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The fossil on the cover is *Nipponitella explicata* HANZAWA, an aberrant uncoiled fusulinacean from the Lower Permian Sakamotozawa Formation, southern Kitakami, Northeast Japan.

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705. A LOWER MIOCENE ICHNOFAUNA OF THE MIDDLE ASHIYA GROUP, NORTH KYUSHU

—ICHNOLOGICAL STUDY OF THE ASHIYA GROUP-I*—

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and

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Abstract. Trace-fossils from the lower Sakamizu Formation of the Ashiya Group (Miocene) of North Kyushu, Japan, were investigated as a part of the paleoecological study of this group. Problems concerning the taxonomy of trace-fossils are discussed briefly. Ophiomorpha ashiyaensis ichnosp. nov. and seven other trace-taxa are classified on the morphological basis and the builder organisms are considered to some extent. Furthermore, short notes on their occurrence and faunal association are given in regard to the sedimento-ecological environments. Finally, a successional bathymetric change recorded in the lower Sakamizu Formation is demonstrated.

I. Introduction

A paleontological research work of the Miocene Ashiya Group was carried out to establish a standard procedure for a community-paleoecological study in a small peninsula of Iwaya and the adjacent area, Kitakyushu City, Southwest Japan in 1969-70 by the present authors. On that occasion, the research work was focused on the analysis of assemblages of body fossils which consist almost exclusively of molluscs (SHUTO and SHIRAISHI, 1971).

A number of trace-fossils were found at several horizons in the strata of the investigated area besides the body fossils. In some cases, trace-fossils are so abundant that the original physical sedimentary structure and texture are quite disturbed. Furthermore, an obvious tendency was that that part of the sequence abound with dense trace-fossils does not or rarely yield body fossils. Accordingly, analysis of trace-fossils is indispensable for understanding ecological history throughout the entire sequence of the Ashiya Group in the Iwaya district. Hence, an ichnological investigation was done in 1976-78 in the same area as the malaco-ecologically studied one. Additional investigation was done in other parts of the Ashiya Group and the uppermost part of the Meinohama Group, which is strati-

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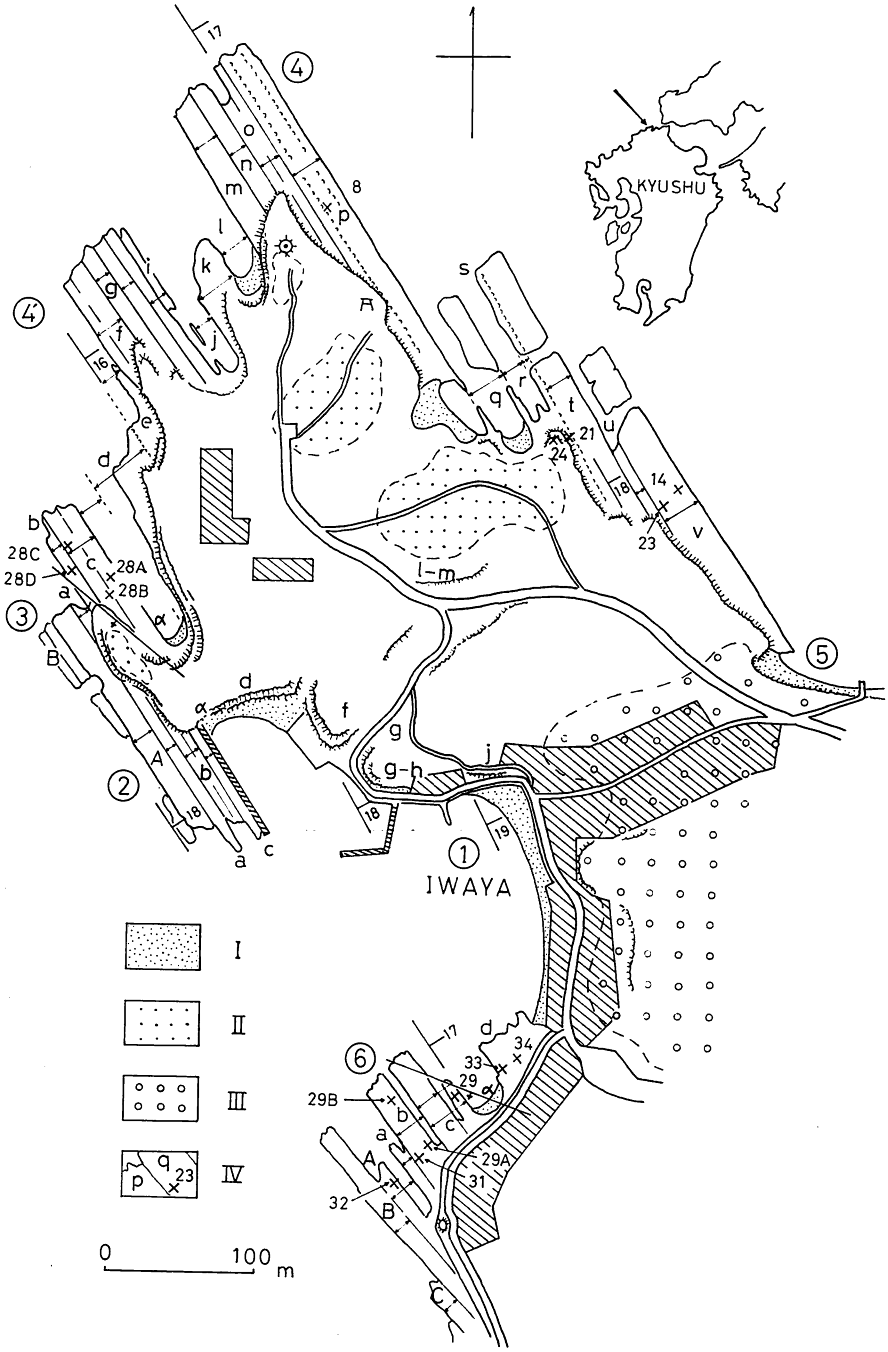


Fig. 1. Geological sketch map of the Iwaya Peninsula, North Kyushu, Japan.

I: Recent beach sand. II: Intra-Würm dune sand. III: Intra-Würm Iwaya gravel. IV: Ashiya Group; p, q, etc. being the alphabetical symbols of the beds examined and the numerical figures being the important molluscan localites.

graphically equivalent to the Ashiya, to obtain data for comparison. Here the descriptions of trace-fossils in question are given in reference to ecological situations of the trace-builders. The result of our biostratigraphical observation of the trace-fossils throughout the entire Ashiya Group will be given in a separate paper.

II. Stratigraphical setting

The well-exposed Jinnoharu Sandstone Member, the lowest of the Sakamizu Formation of the Ashiya Group, is distributed in the investigated area with a general strike of N33-36W and eastward dip of 17-20 degrees (Fig. 1). The strata consist almost wholly of sandstones with a minor intercalation of siltstone (α-bed) and calcareous muddy conglomerate (a-bed) and attain about a thickness of 120 m. The lithology of these sandstones ranges from fine-grained to conglomeratic coarse one and sorted, coarser medium sandstones predominate over others. Lateral change of lithology within a single bed is slight so far as the studied area is concerned. Besides the bedding planes which define the upper and lower boundaries of a bed, minor stratification may be observed within a bed. Some beds have cross-laminations or parallel ones suggesting a high energy condition at the time of deposition (r_1-, o_1-, n_1-, l_1-bed, etc.) and some others show poorly sorted muddy sand facies indicating a relatively low energy condition (v_1- and u_1-bed). The sorted medium sandstone without lamination must have been deposited under a medium high energy condition, which was rough enough to sort detrital grains but quiet enough to preserve organic sedimentary structures. The definition of 32 beds, which were distinguished from each other in our previous work according to their stratigraphic position and lithology along four sections, is somewhat amended (Figs. 1 and 2). Sections 1, 2, 3 and 4 in Fig. 2 are located in the area ④′-④-⑤, ③, ②-① and ⑥ in Fig. 1, respectively.

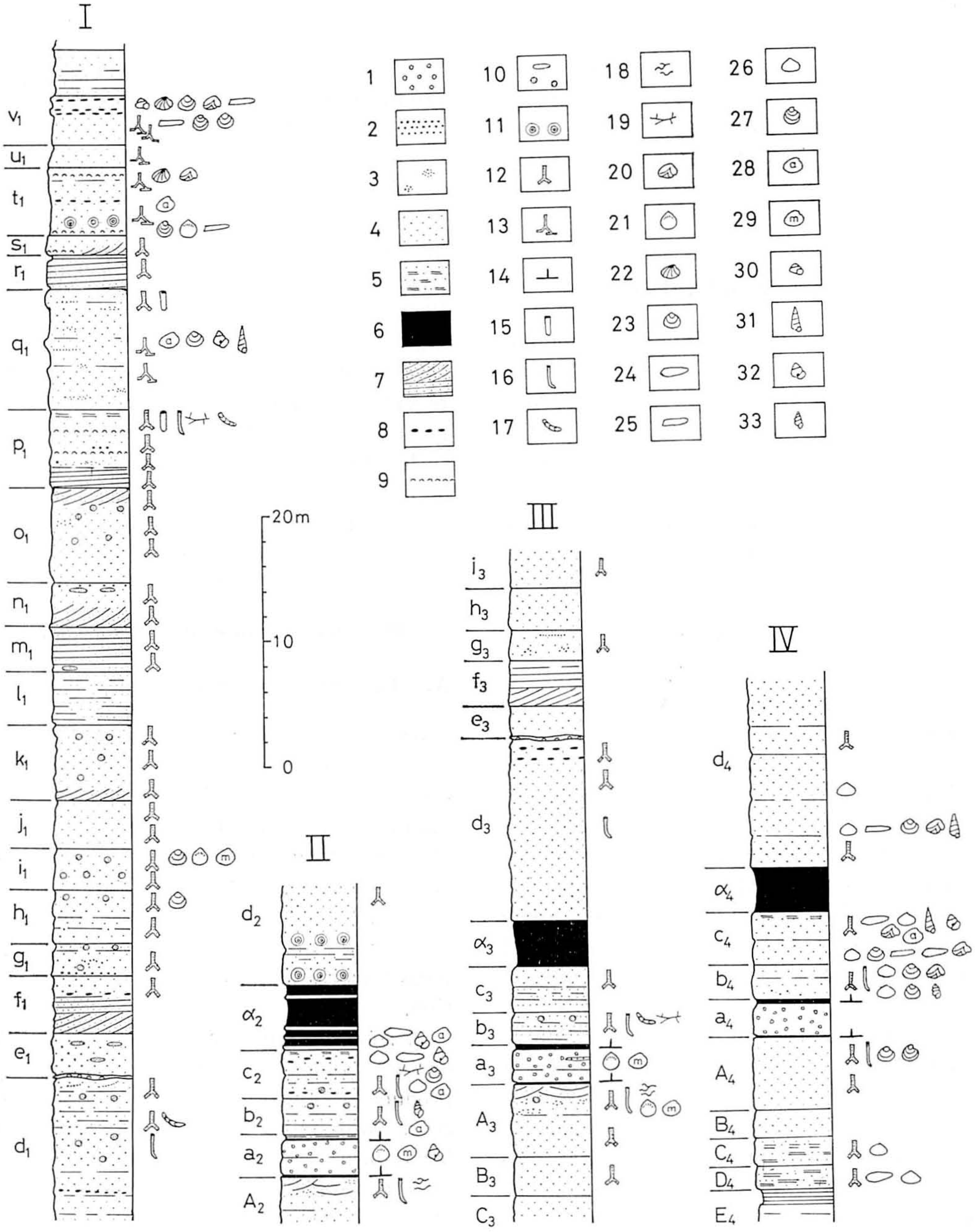
After NAGAO (1928) assigned the Ashiya Group to the Middle Oligocene, several conflicting views have been proposed hitherto as to the age of this group (HATAI, 1938; HIRAYAMA, 1956; MIZUNO, 1960 and KAMADA, 1967 and 1969). Adopting the standard biostratigraphical scheme of MIZUNO (1960), SHUTO (1978) recently discussed the Neogene/Paleogene boundary in North Kyushu. According to his correlation, the Ashiya Group is included in the Miocene and the boundary of the Lower/Middle Miocene lies in the upper part of the Sakamizu Formation.

III. Descriptions of trace-fossils

A. Taxonomy of trace-fossils

At the beginning of the present study, the writers optimistically expected to classify trace-fossils in relation to their builder organisms under the scheme of the International Code of Zoological Nomenclature (STOLL et al., 1964). However, it became evident in the course of the study that the Code can not be generally applied to the trace classification.

Observations of recent traces suggest, on one hand, that a single species may produce a few different trace-structures corresponding to the variability in its behavioral and physiological activities and that, on the other hand, organisms of unrelated taxa may make analogous or identical structures. That is to say, any one type of trace does not necessarily correspond to a single organism. The case must be true with the ancient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B3
C3
IV
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α4
c4
b4
a4
A4
B4
C4
D4
E4

Table 1. Occurrence of the crustacean body fossil in a burrow of Ophiomorpha or Thalassinoides

Mertin (1941)	*Protocallianassa* in Thalassinoides	Up. Cret., Germany
Ehrenberg (1944)	*Callianassa* in Thalassinoides	Mio., Austria
Fiege (1944)	Glypheoid in Thalassinoides	Mid. Trias., Germany
Glaessner (1946)	*Callianassa major* in Thalassinoides	Eo., Australia
Waage (1968)	*Callianassa* in Ophiomorpha	Up. Cret., N. America
Shin (1968)	a shrimp in Thalassinoides	Cret., N. America
Sellwood (1971)	*Glyphea udressieri* in Thalassinoides	Mid. Jura., England

trace-fossils as has been demonstrated by the correspondence of the trilobite to Rusophycus (resting trace), Cruziana (grazing trace) and Diplichnites (walking trace) and by the occurrence of a body fossil of *Protocallianassa, Callianassa* or *Glyphea* in a trace-fossil of Thalassinoides (Table 1). A great difficulty in the biological classification of trace-fossils lies upon this fact. Several authors have tried to overcome this difficulty and to manage the taxonomy of trace-fossils.

