Redescription of Cryptopecten yanagawaensis (NOMURA and ZINBO) : Paleontological Study of the Molluscan Fauna from the Moniwa Formation Part-2

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https://doi.org/10.5109/1546098

出版情報：九州大學理學部紀要 : Series D, Geology. 25 (2), pp.247-269, 1984-11-15. Faculty of Science, Kyushu University

Mem. Fac. Sci., Kyushu Univ., Ser. D, Geol., Vol. XXV, No. 2,
pp. 247-269, text-figs. 1-7, tables 1-2, plates 36-37, Nobember 15, 1984

Redescription of *Cryptopecten yanagawaensis* (NOMURA and ZINBO) (Paleontological Study of the Molluscan Fauna from the Moniwa Formation Part-2)

Yoshio SATO

Abstract

This paper gives a redescription of a Miocene pectinid, *Cryptopecten yanagawaensis* (NOMURA and ZINBO) which occurs mainly in the beds aged 16 Ma, the early Medial Miocene. The present species is one of the most characteristic ones of the molluscan fauna of the Moniwa Formation and is presumed to be ancestor of the Pliocene and Recent species, *C. vesiculosus* (DUNKER). By way of block sampling method the writer collected more than 200 free specimens from 18 samples taken from the Moniwa Formation which yields many best preserved specimens. Redescription of the species is made by applying the results from paleoautoecological analysis. This paper also refers to the geographic and stratigraphic distribution and paleoecology of the species.

Introduction

The present article is the second report on the molluscan fauna of the Moniwa Formation distributed in the environs of Sendai, Miyagi Prefecture, Northeast Japan.

It is well known that the Moniwa Formation yields various kinds of megafossils such as molluscs, brachiopods, barnacles, corals, echinoids and vertebrate-bones in association with micro-fossils such as foraminifers and ostracods. These rich faunas have been studied by many specialists. Subsequently, the molluscan faunas have been restudied with proposal of some new taxa (HATAI, MASUDA and NODA, 1973 and SATO, 1982).

Sedimentary environments of the Moniwa Formation were summarized by OYAMA (1954) and MASUDA (1969), Who presumed a marine condition influenced by warm water of open sea.

Recently, a systematic study of the Moniwa fauna was carried out, in which many block samples were collected from each fossil locality of the Moniwa Formation and treated in the water bath in order to recognize the whole paleontological feature of fossil assemblages and to get environmental information (SATO, 1979 and 1982). A number of species that had not been reported before were found by this procedure. NOMURA's pioneer work (1940) is very valuable but it is taxonomically insufficient, and nothing has been done in paleosynecology. Because his descriptions were based on the specimens obtained in an

Manuscript received July 20, 1984.

unsystematic manner and lack comparison with specimens from other Tertiary deposits and also those with Recent species. Furthermore, he didn't treat the species on the basis of the population concept. Such being the case the writer has been working on revision and description of these molluscs in view of the modern taxonomy.

The shell height, width, depth, apical angle, length of both ears, and number of radial ribs are measured, and the ontogenetical change of the apical angle, proportion of shell height to width, number of radial ribs and differentiation of radial ribs are examined in growth series.

MORISHITA's $R\delta$, coefficient of interspecific association among the characteristic species, is calculated. *Cryptopecten yanagawaensis* shows harmonic association with *Glycymeris derelicta* (YOKOYAMA) and *Placopecten nomurai* MASUDA. Present species is a typical member of *Placopecten nomurai* MASUDA ———— *C. yanagawaensis* (NOMURA and ZINBO) *community*.

Acknowledgements

The writer takes this opportunity to express his deepest gratitude to Professor Tsugio SHUTO of the Department of geology, Faculty of Science, Kyushu University, for his supervision during the whole course of the present study and critically reading the manuscript, and wishes to dedicate this article to this memorial volume in honour of Prof. SHUTO.

Acknowledgements are due to Professor Koichiro MASUDA of the Miyagi University of Education for his valuable suggestion on various ways and photographic works.

During the course of this study the writer has received support from the following persons to whome he takaes this opportunity to express his deep gratitude; Professor Itaru HAYAMI, department of geology, Faculty of Science of the University of Tokyo, for his information of recent species of *Cryptopecten*, Dr. Shoichi SHIMOYAMA, Department of Geology, Kyushu University, for his discussion on paleoautoecology, Dr. Kenshiro OGASAWARA of the Institute of Geology and Paleontology, Tohoku University, for his permission to study the specimens preserved there.

Stratigraphical setting of the Moniwa Formation

The Moniwa Formation, distributed in the southwestern area of Sendai City, is a constituent of the Natori Group. The latter is composed of the Tsukinoki, Takadate, Moniwa, Hatatate and Tsunaki foramtion in ascending order and represents a standard section of the Miocene deposits in the Pacific coast region of Northeast Japan (HANZAWA, S., HATAI, K., IWAI, J. KITAMURA, N. and SHIBATA, T., 1953).

The Moniwa Formation covers the Takadate Formation unconformably. Its basal conglomerate was widely traced by SATO (1979). The Hatatate Formation conformably covers the Moniwa Formation and the boundary between them is defined by a lapilli tuff at the east end of the type section of the Moniwa Formation. In the southwestern area, the transitional part of lithology from green coarse grained sandstone to white fine grained sandstone or silt is considered to correspond to the boundary mentioned above. While the Moniwa Formation is nearly flat in most area, it shows a gentle northward dip with the strike of E-W trend in the eastern area. The Moniwa Formation is distributed surrounding the lower Takadate Formation and shows steep dip at some places where it abuts on the Takadate Formation or is intruded by intrusive rocks. Thickness of the Moniwa Formation ranges from 3 meters to 28 meters and becomes thinner southward from its type locality. Geological age of the Moniwa Formation was assigned to the Early Miocene by molluscan fossils by MASUDA (1973 a). Subsequently, ODA and SAKAI (1977) recognized *Globigerinoides sicanus/Globigerinatella insueta* Zone in the Moniwa Formation and referred it to N 8, the Early Miocene. Recently, TSUCHI (1984) and TSUCHI and SHUTO (1984) also considered that this formation corresponds to belong to N 8 b, early Medial Miocene.

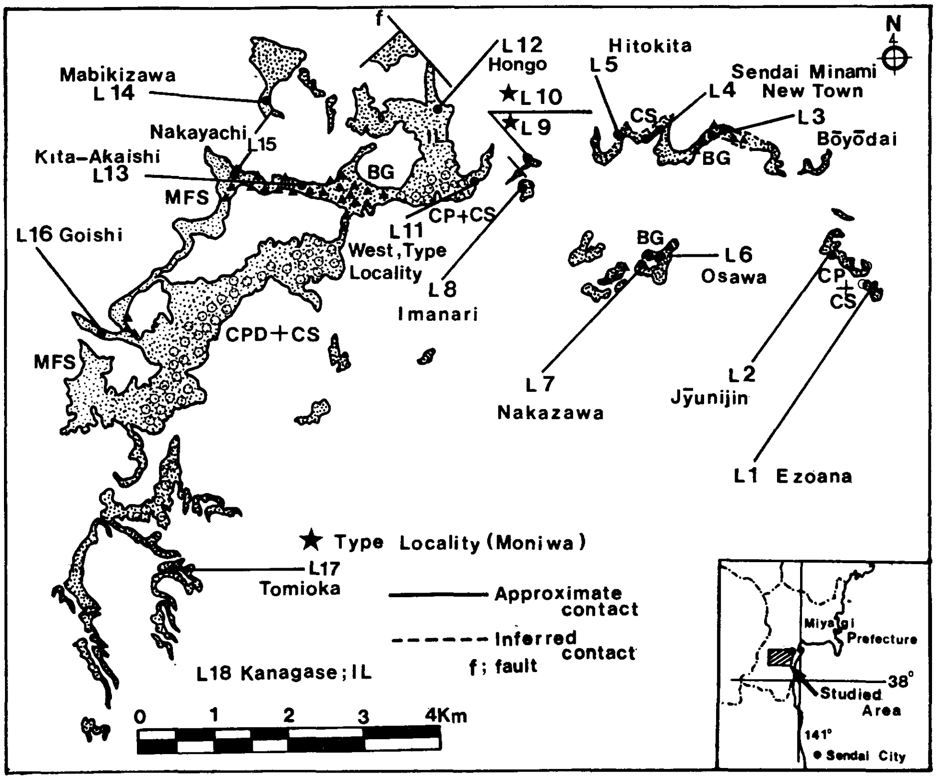

Fig. 1. Horizontal distribution of rock facies and fossil localities. CS (Coarse grained sandstone); MFS (Medium to fine grained standstone); IL (Impure limestone); CPD+CS (Dioritic pebble bearing conglomeratic coarse grained sandstone); CP+CS (Pebble bearing conglameratic coarse grained sandstone). L 18 (Kanagase) is located 14 km south from L 17.

Distribution and lithology of the Moniwa Formation is shown in Fig. 1. This foramtion is generally composed of coarse grained sandstone with andesite pebbles and granules and it gradually grades upward into conglomeratic coarse grained sandstone to coarse grained sandstone. In eastern area greenish coarse grained sandstone is predominant, while blush medium grained sandstone is found in the western area. Sediments are not so hard that fossils are easily detached from the block samples except for the calcareous coarse and fine grained sandstone at fossil locality L 9 and L 13. Pebbles and granules in the Moniwa Formation are so thin and flat that the formation is easily discriminated from other formations. Lithology of these pebbles and granules changes from andesitic to dioritic southward. Surface of the boulders is very smooth and occasionally bored by boring shells (MASUDA, 1968). Calcareous tubes made by worms and attachment scar of *Balanus* and *Ostrea sp.* are observed on the surface of boulders at L 3, L 8 and L 13.

