvanian conodonts, and the horizontal sections N-I and K-I contain the Upper Mississippian conodonts. The present paper treats only upon the Mississippian conodont assemblages from two horizontal sections. The Pennsylvanian conodonts will be published by the author in the near future.

Section N-I: This horizontal section was measured in the outer part of the

Endothyra Zone at the Nishiyama quarry of the Denki-Kagaku Mine in the Itagamine district. More than 25 samples were collected and conodonts were recovered from 6 samples. Numerous conodonts were separated from grey to white sparry limestone, and the following species were discriminated; *Gnathodus bilineatus* (ROUNDY), *G. commutatus* (BRANSON & MEHL), *G. nodosus* (BISCHOFF), *Cavusgnathus unicornis* (YOUNGQUIST & MILLER), *C. sp.*, *Spathognathodus campbelli* REXROAD, *S. minutus* (ELLISON), *Ozarchodina compressa* REXROAD, *Apatognathus?* sp., *Magniratelella* sp., and *Hindeodella sakagami* IGO & KOIKE.

Among the above, *Gnathodus bilineatus*, *G. commutatus* and *Cavusgnathus unicornis* are predominant. The following fossils were found from the preparations; *Eostaffella kanmerai* (IGO), *Endothyranopsis* sp., and *Hexaphyllia* sp. These fossils were known in the Onimaruan of Japan or the Viséan of Europe. Therefore, this measured section, which was referred to the outer part of the *Endothyra* Zone, seems to be able to include the *Eostaffella kanmerai* Zone (WATANABE, 1974) or the *Eostaffella-Millerella* Zone of HASEGAWA et al. (1969).

Section K-I: This section was also measured horizontally in the inner part of the *Endothyra* Zone, which was situated in the central part of this limestone complex. This horizontal section of this stratum is similar to the horizon of *Gigantoproductus edelburgensis*-bed described and illustrated by HAYASAKA (1924). Crinoidal, massive and white sparitic limestone yields many species, namely, *Gnathodus bilineatus* (ROUNDY), *G. cfr. bilineatus* (ROUNDY), *G. commutatus* (BRANSON & MEHL), *G. nodosus* (BISCHOFF), *Spathognathodus campbelli* REXROAD, *S. minutus* (ELLISON), *Ozarchodina compressa* REXROAD, *O. subequalis* (HIG-

GIN), *Neoprioniodus scitulus* (BRANSON & MEHL), *N. loxus* REXROAD, *Hindeodella segaformis* BISCHOFF, *H. sakagami* IGO & KOIKE, *Hindeodus alatoides* (REXROAD & BURTON), *Magniratelella* sp., and Gen. et sp. indet.

This fauna is characterized by the occurrence of *Spathognathodus campbelli*, *Gnathodus bilineatus*, *G. cfr. bilineatus*, *G. commutatus* and *G. nodosus*, and also is marked by the frequent occurrence of *Hindeodella segaformis* and Gen. et sp. indet. The last species is well known in the *Scaliognathus anchoralis* Zone (upper T₁₂) of European Tournaisian (MARKS & WENSINK, 1970; GROESSEMS, 1974). The indeterminable genus is quite enigmatic, because it has four processes. This somewhat resembles *Lambdagnathus* REXROAD from the Chesterian of North American Mississippian, but *Lambdagnathus* consists of three denticulate processes instead of four. However, the present material occurs rarely and fragmental in this section, therefore, the specimens are not referable to any extant genus and so they are thought to be scientifically new and should be named in the future. As cited on Table 1, there are no remarkable faunal change between the collections. The author has not found any primitive fusulinacean from the samples containing many endothyroid foraminiferas. The occurrence of *Gigantoproductus edelburgensis* in this section indicates the Onimaruan of Japan or the Upper Viséan of Europe.

Correlation: The two conodont faunas from the *Endothyra* Zone in the Omi Limestone are quite related with each other, although the K-I horizon seems to be slightly lower than that of the N-I for the occurrence of fusulinacean. Namely, the N-I fauna containing *Eostaffella kanmerai* consists mainly of the two markers *Gnathodus bilineatus* and

G. commutatus, and also the K-I fauna containing *Endothyra* spp. is characterized by the co-occurrence of the three markers *Gnathodus bilineatus*, *G. commutatus* and *G. nodosus*.

Association of conodont elements, comparable with those found in the N-I and K-I faunas, has been reported from various parts of the world. Faunas with *Gnathodus bilineatus*, *G. commutatus* and *G. nodosus* have been recognized in Germany (BISCHOFF, 1958; MEISCHNER, 1962), Belgium (HIGGINS & BOUCKAERT, 1968), England (HIGGINS, 1961; RHODES et al., 1969), Spain (MARKS & WENSINK, 1970), North America (REXROAD & COLLINSON, 1962; WEBSTER, 1969; DUNN, 1965; COLLINSON et al., 1971; LANE & STRAKA, 1974) and Japan (KOIKE, 1967; Hisaharu IGO, 1973; IGO and KOBAYASHI, 1974).

In the Griotte Limestone of Spain, the two bio-zones with many similar associations were discriminated in the Upper Viséan (CuIII α -CuIII γ) by MARKS & WENSINK (1970), which were upwardly the *Gnathodus commutatus commutatus* Zone and *G. commutatus nodosus* Zone. The basal part of the *G. commutatus commutatus* Zone yielded *G. typicus* and in the lower part of the *G. commutatus nodosus* Zone, *Gnathodus girtyi* was associated with the zone markers. The two species are not found in the Omi faunas.