Osgood (1970) pointed out a lack of clean guide line in the International Code of Zoological Nomenclature (Op. Cit.) for the classification of trace-fossils and maintained that body fossils and trace-fossils should have respective generic and specific names. Häntzschel and Kraus (1972) discussed the nomenclature of ichnofossils in line with Osgood and proposed further that the names of ichnotaxa be printed in different way from those of body fossils. Sarjeant and Kennedy (1973) gave a comprehensive discussion on the taxonomical problem of trace-fossils and proposed a "Code for the Nomenclature of Trace-fossils". The present authors have the same opinions in many respects as Sarjeant and Kennedy. Firstly they share the opinion that trace-fossils would inevitably be recognized as form taxa under the present, poor state of knowledge on both fossil and recent traces, because the strict adherence to the biological taxonomy in classifying trace-fossils would certainly provoke a confusion. This does not mean that the classification of trace-fossils should remain a pure form-taxonomy. A passage way is always kept to link each form-taxon of the trace to builder or-

Fig. 2. Columnar sections of the middle Ashiya Group in the Iwaya Peninsula.

The columns I, II, III and IV are respectively observed in the areas ⑤-④-④′, ③, ②-① and ⑥ in Fig. 1. Beds in the columns I, II, III and IV are made distinctive in the text by use of suffix 1, 2, 3 or 4 (ex. a_2, a_3 and a_4).

1: conglomerate, 2: lens of granule, 3: patches of coarse sand, 4: medium sandstone, 5: muddy sandstone, 6: siltstone, 7: cross and parallel laminations, 8: calcareous nodules, 9: *Glycymeris* bed, 10: pellet mound (circular) and washed pellet-sheet (elliptical), 11: onion structure, 12: Ophiomorpha ashiyaensis, 13: Thalassinoides iwayaensis, 14: T. giganteus, 15: Cylindrichnus japonicus, concentric form, 16: C. japonicus, eccentric form, 17: Tosalorbis ? ichnosp., 18: Nankaites kochiensis, 19: Unarites ? ichnosp., 20: *Acila ashiyaensis*, 21: *Glycymeris cisshuensis*, 22: *Venericardia subnipponica*, 23: *Lucinoma nagaoi*, 24: *Cultellus izumoensis*, 25: *Solen connectens*, 26: *Angulus maximus*, 27: *Dosinia chikuzenensis*, 28: *Pitar ashiyaensis*, 29: *P. matsumotoi*, 30: *Diloma* (*Oxystele*) sp., 31: *Turritella* (*Hataiella*) spp., 32: *Euspira ashiyaensis*, 33: other gastropods.

As to the molluscan faunae, only dominant species are illustrated in this figure.

ganism. Correspondence of trace-fossils and builder organisms may be made clear in future at the generic level in many cases, but it is expected possible at species level in only a few exceptional cases. And even a trace-taxon may correspond with two or more genera of organisms. In consequence, the trace-taxonomy can not be quite dissolved in the animal taxonomy and it must necessarily have an independent system. The form-taxonomy may be a system to meet the above requirement. It is really independent from the biological taxonomy, but its methodological procedures must not be quite different from the ICZN except for the inevitably emended parts.

When pure form-taxa are adopted in the trace-taxonomy, a perplexed tendency may be inevitable to split taxa and to give independently different names to respective parts of a single structure. Therefore, the following principle is necessary to avoid confusion that an ichnotaxon should be established by morphological data not on any part of a single trace system or structure, but on a whole system. Under this principle, priority in nomenclature may be called in question, when there are an older and an younger names respectively based on a part and on the whole structure. Priority, of course, should be greatly respected in the nomenclature in general. However, a rule should be claimed that a name based on a whole system or, at least, on an ubiquitous feature has priority as against a name based on a rare feature or a part of the same system (cfr. Ophiomorpha LUNDGREN, 1891 and Gyrolithes De SAPORTA, 1884; see p. 116).

Form-taxonomy may not necessarily be the best method, but is, at least, the most practical solution to deal with trace-fossils. Yet, one should keep the basic fact in his mind that a trace was made by a certain behavioral or physiological activity of an organism. Thus, certain ichnotaxa which were established on the morphological basis must be integrated with one another to cover a more general feature of a trace structure by having another-looks from this standpoint. Through this procedure, the morphological feature of a trace system becomes clearer and, in consequence, the ethological consideration of the trace becomes easier. For example, Ophimorpha chiefly consists of shafts and tunnels, but is associated in some occasions with a spiral shaft (Gyrolithes), pellet-mounds and/or faecal pellets, etc. They may be naturally named separately in the early stage of research, but should be unified under a single name, Ophiomorpha, after enough data are accumulated. This rule is concordant with the above noted our basic view about the taxonomy of trace-fossils.

Recognition of the holotype of a trace taxon is the second difficult problem under the above principle. Whole parts of a single trace system, particularly large and branching one in a consolidated rock, can not always be excavated and even observed because of its three dimensional nature. Accordingly, a taxon can not always be established on the basis of a good specimen which is suitable for a "holotype", but is described synthetically by numberless observations of parts of individual structures. How can one designate the holotype in this case? Free specimens in hand, in this case, represent more or less partial structures. Accordingly, any of them can not be selected as the holotype without objection. Hence, it may be a solution of the problem to designate the holotype on the basis of a photograph of unexcavated specimen as AGER (in SARJEANT and KENNEDY, 1973) advocated, when any of the specimens exposes nearly whole structure or an ubiquitous feature of the structure. However, a completely exposed specimen is hardly expected in case of a large and complicated trace-structure such as Ophiomorpha and Thalassinoides in consolidated rocks. Holotype designation on the basis of the photograph is therefore discarded. Then, from a practical point of view, it is advisable to accept a specimen representing more important or ubiquitous structure as a holotype and a set of specimens, which respectively represent another part of one structure, as paratypes. The last mentioned procedure is adopted in this paper, although the paratype is not formally adopted in the International Code of Zoological Nomenclature. The traces selected as types were photographed before excavation.

In printing names of ichnotaxa, the present authors prefer to adopt roman letters to distinguish them from the taxa named in accordance with ICZN.

A synthesis of a general picture of a trace system from numberless observations of various parts of three dimensionally stretching structures tends to be influenced by a subjective judgement. To minimize subjective judgement, the quadrat-observation-method was employed in this study. A quadrat, 1 m×1 m, was set on cliff-walls, eroded out stratification planes or bench-cut planes. Relative position of any quadrat in the bed was checked at first and then trace-fossils in the quadrat were measured and sketched in detail. A care was particularly given to measure vertical and oblique shafts and horizontal tunnels of such burrow systems as Ophiomorpha and Thalassinoides to calculate a shaft/tunnel ratio, which serves for the recognition of an average configuration of a standard burrow system (Fig. 4 and Table 2).

All the observed trace-fossils are complete structures in the sense of SCHÄFER, (1962).

Whether or not grouping of ichnotaxa into any category above the generic level is useful is a matter of dispute. While several kinds of grouping and ordering of ichnotaxonomic categories have been proposed hitherto, SARJEANT and KENNEDY (1973) regarded the grouping meaningless. From a practical point of view, the present authors consider that an appropriately selected grouping is a great aid for an easy identification of any newly obtained material of trace-fossils. One may be able to search more easily for a taxon identical to or comparable with a newly obtained material when a higher category comprising many similar forms is available, rather than going through an unordered pile of numberless genera and species. Here, the present authors adopted VIALOV's classification (1972), although it is not necessarily satisfactory. Particularly, a weakness lies in an indefinite relation between Cryptoreptida of Fossiglyphia and Apodichnaea of Bioexoglyphia. Furthermore, the latter seems to cover too many divergent forms. However, his classification may possibly be improved with minor emendation.

Following is the systematic list of the trace-fossils from the Middle Ashiya Group.

Vivichnia
 Invertebratichnia
  Bioendoglyphia
   Fossiglyphia
    Endotubida
     Crustolithida large and complicately branching.
      (i) wall with granular ornamentation ....type A,
        Ophiomorpha ashiyaensis ichnosp. nov.
      (ii) wall without ornament

(α) moderately large..type B, Thalassinoides iwayaensis ichnosp. nov.
(β) very large with polygonal tunnel ....type C, Thalassinoides giganteus ichnosp. nov.

Rectotubae
- (i) vertically stretching: wall thick, mucus-coated and multilayered; surface smooth.
  - (α) short (less than 10 cm), opening concentric to the outer wall ....type D, Cylindrichnus japonicus ichnosp. nov. concentric form
  - (β) long (longer than 10 cm), opening eccentric to the outer wall ....type E, Cylindrichnus japonicus ichnosp. nov. eccentric form
- (ii) horizontally and obliquely stretching; wall with septal structure..............type F, Tosalorbis? ichnosp.

Cryptoreptida
- (i) string-like, very small, nearly straight or curved, rarely ramified; surface smooth ..type G, Nankaites kochiensis KATTO
- (ii) moderately small, nearly straight or curved, rarely with thorn-like ramification; surface uneven................type H, Unarites? ichnosp.

B. Descriptions of species

Ichnogenus Ophiomorpha LUNDGREN, 1891

type-species: O. nodosa LUNDGREN
(Monotype)

HÄNTZSCHEL (1952 and 1975) listed the synonyms of Ophiomorpha as follow; Astrophora DEECKE, 1895; Sabellastartites DUDICH, 1962; Cylindrites GÖPPERT, 1842 (partim, C. spongioides) nom. nud; Halymenites STERNBERG, 1821 (partim, H. major and ?H. flexuosus); Spongites GEINITZ, 1842 (partim, S. saxonicus).

While KENNEDY (1967) regarded Gyrolithes DE SAPORTA, 1884, Thalassinoides EHRENDERG, 1844 and Ophiomorpha LUNDGREN, 1891 as synonyms, BROMLEY and FREY (1974) claimed to treat those burrows and Spongeliomorpha DE SAPORTA (1887) as separate taxa. A vertical spiral tunnel, Gyrolithes DE SAPORTA, 1884, was reported as a part of Ophiomorpha borneensis KEIJ from the Upper Miocene Belait Formation of Southwest Saba (KEIJ, 1965) and a similar association of Ophiomorpha nodosa L. and Xenohelix cfr. X. marylandica MANSFIELD (=Gyrolithes) was described by KILPPER (1962) from the Miocene of Germany. These facts strongly suggest a synonymous relation of Ophiomorpha with Gyrolithes. If this is the case, Gyrolithes should be rejected because it is neither founded on a general burrow system nor an ubiquitous feature of the burrow system, although Gyrolithes is a senior synonym to Ophiomorpha.

KENNEDY (1967) described four ichnospecies under the ichnogenus Thalassinoides from the Lower Chalk of southern England. The four species show a granular, reticulate, scratch-marked and smooth texture of the wall-surface, respectively. That is to say, he did not recognize any distinction between Ophiomorpha and Thalassinoides. The joint occurrence of body fossil of *Callianassa* and ichnogenus Ophiomorpha or Thalassinoides (EHRENBERG, 1938; WAAGE, 1968; and GLAESSNER, 1946) seems to support KENNEDY's view. However, the joint occurrence of Ophiomorpha or Thalassinoides with crustacean genera other than *Callianassa* (Table 1) makes the problem complicated. Later, KENNEDY and MACDOUGALL (1969) concerned to use Ophiomorpha and described three types of O. nodosa from the Lower Cretaceous Weald Clay of southeastern England. One is provided with the typical knobby ornament, the second with a scratch-mark and the third with a meniscus structure. The present authors prefer to adopt Ophiomorpha and Thalassinoides as valid names applicable respectively for a large and branched burrow system with knobby ornament on the wall and for those others with a smooth wall.

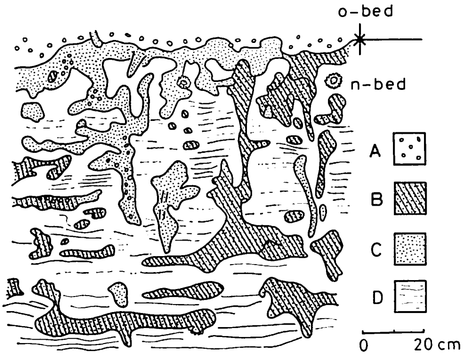

Fig. 3. Bioturbation by Ophiomorpha ashiyaensis ichnosp. nov. in the n-bed.
A: granule, B: obviously tainted portion with organic secretion, C: obscurely affected portion by organic material, D: original laminae in the sediment.