Fossil Localities and Occurrence of Fossils

Eighteen fossil localities are studied (Fig. 1). L 9 and L 10 are situated along the type section of the Moniwa Formation. Stratigraphic position of L 10 is five meters above L 9. L 13 at Kita-akaishi is the same locality as that of NOMURA (1940). Precise description of fossil localities of the present species are listed in the separate chapter.

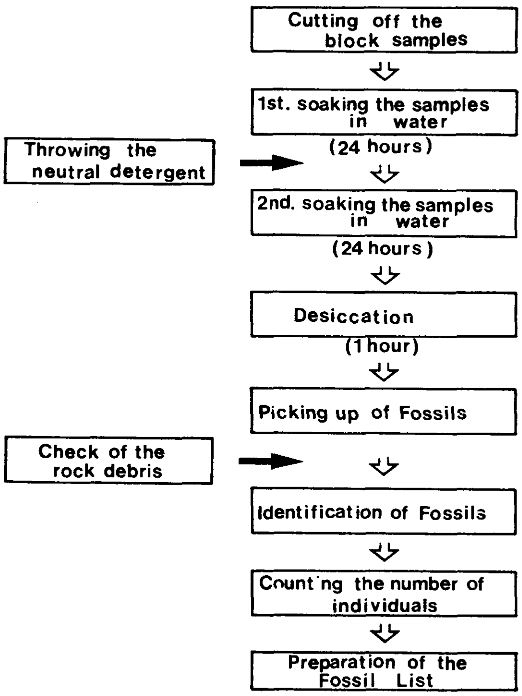

Fig. 3. Treatment of block samples.

Fossils mainly consist of bivalves. They are generally accumulated and inarticulated in fossil beds. Mode of occurrence can be classified into the following three types: (1) shells are accumulated and orientated nearly parallel to the bedding plane, with their convex side upwards, (2) shells accumulated and orientated obliquely or perpendicularly to the bedding palne with their convex side turned dowunward, (3) shells trapped and accumulated in boulder gravels. Of them the type (2) predominates over others.

Method of Sampling and Treatment of Black Samples

Sampling localities where shells are expected to distribute uniformly in the shell bed are carefully selected. The shell bed is cut perpendicularly to the bedding plane at each sampling locality to obtain a block sample of 30 cm long, 30 cm wide and 20 cm thick. Number of blocks at one locality depends upon density of shells in the matrix. Sampling procedure is continued successively until total number of shells exceeds three hundreds. At L 2, additional samples were obtained in order to get more than two hundred valves of the present species. Treatment of block samples is shown in Fig. 2. They are soaked in water for two days and fossils are detached from matrix one hour after leaving water. A fractured shell is counted as an individual, if it holds two-thirds or more of the entire shell is preserved and also the measurement of shell height is possible.

Characteristic Species of the Moniwa Formation

Characteristic species of megafossils such as molluscs, brachiopods and simple corals are listed in Fig. 5. Species occurring at more than six localities with more than fifty individuals are defined in this paper as characteristic species. Characteristic species all indicate a warm, shallow to neritic and open marine environment in which they lived. Pectinidae is by far predominant over the others and the present species is ranked at ninth in the characteristic species. It can be considered that molluscan assemblages of the Moniwa Formation are shallower subtidal ones on the sand, sand with pebbles and rocky bottom belonging to the Kadonosawa Fauna (CHINZEI, 1983) among the Neogene Tertiary molluscan faunas.

Description of *Cryptopecten yanagawaensis* (NOMURA and ZINBO)

Genus *Cryptopecten* DALL, BARTSCH & REHDER, 1938
Type-species:—*Cryptopecten alli* DALL, BARTSCH & REHDER
by orginal designation

Cat. No. 173194, 190440 and 335667. (United States National Museum) No. 173194 Measurements on ; Height 22.1 mm, length, 22.8 mm, diameter of single valve, 3.3 mm.

Table 1. Measurements of *Cryptopecten yanagawaensis* (NOMURA and ZINBO). Right valve.

Reg. No.	Loc.	H	W	E_1	E_2	D	C	A.A.	H/W	N.R.
GK-L9294	L2	10.35	10.80	4.10	2.60	2.40	0.70	93°	0.96	21
9295	L2	11.00	11.20	4.10	2.90	1.95	0.45	91°	0.98	23
9296	L2	12.10	12.10	4.10	3.30	2.50	0.65	93°	1.00	22
9297	L18	12.60	11.70	3.40	3.20	2.50	0.55	89°	1.08	21
9298	L2	12.80	12.40	4.10	3.40	2.80	+	90°	1.03	22
9299	L2	14.50	14.20	4.80	3.90	3.20	0.80	90°	1.02	24
9300	L2	14.50	14.80	4.70	3.60	3.65	0.85	91°	0.98	23
9301	L2	14.50	13.60	4.50	2.50	2.65	0.65	91°	1.07	23
9302	L2	14.70	13.80	4.75	3.30	3.70	0.85	90°	1.07	21
9303	L2	14.70	14.30	5.35	3.60	4.25	0.65	87°	1.03	23
9304	L12	15.25	14.50	5.20	4.80	4.05	0.70	88°	1.05	24
9305	L2	15.40	14.70	4.70	3.10	2.65	0.70	89°	1.05	24
9306	L2	15.90	17.00	+	5.10	3.30	1.00	89°	0.94	24
9307	L2	15.90	15.40	+	5.10	2.90	0.75	88°	1.03	21
9308	L12	16.30	16.70	+	4.80	4.45	1.00	91°	0.98	24
9309	L12	16.60	17.60	5.55	4.00	4.45	0.80	90°	0.94	20
9310	L2	16.70	16.90	+	4.05	3.05	0.80	88°	0.99	23
9311	L2	16.70	17.25	5.80	4.70	2.95	0.85	94°	0.97	22
9312	L2	16.75	16.40	+	3.65	3.60	0.85	90°	1.02	23
9313	L2	17.00	17.00	+	+	3.60	+	90°	1.00	25
9314	L2	17.10	17.80	+	+	+	1.00	+	0.96	+
9315	L2	17.20	17.60	4.50	4.10	3.55	0.80	+	0.98	24
9316	L2	17.20	17.65	+	4.30	3.65	0.85	90°	0.97	22
9317	L2	17.25	17.30	4.40	3.50	3.70	0.80	98°	1.00	24
9318	L2	17.40	17.00	5.20	4.20	4.60	1.00	87°	1.02	23
9319	L2	17.40	17.60	5.30	5.20	3.70	1.00	92°	0.99	24
9320	L2	17.65	17.40	5.60	3.60	5.60	1.00	90°	1.01	24
9321	L2	17.80	18.10	5.10	3.60	4.10	+	90°	0.98	20
9322	L12	17.80	17.60	6.00	5.60	3.20	1.05	91°	1.01	23
9323	L12	18.20	20.30	+	5.10	4.50	0.85	88°	0.90	23
9324	L2	18.25	19.40	7.00	4.95	3.80	0.80	93°	0.94	23
9325	L2	18.35	18.70	+	5.10	5.20	0.98	95°	0.98	23
9326	L2	18.55	19.40	5.40	4.30	4.75	0.90	89°	0.96	22
9327	L2	18.60	18.25	5.65	4.05	3.60	1.00	89°	1.02	22
9328	L2	18.85	19.80	6.00	4.30	3.95	0.85	92°	0.95	21
9329	L2	18.90	18.00	5.15	4.80	4.10	0.80	91°	1.05	25
9330	L12	19.00	20.50	5.80	4.80	4.75	1.00	92°	0.93	22
9331	L12	19.00	22.60	+	+	+	1.00	+	0.84	+
9332	L2	19.10	20.00	4.40	3.85	4.40	0.85	95°	0.96	22
9333	L2	19.30	18.10	6.50	+	3.85	0.80	91°	1.07	21
9334	L12	19.30	19.05	7.05	5.60	4.70	1.00	91°	1.01	24
9335	L2	19.50	20.80	+	+	4.50	0.90	88°	0.92	25
9336	L2	19.55	19.85	6.05	4.60	4.20	0.90	89°	0.98	21
9337	L12	19.95	21.30	7.05	5.60	4.70	1.30	91°	0.94	24
9338	L2	19.95	19.50	4.70	3.70	3.70	1.00	90°	1.02	22
9339	L2	20.00	22.00	6.70	3.60	5.40	1.10	92°	0.91	26
9340	L2	20.20	21.20	5.20	4.10	5.65	+	88°	0.95	23
9341	L2	20.20	18.60	5.40	3.80	5.50	0.90	83°	1.12	25
9342	L2	20.40	21.80	+	5.20	5.10	0.90	92°	0.94	25
9343	L2	20.45	21.80	7.40	5.30	5.70	1.20	91°	0.94	26

(Table 1 continued)