RHODES et al. (1969) found the comparable zonal sequence in the Avon Gorge, England. The three markers, *Gnathodus bilineatus*-*G. commutatus*-*G. nodosus*, were characteristic species in the lower, *Mestognathodus beckmanni*-*G. bilineatus* Zone and the upper, *Gnathodus mononodosus* Zone. *Gnathodus girtyi* and *Mestognathodus beckmanni* were also the characteristics in these zones which were unknown in the Omi faunas. They cor-

related these zones with CuIII α and CuIII β of European zones and with the *G. bilineatus*-*Cavusgnathus charactus* Zone of North America.

It is possible, though not precisely, to correlate the Omi faunas with those from the Chesterian successions in North America. The upper part of the Chesterian was marked by the occurrence of *Kladognathus mehli*, *K. primus*, *Cavusgnathus naviculus*, and *Gnathodus girtyi*. The first two species have not yet been known in the Omi and the other faunas in Japan, except for *Kladognathus* sp. from the upper part of the Nagoe Formation (KOIKE, 1967). The Omi fauna is similar to that of the Lower to Middle Chesterian than of the Upper Chesterian.

The conodont-bearing Carboniferous limestone have been described from a few areas in Japan. KOIKE (1967) reported a succession of conodont fauna from the Nagoe and Kodani Formations in Southwest Japan which ranges from Upper Mississippian to Middle Pennsylvanian. His Mississippian *Gnathodus bilineatus*-*G. commutatus nodosus* Zone correlated to the Middle Chesterian is very similar to that of the Omi ones.

Faunas with *Gnathodus bilineatus*, *G. commutatus*, *G. nodosus*, *G. homopunctatus* and *G. cfr. texanus* was described by Hisaharu IGO (1973) from the Ohkubo area of the Lowest Akiyoshi Limestone, Southwest Japan. This Ohkubo fauna was correlated by him to the Upper Viséan or the Chesterian.

Recently Hisayoshi IGO and KOBAYASHI (1974) reported a succession of conodont faunas from the Mitsuzawa Limestone, western part of Tokyo. The lower conodont fauna with *G. bilineatus*, *G. nodosus* and *G. commutatus* was concluded by them to the late Chesterian of North America or the early Namurian rather than the late Viséan of Europe.

Table 1. Distribution of conodonts from the Omi Limestone.

Sections Sample number	N-I						K-I						
	1	2	3	4	6	8	2	4	6	7	9	10	11
<i>Gnathodus bilineatus</i>	1	21	—	1	29	8	—	—	1	2	—	—	—
<i>G. cf. bilineatus</i>	—	—	—	—	—	—	—	1	2	1	—	—	—
<i>G. commutatus</i>	2	3	3	—	3	2	—	—	—	12	2	7	—
<i>G. nodosus</i>	—	—	1	—	—	—	3	—	—	5	2	—	—
<i>Cavusgnathus unicornis</i>	1	3	—	—	3	—	—	—	—	—	—	—	—
<i>C. sp.</i>	1	3	—	—	—	—	—	—	—	—	—	—	—
<i>Spathognathodus campbelli</i>	1	1	—	—	—	—	—	—	5	18	13	159	2
<i>S. minutus</i>	1	—	—	—	—	1	—	—	—	—	3	—	—
<i>Ozarchodina compressa</i>	1	—	—	—	—	—	—	—	—	—	—	2	—
<i>O. subaequalis</i>	—	—	—	—	—	—	—	—	—	—	3	—	—
<i>Neoprioniodus scitulus</i>	—	—	—	—	—	—	—	—	4	4	6	1	—
<i>N. loxus</i>	—	—	—	—	—	—	—	—	—	—	2	—	—
<i>Hindeodella segaformis</i>	—	—	—	—	—	—	—	—	—	f	f	f	—
<i>H. sakagamii</i>	f	f	—	f	f	—	—	—	—	—	—	—	—
<i>Hindeodus alatoides</i>	—	—	—	—	—	—	—	—	—	—	—	2	—
<i>Magniratelella sp.</i>	1	—	—	—	—	—	—	—	2	—	—	f	—
<i>Apatognathus ? sp.</i>	—	—	—	—	—	2	—	—	—	—	—	—	—
Gen. et sp. indet.....	—	—	—	—	—	—	—	—	—	4	—	—	—
Total	10	31	4	1	45	13	3	1	15	48	30	170	2

f: fragment

According to the repeating studies regarding the corals, smaller foraminifers and brachiopods, the age of above mentioned faunas of Japan has been thought to be the early to late Viséan.

In conclusion, the conodont fauna from the *Endothyra* Zone of the Lowest Omi Limestone is entirely lacking *Gnathodus girtyi* and its subspecies, which are rather common in European Viséan or the late Chesterian and also does not yield *Gnathodus texanus* and its related species which are the characteristic in the Middle Valmeyeran of North America. Therefore, the present fauna is considered to

represent a part of the Middle Chesterian of North America or the Upper Viséan of Europe.

Systematic description

Genus *Cavusgnathus* HARRIS & HOLLINGWORTH, 1933

Type species: *Cavusgnathus altus* HARRIS & HOLLINGWORTH, 1933

Cavusgnathus sp.