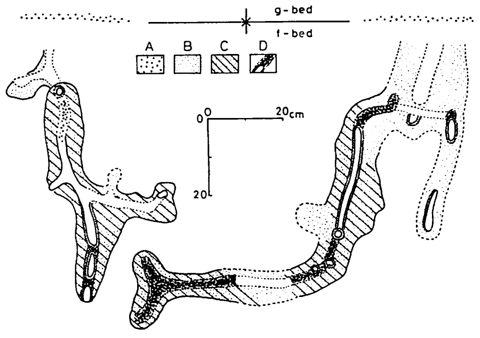

Fig. 4. Two burrows of Ophiomorpha ashiyaensis ichnosp. nov. in the f-bed on a vertical cliff.
A: granule, B: obscurely affected portion by organic material, C: obviously tainted portion by organic secretion, D: granular wall of burrows.

Ophiomorpha ashiyaensis ichnosp. nov.
(Crustolithida, type A)

Pl. 16, Figs. 3 and 4, Pl. 17, Figs. 1, 2 and 8, Pl. 18, Figs. 1 and 2, Text-figs. 3, 4 and 5B and C.

Holotype: GK-L 8725a and Paratypes GK-L 8725 b and c from the o_1-bed.

Diagnosis: Large and complicately branched burrow system attaining more than 100 cm deep and consisting mainly of shafts, tunnels and turn-around globes and normally associated with pellets-mound. Wall of shaft and tunnel being provided with granular ornamentation.

Morphology: Burrows of the type A extend downward from pleural openings on an omission plane to a depth of 70–170 cm and its lateral extension attains a maximum length of 117 cm. It has distinct mounds consisting of ovoidal pellets. Pellets are usually as large as a rice grain, but are seldom 7–8 mm in diameter. In some cases mounds are denuded and pellets are scattered in thin film over two meters from the original mounds. It has not been made clear how many pleural openings a single burrow system have, but some of the observed burrow systems are apparently provided with two or three openings. Shafts, extending from pleural openings, converge one after another at some depth. Once converged, the shaft may or may not branch off along the downward course. Horizontal tunnels radiate from the vertical shaft and branch out in a complicated zigzag, dendroid or Y-shaped fashion. Shaft is round in transverse section with a diameter of 2.0-2.5 cm and rarely of about 1.0 cm. There may be or may not be a globe at the point of branching. A shaft between the neighbouring ramifications is generally straight, but may be curved in some instances. Branching angle may be acute or obtuse. Shafts and tunnels have walls of 2-3 mm thick, which are lined with mud and probably

Table 2. Frequency of shafts and tunnels of Ophiomorpha ashiyaensis ichnosp. nov. and Thalassinoids iwayaensis ichnosp. nov. on a stratification plane (S in orientation), steeply inclined cliff (V) or wave-cut horizontal bench (B).

Frequency is represented by observed counts in a quadrat, 1m×1m. Sum of the measured length of the exposed tunnels is also indicated. To indicate the relative position of a quadrat in a bed, a square (steeply inclined cliff), oblique bar (bench) and horizontal bar (stratification plane) are employed.

Ophiomorpha ashiyaensis

locality	f_1-1	f_1-2	f_1-3	k_1-1	k_1-2	n_1-1	n_1-2	o_1-1
quadrat								
number (Q)	10	4	2	3	2	1	1	4
orientation	V	B	B	B	V	S	V	B
shaft								
vert.	67	54	3	48	27	14	12	41
obl.	27	12	0	12	11	0	5	6
tunnel								
hor.	25	34	0	26	13	6	20	100
length (cm)	-	685	-	470	-	85	-	2580
position in the bed	□	/	/	/	□	—	□	/

locality	p_1-1	p_1-2	r_1-1	r_1-2	r_1-3	s_1-1	s_1-2
quadrat							
number (Q)	1	1	2	1	1	1	1
orientation	B	S	V	S	S	S	S
shaft							
vert.	80	31	15	18	112	19	33
obl.	17	0	4	7	4	3	3
tunnel							
hor.	62	0	7	6	3	15	6
length (cm)	585	-	-	125	70	285	85
position in the bed	/	—	□	—	—	—	—

Thalassinoides iwayaensis

locality	t_1-1	u_1-1	v_1-1	v_1-2	v_1-3	v_1-4	v_1-5
quadrat							
number	2	2	4	2	2	2	2
orientation	B	B	V	V	S	B	B
shaft							
vert.	159	63	42	26	139	191	29
obl.	20	2	19	8	10	14	10
tunnel							
hor.	19	2	89	6	11	14	71
length (cm)	165	15	-	-	49	210	710
position in the bed	/	/	□	□	—	/	/

mucus. The texture of a wall is granular on the outer surface but is seemingly smooth inside. Pellets of about 3 mm in diameter are coarsely packed on the wall with a random orientation. Owing to the wall-structure mentioned above, the shaft and tunnel are readily distinguished from the surrounding sediment by a sharp boundary. It must owe to this reinforcement that both shaft and tunnel do not show any sign of collapse by the load of sediments except for the terminal part of a horizontally stretching tunnel. Some shaft have broad cells with a diameter of 5 cm and length of 15 cm, which are bordered by a constriction.

Comparison: Ophiomorpha LUNDGREN, 1891, consists of shafts and tunnels and is rather large attaining the depth of 30–90 cm and diameter of 0.95-2.5 cm. It is provided with a knob-like texture on the outer surface of walls and mud lining inside. It shows various patterns of branching and has often a globe at the point of branching. The type A burrow is asigned to Ophiomorpha on the basis of the morphology as described above and named O. ashiyaensis. The observed morphology of the examples from the Middle Ashiya Group conforms well with those described by FREY, HOWARD and PRYOR (1978).

Ophiomorpha ashiyaensis apparently includes two types. One is typically found in clean, coarser medium sandstones and is characterized by a longer shaft and less well-developed horizontal tunnels. The other abundantly occurs in less sorted and less stratified sandstones and is featured by a more complicated tunnel system. It is not clear whether the difference in the burrow system is related to an intraspecific ecological divergence or to the taxonomic difference of the builders.

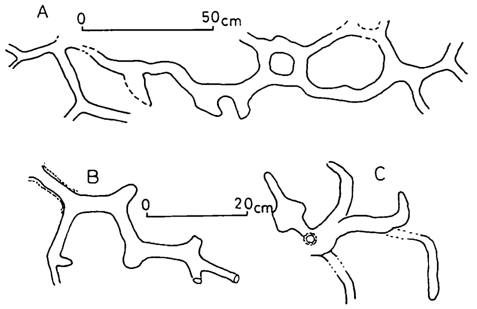

Fig. 5. Plan of horizontal tunnels.
A: Thalassinoides giganteus ichnosp. nov.
B and C: Ophiomorpha ashiyaensis ichnosp. nov.

Body fossil ever found in the Ophiomorpha burrows is *Callianassa* as indicated in the Table 2. Ophiomorpha from the Middle Ashiya Group is also similar to the burrow of living *Callianassa* and the former is most probably attributed to an ancient *Callianassa.* Thalassinidae including *Callianassa, Upogebia, Alpheus* etc. is one of the most extensively investigated groups of Recent trace builders.

Ophiomorpha major (LESQUEREUX), which has long been regarded as an algal structure, has a geological range from Recent back to the Cretaceous in central and southeastern U. S. A. and its builder was referred to *Callianassa major* SAY (HOYT and WEIMER, 1963). POHL (1956) and WEIMER and HOYT (1964) mentioned of the small upper part of the shaft of the burrow of *C. major* with a diameter of 5-10 mm and length of 10-20 cm. The following parts, although their descriptions do not necessarily agree with each other, become gradually larger downward to a diameter of 20 mm and have several branches. Its vertical extension is 90–180 cm. O. ashiyaensis is similar in size to the burrow of *Callianassa major* SAY described by these authors, but does not reveal a gradual increase in the diameter of shaft in the second segment. Moreover, O. ashiyaensis has more finely knobby wall.

WEIMER and HOYT (1964) and FREY et al. (1978) referred the North American Upper Cretaceous species of Ophiomorpha to O. nodosa L. However, the North American species are clearly distinguishable from O. nodosa in the wall texture. While O. nodosa has ovoidal pellets whose long axes are arranged perpendicularly to the direction of shaft, the North American "O. nodosa" shows a single-pellet wall construction. The latter actually belongs to O. major.

Ophiomorpha nodosa L. ranging from the Jurassic to the Miocene in Europe, consists mainly of shafts and has few tunnels. In this feature, the present ichnospecies from the offshore-bar facies is similar to O. nodosa, but is readily distinguished from the latter by the wall texture as mentioned above.

Ophiomorpha borneensis KEIJ from the Upper Miocene Belait Formation of Labuan, Southwest Saba, has a similar burrow system to the present species with many horizontal tunnels. The former is, however, distinguished from the latter in having cocoon-like pellets with double cones.

HATAI et al. (1968 and 1970) reported pellet mounds from the Pliocene Kogota Formation, Miyagi Prefecture, Japan. The pellets, in this case, are somewhat cylindrical, gently curved, and are readily distinguishable from the ovoidal pellets of the present species.

Occurrence: Ophiomorpha ashiyaensis is typically yielded in well-sorted coarser medium sandstone with parallel lamination (n_1-, lower p_1-, r_1- and s_1-bed) which laterally grades into a cross-laminated sandstone. Both of these sandstones represent an offshore-bar facies. It also commonly occurs in a well sorted massive sandstone (A-, f_1- and upper n_1-bed). Bioturbation by this ichnospecies is more vigorous in some of less sorted medium sandstones with finer component (b-, d_1-, i_1-, k_1-, o_1- and upper p_1-bed). Finer sandstones (h_1- and j_1-bed) sporadically contains traces of this ichnospecies. It rarely exists in coarse sandstones, even in conglomeratic sandstone (g_1-bed) and silty sandstone (top of p_1-bed). Burrows often cross the intrastratal stratification but do not penetrate interstratal bedding planes. Sometimes, they remarkably disturb the original sedimentary structure and show an obvious tendency to form calcareous nodular lenses and layers.

Burrows of this type are more densely distributed in the area ②-③ than in ⑥. In a single bed, shafts occur much more densely than tunnels in the upper 50 cm below the omission plane and a reverse relation is observed near the lower boundary plane. The ratio of the number of shafts and tunnels is nearly 2:1 on an erosion plane parallel to the bedding at the middle part of all the examined beds (Table 2).

Pellets associated with O. ashiyaensis show two types of occurrence. One is a pellet-mound which keeps the original form (d_1-, h_1-, i_1-, k_1- and o_1-bed) and the other is a spread sheet (e_1-, m_1- and n_1-bed). The former indicates a rather quiet environment below the tidal zone, while the latter reveals a weak winnowing action of water. Under a higher energetic condition, pellet mound would be utterly destroyed and did not leave any sign of original mound nor secondary sheet. The last case is exhibited by the association of *Glycymeris cisshuensis* and O. ashiyaensis in the p_1-bed, in which *Glycymeris* forms a shell layer suggestive of a rough sea condition by hydrostable orientation of its heavy valves.

Ophiomorpha ashiyaensis shows the widest variety of species association, which is simply defined here as the cooccurrence of both ichno- and biospecies at a single horizon of any locality. Although the present ichnospecies is not associated with any other fossil in the offshore-bar facies, it occurs frequently together with the type D in less sorted and finer sandstones. This association may be accompanied with the type F, G, H or a molluscan assemblage of *Angulus maximus-Pitar ashiyaensis-Lucinoma nagaoi.* While O. ashiyaensis occurs in a coarse sandstone together with *Glycymeris cisshuensis, Lucinoma nagaoi* and *Pitar matsumotoi* (p_1-bed), it is associated in a silty sandstone with *Phaxas izumoensis* and *Angulus maximus* (c_1-, c_4- and d_4-bed). The most diversified association consisting of Ophiomorpha ashiyaensis, the type F, D, E and H is seen in a silty sandstone of the uppermost p_1-bed.

Ophiomorpha has been regarded as a good indicator of both the shallow sublittoral and littoral facies (PATTERSON, 1942; HOYT and WEIMER, 1963; KEIJ, 1968; WAAGE, 1968; and DIKE, 1972), although rare examples are known from a non-marine (Middle Eocene Helmstedt Lignite Formation, HILLMER, 1963) and deeper marine facies (upper part of the glauconite-forming zone, DIKE, 1972). The present example well agrees with the typical occurrence with rare exception. That is to say, the builder of O. ashiyaensis generally had its habitat in the submerged part of offshore-mound (OB type burrows) and lower foreshore (FS type burrows). The FS type burrows occasionally extends to a deeper zone, i. e. sublittoral zone with substrate of muddy sand. LUTZE (1938) mentioned that the North Sea and Mediterranean species of *Callianassa* have their habitats in the middle to lower sublittoral zone and uppermost sublittoral zone, respectively. This suggests a tendency of bathymetric gradation of *Callianassa* according to aquatic climate. If this tendency is a general rule, and the builder of Ophiomorpha ashiyaensis was *Callianassa* species, its habitats might have been covered by a warm water.

Ichnogenus Thalassinoides
EHRENBERG, 1944

type-species: T. callianassae
EHRENBERG. (o. d.)

Thalassinoides iwayaensis ichnosp. nov.
(Crustolithida, type B)

Pl. 16, Fig. 6 and Pl. 17, Figs. 3-7 and 9.

Holotype: GK-L 8731a and paratype GK-L 8731b from the t_1-bed.

Diagnosis: Large and complicately branched burrow system attaining more than 100 cm deep and consisting of shafts, tunnels and globes. Wall of shaft and tunnel smooth.