Reg. No.	Loc.	H	W	E_1	E_2	D	C	A.A.	H/W	N.R.
GK-L9344	L12	20.50	22.75	+	+	5.45	1.05	91°	0.90	24
9345	L2	20.60	22.65	7.90	5.50	5.90	1.30	91°	0.91	25
9346	L2	20.65	20.20	5.70	3.60	4.10	1.00	88°	1.02	23
9347	L2	20.75	22.40	7.60	5.80	4.55	0.90	89°	0.93	23
9348	L2	21.00	21.90	+	5.70	4.90	1.00	87°	0.96	23
9349	L12	21.50	23.10	9.50	6.80	5.00	1.20	90°	0.93	24
9350	L2	21.60	23.10	8.55	5.50	5.80	1.00	91°	0.94	24
9351	L2	21.70	22.00	7.00	5.30	5.20	1.20	89°	0.99	26
9352	L2	21.70	20.60	5.00	3.80	4.10	+	88°	1.05	23
9353	L2	21.80	24.25	7.85	6.00	6.10	1.20	88°	0.89	23
9354	L2	22.00	24.95	+	+	5.50	1.00	92°	0.88	26
9355	L2	22.25	23.40	6.45	4.90	3.00	+	92°	0.95	25
9356	L2	22.60	25.70	8.60	5.05	6.50	1.20	90°	0.88	25
9357	L2	23.00	25.25	8.75	6.40	7.65	1.40	89°	0.91	23
9358	L2	23.20	24.15	+	6.10	4.45	1.25	91°	0.96	22
9359	L12	23.20	23.40	+	5.40	5.20	+	86°	0.99	24
9360	L2	23.60	25.60	7.30	+	4.60	1.30	+	0.92	+
9361	L2	23.80	22.30	6.70	5.70	5.70	1.30	82°	1.07	22
9362	L2	24.10	27.10	6.60	5.90	5.70	1.20	92°	0.89	23
9363	L2	24.25	26.80	7.90	+	5.50	1.00	91°	0.90	22
9364	L2	24.40	27.90	9.10	5.85	9.10	1.10	92°	0.87	23
9365	L2	24.55	26.40	+	5.80	5.80	1.20	91°	0.93	23
9366	L2	24.75	26.60	7.50	4.35	6.00	1.05	88°	0.93	22
9367	L2	25.00	27.65	+	6.60	5.60	1.25	92°	0.90	23
9368	L2	25.10	26.80	9.30	6.80	7.00	1.00	91°	0.94	22
9369	L2	25.10	28.05	8.90	+	5.75	+	90°	0.89	22
9370	L12	25.30	27.20	8.40	6.05	5.90	1.10	91°	0.93	23
9371	L2	25.65	27.30	+	+	4.90	1.25	90°	0.94	23
9371	L2	25.65	27.30	+	+	4.90	1.25	90°	0.94	23
9372	L2	26.40	25.65	+	6.20	5.40	1.05	78°	1.03	23
9373	L2	26.90	38.90	7.10	+	3.95	1.25	90°	0.69	22
9374	L9	27.00	29.45	8.00	5.20	6.20	+	91°	0.92	24
9375	L2	27.05	28.75	+	5.70	6.55	1.25	86°	0.94	22
9376	L2	27.10	27.30	+	4.90	4.85	1.10	89°	0.99	24
9377	L2	28.00	28.95	6.70	5.80	6.25	1.10	90°	0.97	25
9378	L2	28.10	30.50	9.70	+	4.55	1.30	+	0.92	+
9379	L18	28.15	27.40	+	6.00	+	1.25	+	1.03	22
9380	L2	28.20	33.65	9.30	+	9.30	1.10	88°	0.84	24
9381	L2	28.40	29.20	8.05	5.50	5.25	1.00	86°	0.97	23
9382	L2	29.30	34.60	9.50	+	7.90	1.25	91°	0.85	23
9383	L2	29.60	33.00	9.95	7.15	6.60	1.30	89°	0.90	23
9384	L2	29.80	31.60	8.00	5.40	7.75	1.40	89°	0.94	23
9385	L2	30.00	30.65	8.70	6.80	7.00	1.10	90°	0.98	24
9386	L9	30.10	31.10	+	6.80	7.90	+	+	0.97	+
9387	L2	31.10	32.20	9.75	4.95	6.10	1.10	94°	0.97	24
9388	L2	32.90	37.90	10.80	9.60	7.20	1.25	92°	0.87	24
9389	L2	38.10	41.20	+	6.85	7.30	1.60	90°	0.92	24
9526	MZ	11.50	11.80	+	+	+	+	+	0.94	21
9527	MZ	17.60	18.80	6.20	4.80	+	+	+	0.94	21
9528	MZ	28.00	29.00	+	+	+	+	+	0.97	21
9529	BG	10.15	9.40	4.20	3.10	3.20	+	96°	1.08	23

(Table 1 continued)

Reg. No.	Loc.	H	W	E_1	E_2	D	C	A.A.	H/W	N.R.
GK-L9530	BG	11.90	11.85	5.00	3.85	+	+	+	1.00	20
9531	BG	13.00	12.80	+	3.85	+	+	+	1.02	+
9532	BG	13.15	12.70	4.70	2.80	2.80	+	89°	1.04	23
9533	BG	15.30	15.30	+	3.60	+	+	+	1.00	+
9534	BG	+	16.90	4.45	4.10	+	+	+	+	23
9535	BG	17.20	18.10	6.60	4.55	+	+	+	0.95	20

Table 2. Measurements of *Cryptopecten yanagawaensis* (NOMURA and ZINBO). Left valve.

Reg. No.	Loc.	H	W	E_1	E_2	D	C	A.A.	H/W	N.R.
GK-L9390	L2	8.80	8.10	2.90	2.40	1.40	0.40	91°	1.09	23
9391	L2	11.70	10.10	2.65	+	2.15	0.60	90°	1.16	23
9392	L2	12.20	11.20	4.15	2.50	2.30	0.65	87°	1.09	23
9393	L12	12.40	12.70	5.15	3.80	2.30	0.55	90°	0.98	22
9394	L2	12.60	11.70	+	+	2.30	0.80	89°	1.08	22
9395	L2	13.10	13.60	5.10	+	3.00	0.50	89°	0.96	24
9396	L2	13.80	13.80	4.80	3.50	3.20	0.85	95°	1.00	22
9397	L12	13.80	13.60	3.80	+	2.90	0.75	88°	1.02	22
9398	L2	14.10	14.55	5.80	3.40	3.00	0.75	92°	0.97	23
9399	L2	14.10	14.90	5.00	+	2.80	1.00	93°	0.95	22
9400	L2	14.40	14.40	5.70	3.35	3.30	0.75	91°	1.00	24
9401	L2	14.60	14.40	4.90	3.35	2.90	0.70	93°	1.01	23
9402	L2	14.60	13.40	5.20	2.90	2.80	0.60	91°	1.09	22
9403	L2	14.70	14.20	4.60	3.70	2.50	0.80	94°	1.04	22
9404	L2	14.80	13.80	4.95	3.10	2.55	0.80	88°	1.07	23
9405	L12	14.80	14.70	5.30	3.90	2.10	0.70	90°	1.01	21
9406	L2	15.10	15.70	4.40	2.80	3.60	0.85	+	0.96	24
9407	L12	15.30	9.55	4.40	+	1.95	0.70	89°	1.60	23
9408	L12	15.60	15.80	4.55	+	3.35	0.85	90°	0.99	23
9409	L2	15.70	15.90	+	+	3.40	0.90	93°	0.99	23
9410	L18	15.80	16.30	5.65	3.65	3.40	+	91°	0.96	24
9411	L9	15.80	16.20	+	4.70	2.90	0.75	+	0.98	+
9412	L18	16.00	15.00	4.60	3.80	2.60	+	88°	1.07	26
9413	L2	16.45	17.30	5.80	3.80	2.90	0.70	90°	0.95	23
9414	L2	16.85	17.05	5.15	3.70	3.40	0.85	91°	0.99	22
9415	L12	17.00	17.20	4.60	+	3.10	0.99	92°	0.99	23
9416	L12	17.30	17.45	6.00	4.55	3.15	1.00	90°	0.99	22
9417	L2	17.50	19.10	6.40	4.40	3.50	1.00	95°	0.92	23
9418	L2	17.65	17.65	5.00	3.10	2.90	0.85	91°	1.00	22
9419	L2	17.80	18.00	5.80	2.90	3.40	0.90	91°	0.99	22
9420	L2	18.00	17.40	6.60	4.15	4.00	0.80	91°	1.03	22
9421	L2	18.00	18.35	6.00	+	4.60	1.05	92°	1.08	22
9422	L2	18.10	16.80	5.50	3.35	4.20	0.70	90°	1.08	22
9423	L12	18.10	19.80	+	5.30	3.60	1.00	92°	0.91	22
9424	L12	18.35	18.10	6.40	5.20	4.00	1.10	89°	1.00	23
9425	L2	18.40	20.40	+	+	4.40	0.95	102°	0.90	21
9426	L2	18.40	18.35	5.30	4.20	3.70	1.00	92°	1.01	22
9427	L2	18.40	20.20	6.00	5.00	4.80	0.80	92°	0.91	+

(Table 2 continued)