Pl. 15, Fig. 3

Remarks: The present material is fragmental, but it is similar to *Cavusgnathus unicornis* with short stout shape, high platform, deep medium trough and short blade. However, it is distinguished from *Cavusgnathus unicornis* by the absence of hornlike posterior denticle of blade.

Material studied and occurrence: 4 specimens from (1) and (2) of the Sec. N-I.

Reg. Nos.: TGU 1100, 1101.

Cavusgnathus unicornis
YOUNGQUIST & MILLER

Pl. 15, Figs. 1, 2, 4-6

Cavusgnathus unicornis YOUNGQUIST & MILLER, 1949, p. 619, pl. 101, figs. 18-23; REXROAD, 1957, p. 17, pl. 1, fig. 7; REXROAD, 1958, p. 17, pl. 1, figs. 6-11.; REXROAD & BURTON, 1961, p. 1152, pl. 138, figs. 10-12; REXROAD & COLLINSON, 1963, p. 9, pl. 1, figs. 26, 27; REXROAD & FURNISH, 1964, p. 670, pl. 111, fig. 6; REXROAD & NICOLL, 1965, p. 18, pl. 1, figs. 18-20; KOIKE, 1967, p. 294, 295, pl. 1, figs. 2, 3; T HOMPSON & GOEBEL, 1968, p. 23, pl. 1, figs. 2, 5, 6, 8.

Remarks: Immature forms (Pl. 15, Figs. 4-6) have distinct transverse ridges and a large horn-like posterior denticle of blade than that of the adult form (Pl. 15, Figs. 1, 2).

Material studied and occurrence: 7 specimens from (1), (2) and (6) of the Sec. N-I.

Reg. Nos.: TGU 1102, 1103, 1104.

Genus *Gnathodus* PANDER, 1856

Type species: *Gnathodus mosquensis* PANDER, 1856.

Gnathodus bilineatus (ROUNDY)

Pl. 14, Figs. 1-5

Polygnathus bilineatus ROUNDY, 1926, p. 13, pl. 3, figs. 10a-10c.

Gnathodus bilineatus, HASS, 1953, p. 79, pl. 14, figs. 25-29; REXROAD & FURNISH, 1964, p. 670; DUNN, 1965, p. 1148, pl. 140, figs. 7-9; WIRTH, 1967, p. 205, pl. 19, figs. 6-9; KOIKE, 1967, p. 296, pl. 1, figs. 9-11; GLOBENSKY, 1967, p. 440, pl. 58, figs. 9, 13; IGO & KOIKE, 1968, p. 29, pl. 3, fig. 6; RHODES, AUSTIN & DRUCE, 1969, p. 94, pl. 18, figs. 14-17; WEBSTER, 1969, p. 30, pl. 5, figs. 11-12; DUNN, 1970, p. 330-331, pl. 62, figs. 13, 14; MARKS & WENSINK, 1970, p. 258, pl. 2, figs. 3a-b, 4; Hisaharu IGO, 1973, p. 192-193, pl. 29, figs. 1-6; IGO & KOBAYASHI, 1974, p. 419-420, pl. 56, figs. 1-3; LANE & STRAKA, 1974, p. 72-77, pl. 32, figs. 1-5, 7, 9, 11-13; pl. 33, figs. 11-13, 19-23, 25, 28-32; pl. 34, figs. 13-26; pl. 40, fig. 27.

Gnathodus bilineatus bilineatus, BISCHOFF, 1957, p. 21-22, pl. 3, figs. 11, 15; pl. 4, fig. 1; HIGGINS & BOUCKAERT, 1968, p. 29, pl. 3, fig. 9.

Remarks: LANE and STRAKA (1974) described many specimens from the late Mississippian of Arkansas and Oklahoma and discriminated four morphotypes based on the outer lobate platform ornament. The Omi specimens have concentric nodose ridges parallel to the outer margin of the lobate platform, therefore, which are referred to morphotype β of *Gnathodus bilineatus*.

Material studied and occurrence: 60 specimens from (1), (2), (4), (6) and the Sec. N-I, and 3 specimens from (6) and (7) of the Sec. K-I.

Reg. Nos.: TGU 1105, 1106, 1107, 1108, 1109, 1110.

Gnathodus cfr. *bilineatus* (ROUNDY)

Pl. 14, Figs. 6, 7

Remarks: The present specimen is

similar to *Gnathodus commutatus*, however, the inner platform is widely in posterior part along the carina and has a low ridge. Some nodes developed on the inner platform.

Material studied and occurrence: 4 specimens from (4), (6) and (7) of the Sec. K-I.

Reg. No.: TGU 1111.

Gnathodus commutatus

(BRANSON & MEHL)

Pl. 14, Figs. 8-11

Spathognathodus commutatus BRANSON & MEHL, 1941, p. 98, pl. 19, figs. 1-4.

Gnathodus commutatus, REXROAD & BURTON, 1961, p. 1153, pl. 39, figs. 1-3; HIGGINS & BOUCKAERT, 1968, p. 30, pl. 2, fig. 5; RHODES, AUSTIN & DRUCE, 1969, p. 95, pl. 19, figs. 9-12; WEBSTER, 1969, p. 31, pl. 5, fig. 13; Hisaharu IGO, 1973, p. 193-194, pl. 29, figs. 8-13; IGO & KOBAYASHI, 1974, p. 420-421, pl. 56, figs. 6, 7.