Morphology: The burrow consists of shafts, globes and tunnels and attains more than 100 cm in depth. A globe is situated, when exists, at the point of bending or turning of the shaft. The transverse section of a shaft is usually circular with a diameter of 2.0-2.5 cm and unusually of only 0.7 cm (Table 3). Even one and a single shaft varies its diameter from part to part noticeably. A vertical shaft goes down from a globe by some distance to the other globe. Further downward extension of the shaft may be vertical or oblique and, finally, the lowest part spreads horizontally by complicated branching. Horizontal tunnels are not always sharp at the boundary between sediment outside.

Globes and branching of shafts are observed at irregular intervals. Branching of upturned Y-shape is common. Boundary between mucus-coated wall of burrows and the surrounding sediment is

Table 3. Size-frequency of shafts of Thalassinoides iwayaensis ichnosp. nov. in the v-bed.

Diameter of shaft	5-10	10-15	15-20	20-25	25-30	30-35	35-40
frequency	28	27	35	20	4	1	1

readily recognized on globes and connecting shafts, but is very obscure on the branching part of shafts without globe. Horizontally spread tunnels, which may be feeding traces, are often deformed by load of sediments to show irregularly oval shape in transverse section. In more deformed cases, they do not reveal tubular feature at all. Ornament is not observed on the wall-surface of any part of burrow.

Comparison: The type B consists of a burrow system of vertical shafts, horizontal tunnels and globes on its downward extension and is provided with a smooth wall. Accordingly it is referred to Thalassinoides Ehrenberg, 1944 and is named T. iwayaensis.

The frequency of shafts and tunnels of Thalassinoides iwayaensis in an observed quadrat shows a tendency similar to that of Ophiomorpha ashiyaensis, but the tendency is much more exaggerated in T. iwayaensis than in O. ashiyaensis. That is to say, shafts are much denser than tunnels in the upper part of each bed and are scarcer in the lower part (shaft/tunnel ratio in a vertical quadrat being 12:1 and 2:3 respectively in the upper and lower part) (Table 2).

The present ichnospecies is similar to Thalassinoides callianassae EHRENBERG, the type-species of the ichnogenus Thalassinoides, from the Burdigalian bank sandstone of Burgschleinitz, Austria, but the former is distinguished from the latter in having much denser and more complicated network of tunnels.

GLAESSNER (1964) described a burrow system of *Callianassa major* SAY from the Eocene Pebble Point Beds, Victoria. On that occasion he emphasized its characteristic features as follow; (1) generally straight shaft with more or less angular change in direction, (2) bifurcating but not arborescent branching, (3) limited size range, (4) smooth surface of wall without agglutination of pellets or sands, and (5) occurrence of blind ends. This burrow system is evidently different from Ophiomorpha major, which includes the burrow of living *Callianassa major,* in being devoid of pellet-coated wall of the shaft and must be referred to Thalassinoides. T. iwayaensis is somewhat similar to GLAESSNER's specimen, but the former is separated from the latter in being provided with complicated network of tunnels.

Thalassinoides paradoxica (WOODWARD) from the Lower Chalk of southern England (KENNEDY, 1968) is similar to the present species in a general pattern of the burrow system, particularly in its horizontal and branching network, but the former penetrates to a shallower depth and has larger shafts and tunnels than the latter.

Thalassinoides iwayaensis shows some resemblance to T. ichnosp. [=Spongites ichnosp.] from the Miocene Upper Marine Molasse of Swiss (SEILACHER, 1955), but the latter is much more regular in alternately branching system than the former.

OHSHIMA and NEMOTO (1968) reported a feeding structure of *Callianassa japonica* ORTMANN from the Eocene Wakkanabe Formation, Hokkaido, Japan, which shows a circular transverse section with a diameter of 1.0-1.5 cm and has globes at the points of bending and bifurcation. T. iwayaensis is distinguished from the burrows described by OHSHIMA and NEMOTO in much larger diameter and closer to GLAESSNER's specimen.

IMAIZUMI (1959) recorded "sandpipes" associated with *Callianassa bona* IMAIZUMI in the Middle Miocene Hatatate Formation of the Natori Group, Miyagi Prefecture, Japan. Although he did not give any descriptive feature of these sandpipes, his mention of the similarity of his sandpipes to GLAESSNER's *Callianassa* burrow (GLAESSNER, 1964) suggests a presumable similarity between T. iwayaensis and the Hatatate specimens.

ARAKI (1959) described the elbow-shaped sandpipes from a siltstone of the Miocene Kaisekizan Formation, Mie Prefecture, Japan. He reported them in association with the detached palms of *Callianassa* cfr. *C. yagii* IMAIZUMI, *Panope, Dosinia, Cultellus, Chione* and *Glycymeris* in one and the same bed and he referred to the identity of those trace structures to *Callianassa yagii.* His specimens are somewhat similar to T. iwayaensis in shape and size, but sufficient comparison can not be done because his specimen represents only a small portion of a burrow system. NOMURA and HATAI (1936 and 1937) reported parts of large burrows from the basal member of the Miocene Suenomatsuyama Formation, Ninohe district, Aomori Prefecture and the Miocene Yanagawa Formation, Fukushima Prefecture, North Japan, but a detailed comparison of those fossils with C. iwayaensis is impossible by the same reason as for the preceding example.

Thalassinoides iwayaensis resembles a burrow of Recent *Callianassa japonica* ORTMAN, which, according to OHSHIMA (1967a and b), is characterized by a Y-shaped pattern of the upper shaft above the turnaround, a very narrow entrance with a knobby wall, a pellet mound around the opening and the irregularly branching lower part. Any perfect burrow system of T. iwayaensis was not observed. However, its average feature is different from the burrow of *Callianassa japonica* in lacking the extremely narrow uppermost shaft with knobby wall and in having more complex tunnels.

Occurrence: Thalassinoides iwayaensis occurs densely in muddy fine sandstones of the t_1-, u_1- and v_1-beds. The t_1-bed is lithologically differentiated into a few parts and T. iwayaensis extends downward beyond the lithological boundary, although the boundary is rather gradational. Namely, burrows penetrate through the upper *Glycymeris* layer into the underlying muddy sandstone. The density of shafts is highest (2.3/100 cm^2, averaged from the counts made in one quadrat) in the upper part and decreases toward the lower part, which is featured by onion structure. Sediment, filled in burrows, is laminated and coarser than the surrounding sediment. In the u_1-bed, burrows are distributed uniformly and extend downward from the upper boundary of the bed. Obvious globes are preserved. In the v_1-bed, burrows are distributed densely below the middle of the bed and associated with a *Dosinia-Solen* assemblage, while their numbers gradually decrease toward the fine sandstone in the upper part, which contains a *Venericardia-Acila* assemblage (loc. I-14).

Thalassinoides iwayaensis is yielded in the upper t_1-bed together with apparently autochthonous individuals of *Solen connectens,* which were found conjoined and in life-position holding their long axes vertically. T. iwayaensis rarely coexists with *Acila ashiyaenssis* and *Venericardia subnipponica* (loc. I-14) and with *Pitar ashiyaensis* and *Euspira ashiyaensis* (loc. I-24). That is to say, the present ichnospecies is most typical of the lower tidal and upper subtidal zones affected by the coastal water, but shows a wide range of association with such molluscan species indicative of environments ranging from a protected embayment to an offshore environment.

Thalassinoides giganteus ichnosp. nov.
(Crustolithida, type C)

Pl. 16, Figs. 1, 2, 5, 7 and 8 and Text-fig. 5A

Holotype: GK-L 8735a and paratype GK-L 8735b from the a_2-bed.

Diagnosis: Large and complicately branched burrow system attaining about 100 cm deep and 300 cm wide and consisting of shafts, tunnels and globes. Tunnels forming polygonal network. Wall of shaft and tunnel smooth.

Morphology: The burrow system of the type C consists of shafts with smooth wall and network of horizontal tunnels and is referred to Thalassinoides. It is very large penetrating downward to a depth of 100 cm and spreading horizontally in two to three meters. Shafts and tunnels have a diameter of 4-5 cm. A single burrow system has two or more openings, immediately below which some shafts are remarkably narrowed to form nozzle-shape. Shafts often converge, curve and ramify in their downward course irregularly. Horizontal tunnels form complicated, often polygonal, network and tend to be deformed by load of sediment exhibiting a flattened profile. They have usually blind ends. Globes exist often at the points of branching and chamber-like spaces are rarely seen on some shafts. A mucus-coated wall is discernible on vertical shafts but is not observed on horizontal tunnels. The wall is 3 mm thick and smooth both inside and outside. In-fillings of the burrow are mixture of coarse sand and mud.

Comparison: Thalassinoides giganteus is featured by its very large size, nozzle-like opening, smooth wall and polygonal network of horizontal tunnels. It is similar to T. saxonicus (GEINITZ), particularly those from the Lower Chalk of southern England (KENNEDY, 1967), but the former is distinguished from the latter in the surface texture of the shaft and tunnel. While T. saxonicus has mammilated wall of shafts with elongate mamillae arranged their long axes parallel to the direction of the shaft, T. giganteus has smooth wall of shafts.

Thalassinoides giganteus somewhat resembles the burrow of living *Laomedia astacina* DE HAAN. According to OHSHIMA (1967a), *L. astacina*, a detritus feeding sandy mud dweller, builds a mound around the opening of the burrow. Its burrow system consists of three parts; the first cylindrical small shaft immediately below the pleural opening, succeeding looping second part and remarkably larger and longer third part. T. giganteus is obviously devoid of the looped part. UTASHIRO et al. (1968) described the burrows of *L. astacina* in detail. On that occasion they referred to the complicately branched lower part and very large pellets (20 mm × 16 mm × 16 mm) of rhomboid or ellipsoid shape. The above features of *L. astacina* are clearly different from T. giganteus.

Occurrence: Thalassinoides giganteus occurs in poorly sorted sandy mudstones with coarse sand patches in the top part of the a_2-, a_3- and a_4-beds and black siltstones with wood-fragments in the basal part of the same beds. These beds probably represent a lagoonal facies. T. giganteus in the upper sandy mudstone never extends upward to the sorted medium sandstone of the b-bed with Ophiomorpha ashiyaensis and downward

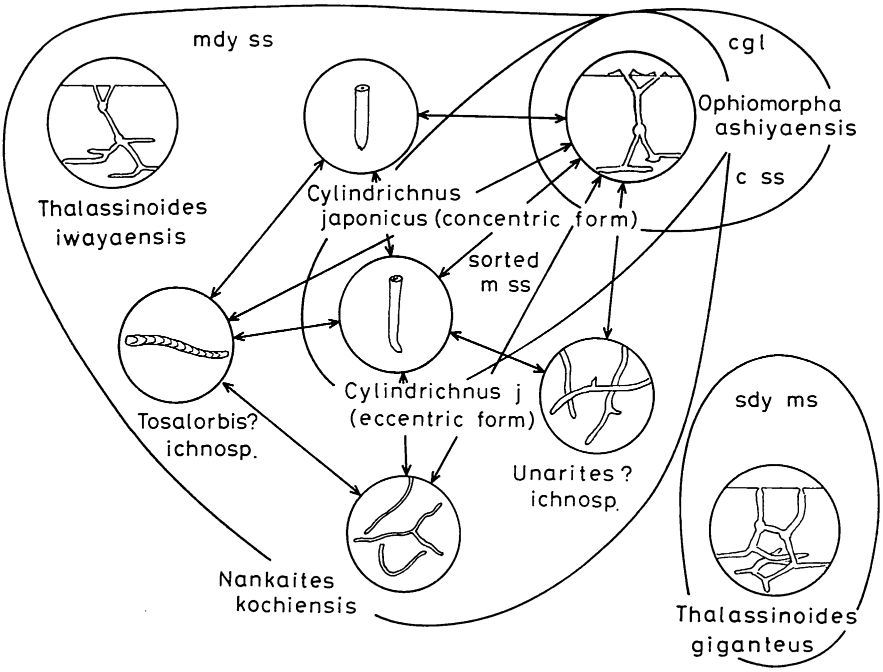

Fig. 6. Faunal and lithological association of the ichnospecies in the Jinnoharu Sandstone Member of the middle Ashiya Group.
Areas encircled by solid lines respectively represent one lithological type. Ichnospecies occurring together are connected by arrows.

to the calcareous muddy conglomerate beyond the lithological boundary. In the basal a-bed, they never cross the lower lithological boundary too and are often truncated at the upper portion (truncated pre-erosion burrow). In general, T. giganteus does not associate with any other ichno- and biospecies.

Ichnogenus Cylindrichnus HOWARD, 1966

type-species : Cylindrichnus concentricus HOWARD, monotype

Cylindrichnus japonicus ichnosp. nov. (Rectotubae, type D)

This ichnospecies includes distinct two forms, concentric and eccentric forms.

Holotype: GK-L 8737 from the p_1-bed representing the concentric form. Paratype: GK-L 8739 from the same bed representing the eccentric form.

C. japonicus, concentric form

Pl. 18, Figs. 3, 5 and 6

Diagnosis: Concentrically multilayered, cylindrical, vertical and straight. Size moderate, 10-25 mm in diameter and 10 cm or less in depth.

Morphology: The burrow is a cylindrical tube consisting of many concentric layers. It is circular in transverse section with an outer diameter of 10-25 mm (max. 30 mm), straight and vertical or slightly bent without ramification to attain about 10 cm long or less. It has generally a small opening of about 5 mm in diameter on an omission plane. The opening is situated at the center of a burrow and almost constant in diameter irrespective of the outer diameter of the burrow. That is to say, a larger burrow has a thicker wall, which is whitish, somewhat calcareous, thick and concentrically multilayered.