Reg. No.	Loc.	H	W	E_1	E_2	D	C	A.A.	H/W	N.R.
GK-L9428	L2	18.60	18.85	6.90	5.50	4.20	1.00	95°	0.99	23
9429	L12	18.60	19.20	6.40	4.60	2.90	0.75	90°	0.97	21
9430	L2	18.80	17.80	5.20	3.80	3.80	0.85	91°	1.06	22
9431	L12	18.80	18.90	6.90	4.45	3.40	1.00	91°	0.99	23
9432	L2	18.85	17.80	5.10	3.60	3.40	0.90	91°	1.06	21
9433	L12	18.95	19.30	6.30	3.80	4.10	1.20	89°	0.98	22
9434	L12	19.10	20.10	+	6.10	3.90	1.00	92°	0.95	24
9435	L12	19.10	19.20	+	3.80	3.20	0.90	88°	0.99	23
9436	L2	19.10	19.80	5.80	3.40	4.40	1.00	94°	0.96	22
9437	L12	19.70	21.10	7.50	5.80	4.05	1.05	91°	0.93	24
9438	L2	19.80	20.40	6.60	5.00	4.10	1.00	90°	0.97	22
9439	L12	20.00	20.80	5.50	4.00	4.80	1.25	88°	0.96	+
9440	L18	20.00	20.50	7.15	4.60	4.20	1.10	88°	0.98	21
9441	L2	20.00	19.50	6.00	4.40	3.70	1.05	89°	1.03	22
9442	L2	20.10	20.50	5.25	4.10	4.70	1.00	92°	0.98	22
9443	L2	20.10	20.15	6.35	+	4.30	+	86°	1.00	19
9444	L12	20.30	20.20	5.70	4.00	4.90	1.20	91°	1.00	25
9445	L12	20.40	20.50	+	4.60	5.00	1.00	90°	1.00	23
9446	L12	20.45	20.40	6.10	4.10	3.40	1.10	91°	1.00	23
9447	L2	20.50	20.20	5.20	4.20	4.50	1.00	99°	1.01	23
9448	L12	20.50	20.60	6.70	4.70	4.00	1.00	88°	1.00	23
9449	L2	20.60	20.30	5.80	4.40	4.50	1.20	91°	1.01	23
9450	L2	20.65	22.05	7.00	6.20	4.70	1.05	96°	0.94	23
9451	L2	20.75	20.80	5.10	3.45	4.15	1.00	94°	1.00	23
9452	L2	20.80	22.00	6.70	5.40	4.20	1.30	93°	0.95	25
9453	L12	20.85	21.40	7.60	4.10	4.50	1.10	96°	0.97	22
9454	L2	20.90	21.00	6.45	3.75	4.00	1.20	93°	1.00	22
9455	L12	21.10	20.80	7.30	4.35	4.05	1.00	88°	1.01	23
9456	L2	21.40	22.20	7.55	4.55	+	1.30	96°	0.96	23
9457	L2	21.40	21.80	6.80	5.25	4.20	1.00	93°	0.98	26
9458	L2	21.40	22.20	6.80	4.50	4.00	1.00	92°	0.96	23
9459	L2	21.60	24.55	8.10	5.85	3.80	1.25	91°	0.88	21
9460	L12	21.60	23.10	7.30	4.70	3.50	1.00	95°	0.94	22
9461	L12	22.20	24.80	+	5.30	3.40	1.00	92°	0.90	23
9462	L12	22.30	23.40	7.60	5.50	5.25	1.20	91°	0.95	21
9463	L2	22.40	22.40	6.85	5.60	4.80	1.10	92°	1.00	23
9464	L2	22.40	22.40	6.20	4.70	4.60	0.80	92°	1.00	21
9465	L12	22.50	25.05	7.90	5.85	4.95	1.00	94°	0.90	22
9466	L2	22.60	24.00	7.60	5.50	4.20	0.85	93°	0.94	23
9467	L12	22.70	25.00	6.90	6.20	5.25	1.00	97°	0.91	23
9468	L2	22.90	24.40	5.80	+	6.30	1.05	93°	0.94	24
9469	L2	23.00	24.20	7.00	5.00	5.50	1.20	86°	0.95	22
9470	L2	23.20	24.60	7.90	6.00	5.60	1.00	93°	0.94	25
9471	L2	23.75	21.40	6.60	4.30	5.70	1.00	89°	1.11	21
9472	L2	24.60	24.80	7.00	+	+	1.25	+	0.99	23
9473	L2	24.80	25.80	9.00	6.00	4.70	1.15	100°	0.96	22
9474	L2	24.90	26.40	8.20	5.80	5.50	1.05	93°	0.94	22
9475	L2	25.00	26.00	6.60	5.60	4.55	1.20	95°	0.96	22
9476	L9	25.50	26.60	8.60	6.80	5.20	1.45	+	0.96	22
9477	L2	25.90	27.10	9.30	6.70	5.70	1.20	96°	0.96	23
9478	L2	26.10	23.35	6.90	3.90	6.45	1.40	91°	1.12	23

(Table 2 continued)

Reg. No.	Loc.	H	W	E_1	E_2	D	C	A.A.	H/W	N.R.
GK-L9479	L2	26.20	29.20	7.00	5.80	6.00	+	97°	0.90	24
9480	L2	26.40	27.50	8.30	5.60	6.40	1.40	100°	0.96	22
9481	L12	26.50	28.70	10.90	7.30	+	1.40	+	0.92	+
9482	L2	26.70	29.00	8.35	6.20	6.30	1.45	93°	0.92	23
9483	L2	27.40	27.00	7.60	+	7.20	1.35	+	1.01	23
9484	L2	27.60	30.50	8.85	5.90	5.60	1.20	100°	0.90	23
9485	L2	28.00	27.30	9.30	6.60	5.95	1.00	90°	1.03	24
9486	L2	28.10	27.60	7.60	4.40	6.60	1.25	88°	1.02	22
9487	L2	28.20	29.55	9.70	7.15	4.95	0.95	93°	0.95	23
9488	L2	28.20	30.40	9.00	6.50	5.10	1.10	93°	0.93	23
9489	L2	28.70	30.60	9.90	7.00	6.70	1.35	100°	0.94	24
9490	L12	29.10	31.60	10.00	6.60	7.15	1.20	88°	0.94	23
9491	L2	30.00	38.50	8.90	7.20	7.45	1.40	91°	0.80	22
9492	L2	30.00	33.00	9.60	6.40	6.20	1.30	87°	0.90	22
9493	L2	30.20	31.80	8.90	6.10	6.80	0.95	90°	0.95	24
9494	L2	30.20	34.10	10.90	6.80	8.00	1.60	89°	0.89	23
9495	L2	30.70	33.15	9.90	6.30	6.40	1.55	94°	0.93	22
9496	L2	30.70	33.30	8.20	6.20	6.80	1.40	93°	0.92	23
9497	L2	31.30	32.40	7.70	5.50	6.40	1.30	92°	0.91	21
9498	L2	31.30	34.30	9.90	6.50	7.80	1.40	93°	0.91	21
9499	L2	32.40	32.00	7.20	5.80	7.40	1.45	95°	0.95	22
9500	L2	32.60	34.40	7.60	5.80	5.50	1.20	93°	0.95	22
9501	L2	33.80	34.60	8.80	6.80	8.10	1.35	88°	0.98	24
9502	L2	34.40	37.00	10.15	6.30	8.60	1.30	92°	0.93	24
9503	L2	34.40	39.10	9.80	7.60	8.60	1.65	96°	0.88	22
9504	L2	35.20	39.30	+	+	7.70	1.55	+	0.90	24
9505	L2	35.20	38.10	11.80	7.00	9.80	1.60	92°	0.93	24
9506	L2	35.35	34.80	10.10	6.30	7.00	1.25	+	1.02	25
9507	L2	35.50	35.05	9.00	6.05	8.50	1.05	96°	1.01	24
9508	L2	35.60	41.30	9.60	7.50	11.30	1.70	92°	0.86	22
9509	L2	36.60	+	9.80	7.70	8.50	1.40	94°	+	23
9510	L2	39.40	36.60	11.20	7.15	9.00	1.50	89°	1.08	24
9511	L2	40.00	+	9.55	6.75	8.60	1.45	94°	+	23
9512	MZ	16.00	16.50	+	+	+	+	+	0.97	22
9513	MZ	19.30	20.80	4.80	+	+	+	+	0.93	21
9514	MZ	19.30	20.30	8.20	5.50	+	+	+	0.95	22
9515	MZ	26.20	29.00	8.60	+	+	+	+	0.90	23
9516	MZ	31.00	33.50	+	+	+	+	+	0.93	24
9517	BG	8.60	7.70	3.50	2.20	+	+	91°	1.12	24
9518	BG	9.40	8.80	+	+	+	+	+	1.07	24
9519	BG	10.70	9.60	4.45	+	+	+	+	1.11	23
9520	BG	10.90	9.80	4.40	2.90	+	+	+	1.11	22
9521	BG	+	11.80	+	+	+	+	+	+	+
9522	BG	13.40	12.50	4.35	+	+	+	+	1.07	23
9523	BG	14.20	14.40	+	3.90	+	+	+	0.86	+
9524	BG	14.55	15.30	4.50	4.00	+	+	93°	0.95	23
9525	BG	16.40	18.20	6.60	+	3.20	+	89°	0.90	23

Cryptopecten yanagawaensis (NOMURA and ZINBO)
(right; pl. 36. figs. 1–17b and left; pl. 37. figs. 1–20)

1936. *Pecten (Aequipecten ?) yanagawaensis* NOMURA and ZINBO, *Saito Ho-On Kai Mus. Res. Bull.*, (10), p. 337, pl. 20, figs. 2a–b.
1940. *Pecten (Aequipecten) yanagawaensis*, NOMURA, *Sci. Rep. Tohoku Imp. Univ.*, [2], **21**, (1), p. 19, pl. 1, figs. 10–13.
1958. *Cryptopecten yanagawaensis*, MASUDA, *Trans. Proc. Paleont. Soc. Japan, N.S.*, (30), p. 189, pl. 27b, figs. 1–8.
1962. *Aequipecten yanagawaensis*, MASUDA, *Sci. Rep. Tohoku Univ.*, [2], **33**, (2), p. 192, pl. 26, fig. 8.
1965. *Aequipecten yanagawaensis*, MASUDA and TAKEGAWA, *Saito Ho-On Kai Mus. Res. Bull.*, (40), pl. 1, figs. 12–13.
?1973. *Aequipecten (Cryptopecten) yanagawaensis*, SHIKAMA, *Sci. Rep. Tohoku Univ.*, [2], Spec. Vol., (6), p. 190, 194. (P. 190, in the Table 2).
1973b. *Aequipecten yanagawaensis*, MASUDA, *Atlas of Japanese Fossils*, (33), pl. N-54, figs. 14, 16.
1974. *Cryptopecten yanagawaensis*, ITOIGAWA in ITOIGAWA, SHIBATA and NISHIMOTO, *Bull. Mizunami Fossil Mus.* (1), p. 67, pl. 11, figs. 6–9b.
1976. *Aequipecten yanagawaensis*, OGASAWARA, *Sci. Rep. Tohoku Univ.* [2], **46**, (2), p. 44, pl. 3, fig. 3, 6.
1979. *Cryptopecten yanagawaensis*, TAGUCHI, ONO and OKAMOTO, *Bull. Mizunami Fossil Mus.*, (6), pl. 4, figs. 1, 2.
1981. *Aequipecten yanagawaensis*, ITOIGAWA, SHIBATA, NISHIMOTO and OKUMURA, *Monogr. Mizunami Fossil Mus.*, (3A), pl. 7, figs. 2, 3.
1982. *Aequipecten yanagawaensis*, ITOIGAWA, SHIBATA, NISHIMOTO and OKUMURA, *Monogr. Mizunami Fossil Mus.* (3B), p. 46.
1982. *Cryptopecten yanagawaensis*, HAYAMI, *Venus*, **41**, (3), p. 235.
1984. *Cryptopecten yanagawaensis*, HAYAMI, *Bull. Univ. Mus. Univ. Tokyo*, (24), p. 113, pl. 8, figs. 6–9.