Gnathodus commutatus commutatus, BISCHOFF, 1957, p. 23, pl. 4, figs. 2-6, 15; KOIKE, 1967, p. 296, pl. 1, figs. 12-16; WIRTH, 1967, p. 206, pl. 19, figs. 10, 11; DUNN, 1970, p. 331, pl. 62, figs. 11, 12; MARKS & WENSINK, 1970, p. 285, pl. 3, figs. 1a-b; LANE & STRAKA, 1974, p. 77-78, pl. 37, figs. 1-9; pl. 40, figs. 15-18, 23-26.

Gnathodus scotiaensis GLOBENSKY, 1967, p. 441, pl. 58, figs. 2-7, 10, 12.

Remarks: A detailed synonymy was given by RHODES, AUSTIN & DRUCE (1969, p. 95-96).

Material studied and occurrence: 13 specimens from (1), (2), (3), (6) and (8) of the Sec. N-I and 21 specimens from (7), (9) and (10) of the Sec. K-I.

Reg. Nos.: TGU 1112, 1113, 1114, 1115, 1116, 1117, 1118.

Gnathodus nodosus BISCHOFF

Pl. 14, Figs. 12-16

Gnathodus commutatus nodosus BISCHOFF, 1957, p. 23-24, pl. 4, figs. 12, 13; HIGGINS, 1961, p. 213, pl. 10, figs. 7, 8; KOIKE, 1967, p. 297, pl. 1, fig. 19; WIRTH, 1967, p. 207-208, pl. 2, figs. 15-18; MARKS & WENSINK, 1970, p. 260, pl. 3, figs. 3, 4.

Gnathodus nodosus, RHODES, AUSTIN & DRUCE, 1969, p. 104-105, pl. 19, figs. 16a-20c; Hisaharu IGO, 1973, p. 194, pl. 19, figs. 14-17; IGO & KOBAYASHI, 1974, p. 421, pl. 56, figs. 8-12.

Remarks: All recovered specimens referable to *Gnathodus nodosus* BISCHOFF from the Omi Limestone vary in form from nodose ridge on both sides of the platform to fused into a lengthened node extending anteriorly. These specimens occur within one rock sample. Therefore, it seems to display some morphological gradation within a species.

Material studied and occurrence: 1 specimen from (3) of the Sec. N-I and 10 specimens from (2), (7) and (9) of the Sec. K-I.

Reg. Nos.: TGU 1119, 1120, 1121, 1122.

Genus *Hindeodella* ULRICH

& BASSLER, 1926

Type species: *Hindeodella subtilis* BASSLER, 1925.

Hindeodella segaformis BISCHOFF

Pl. 15, Figs. 8-10

Hindeodella segaformis BISCHOFF, 1957, p. 28-29, pl. 5, figs. 40, 41a-b, 43; MARKS & WENSINK, 1970, p. 265, pl. 1, figs. 2a-b; AUSTIN & GROESSENS, 1972, pl. 1, figs. 13, 19.

Remarks: The present specimens are fragmentary. However, it is distinguished from the other hindeodellids by

the pronounced angular zig-zag bending bar and a larger denticles on the apex of each bend.

Material studied and occurrence: Only fragments from (7), (9) and (10) of the Sec. K-I.

Reg. Nos.: TGU 1123, 1124.

Hindeodella sakagamii IGO & KOIKE

Pl. 15, Fig. 7

Hindeodella sakagamii IGO & KOIKE, 1964, p. 184, pl. 27, figs. 1, 2; IGO & KOIKE, 1965, p. 85, pl. 8, figs. 1, 2; KOIKE, 1967, pl. 4, fig. 4.

Material studied and occurrence: Only fragments from (1) to (8) of the Sec. N-I and (2) of the Sec. K-I.

Reg. No.: TGU 1125.

Genus *Hindeodus* REXROAD
& FURNISH, 1964

Type species: *Trichonodina imperfecta* REXROAD, 1957.

Hindeodus alatooides
(REXROAD & BURTON)

Pl. 15, Fig. 17

Falcodus? alatooides REXROAD & BURTON, 1961, p. 1152, pl. 140, fig. 8.

Hindeodus alatooides (REXROAD & BURTON), REXROAD & FURNISH, 1964, p. 67, pl. 111, figs. 18, 19; REXROAD & NICOLL, 1965, p. 20, pl. 2, fig. 10; KOIKE, 1967, p. 304, pl. 4, figs. 5-10.

Remarks: The above mentioned synonymy was given by REXROAD & NICOLL (1965, p. 20).

Material studied and occurrence: 1 specimen from (10) of the Sec. K-I.

Reg. No.: TGU 1126.

Genus *Magnilaterella* REXROAD
& COLLINSON, 1963

Type species: *Magnilaterella robusta* REXROAD & COLLINSON, 1963.

Magniraterella sp.

Pl. 15, Figs. 15, 16

Remarks: The present specimen is closely related to a species of *Ligonodina*. The largest denticle on the lateral bar, which is characteristic in this genus, occurs near the midpoint.

Material studied and occurrence: 1 specimen from (1) of the Sec. N-I and 2 specimens from (6) of the Sec. K-I.

Reg. No.: TGU 1127.

Genus *Ozarchodina* BRANSON
& MEHL, 1933

Type species: *Ozarchodina typica* BRANSON & MEHL, 1933.