Comparison: Multilayered cylindrical burrows of the type D are referred to Cylindrichnus HOWARD, 1966. Comparing with slightly conical C. concentricus HOWARD, the type-species of the ichnogenus, the present ichnospecies is much more cylindrical.

The burrow of this type reminds the epi-siphonal mucus-coated structure of deeply burrowing bivalves (Exogenbedingte Mehrwandigkeit, REINECK, 1968). According to his explanation of the origin, mucus-coated concentric layers become multiplied when the burrower dwells for relatively long duration at one and the same burrow under very slow or non-depositional condition. It is not clear whether or not the trace producer of the concentric form of C. japonicus is bivalve, because no body fossil was found in the burrow in a life position. However, it is very suggestive that the present form is frequently associated with deep burrowing bivalves, *Lucinoma nagaoi* OYAMA and MIZUNO or *Angulus maximus* (NAGAO).

Burrows of *Scopimera globosa* DE HAAN and *Ilyoplax pusillus* (de HAAN) described by UTASHIRO and HORII (1965) have somewhat similar configuration to the present ichnospecies, but the former two are distinguished from the latter in being devoid of multi-layered structure and in difference in size.

Occurrence: The concentric form of C. japonicus occurs in muddy sandstone of the uppermost part of the p_1-bed in association with trace-fossils of Ophiomorpha ashiyaensis, eccentric form of Cylindrichnus japonicus, Tosalorbis ? ichnosp. and Unarites ? ichnosp. and body fossils of *Lucinoma nagaoi* and *Angulus maximus*. No other bivalve species is known in association with the present ichnospecies.

C. japonicus, eccentric form
(Rectotubae, type E)

Pl. 18, Fig. 3

Diagnosis: Eccentrically multilayered, cylindrical and straight burrow. Sometimes curved in the lower part. Size moderate attaining about 10 mm in diameter and 15 cm in depth.

Morphology: Burrows of the type E are multilayered, regularly cylindrical and vertical with length of about 15 cm. Majority of them are straight, but some are slightly curved at the lower part forming J-shape or hook-shape. Transverse section of the burrow is circular with an outer diameter of about 10 mm. Burrows open their entrance on an omission plane and stretch downward without ramification. A small opening, about 5 mm in diameter, is not situated at the center of a burrow but is eccentrically located. An opening is rarely covered by a white lid-like object. Burrows do not show any sign of collapse by load. The wall is whitish, 1-2 mm thick and concentrically multilayered.

Comparison: The eccentric form of C. japonicus closely resembles the above described concentric one, but the typical eccentric form is smaller in diameter and longer in extension than the latter and its opening is not situated at the center of a tube. Frequency-distribution of morphological characters of the two forms suggests that they are not necessarily continuous morphologically to each other and that the two might have been made by different organisms. However, the data, particularly those of the concentric form, are not satisfactorily plenty and some specimens show intermediate features between the two. Hereby the two forms are described as different forms within a single ichnospecies.

Deeply burrowing bivalves which occur together with this mucus-coated multilayered burrow are *Angulus maximus* and *Lucinoma nagaoi*. However, the contributor of the eccentric form is not confirmed, because the association of the burrows and *Angulus* and *Lucinoma* is exemplified only by a single case (loc. I-28b, lower part of the b_2-bed). And even in this case, the body fossils do not lie at the base of the ichnofossils, but are separated from the latter at some short distance.

Occurrence: The eccentric form occurs at several horizons and their density is very high attaining 5 per $100 cm^2$ (average of the counts in a quadrat of $40 cm \times 50$ cm at the uppermost part of the b_2-bed). It coexists with Ophiomorpha ashiyaensis without any exception, but does not occur or occurs very rarely where O. ashiyaensis is extremely dense. This form is also associated with O. ashiyaensis in the muddy sandstone of the uppermost part of the A_2-bed together with traces of the type G. In the latter case, clusters of the eccentric form and the type G are separated from each other. This fact must suggest microhabitat-seggregation of the builders of two ichnospecies.

Ophiomorpha ashiyaensis, associated with the eccentric form of C. japonicus, is devoid of a pellet mound in the A_2-, lower b_2- and upper q_1-beds and provided with a mound in the A_3-, middle b_2-, upper b_3- and d_1-beds. This fact suggests that the above tracefossils were formed in the tidal zone and in a quiet subtidal zone.

Ichnogenus Tosalorbis KATTO, 1960

type-species: Tosalorbis hanzawai
KATTO, o.d.

Tosalorbis ? ichnosp.
(Rectotubae, type F)

Pl. 18, Fig. 7

Representative specimen: GK-L 8740 from the p_1-bed.

Morphology: A horizontally or slightly obliquely lying holostructure. About 1 cm wide and 10-20 cm long. The structure shows various shapes ranging from simple arc to sigmoid or U-shape and is circular in transverse section. One extremity of a trace is round and somewhat larger than the tapering opposite extremity. The most conspicuous feature of this trace fossil is a close-set septa-like structure which is obliquely orientated to the longitudinal axis. The septa-like part seems materially similar to the mucus-cemented outer wall and may represent a spreite structure.

Comparison: The present trace-fossil reminds the moving trace of heart urchin, but the mucus cemented structure of the former is much smaller and more regular in shape than the latter.

It is also similar to Scalarituba WELLER, 1899, but is easily distinguished from the latter by its three to four times larger size and less conical septa-like structure. KATTO (1960) described Tosalorbis hanzawai and T. peculiaris on the basis of the material from the Paleogene of Shikoku, Japan. According to the original author, Tosalorbis is a complete structure characterized by its "serpentine-like feature" with "parallel rings". Therefore the present trace-fossil from the Ashiya

Group basically resembles Tosalorbis. T. hanzawai is represented by a fragment of 55 mm long and has 18 septa per 10 mm, while T. peculiaris is more than 20 cm long and has 10 septa per 10 cm. The present ichnospecies is apparently closer to T. peculiaris than to T. hanzawai in regard to the septal structure. However, definite identification is suspended here because of insufficient material.

Occurrence: Tosalorbis ichnosp. occurs in the uppermost part of the p_1-bed together with Ophiomorpha ashiyaensis, Cylindrichnus japonicus, C. eccentricus and the type H. T. ichnosp. forms clusters in the middle part of the d_1-bed. Although their position in the sediment is immediately below a stratification plane, they are not strictly horizontal, but may be obliquely curved inward in some cases.

Ichnogenus Nankaites KATTO, 1964

type-species: Nankaites kochiensis KATTO, o. d.

Nankaites kochiensis KATTO (Cryptoreptida, type G)

Pl. 18, Fig. 4

1964, Nankaites kochiensis KATTO, Res. Rep. Kochi Univ., Vol. 13, Nat. Sci. I, No. 6, p. 55(11), pl. 6, fs. 3 and 4.

Representative specimen: GK-L 8741 from the A_3-bed.

Morphology: A small full structure with width of 2 mm and length of about 30 mm. The shape of a cross-section is oval and wider than thick. Traces may be straight, sinuous or irregularly curved and very rarely ramified. The surface of a trace is not very smooth and devoid of any ornament.

Comparison: The present ichnospecies is quite identical to Nankaites kochiensis KATTO from the Eocene Shimizu Formation of Tosashimizu, Shikoku, except for a slight difference that the former is less flat than the latter. The last mentioned feature, however, is not a diagnostic to the ichnospecies, but may be a result of a influence of the post-depositional condition.

It is also similar to Torrowangea WEBBY, 1970, but the former lacks the transverse annulation. Nankaites kochiensis is similar to the trace made by some Polychaeta, for example, the trace of *Streblospio benedicti* WEBSTER illustrated by FREY (1968). The latter is 20–30 mm long, almost horizontally lying, nearly straight, weakly sigmoidal or slightly curved. Surface is simple and smooth. However, concrete reference to the identity of the builder can not be given here, because the structure is too simple and many organisms are expected to build similar structure.

Occurrence: Nankaites kochiensis occurs in cluster near the upper boundary of the muddy sandstone of the uppermost part of the A_2- and the A_3-bed in association with Ophiomorpha ashiyaensis and Cylindrichnus eccentricus.

Ichnogenus Unarites MACSOTAY, 1967

type-species: Unarites suleki MACSOTAY, monotype

Unarites ? ichnosp. (Cryptoreptida, type H)

Pl. 18, Figs. 8 and 9

Representative specimen: GK-L 8743 from the c_2-bed.

Morphology: Horizontally orientated small epirelief with length of about 10 cm. Diameter is variable even in a single trace ranging from 2.5 to 5.0 mm (rarely

10 mm). Majority of traces are straightened, slightly sinuous and not ramified, but some have short thorn-like ramifications. Traces often cross over others and have superficially an appearance of ramification of T-shape, Y-shape or cross-shape. Sometimes globe-like broad spaces exist irregularly. The surface is somewhat uneven, but does not show any definite or regular sculpture.

Comparison: The present ichnospecies is similar to the preceding one, but the former is readily distinguished from the latter in larger and straight form with short thorn-like ramification.

KSIAZKIEWICZ (1970) reported Unarites submontana (AZPEITIA) as Palaeochorda submontana from the Lower Eocene Beloveza Beds of the Polish Carpathians. The present ichnospecies closely resembles U. submontana in size, general shape and particularly in ramification, but the former is distinguished from the latter in straighter form. Concrete reference of the present ichnospecies to Unarites Macsotay, 1967, is suspended, because the former is epichnial instead of hypichnial nature of the latter.

Occurrence: The present ichnospecies lies horizontally on the scoured plane at the top of both the b_3- and the p_1-bed and on the lower omission plane within the c_2-bed in association with Ophiomorpha ashiyaensis (b_3-, p_1- and c_2-bed), Cylindrichnus eccentricus (do.) and Tosalorbis ichnosp. (b_3- and p_1-bed).

IV. Bathymetric change through the middle Ashiya Group

SHUTO and SHIRAISHI (1971) discussed on bathymetric and hydroenergetic conditions of the ecological environments for the molluscan fossil communities of the Iwaya district through a comparison of the fossil and recent benthic molluscan

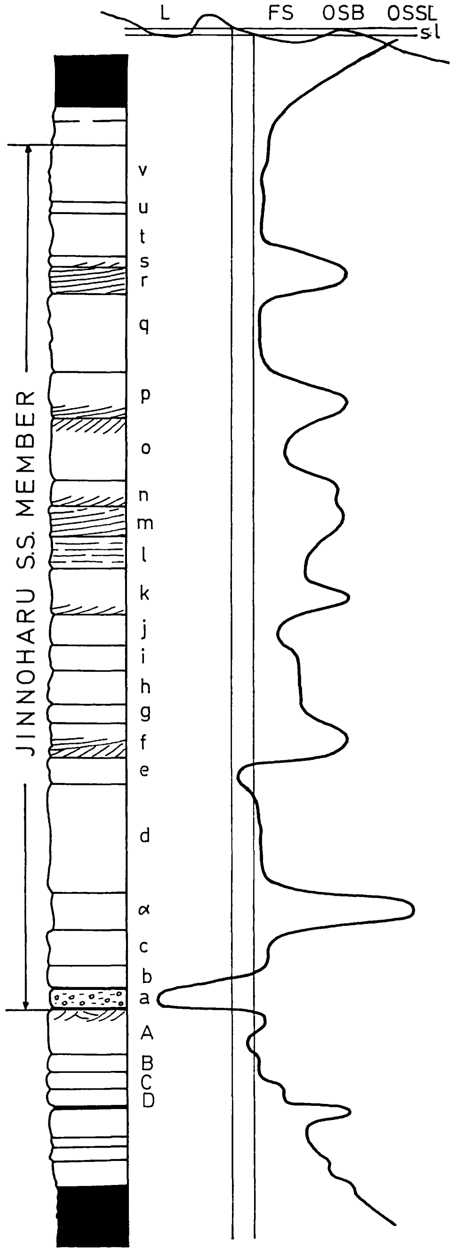

Fig. 7. Fractuation in the marine condition through the middle Ashiya Group.
L : lagoonal facies, FS : foreshore facies, OSB : offshore-bar facies, OSSL : offshore sublittoral, sl : sea-level at high and low tide. Lithology cfr. Fig. 2.

communities and sedimentary indices of their environmental factors. However, many of the strata remained unexplained, because molluscan faunules are yielded in the limited horizons. This time, environmental consideration is supplemented by the knowledge on the trace-fossils.