Measurements:—Measured parts are shell height (H), shell width (W), apical angle (A.A.). length of anterior (E_1) and posterior ear (E_2) and prominence of radial ribs (C) on both valves. Maximum number of primary radial ribs are also counted (N.R.).

Typology:—Holotype (Left valve) SM, Reg. No. 8353 (Saito Ho-On Kai Museum).

H (mm)	W (mm)	E_1 (mm)	E_2 (mm)	D (mm)	A.A. (degree)	H/W	N.R.
10.00	21.50	+	+	5.00	110°	0.93	+

Type locality and Geological formation:—Cliff of the Hirose River at the southeast end of the Yanagawa Park, Yanagawa-machi Date-gun, Fukushima Prefecture (Lat. 37°51′05″N, Long. 140°36′05″E).

Material:—See the Table 1 and 2. The number of total individuals is 243 (106 right valves and 137 left ones). Material almost consist of samples from the fossil locality L 2.

Diagnosis:—Shell orbicular, moderate in size and thickness, valves less convexed than those of other species of *Cryptopecten*, laterally much convexed, with concentric lamellae on both valves and apical angle of about 90°. Byssal notch and ctenolium conspicuous. Stout, broad and flat-topped radial ribs with oppositely disposed imbricated scales of about twenty three.

Description:—Shell is moderate in size. While maximum, minimum and mean shell height (H) are 38.10 mm, 10.35 mm and 20.98 mm respectively, on right valve, they are 40.00 mm, 8.80 mm and 22.29 mm on left valve. It is moderately thick, suborbicular in outline and nearly equivalve. Right is a little more convex than the left valve in the younger stage. Length of the posterior side is longer than that of the anterior one and inequilateral on both valves in

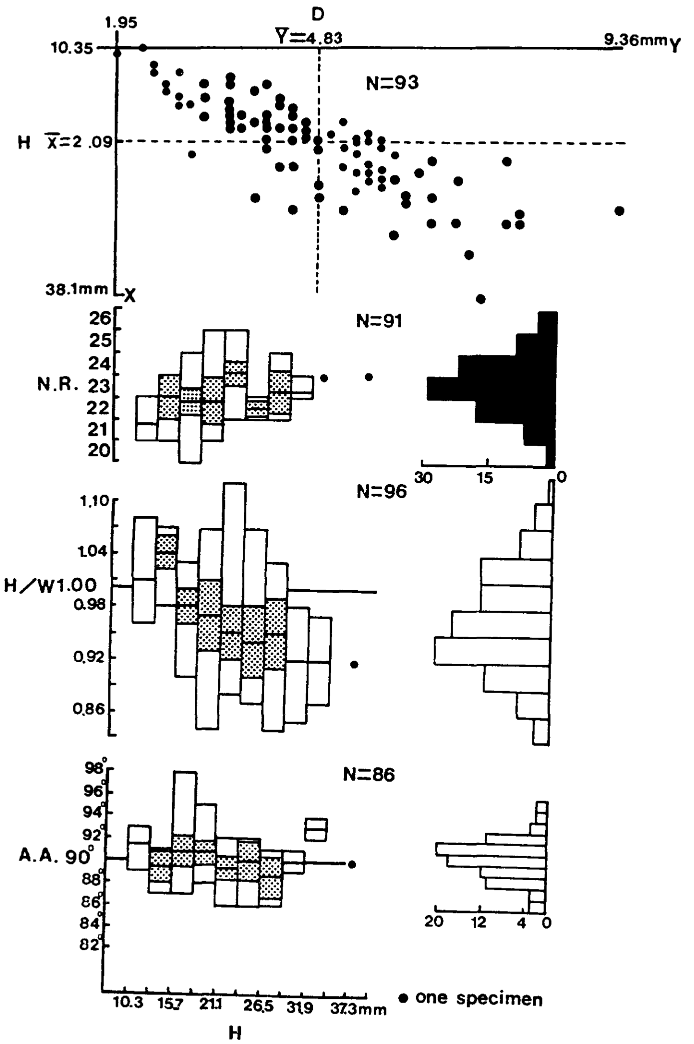

Fig. 3. Variation of apical angle (A.A.), proportion of shell height to width (H/W) and number of radial ribs (N.R.) and scatter diagram showing relationshop between shell height (H) and shell depth (D) on right valve of *Cryptopecten yanagawaensis* (NOMURA and ZINBO) from the Moniwa Formation. Each bar shows mean value. The dotted rectangles represent 90 percent confidence limits for the mean.

the adult stage. Ratio of shell height (H) to width (W) clearly changes within growth series (Fig. 3 and 4). Shell-width increases rapidly after shell-height attains 20 mm on both valves. Posterior submargins are longer than anterior and regularly concave. Apical angle is about 90°, averaging 92°, on left valve and 90° on right valve. Valves are radiately ribbed. Ribs on right valve are countable about 23, elevated, more or less squarish in the younger stage and rounded in the adult stage. Ribs are accompanied by a fine imbricated thread each on both sides. On many specimens top of radial ribs is worn and smooth,

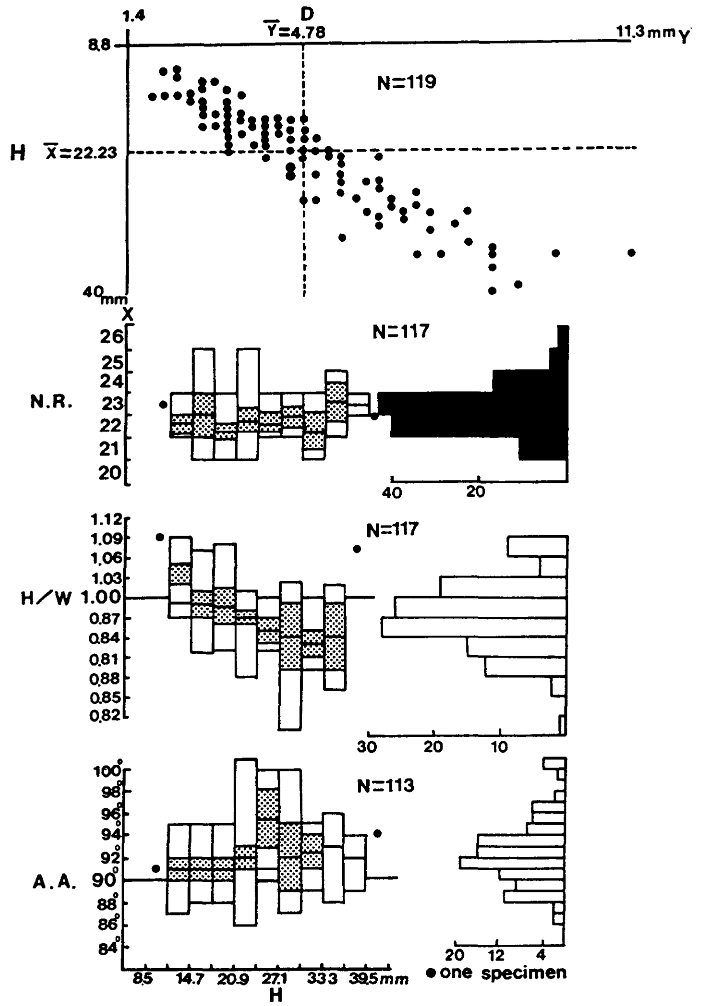

Fig. 4. Variation of apical angle (A.A.), proportion of shell height to width (H/W) and number of radial ribs (N.R.) and scatter diagram showing relationship between shell height (H) and shell depth (D) on left valve of *Cryptopecten yanagawaensis* (NOMURA and ZINBO) from the Moniwa Formation. Each bar shows mean value. The dotted rectangles represent 90 percent confidence limits for the mean.

although numerous concentric lamellae are observed on well preserved specimens collected from L 12 and L 18. Interspaces are nearly equal to or a little broader than ribs themselves and sculptured with numerous transverse fine lamellae. Anterior auricle is large than posterior one, sculptured with fine, distinct and imbricated radial ribs and concentric lines, and furnished with deep byssal area. Posterior auricle is triangular and truncated behind at right angle and similar to the anterior one in its sculpture, though radial threads are less distinct than the anterior. Radial ribs are oppositely scaled on both valves. The manner of disposition of scale is the same as that of *C. vesiculosus*. Hinge line is straight. Hinge has narrow but deep resilial pit. Triangular plane and teeth on both sides of resilial pit are distinct. Ctenolium and cardinal crura are conspicuous and ornamented by fine transverse incision. Radial ribs on the left valve have similar sculpture to the right one. Internal surface of both valves is rather smooth except for the characteristic ventral serration (pl. 37. fig. 19.).

Ontogeny:—Though growth rings are rather obscure, three inferred annual rings are discernible, at growth stages with the shell-height of about 20 mm, 25 mm and 35 mm. Radial ribs are distinct even on the smallest specimens of less than 10 mm high. Depth of shell (D) increases in proportion to shell height. There is no statistical difference of shell depth between the right and left valves among the specimens larger than 13 mm high (fig. 20 in pl. 37. and 15 b in pl. 36.). Byssal notch and ctenolium are distinct in the younger stage but becomes obscure in the adult stage. Proportion of shell height to width changes with growth. It is larger than 1.0 until shell attains to 20 mm high, then it decreases but becomes stable after attaining 30 mm in height. Radial rib is square in profile of cross-section in the younger stage and nearly triangular as shell attains above 30 mm in height. Radial ribs are bipartited respectively by intercalation of a shallow longitudinal furrow each on both valves in the adult stage. Posterior ends of both valves are considerably elongated in the adult stage. Maximum height of commissure-waves in ventral view (C) increases in proportion to shell height (Fig. 7). Fine lateral threads appear on both sides of radial ribs when shell attain 10 mm high. Interspace between the fine thread and radial rib is decked with slender concentric lamellae to form a series of chambers, although these chambers are usually broken by abrasion except for excellently preserved specimens.