Ozarchodina compressa REXROAD

Pl. 14, Figs. 20, 21

Ozarchodina compressa REXROAD, 1957, p. 36, pl. 2, figs. 1, 2; REXROAD, 1958, p. 24, pl. 6, figs. 1, 2; REXROAD & BURTON, 1961, p. 1156, pl. 141, figs. 16, 17; REXROAD & NICOLL, 1965, p. 24, pl. 2, figs. 3, 4; THOMPSON & GOEBEL, 1968, p. 40, pl. 3, figs. 17, 20.

Remarks: The present specimens recovered are closely similar to the type specimens.

Material studied and occurrence: 1 specimen from (1) of the Sec. N-I and 2 specimens from (10) of the Sec. K-I.

Reg. Nos.: TGU 1128, 1129.

Ozarchodina subaequalis (HIGGINS)

Pl. 14, Figs. 22, 23

Subbryantodus subaequalis HIGGINS, 1961, p. 219, pl. 12, fig. 15, text-fig. 6-1.*Ozarchodina subaequalis*, MARKS & WENSINK, 1970, p. 267-268, pl. 1, fig. 13 only.*Ozarchodina* cfr. *recta*, DUNN, 1970, p. 338, pl. 62, figs. 25-26.

Remarks: The present specimen recovered in this study is closely similar to *Ozarchodina subaequalis* described by MARKS & WENSINK (1970). This species differs from the other ozarchodinids in the presence of discrete, down-curved posterior blade.

Material studied and occurrence: 3 specimens from (9) of the Sec. K-I.

Reg. No.: TGU 1130.

Genus *Neoprioniodus* RHODES
& MÜLLER, 1956

Type specimen: *Prioniodus conjunctus* GUNNELL, 1931.

Neoprioniodus loxus REXROAD

Pl. 14, Fig. 19

Neoprioniodus loxus REXROAD, 1957, p. 34, pl. 2, figs. 8, 9; REXROAD, 1958, p. 23, pl. 5, figs. 7-9; REXROAD & BURTON, 1961, p. 1155, pl. 140, fig. 12; REXROAD & COLLINSON, 1963, p. 18, pl. 2, fig. 28; REXROAD & FURNISH, 1964, p. 674, pl. 111, fig. 26; REXROAD & NICOLL, 1965, p. 23, pl. 2, fig. 23; THOMPSON & GOEBEL, 1968, p. 38, pl. 3, figs. 4, 12; WEBSTER, 1969, p. 39, pl. 7, fig. 12.

Remarks: A detailed synonymy was given by WEBSTER (1969, p. 39).

Material studied and occurrence: 2 specimens from (9) of the Sec. K-I.

Reg. No.: TGU 1131.

Neoprioniodus scitulus

(BRANSON & MEHL)

Pl. 14, Figs. 17, 18

Prioniodus scitulus BRANSON & MEHL, 1941, p. 173, pl. 5, figs. 5, 6.

Neoprioniodus scitulus, REXROAD, 1957, p. 35, pl. 2, figs. 22, 26; REXROAD & NICOLL, 1965, p. 23, pl. 2, figs. 11, 12; KOIKE, 1967, p. 307-308, pl. 4, figs. 31, 32; WEBSTER, 1969, p. 39-40, pl. 7, fig. 13; RHODES, AUSTIN & DRUCE, 1969, p. 162-163, pl. 22, figs. 9a-10b; Hisaharu IGO, 1974, p. 195, pl. 29, figs. 30, 31.

Remarks: A detailed synonymy was given by WEBSTER (1969, p. 39-40).

Material studied and occurrence: 15 specimens from (6), (7), (9) and (10) of the Sec. K-I.

Reg. Nos.: TGU 1132, 1133, 1134.

Genus *Spathognathodus* BRANSON
& MEHL, 1941

Type species: *Spathodus primus* BRANSON & MEHL, 1933.

Spathognathodus campbelli REXROAD

Pl. 15, Figs. 11-14

Spathognathodus campbelli REXROAD, 1957, p. 37, pl. 3, figs. 13-15; REXROAD, 1958, p. 25, pl. 6, fig. 9; REXROAD & BURTON, 1961, p. 1156, pl. 141, fig. 15; HIGGINS, 1962, pl. 2, fig. 20; REXROAD & FURNISH, 1964, p. 674, pl. 111, figs. 23, 24; REXROAD & NICOLL, 1965, p. 26, pl. 1, fig. 6; GLOBENSKY, 1967, p. 447, pl. 55, figs. 12, 20; KOIKE, p. 310, pl. 3, figs. 26-34; WIRTH, 1967, p. 233-234, figs. 14-16; THOMPSON & GOEBEL, 1968, p. 41-42, pl. 4, fig. 11; WEBSTER, 1969, p. 43-44, pl. 7, fig. 5; DUNN, 1970, p. 339, pl. 64, fig. 31; MARKS & WENSINK, 1970, p. 270, pl. 4, figs. 9-10; Hisaharu IGO, 1973, p. 196,

pl. 29, fig. 23.

Spathognathodus cf. *campbelli*, RHODES, AUSTIN & DRUCE, 1969, p. 223, pl. 8, figs. 1-4.

Remarks: Numerous specimens referred to this species indicate conspicuous variation in the arrangement of denticles, which were already remarked by KOIKE (1967, p. 310).

Material studied and occurrence: 2 specimens from (1) and (2) of the Sec. N-I and 197 specimens from (6), (7), (9), (10) and (11) of the Sec. K-I.