A shallowing sedimentary environment is clearly indicated by a gradual change of lithology from finely stratified mudstone with Palaeotaxodonta assemblages of the main part of the Norimatsu member to medium sandstone with Ophiomorpha of the top of the member (A-bed) through muddy sandstone and fine sandstone. Bathymetric change from the lower sublittoral to the foreshore zone may be presumable. The overlying muddy calcareous conglomerate accompanying carbonaceous siltstone layers both in its upper and lower parts (a-bed, basal Jinnoharu Member) may represent a lagoonal facies. Then, the foreshore facies was maintained until the deposition of the e-bed with an ephemeral interuption by sublittoral silty facies (α-bed). After the deposition of the e-bed, offshore-bar facies prevailed in the area (f- to p-bed). During the deposition of the q- to v-bed, a quiet foreshore facies protected by offshore bars prevailed with intercalation of offshore mound facies (r- and s-bed). Thereafter the sedimentary environment again became gradually deeper (Fig. 7)

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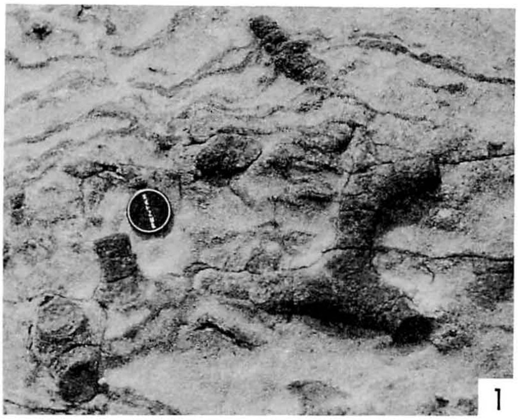
Explanation of Plate 16

Figs. 1, 2, 5, 7 and 8. Thalassinoides giganteus ichnosp. nov.
- 1 and 2: tunnels and parts of shafts in the a_3-bed.
- 5 and 7: polygons of tunnels in the a_2-bed. Holotype specimen GK-L 8735a is a part of the polygons in Fig. 5.
- 8: nozzle-like uppermost part of a shaft. Paratype GK-L 8735b.

Figs. 3 and 4. Ophiomorpha ashiyaensis ichnosp. nov.
- 3: pellet-coated tunnel. Holotype specimen GK-L 8725a was obtained from the figured tunnel.
- 4: pellet-coated shaft. Paratype specimen GK-L 8725c was obtained from the figured shaft.

Fig. 6. Distribution of shafts of Thalassinoides iwayaensis ichnosp. nov. in the v_1-bed on a wave-cut bench.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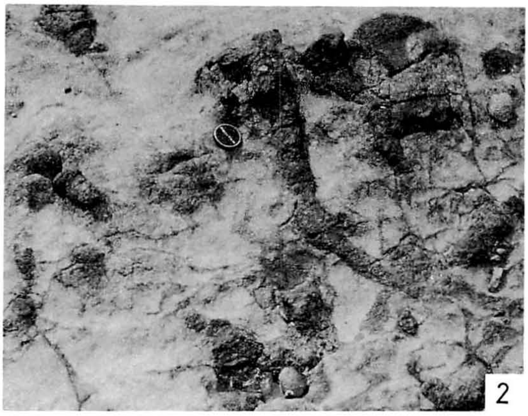
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Explanation of Plate 17

Figs. 1, 2 and 8. Ophiomorpha ashiyaensis ichnosp. nov.
1: infillings of a branched tunnel in the e_1-bed.
2: ditto, in the o_1-bed.
8: shafts and tunnels in the o_1-bed on a wave-cut bench.

Figs. 3-7 and 9. Thalassinoides iwayaensis ichnosp. nov.
3, 5, 7 and 9: shafts and tunnels in the v_1-bed on a steep cliff.
4: branching part of a tunnel (Holotype GK-L 8731a) obtained from the t_1-bed.
9: oblique shafts in the p_1-bed with association of *Solen connectens* NAGAO. Paratype GK-L 8731b being the larger shaft.


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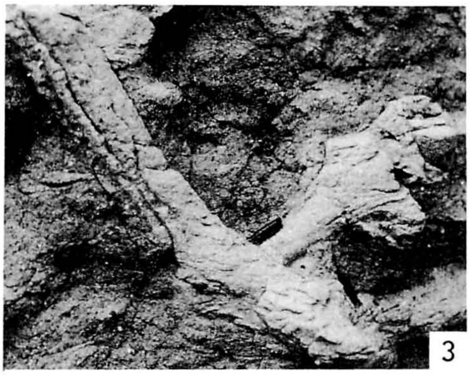
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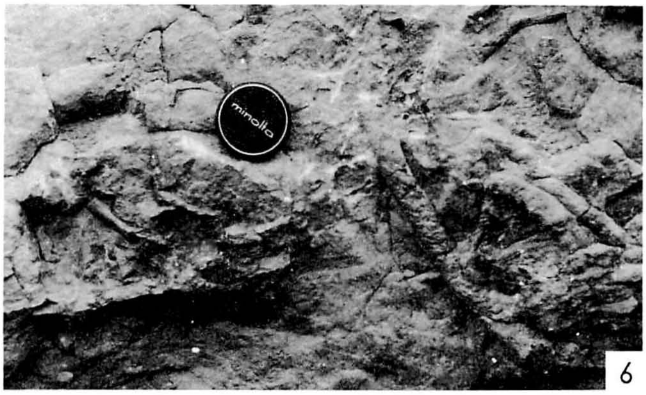

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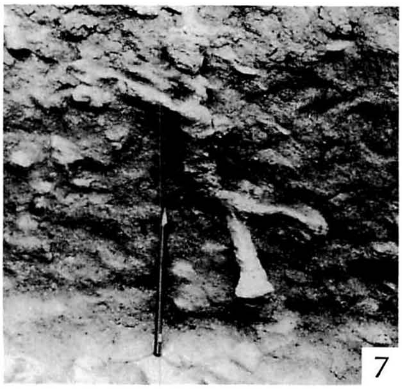
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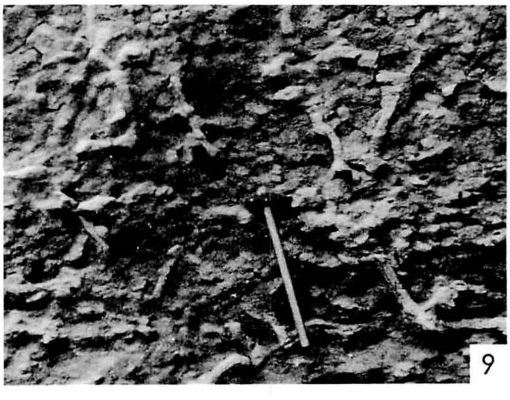
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北九州市若松区岩屋地区に分布する芦屋層群坂水層陣の原砂岩部層の生痕学的研究を行った。生痕化石の記載・分類に関してまだ定着した方法がないので，この研究で採用した筆者らの考え方と手法をまず明らかにした。次に形態に基づいて同砂岩部層産の生痕化石を記載し，生態的な考察をも加えた。最後に同砂岩部層堆積時の水深・地形等にかかわる環境変遷に言及した。

首藤次男・白石成美

Explanation of Plate 18

Fig. 1. Pellet-mound of Ophiomorpha ashiyaensis ichnosp. nov. in the k_1-bed.

Fig. 2. Bioturbation by Ophiomorpha in the o_1-bed.

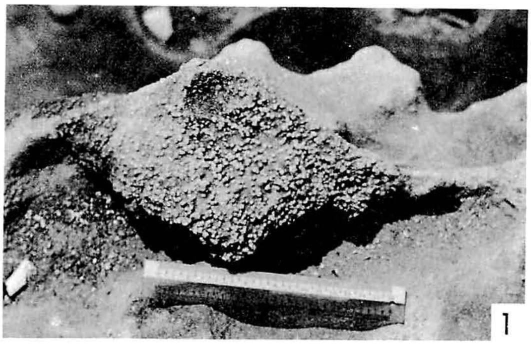
Fig. 3. Cylindrichnus japonicus ichnosp. nov., concentric form and eccentric form (with arrow mark) in the p_1-bed.

Fig. 4. Nankaites kochiensis KATTO in the A_2-bed. GK-L 8741.

Fig. 5 and 6. Cylindrichnus japonicus ichnosp. nov., concentric form on a vertical fracture wall.

Fig. 7. Tosalorbis ? ichnosp. from the p_1-bed. GK-L 8740.

Fig. 8 and 9. Unarites ? ichnosp. from the c_2-bed. GK-L 8743 being obtained from the cluster in Fig. 8.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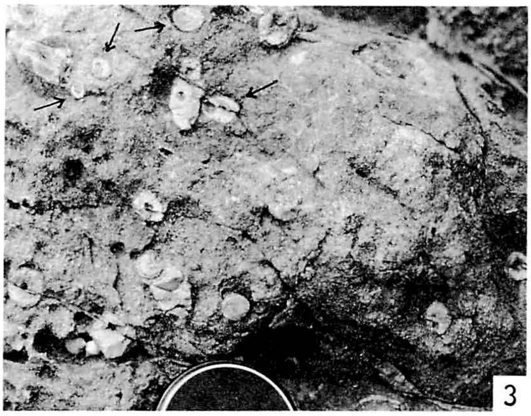
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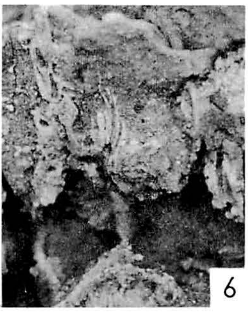
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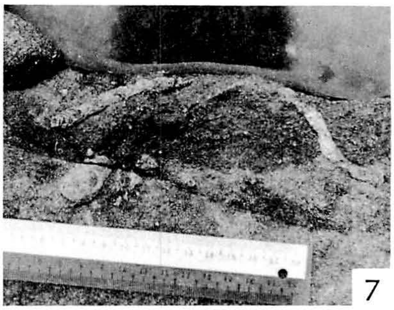
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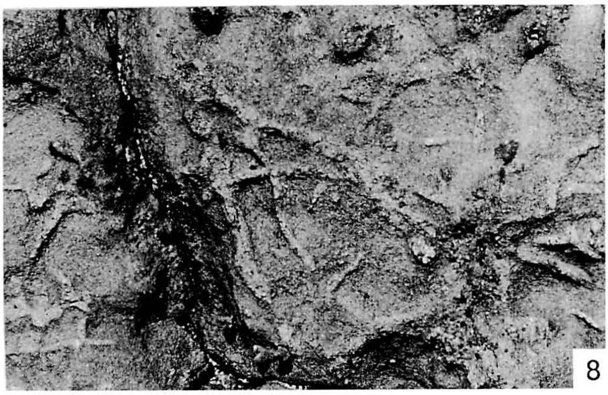
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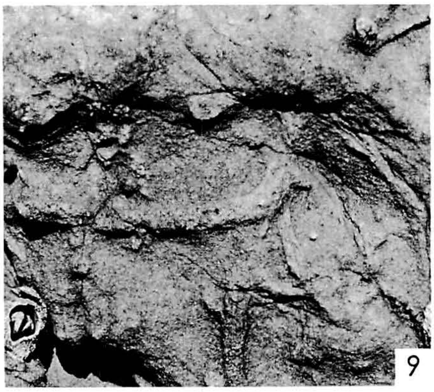
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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 115, pp. 135-142, pls. 19, 20, Sept. 30, 1979

706. SOME INTERESTING FOSSILS FROM THE UPPER PALEOZOIC IN CHAPARRA AREA, SOUTHWEST PERU*

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Abstract. Four fusulinid species and one new coral species described in this article were found from the Upper Paleozoic at the south of Pampa Lobos, Chaparra area, Southwest Peru. Judging from the paleontological data, the present fossil assemblage indicates an early Wolfcampian age.

Introduction

Some fusulinid and coral specimens were found in a rock fragment collected by Eng. ORCHAUSKI from the Upper Paleozoic limestone exposed at the south of Pampa Lobos, Chaparra area, Southwest Peru (15°58′ S. Lat., 73°50′ W. Long.). In this article, the following four fusulinids and one new coral are described, and their age is discussed.

Fusulinids:	*Triticites cellamagnus* THOMPSON & BISSELL
	T. meeki (MÖLLER)
	T. sp. A
	T. sp. B
Coral:	*Durhamina? andensis* n. sp.

Triticites cellamagnus was originally described from the Lower Wolfcampian part of the Oquirrh Formation, Central Utah (THOMPSON and BISSELL in THOMPSON, 1954); it is associated with *Schubertella kingi, Pseudofusulinella utahensis, Dunbarinella hughsensis* and *Schwagerina* ? sp. Some specimens referred to it with a query were found in the Lower Wolfcampian Bursum Formation of Hueco mountains, Texas (THOMPSON and BISSELL in THOMPSON, 1954); they are associated with *Schwagerina* sp. Later *Triticites cellamagnus* was found from the Lower Wolfcampian part of the Earp Formation in Southeast Arizona (SABINS and ROSS, 1963) together with *T. meeki* and *Schwagerina compacta.* THOMPSON, DODGE and YOUNGQUIST (1958) and SLADE (1961) also reported it from the Lower Wolfcampian of Idaho and Nevada.

According to THOMPSON (1954) and SLADE (1961), *Triticites meeki* occurs in the Lower Wolfcampian of Kansas, Nebraska, Oklahoma, Texas, Arizona, Nevada and Wyoming. It was also found from the Lower Wolfcampian part of the Earp Formation, Southeast Arizona (SABINS

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* Received Dec. 12, 1978; read June 3, 1978 at Tsukuba University.

and ROSS, 1963) together with *Schubertella kingi, Triticites creekensis, T. cellamagnus* and *Schwagerina grandensis.* It closely resembles *Triticites pajerensis* and *T.* cf. *victoriensis* described by ROBERTS in NEWELL, CHRONIC and ROBERTS (1953) from the *Silvaseptopora* zone of the Lower Wolfcampian part of the Copacabana Group in Peru.