Variation:—MASUDA (1958) reported that the number of radial ribs varies

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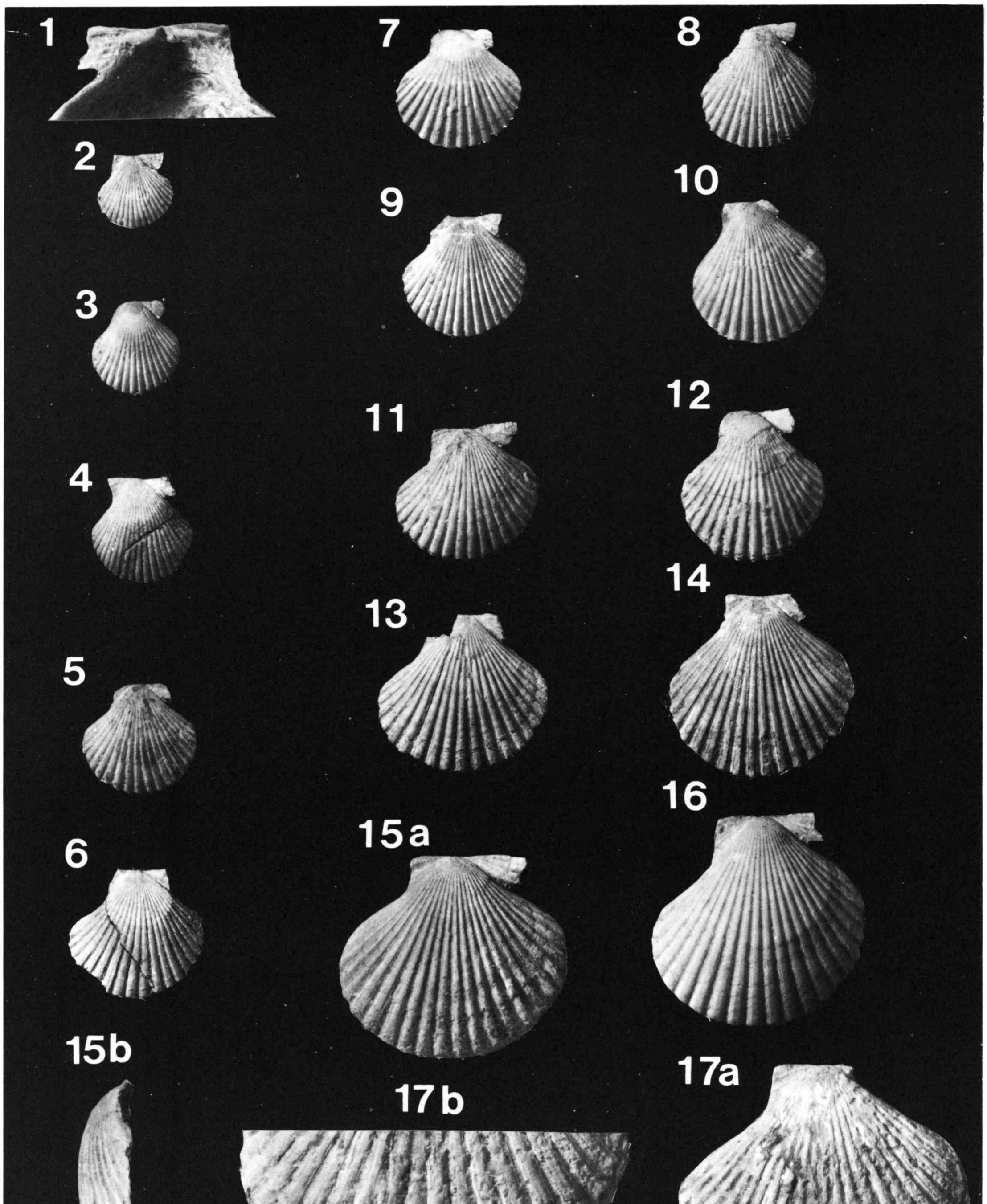
Explanation of Plate 36

(All figures are in natural size and all specimens are collected from L 2 unless otherwise stated.)

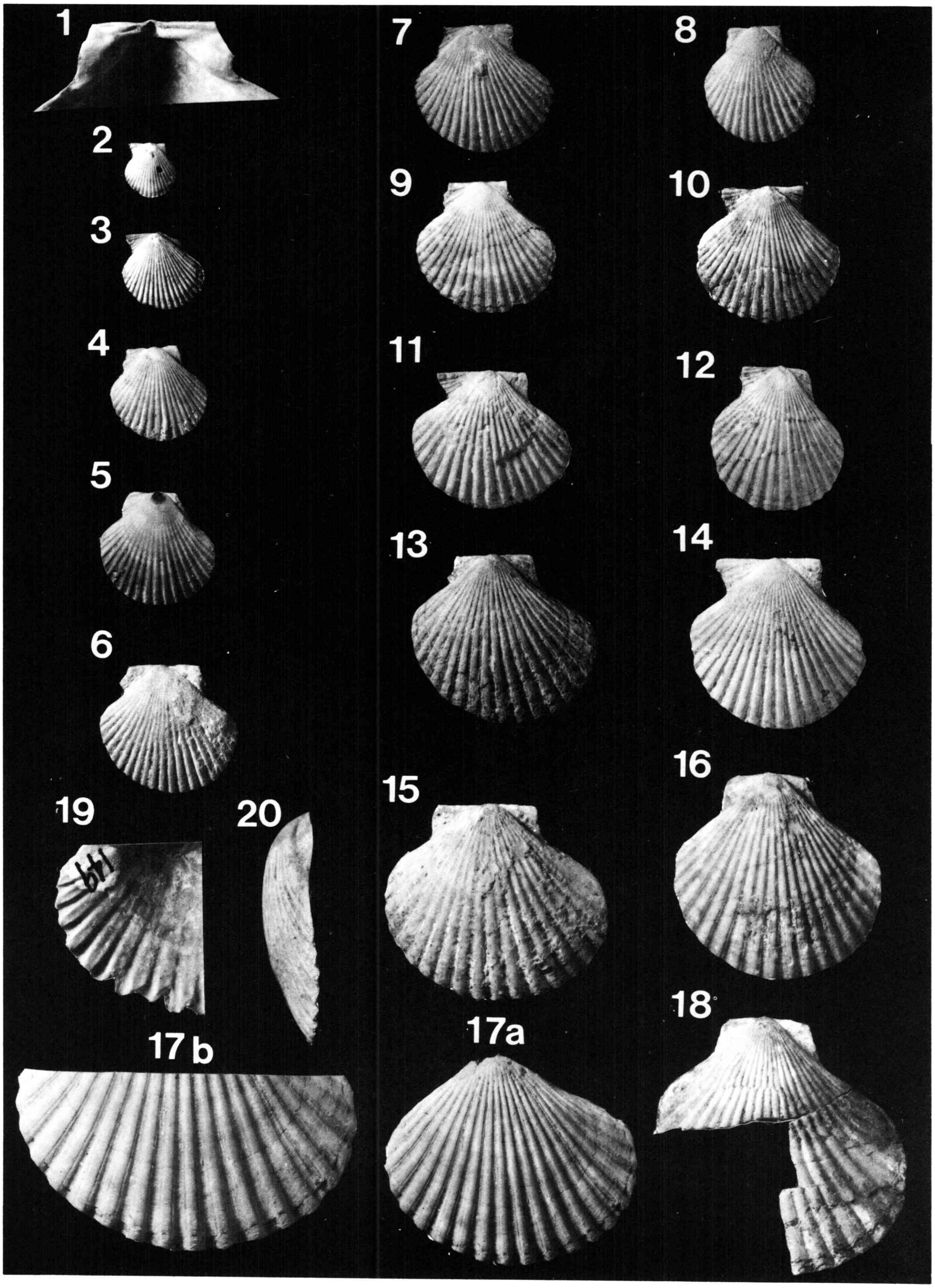
Cryptopecten yanagawaensis (NOMURA and ZINBO)

Right valve.

1. GK-L9385. 2. GK-L9394. 3. GK-L9302. 4. GK-L9304 (L 12).
5. GK-L9311. 6. GK-L9319 (L 12). 7. GK-L9326. 8. GK-L9333.
9. GK-L9328. 10. GK-L9352. 11. GK-L9345. 12. GK-L9361.
13. GK-L9366. 14. K-L9381. 15 and b, GK-L9383 (b, ×1.2).
16. GK-L9385. 17a and b, GK-L9389.



Y. SATO: Redescription of *Cryptopecten yanagawaensis*



Y. SATO: Redescription of *Cryptopecten yanagawaensis* between 16 and 26 (averaging 21) on both valves, but it ranges from 21 to 26 (averaging 23) on both valves in the present material (Fig. 3 and 4). Its range is nearly equal to that of Recent *Cryptopecten vesiculosus.* Apical angle (A.A.) is independent of shell height and ranges from 86° to 101° (averaging 92°) on the right valve and from 86° to 98° (averaging 90°) on the left valve. As a rule, there is no intercalary rib or thread on the interspaces between radial ribs, but an intercalary thread is rarely found at posterior and anterior ends. The last mentioned type is also found in the specimens collected from the Bihoku Group, Okayama Prefecture. Two phenotypes recognized in the Pliocene and Recent *C. vesiculosus* regarding the relative elevation of radial ribs (HABE and KOSUGE, 1967 and HAYAMI, 1973 and 1984) can not be observed in the present material of C. *yanagawaensis.* Shell-width increases more rapidly than shell-height after certain stage of growth as mentioned before, but there is a type with shell height still larger than shell-width even in the adult stage (fig. 15 and 16 in pl. 36. and fig. 17 a and 18 in pl. 37.). Specimens of this type are usually observed in those specimens collected from L 2. In this type, however, the other characteristics of morphology are the same as those of the normal type.