Reg. Nos.: TGU 1135, 1136, 1137, 1138.

Spathognathodus minutus (ELLISON)

Pl. 15, Fig. 18

Spathognathodus minutus (ELLISON), REXROAD & BURTON, 1961, p. 1156-1157, pl. 141, figs. 10-11; IGO & KOIKE, 1965, p. 88-89, pl. 9, figs. 16-18; KOIKE, 1967, p. 311, pl. 3, figs. 39-42; WEBSTER, 1969, p. 44, pl. 7, fig. 4; DUNN, 1970, p. 339, pl. 61, figs. 27, 30; DUNN, 1965, p. 140, figs. 15, 21, 24. *Spathognathodus rexroadi* WEBSTER, 1969, p. 45, pl. 7, figs. 2, 3.

(Further synonyms: see MERRILL (1973, p. 305-306))

Remarks: MERRILL (1973) summarized the Mississippian-Pennsylvanian spathognathodids depending on the biometrics and discriminated between *Spathognathodus minutus*-group and *S. ellisoni*-group in the already known specimens of *S. minutus*.

The present specimen fall in the transitional form of them. However, the Omi specimen is closely similar to *Spathognathodus rexroadi* WEBSTER (= *S. minutus* by MERRILL) described by WEBSTER (1969) from Southern Nevada.

Material studied and occurrence: 2 specimens from (1) and (8) of the Sec. N-I and 3 specimens from (9) of the Sec.

K-I.

Reg. Nos.: TGU 1139, 1140.

Gen. et sp. indet.

Pl. 15, Figs. 21-24

Description: Complex unit consisting of four processes; a carina-like posterior process, two lateral processes and a blade-like anterior process. Anterior denticulate process is thin with apical denticles, usually triangular in shape. Postero-lateral processes are thick and rod-like with stout denticles bending antero-posteriorly. A basal pit is located on the lower surface at the juncture of the lateral processes with blade-carina from which the keel and secondary keels extend posteriorly and toward the lateral processes. The anterior blade inclines somewhat outward and downward, and it may be slightly sinuous.

Remarks: The present specimens recovered are fragmentary. However, the general form is most similar to a species of the genus *Ancyrodella* with no or considerably reduced platform. Namely, *Ancyrodella ioides* described by ZIEGLER (1958, p. 42, pl. 11, figs. 4-11) from the early Upper Devonian of Europe is closely similar to the present specimens with a long high blade and two lateral branches. Probably, it is thought to be a descendant form of the above species-group. Also, the present ones are related with *Lambdagnathus* REXROAD described from the Chesterian of North America, but it differs particularly in having of four processes instead of three.

Material studied and occurrence: 4 specimens from (7) of the Sec. K-I.

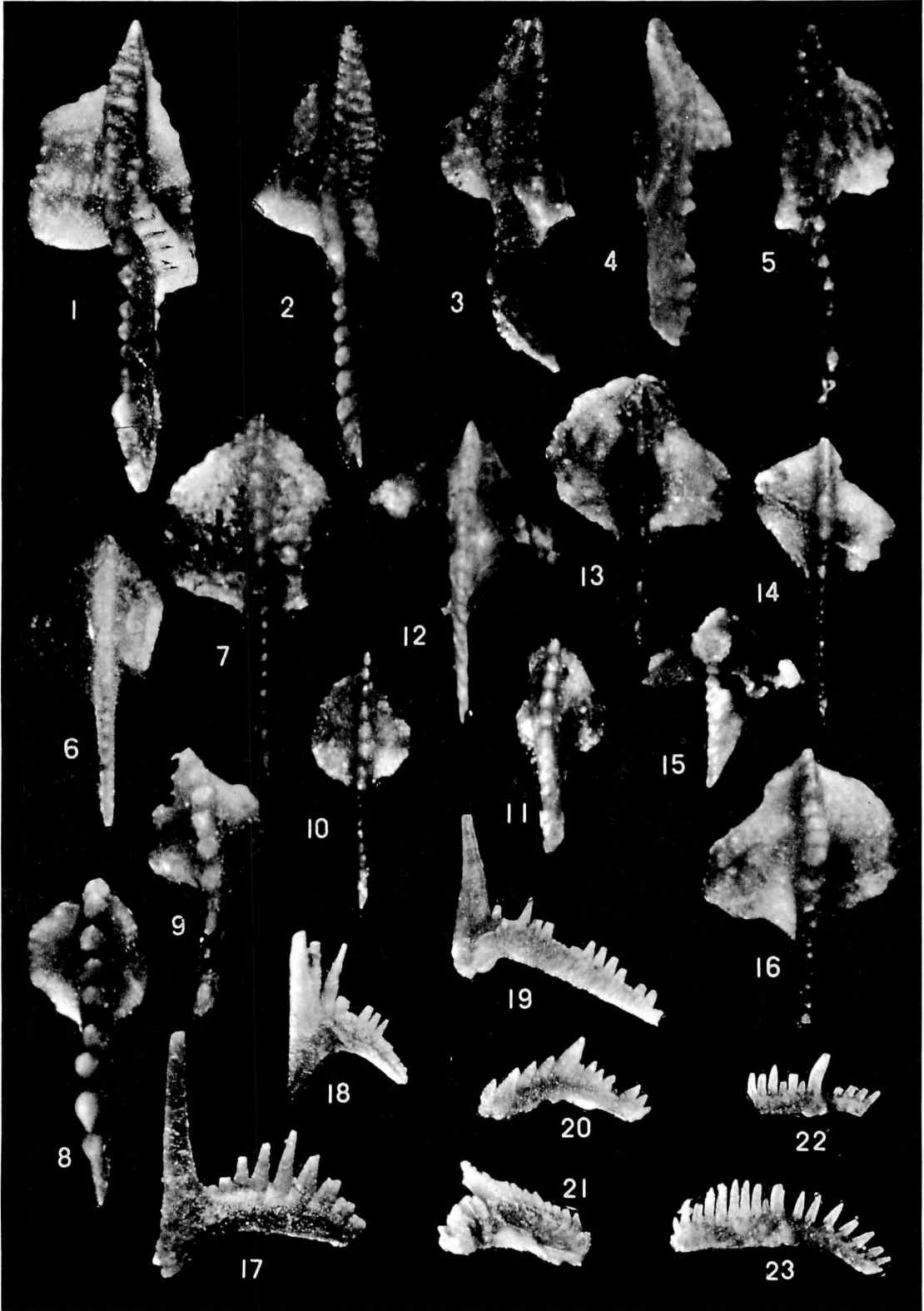
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Explanation of Plate 14