Triticites sp. A resembles *T. californicus* and *T. pinguis. Triticites californicus* has been found from the Wolfcampian part of the Bird Spring Formation, California (THOMPSON and HAZZARD in THOMPSON, WHEELER and HAZZARD, 1946), where it occurs in association with *Schwagerina proutdens, Dunbarinella concisa, Pseudoschwagerina voeseleri, Schubertella kingi* and *S. masoni.* It also occurs in the Lower Wolfcampian of the Great Basin region, North America, according to BRILL (1963). *Triticites pinguis* was originally described from the Lower Wolfcampian in Texas (DUNBAR and SKINNER, 1937). Later it was discovered from the Lower Wolfcampian Neal Ranch Formation, Texas (ROSS, 1963) and from the Lower Wolfcampian part of the Earp Formation, Southeast Arizona (SABINS and ROSS, 1963).

Triticites sp. B somewhat resembles such specimens as *T. titicacaensis* and *T.* aff. *titicacaensis* described from the Wolfcampian part of the Copacabana Group in Peru (ROBERTS in NEWELL, CHRONIC and ROBERTS, 1953; MAEDA, YAMAGIWA, BELLIDO and RANGEL, 1974). However, the former is distinct from the latter two in some important characters (see description).

On the other hand, one new coral species, *Durhamina? andensis* n. sp. resembles *D. ? uddeni* (ROSS and ROSS, 1963; MINATO and KATO, 1965) from the Virgilian Gaptunk Formation of Texas and *D. hessensis* (ROSS and ROSS, 1962; MINATO and KATO, 1965) from the Upper Wolfcampian Lenox Hills Formation, Texas.

Judging from these fossils the present assemblage shows an affinity with those from the Lower Wolfcampian in North America and Peru. The writers consider that the present fossils also indicate an early Wolfcampian age.

Triticites sp. A, *T.* sp. B and *T.* sp. C were formerly discovered and illustrated by BELLIDO and NARVAEZ (1960) from the Upper Paleozoic in Atico area, Southwest Peru. According to them, the fusulinids indicate a Pennsylvanian age. However, the writers consider that the fusulinids may be related to the present fauna in specific assemblage and may indicate an early Wolfcampian age.

Acknowledgements

The writers wish to express their hearty thanks to Eng. E. ORCHAUSI (Instituto de Geologia y Mineria, Lima) who perimitted them to study the present interesting materials, to Prof. Emeritus H. FUJIMOTO (Tokyo University of Education), Prof. S. MAEDA (Chiba University) and ex-director E. BELLIDO (Instituto de Geologia y Mineria, Lima) for their kind suggestions and to Dr. Y. TAKEI (Geological Survey of Japan) for his assistance in consulting many needful references. Photographic work was done by Mr. K. NARUHASHI (Osaka Kyoiku University) to whom the writers extend their thanks.

Description of Species

Superfamily Fusulinacea von MÖLLER, 1878

Family Fusulinidae von MÖLLER, 1878

Subfamily Schwagerininae DUNBAR and HENBEST, 1930

Genus *Triticites* GIRTY, 1904

Triticites cellamagnus THOMPSON and BISSELL

Plate 19, fig. 1

1954. *Triticites cellamagnus* THOMPSON and BISSELL in THOMPSON, p. 43, pl. 11, figs. 1-12.
1954. *Triticites cellamagnus* (?), THOMPSON and BISSELL in THOMPSON, p. 43, pl. 10, figs. 14-17.
1958. *Triticites cellamagnus*: THOMPSON, DODGE and YOUNGQUIST, p. 121, pl. 19, figs. 13-15.
1961. *Triticites cellamagnus*: SLADE, p. 72, pl. 10, fig. 2.
1963. *Triticites cellamagnus*: SABINS and ROSS, p. 345, pl. 36, figs. 13-15.

Shell is medium in size, fusiform, with straight axis of coiling and bluntly pointed poles. Lateral slopes of mature shell are slightly convex and nearly straight. The first volution is subspherical in shape; beyond the first volution, the shapes gradually become elongate. A specimen having five volutions (pl. 19, fig. 1) is 6.0 mm in length and 2.8 mm in width, giving a form ratio of about 2.1. Proloculus is large in size, spherical in shape. Its outside diameter is 0.42 mm. Height of chambers in the first to the fifth volution of the above mentioned specimen is 0.09, 0.14, 0.16, 0.22 and 0.25 mm, respectively. Spirotheca is thick, composed of a tectum and coarse alveolar keriotheca. Its thickness in the first to the fifth volution of the above mentioned one is 0.04, 0.06, 0.07, 0.10 and 0.11 mm, respectively. Septa are strongly fluted in extreme polar regions, but gradually decreasing in fluting towards the center of shell, and almost unfluted above tunnel. Chomata are distinct and massive throughout the shell except the last volution. Tunnel angles in the first to the fourth volution of the above mentioned one are 25, 28, 30 and 35 degrees, respectively.

Remarks: The distinct characters of the present form are its large proloculus, fusiform shell of medium size, thick spirotheca and loosely coiled shell. The features mentioned above practically agree with those of the original specimens of *Triticites cellamagnus* and *T. cellamagnus* (?) described by THOMPSON and BISSELL in THOMPSON (1954). The present form resembles *Triticites* sp. A in this article in many respects, but the former differs from the latter in having larger proloculus. It is also similar to *Triticites meeki* (MÖLLER). However, the former has larger proloculus and shorter shell. It is distinguishable from *Triticites creekensis* THOMPSON (1954, p. 42, pl. 9, figs. 21-26, pl. 10, figs. 1-13; SLADE, 1961, p. 73, pl. 10, fig. 4; CASSITY and LANGENHEIM, 1966, p. 951, pl. 113, figs. 19-22; STEINER and WILLIAMS, 1968, p. 56, pl. 11, figs. 1-5) in having larger proloculus and convex or straight lateral slopes.

Occurrence: Limestone at the south of Pampa Lobos, Chaparra area, Southwest Peru. The present form is associated with *Triticites meeki*, *T.* sp. A, *T.* sp. B and *Durhamina? andensis* n. sp.

Repository: Reg. no. NSM-MPC 1844 (National Science Museum).

Triticites meeki (MÖLLER)

Plate 19, figs. 5-7

1858. *Fusulina cylindrica* var. *ventricosa*: MEEK and HAYDEN (part), p. 261.
1865. *Fusulina cylindrica*: MEEK and HAYDEN (part), p. 14, pl. 1, fig. 6a.
1879. *Fusulina ventricosa* var. *meeki*: MÖLLER (part), p. 4.
1928. *Triticites ventricosus*: DUNBAR and CONDRA (part), p. 84, pl. 1, fig. 2, pl. 3, fig. 1, pl. 4, fig. 4.
1954. *Triticites meeki*: THOMPSON (part), p. 39, pl. 12, figs. 1-11, pl. 13, figs. 1-12.

1961. *Triticites meeki*: SLADE, p. 72, pl. 10, fig. 3.
1963. *Triticites meeki*: SABINS and ROSS, p. 339, pl. 36, figs. 4-5.

Shell is elongate fusiform in shape, with bluntly pointed poles. Axis of coiling is almost straight. Lateral slopes are convex to slightly concave. A mature specimen having seven volutions (pl. 19, fig. 6) is 4.3 mm in half length and 1.4 mm in half width, giving a form ratio of about 3.1. Proloculus is medium in size, spherical in shape, having outside diameter of 0.22 to 0.24 mm. Average height of chambers in the third to the seventh volution is 0.10, 0.14, 0.19, 0.24 and 0.27 mm, respectively. Spirotheca is relatively thick, composed of a tectum and coarse alveolar keriotheca. Its average thickness is 0.02, 0.04, 0.05, 0.06, 0.08, 0.11 and 0.09 mm in the first to the seventh volution, respectively. Septa are strongly fluted in polar regions and weakly fluted in central part. Chomata are distinct and asymmetrical in shape. Average tunnel angles in the second to the sixth volution are 18, 20, 29, 38 and 36 degrees, respectively. Septal counts in the second to the sixth volution of a specimen illustrated as fig. 7 on plate 19 are 16, 18, 20, 21 and 23, respectively.

Remarks: The present specimens are characterized by their elongate fusiform outline, less inflated central area, medium size of proloculus and mode of septal fluting. These features practically agree with those of *Triticites meeki* (MÖLLER). *Triticites meeki* is very similar to *T. pajerensis* ROBERTS in NEWELL, CHRONIC and ROBERTS (1953, p. 186, pl. 37, figs. 3-5) and *T.* cf. *victoriensis* DUNBAR and SKINNER by ROBERTS in NEWELL, CHRONIC and ROBERTS (1953, p. 191, pl. 37, fig. 8). However, it seems to have more weakly fluted septa than the two species. They may belong to *Triticites meeki.*

Occurrence: Limestone at the south of Pampa Lobos, Chaparra area, Southwest Peru. The associated fossils are *Triticites cellamagnus, T.* sp. A, *T.* sp. B and *Durhamina? andensis* n. sp.

Repository: Reg. nos. NSM-MPC 1848-1850 (National Science Museum).

Triticites sp. A

Plate 19, figs. 2-4

Shell is medium in size, inflated fusiform in shape, with bluntly pointed poles, straight axis of coiling and convex lateral slopes. A specimen illustrated as fig. 2 on plate 19 having five and a half volutions is 5.7 mm in length and 3.3 mm in width, with a form ratio of about 1.7. Proloculus is medium in size, subspherical in shape, with outside diameter of 0.24 to 0.26 mm. Average height of chambers in the first to the seventh volution is 0.07, 0.09, 0.13, 0.18, 0.26, 0.28 and 0.29 mm. respectively. Spirotheca consists of a tectum and keriotheca with coarse alveoli. Average thickness of the spirotheca in the first to the sixth volution is 0.03, 0.05, 0.08, 0.09, 0.10 and 0.11 mm, respectively. Septa are strongly fluted in polar regions, but weakly fluted in central portion. Septal counts in the second to the sixth volution for one specimen (pl. 19, fig. 4) are 20, 21, 22, 21 and 23, respectively. Average tunnel angles in the second to the fifth volution are 23, 22, 27 and 30 degrees, respectively. Chomata are generally asymmetrical in shape, but indistinct in outer volutions.

Remarks: The present species resembles *Triticites californicus* THOMPON and HAZZARD in THOMPSON, WHEELER and HAZZARD (1946, p. 42, pl. 10, figs. 10-14) in inflated fusiform shape, medium size of proloculus, mode of septal fluting, narrow tunnel angles and asymmetrical chomata. However, the former differs from the latter as follows. (1) The septal counts of the former are less numerous than the latter. (2) The former shows smaller form ratio than the latter. (3) The chomata of the former in outer volutions are indistinct. The present specimens are also similar to the original specimens of *Triticites pinguis* DUNBAR and CONDRA (1937, p. 620, pl. 47, figs. 12-19), but differs from them in having less numerous septal counts, indistinct chomata in outer volutions, larger form ratio and smaller proloculus. They are somewhat related to *Triticites pinguis* by SABINS and ROSS (1963, p. 343, pl. 36, figs. 6-12) and ROSS (1963, p. 109, pl. 6, figs. 1, 3-4). However, they have more loosely coiled shell and indistinct chomata in outer volutions. They are distinguished from *Triticites* cf. *plummeri* DUNBAR and CONDRA (SABINS and ROSS, 1963, p. 347, pl. 36, fig. 7) in having more loosely coiled shell and broader tunnel angles.

Occurrence: Limestone at the south of Pampa Lobos, Chaparra area, Southwest Peru. The present specimens are associated with *Triticites cellamagnus*, *T. meeki*, *T.* sp. B and *Durhamina? andensis* n. sp.

Repository: Reg. nos. NSM-MPC 1845, 1846, 1847 (National Science Museum).

Triticites sp. B

Plate 19, fig. 8

Shell is small in size, inflated fusiform in shape, with straight axis of coiling and bluntly pointed poles. Lateral slopes of mature shell slightly convex. A specimen (pl. 19, fig. 8) of five and a half volutions is 2.9 mm in length and 1.7 mm in width, giving a form ratio of about 1.7. Proloculus is spherical in shape, with outside diameter of 0.18 mm. Height of chambers in the second to fifth volution is 0.07, 0.08, 0.12 and 0.12 mm, respectively. Spirotheca consists of a tectum and keriotheca. Its thickness in the third to fifth volution is 0.03, 0.04 and 0.06 mm, respectively. Septa are highly fluted in polar regions, but they become weakly fluted towards the middle portion. Chomata asymmetrical in shape, but indistinct in outer volutions. Tunnel angles in the second to the fourth volution are 12, 20 and 23 degrees, respectively.

Remarks: This form is represented only by one axial section. It somewhat resembles the specimens described as *Triticites titicacaensis* by ROBERTS in NEWELL, CHRONIC and ROBERTS (1953, p. 182, pl. 36, figs. 19-20) and as *T.* aff. *titicacaensis* by MAEDA, YAMAGIWA, BELLIDO and RANGEL (1974, p. 9, pl. 1, fig. 4). However, those specimens have more distinct chomata than the present specimen. Six original specimens of *Triticites titicacaensis* described by DUNBAR and NEWELL (1946, p. 479, pl. 11, figs. 1-6) distinctly differs from the above mentioned specimens containing the present one in having strongly fluted septa throughout the shell. Therefore, the latter specimens must be excluded from *Triticites titicacaensis.* The original specimens of *Triticites titicacaensis* were formerly transferred to the genus *Schwagerina* by the strongly fluted septa (THOMPSON and MILLER, 1949, p. 3). But the writers consider that they may belong to the genus *Dunbarinella* than the genus *Schwagerina* in view of the distinct chomata and strongly fluted septa.