Comparison with fossil species:—As pointed out by VOKES (1967 and 1980), *Aequipecten* FISHER, 1886 was proposed earlier than *Crytopecten* DALL, BARTSCH and REHDER, 1938. On the basis of fossil material the following species have been reported under the genus *Aequipecten* in Japan (MASUDA and NODA, 1976); *vesiculosus* (YOKOYAMA, 1911 and 1922), *kyushuensis* (NAGAO, 1928), *kikaiensis* (NOMURA and ZINBO, 1934), *yanagawaensis* (NOMURA and ZINBO, 1936), *sematensis* (TAKI and OYAMA, 1954), *hataii* (KANNO, 1958) and *matsunagiensis* (MASUDA, 1966). While HIRAYAMA (1954) described *oyamaensis* under the genus *Cryptopecten.* Among these species, *kyushuensis, kikaiensis, sematensis* and *vesiculosus* are considered to belong to *Cryptopecten* because they posses the characteristic hollow chambers on both sides of radial ribs. *C. kyushuensis* is distinguishable from *yanagawaensis* by smaller and more convex shell, and distinctly elevated, round topped radial ribs of smaller number. *C. vesiculosus* from the Pliocene and Pleistocene formations differs from the present species in having fewer radial ribs accompanied with a imbricated thread on each lateral sides of them and a few number of imbricated intercalary threads on the interspaces of ribs on lower part of disc, and also having flatter left valve. *C. kikaiensis* was included into *nux* by HAYAMI (1984) as subspecies. New species of *Cryptopecten, C. spinosus,* and two new subspecies of *C. vesiculosus, vesiculosus makiyamai* and *v. sematensis,* were proposed by HAYAMI (1984). Present

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Explanation of Plate 37

Cryptopecten yanagawaensis (NOMURA and ZINBO)
Left valve.
1. GK-L9479. 2. GK-L9390. 3. GK-L9393. 4. GK-L9400.
5. GK-L9429. 6. GK-L9437 (L 12). 7. GK-L9450. 8. GK-L9432.
9. GK-L9459. 10. K-L9471. 11. GK-L9466. 12. GK-L9457.
13. GK-L9390. 14. GK-L9477. 15 and 20, GK-L9491 (20, ×1.2).
16. GK-L9499. 17a, b. GK-L9604. 18. GK-L9611, 19. GK-L9490.

species is distinguishable from *makiyamai* and *spinosus* by their larger number of radial ribs than the latter and from *sematensis* by difference of imbrication which appears in alternative disposition in *sematensis*. Fossil species of *Cryptopecten* has not been reported from the the West Coast of North America.

Comparison with recent species:—HABE (1977) distinguished five living species of *Cryptopecten* in the Japanese waters. They are *vesiculosus, tissotii, nux, owenii* and *inaequivalvis*. *Subsequently*, HAYAMI (1984) regarded *tissoti* and *alli* as synonyms of *bullatus* and he recognized four species of *Cryptopecten, bullatus, nux, vesiculosus* and *phrygium*. *C. nux* (REEVE) known from the Early Miocene to Recent in the Indo-Pacific is distinguishable from the present species by its smaller and more convex shell. *C. bullatus* (DATZENBERG and BAVAY) from the Late Pliocene to Recent in the Southeast Asia is also different from the present species by the smaller number of radial ribs and flatter left valve. Fossil and Recent *vesiculosus* is distinguishable from the present species by its smaller number of radial ribs, intercalary imbricated thread between radial ribs and flatter left valve. *C. phrygium* (DALL) from the western Atlantic Ocean differs from the present species by its smaller number of radial ribs and ill-developed byssal notch in the right valve.

Coefficient of interspecific assciation (Rδ X 1000) / Specific Name	Glycymeris derelicta(YOKOYAMA)	Coptothyiris grayi miyagiensis HATAI MASUDA and NODA	Nanaochlamys notoensis (YOKOYAMA)	Chlamys arakawai (NOMURA)	Flabellum sp.	Kotorapecten kagamianus (YOKOYAMA)	Ostrea sp.	Clinocardium sp.	Cryptopecten yanagawaensis (NOMURA and ZINBO)	Dentalium sp.	Nipponopecten akihoensis (MATSUMOTO)	Oxyperas takadatensis (MATSUMOTO)	Placopecten nomurai MASUDA
Glycymeris derelicta(YOKOYAMA)		-535	-284	-802	1638	-060	578	1417	105	1225	-681	784	-617
Coptothyris grayi miyagiensis HATAI MASUDA and NODA			516	1064	2041	-853	165	-675	-500	-674	-990	276	-989
Nanaochlamys notoensis (NOMURA)		■		005	1238	-121	374	-147	149	-114	-713	314	-417
Chlamys arakawai (YOKOYAMA)		■	■		-304	-020	2671	-851	-690	-399	-926	-774	-856
Flabellum sp.	■	■	■			-029	356	038	-447	-610	-821	303	-276
Kotorapecten kagamianus (YOKOYAMA)							646	-956	-382	720	865	-444	-829
Ostrea sp.			■	■				-779	-287	-801	-820	-081	-756
Clinocardium sp.	■				■				-968	-952	-966	-767	4500
Cryptopecten yanagawaensis NOMURA and ZINBO	■		■							-1406	-335	1209	190
Dentalium sp.	■					■					-374	1170	-269
Nipponopecten akihoensis (MATSUMOTO)						■						001	-695
Oxyperas takadatensis (MATSUMOTO)	■	■	■		■				■	■	■		-270
Placopecten nomurai MASUDA								■	■				

■ Harmonic association

Fig. 5. Coefficient of interspecific associations calculated among characteristic species of the Moniwa Formation (numerical values are shown by a thousand times of $R\delta$).

Affinity:—MASUDA (1958 and 1962) and HAYAMI (1973) considered that *C. yanagawaensis* is an ancestral to *C. vesiculosus*. Subsequently, HAYAMI (1984) mentioned that the phylogeny of *Cryptopecten* can be divided into *C. vesiculosus* and *C. nux* lines by the manner of disposition of imbricated scales and *C. vesiculosus* is the direct off-shoot of the present species. However, according to the observation of the present author, *Cryptopecten* from the Kumano Group, Wakayama Prefecture, show an intermediate number of radial ribs between the present species and *vesiculosus* and its manner of scale disposition is the opposite type. The specimens from the Kumano Group may represent an intermediate taxon between *C. yanagawaensis* and *vesiculosus* in that phyletic line.

Associate species:—MORISHITA's coefficient of interspecific association (MORISHITA, 1959), $R\delta$, calculated on the composition matrix of fossil assemblages indicates that present species shows a high degree of association with *Glycymris derelicta* (YOKOYAMA), *Nanaochlamys notoensis* (YOKOYAMA), *Oxyperas takdatensis* (MATSUMOTO) and *Placopecten nomurai* MASUDA (Fig. 5.). Most of the above species are considered to be ecologically associated with *C. yanagwaensis,* but *N. notoensis* must be regarded to be taphonomically associated because *N. notoensis* is a dweller of rocky and gravelly bottom and is ecologically separated from the others.

Mode of occurrence:—While shells are orientated nearly parallel to the bedding plane with convex side upward at L 10 and they are orientated obliquely or perpendicularly to the bedding plane with convex side downward at L 2, L 9, L 12 and L 18. Shell surfaces, especially radial ribs, ctenolium and ears, are mostly abraded on specimens from most locality except for L 9, L 12 and L 18. Ctenolium is perfectly preserved at L 9, L 12 and L 18. Attachment scars of sessile animals are found on inner side of shell at L 2 and L 10. The above mentioned occurrence suggests that the present species at L 9 may be nearly autochthonous. In accordance with the mode of occurrence, size frequency distribution of shell-height is skewed toward smaller size only at L 9. On account of microfaults fossils are considerably destroyed and deformed at a fossil locality 1 Km north from L 2.

Local variation of distribution in the Moniwa Formation:—Horizontal change of distribution of *C. yanagawaensis* in terms of individuals density (individuals/1 U.) in the Moniwa Formation is shown in Fig. 6. Present species is distributed mainly in eastern area and particularly dense in two parts of that area, one is composed of L 9 and L 10, the type locality of the Moniwa Formation, and another includes L 2 and an additional locality, L 18, which is located 20 Km south from L 9.