- Figs. 1-5. *Gnathodus bilineatus* (ROUNDY)
1. Oral view. $\times 30$, from (7) of the Sec. K-I; 2-5. Oral views. $\times 40$, from (2), (4), (6) and (8) of the Sec. N-I.
- Figs. 6, 7. *Gnathodus* cfr. *bilineatus* (ROUNDY)
6, 7. Oral views. $\times 40$, from (4) and (7) of the Sec. K-I.
- Figs. 8-11. *Gnathodus commutatus* (BRANSON & MEHL)
8, 9. Oral views. $\times 40$, from (3) and (6) of the Sec. N-I; 10, 11. Oral views. $\times 40$, from (7) and (9) of the Sec. K-I.
- Figs. 12-16. *Gnathodus nodosus* BISCHOFF
12, 13. Oral views. $\times 40$, from (3) of the Sec. N-I; 14-16. Oral views. $\times 40$, from (7) and (9) of the Sec. K-I.
- Figs. 17, 18. *Neoprioniodus scitulus* (BRANSON & MEHL)
17, 18. Lateral views, $\times 30$, from (6) and (9) of the Sec. K-I.
- Fig. 19. *Neoprioniodus loxus* REXROAD
19. Lateral view. $\times 30$, from (9) of the Sec. K-I.
- Figs. 20, 21. *Ozarchodina compressa* REXROAD
20. Lateral view. $\times 30$, from (1) of the Sec. N-I; 21. Lateral view. $\times 30$, from (10) of the Sec. K-I.
- Figs. 22, 23. *Ozarchodina subaequalis* (HIGGINS)
22, 23. Lateral views. $\times 30$, from (9) of the Sec. K-I.

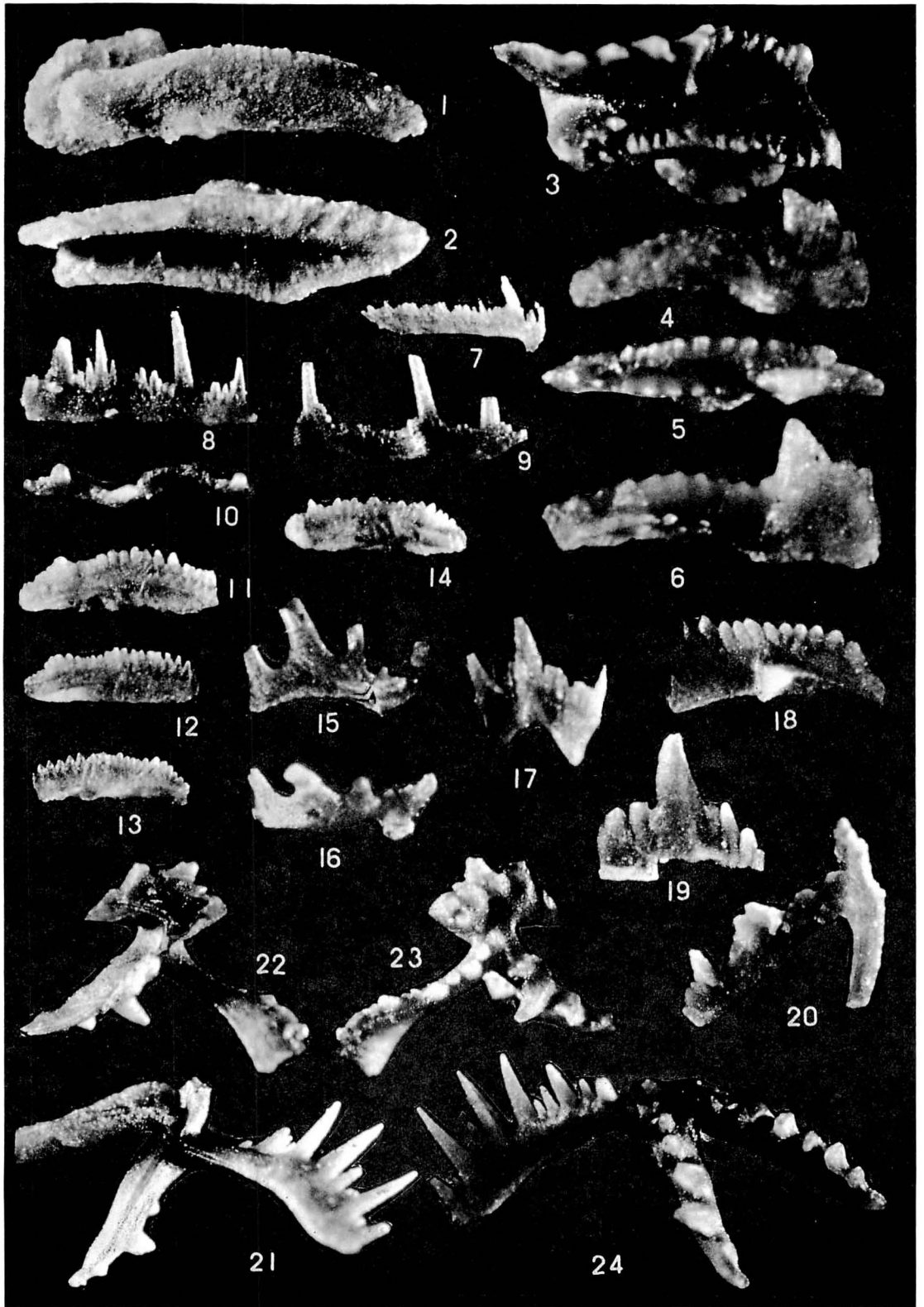


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Explanation of Plate 15

- Figs. 1, 2, 4-6. *Cavusgnathus unicornis* YOUNGQUIST & MILLER
1, 4, 6. Lateral views. 2-5. Oral views. 1, 2. $\times 30$, 4-6. $\times 40$, from (1), (2) and (6) of the Sec. N-I.
- Fig. 3. *Cavusgnathus* sp.
3. Oral view. $\times 30$, from (2) of the Sec. N-I.
- Fig. 7. *Hindeodella sakagami* IGO & KOIKE
7. Lateral view. $\times 30$, from (1) of the Sec. N-I.
- Figs. 8-10. *Hindeodella segaformis* BISCHOFF
8, 9. Lateral views. 10. Oral view. $\times 30$, from (7) and (9) of the Sec. K-I.
- Figs. 11-14. *Spathognathodus campbelli* REXROAD
11-14. Lateral views. $\times 30$, from (6), (7), (10) and (11) of the Sec. K-I.
- Figs. 15, 16. *Magniraterella* sp.
15. Lateral view. 16. Oral view. $\times 30$, from (6) of the Sec. K-I.
- Fig. 17. *Hindeodus alatooides* (REXROAD & BURTON)
17. Lateral view. $\times 30$, from (10) of the Sec. K-I.
- Fig. 18. *Spathognathodus minutus* (ELLISON)
18. Lateral view. $\times 30$, from (1) of the Sec. N-I.
- Fig. 19. *Lonchodina* ? sp.
19. Lateral view. $\times 30$, from (2) of the Sec. N-I.
- Fig. 20. *Apathognathus* ? sp.
20. Lateral view. $\times 30$, from (8) of the Sec. N-I.
- Figs. 21-24. Gen. et sp. indet.
23, 24. Oral views. 21, 22. Aboral views. $\times 30$, from (7) of the Sec. K-I.



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**POLICY PROVISIONS OF THE TRANSACTIONS AND PROCEEDINGS OF
THE PALAEOLOGICAL SOCIETY OF JAPAN**

(January 16, 1973)

I Publication and Editing

IA Issue

- 1 The "Transactions and Proceedings of the Palaeontological Society of Japan" (TPPSJ) will be published quarterly.

IB Contents

- 1 TPPSJ will include original papers and notes that comply with Article 2 of the Constitution of the Society as well as the proceedings of the Society meetings and news concerning any aspect of palaeontology.
- 2 Contributions will be published in the order of the acceptance by the Editorial Board.

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- 1 All members of the Society and some organizations specified by the Council will generally receive TPPSJ free of charge. Non-members and institutions are invited to become subscribers.

ID Editorial Board

- 1 The Editorial Board will be responsible for editing TPPSJ according to the policy provisions of the Society.
- 2 The Editorial Board will be composed of the Editor in Chief, who must be a member of the Council, and several members designated by the Executive Committee. All editorial meetings will be called by the Editor in Chief.
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- 4 The final decision on the acceptance or rejection of submitted manuscript will be made by the Editorial Board at an editorial meeting. The Editor in Chief will report the results of the meeting to the Executive Committee.
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- 1 Manuscript should be typewritten, and should be limited to 24 printed pages including tables and text-figures. Two plates may also be added to it. Plates may not be attached to the articles of up to 4 printed pages only without the approval of the Editorial Board. Notes may not exceed one printed page, and no plate may be used for it.

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- ii) The approved policy provisions will nullify and replace existing "Regulations for Publication in Transactions and Proceedings of the Palaeontological Society of Japan".

例会等の通知

	開催地	開催日	講演申込締切日
116回例会	金沢大学	1975年9月23,24日	1975年7月20日
1976年総会・年会	鳴子川渡 共同セミナーハウス	1976年1月30,31日	1975年11月20日
117回例会	北海道大学(予定)	1976年6月下旬	1976年4月20日

◎ 116回例会ではコロキウム「硬組織の付加生長と生長線」(世話人・小西健二)が予定されている。

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