Stratigraphical distribution and lithology:—Bihoku Group (Lower sandstone Member) :—occurrence; common in medium grained sandstone, Okayama Prefecture. Akeyo Formation (Shukunohora facies) and Oidawara Formation: —occurrence; comon in very coarse grained sandstone and few in granule conglomeratic medium grained sandstone, Gifu Prefecture. Nagaoka Formation:—occurrence; few in tuffaceous coarse grained sandstone, Tochigi Prefecture. Sunakozawa Formation:—occurrence; common in the tuffaceous sandstone, Kanazawa Prefecture. Yanagawa Formation:—occurrence; few in granule con-

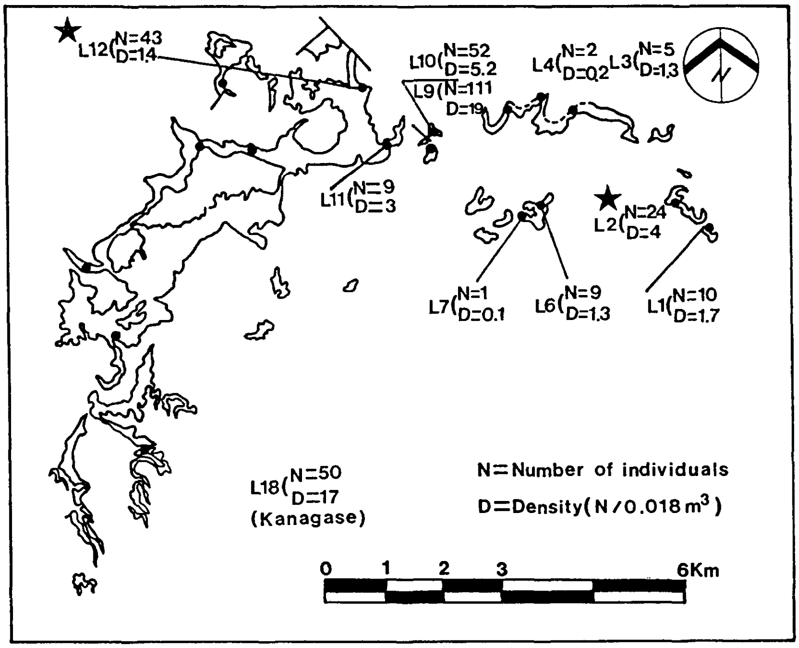

Fig. 6. Local variation of distribution of *Cryptopecten yanagawaensis* (NOMURA and ZINBO) in the Moniwa Formation. N=Number of individuals. D=Density (Number of individuals per 1 Unit, 0.018 m^3. ★=Additionally sampled locality.

glomeratic very coarse grained sandstone, Fukushima Prefecture. Moniwa Formation:—occurrence; common in granule conglomeratic very coarse grained sandstone, Miyagi Prefecture.

Geographical distribution of the present species is limited in the Paleo-Setouchi and northern basins of the Early Medial Miocene. Its northern extremity is the Sendai area.

Geological range:—MASUDA (1962 and 1973 a) reported that geological range of the present species is restricted to the Early Miocene. Also in the Paleo-Setouchi province, the Lower sandstone Member of the Bihoku Group is assigned to BLOW's number N 8 i.e. the Early Miocene and contemporaneous with the Moniwa Formation. The Oidawara Formation is assigned to BLOW's number N 9 i.e. the Medial Miocene (TSUCHI et al., 1979 and 1981). Consequently, it seems to be probable that present species ranges in the early Medial Miocene.

Remarks:—Distinct geographic variation of the average number and prominence of radial ribs are not observed. The shells of the Bihoku Group are somewhat thinner than those of the Moniwa Formation. Paleogeographical distribution of present species is concordant with inferred paleo-current systems of warm water by CHINZEI (1981). *Cryptopecten bullatus* and *C. vesiculosus* living in the Pacific and Japan Sea are warm water elements. They live in shallow sea bottoms consisting of fine sands with pebbles to rocky bottoms free from muddy materials. Lithology of the fossil localities in the Moniwa Formation is harmonious with those substrates of habitats of the living species mentioned above. According to HAYAMI (1984), *C. vesiculosus* lives in the rather shallower sea than other species. Therefore, it is suggested that there is no ecological differences between the living species and the present species. This assumption is also substantiated by the ecological condition of associate species in the Moniwa. Formation. Present species also occurs in association with *Glycymeris cisshuensis* and *Hyotissa hyotis* and is a constituent of *Aequipecten* ———— *Hyotissa* Assemblage in the Shukunohora facies of the Mizunami Group (ITOGAWA, SHIBATA, NISHIMOTO and OKUMURA, 1981). HAYAMI (1973) pointed out that adherence of serpuloids, bryozoans and many other organisms to the left valves of *C. vesiculosus* is probably owing to the normal living posture with its flatter left valve upside. As noted in earlier lines, convexity of left and right valves is nearly equal in the shells larger than 13 mm in shell height in the present species. Therefore, it may be considered that the present specis may change its life style corresponding to change in relative convexity of valves (STANLEY, 1970), but further material of *C. vesiculosus* and present species are necessary to settle this problem. HAYAMI (1973 and 1984) reported that *C. vesiculosus* can be divided into two distinct phenotypes, phenotype Q and R, by the value of 100 C/H, Q and R, but in the present species two types can not be discriminated (Fig. 7). All the specimens collected from the Moniwa Formation are included into the phenotype Q (100 C/H=3.85).

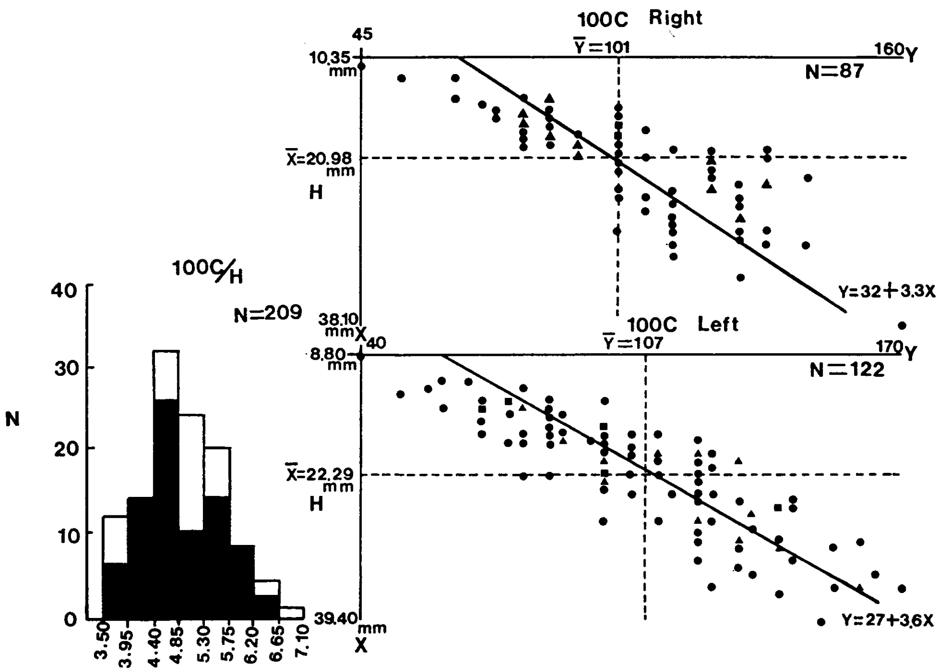

Fig. 7. Scatter diagrams showing the relationship between shell height (H) and prominence of radial ribs (100C) and Frequency distribution of 100C/H. (● =one specimen. ▲=two specimens. ■=three specimens.)

List of Fossil Localities Yielding Present Species

L 1 (Ezoana): Road-side cliff at the northern slope of a ridge. 100 m south of a prefectural road from Kagitori to Masuda. Kumanodo, Natori City (Long. 140°51′41″E, Lat. 38°12′01″N).

L 2 (Jyunijin): Eastern cliff at Jyunijin, 300 m southwest of a prefectural road from Kagitori to Masuda, Kumanodo, Natori City (Long. 140°50′13″E, Lat. 38°12′19″N).

L 3 (Boyo-dai): Southern cliff under Boyo-Dai housing area, Hagurodai, Sendai City (Long. 140°49′05″E, Lat. 38°13′04″N).

L 4 (Sendai Minami New Town): Road cut at 1.5 Km north from the entrance of a housing area, Moniwa, Sendai City (Long. 140°48′03″E, Lat. 38°13′05″N).

L 6 (Osawa): Northern cliff in a swamp area, 300 m east of L 7, Osawa, Natori City (Long. 140°48′41″E, Lat. 38°12′12″N).

L 7 (Nakazawa): River-side cliff of Nakazawa, 800 m upstream from the conjunction with Natori River, Nakazawa, Natori City (Long. 140°48′29″E, Lat. 38°12′33″N).

L 9 (Type locality of the Moniwa Formation-Lower): River floor at Iwano-sawa under the Moniwa Electric Power Plant, 100 m upstream from the conjunction with Natori River, Moniwa, Sendai City (Long. 140°47′28″E, Lat. 38°12′59″N).

L 10 (Type locality of Moniwa Formation-Upper): River-floor of Iwano-sawa 50 m upstream from L 9, Moniwa, Sendai City. (Long. 140°47′28″E, Lat 38°12′58″N).

L 11 (Type locality of the Moniwa Formation-West): Southern cliff in a northwestern small swamp, 6.8 Km west of the Type locality of the Moniwa Formation, Sendai City (Long. 140°47′E, Lat. 38°12′50″N).

L 12 (Hongo): Road-cut at the Kumanosawa path, 700 m from the entrance, Moniwa, Sendai City (Long. 140°47′E, Lat. 38°12′50″N).

L 18 (Kanagase): Road-cut at Shima, 20 m north of Tohoku New Rail way, Kanagase, Ogawara-machi (Long. 140°41′54″E, Lat. 38°2′45″N).

MZ (Mizunami): Suganuma, Nakahara Hiyoshi-machi, Mizunami City, Gifu Prefecture (Long. 137°16′41″E, Lat. 35°24′15″N).

BG (Bihoku Group Lower Horizon): Small cliff along the Kishin railway line at Imai, 300 m southwest from Tajibe Station, Tajibe, Osa machi, Atetsu-gun, Okayama Prefecture (Long. 133°33′19″E, Lat. 35°2′27″N).

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Appendix

Alphabetical index of place names with Japanese writing.

1. Boyo-dai (望洋台)
2. Ezoana (エゾ穴)
3. Goishi (碁石)
4. Hitokita (人来田)
5. Hongo (本郷)
6. Imanari (今成)
7. Jyunijin (十二神)
8. Kanagase (金ケ瀬)
9. Kita-akaishi (北赤石)
10. Mabikizawa (馬引沢)
11. Moniwa (茂庭)
12. Nakazawa (中沢)
13. Nakayachi (中谷地)
14. Osawa (大沢)
15. Sendai Minami New Town (仙台南ニュータウン)
16. Tomioka (富岡)