Occurrence: Limestone at the south of Pampa Lobos, Chaparra area, Southwest Peru. This form is associated with *Triticites cellamagnus*, *T. meeki*, *T.* sp. A and *Durhamina? andensis* n. sp.

Repository: Reg. no. NSM-MPC 1851 (National Science Museum).

Order Rugosa MILNE-EDWARDS and HAIME, 1850

Family Durhaminidae MINATO and KATO, 1965

Genus *Durhamina* WILSON and LANGENHEIM, 1962

Durhamina? andensis n. sp.

Plate 20, figs. 1-6

Corallum is compound and fasciculate. Corallites are in contact in many points.

In transverse section, the corallites show round to subpolygonal outlines owing to their contactness to the neighboring ones (pl. 20, figs. 4-6). Mature specimens are often more than 15.0 mm in diameter (pl. 20, fig. 1). External wall is relatively thin. Sapta are in two orders, major and minor, alternating, showing more or less sinuous or nearly straight. They show the diffuso-trabeqular or the fibro-normal types under microscope. Major ones are about 30 in number in mature stage (pl. 20, fig. 1), but 20 to 28 in number in early mature ones (pl. 20, figs. 2, 4-6); they are thick in middle part and thinner towards both ends, but become thick at proximal end. Minor ones are very short, sometimes lacking. Dissepimentarium is rather narrow and generally arranged in pseudoherring bone dissepiments, but sometimes in concentric ones and rarely in lonsdaleoid ones. It is very narrow in early mature ones. Inner wall is often seen around the inner part of the dissepimentarium. In mature stage, axial structure is cobweb structure in shape and small in size, about 1/6 the diameter of a corallite. It is composed of a few septal lamellae, axial tabellae and a long median plate. The septal lamellae in contact with the major ones. In early mature stage, the axial structure is simple and irregular; septal lamellae mostly unite with some major ones.

In longitudinal section, dissepimentarium is narrow and composed of globose and elongate dissepiments with their convex sides inwards. Tabularium is broad, consists of tabulae and axial structure. Tabulae are incomplete and composed mostly of long vesicles with their convex sides generally upwards and outwards, ascending to the axial structure. Clinotabulae rarely present. In axial structure, dome-like axial tabellae, edges of septal lamellae and a median plate are seen.

Remarks: The present form is very similar to the species of the genus *Heritschioides* in having tabulae composed

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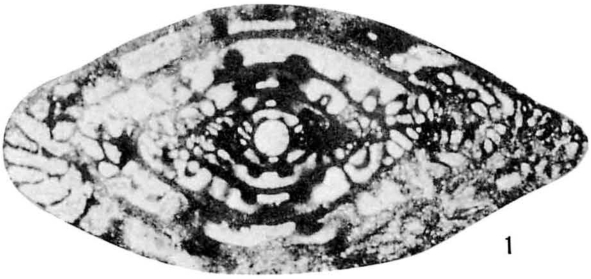
Explanation of Plate 19

Fig. 1. *Triticites cellamagnus* THOMPSON and BISSEL
  1. Axial section .... ×13.0 (NSM-MPC 1844)
Figs. 2-4. *Triticites* sp. A
  2. Axial section .... ×13.0 (NSM-MPC 1845)
  3. Axial section .... ×13.0 (NSM-MPC 1846)
  4. Sagittal section .... ×13.0 (NSM-MPC 1847)
Figs. 5-7. *Triticites meeki* (MÖLLER)
  5. Axial section .... ×13.0 (NSM-MPC 1848)
  6. Axial section .... ×13.0 (NSM-MPC 1849)
  7. Sagittal section .... ×13.0 (NSM-MPC 1850)
Fig. 8. *Triticites* sp. B
  8. Axial section .... ×13.0 (NSM-MPC 1851)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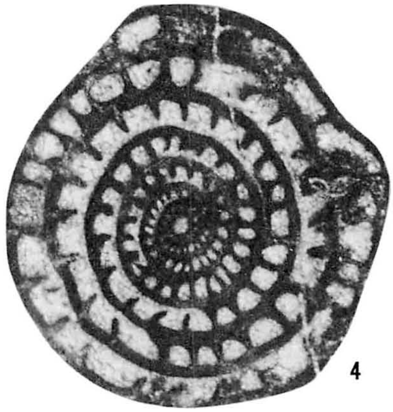
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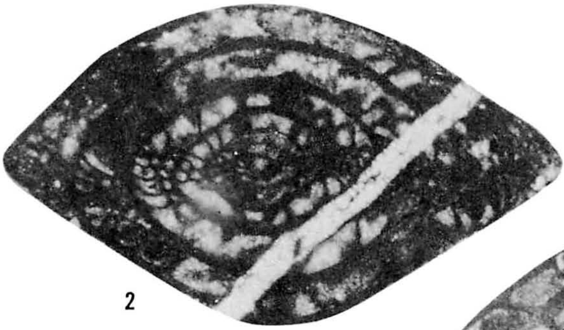
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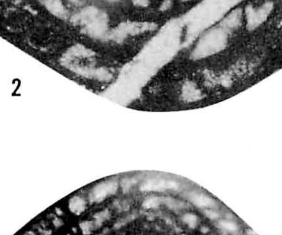
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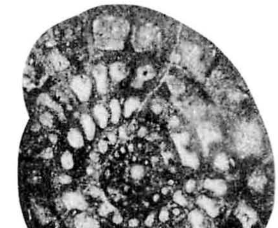
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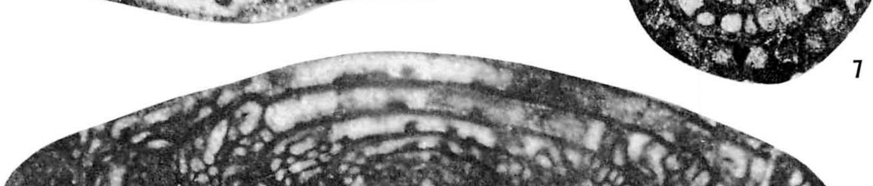
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of vesicles with their convex sides upwards and outwards in longitudinal section. However, it may beleng to the genus *Durhamina* then the genue *Heritschioides* in having simple axial structure in early mature stage, narrow dissepimentarium, lonsdaleoid dissepiments and very short minor septa. It closely resembles *Durhamina? uddeni* (ROSS and ROSS, 1963, p. 415, pl. 49, figs. 5-9; MINATO and KATO, 1965, p. 38) in the following characters. (1) Medium size of corallites. (2) Long median plate in axial structure in mature stage. (3) Neighboring corallites are often in contact. (4) Pseudoherring bone dissepiments present. (5) Tabulae ascending to the axial structure in longitudinal section. However, the former is distinguishable from the latter in having inner wall around the inner part of the dissepimentarium and shorter minor septa. It is also similar to *Durhamina hessensis* (ROSS and ROSS, 1962, p. 1175, pl. 162, fig. 12, pl. 163, figs. 1-3, text-fig. 4L; MINATO and KATO, 1965, p. 43, pl. 1, text-figs. 9-10) in many respects, but the former differs from the latter in having long median plate in axial structure and tabulae ascending to the axial structure in longitudinal section. According to ROWETT (1971), the species belonging to the family Durhaminidae occurs in the Lower Permian in Peru, but is not yet described.

Occurrence: Limestone at the south of Pampa Lobos, Chaparra area, Southwest Peru. The associated fossils are *Triticites cellamagnus*, *T. meeki*, *T.* sp. A and *T.* sp. B.

Repository: Reg. nos. NSM-PA 11999 (holotype), 12000, 12001 (National Science Museum).

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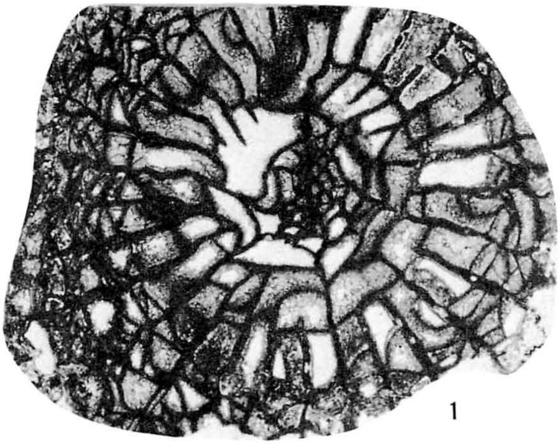
ペルー西南部，チヤパラ地域に分布する上部古生界産出の紡錘虫および珊瑚化石について：今回，筆者等はペルー西南部，チヤパラ地域のパンパロボス南方に分布する上部古生界中の石灰岩から，Orchauski 技師によって採集された保存良好な紡錘虫および珊瑚化石を研究した。その結果，紡錘虫化石として *Triticites cellamagnus, T. meeki, T.* sp. A および *T.* sp. B，珊瑚化石として *Durhamina ? andensis* n. sp. を発見，記載報告すると共に，それらの化石群集の時代が初期 Wolfcampian 階をしめすことを論述した。

山際延夫・C. Rangel

Explanation of Plate 20

Figs. 1-6. *Durhamina? andensis* n. sp.

1.	Transverse section	×5.0	(NSM-PA 11999a)
2.	Transverse section	×5.0	(NSM-PA 11999b)
3.	Longitudinal section	×5.0	(NSM-PA 11999c)
4.	Transverse section	×5.0	(NSM-PA 12000a)
5.	Transverse section	×5.0	(NSM-PA 12000b)
6.	Transverse section	×5.0	(NSM-PA 12001)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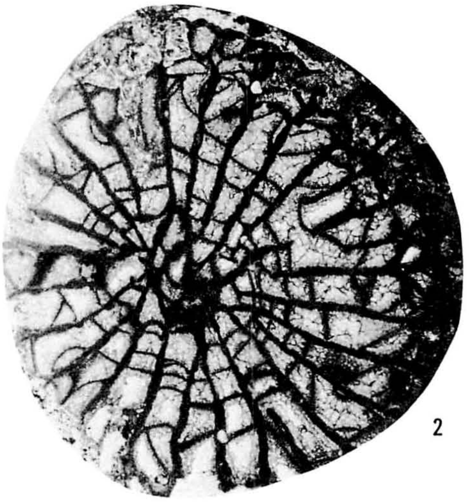
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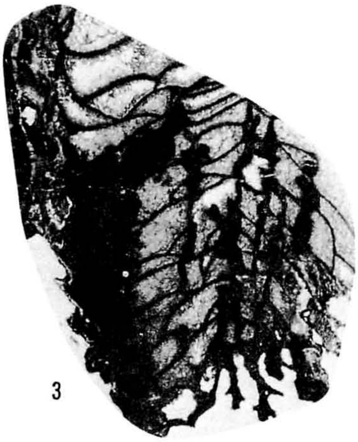
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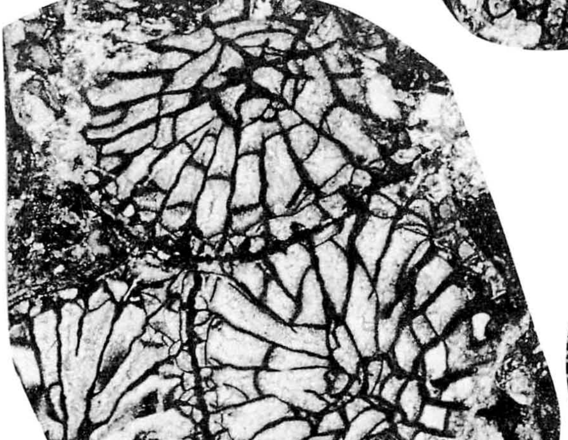
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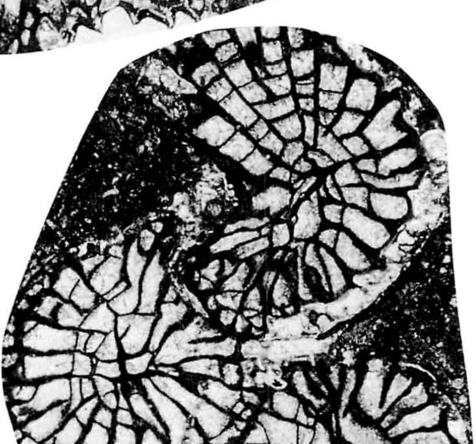
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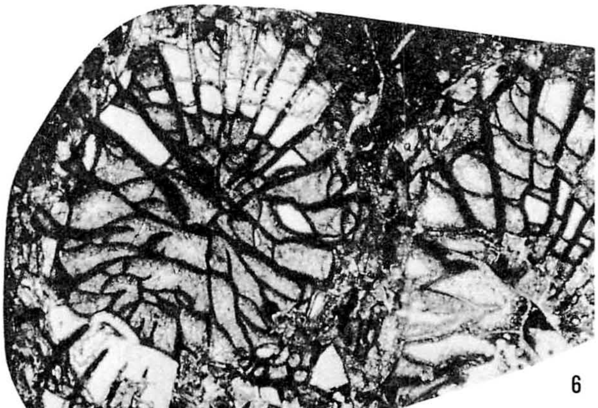
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Trans. Proc. Palaeont. Soc. Japan, N. S., No. 115, pp. 143-173, pls. 21-23, Sept. 30, 1979

707. STRATIGRAPHY AND OSTRACODA FROM LATE CENOZOIC STRATA OF THE OGA PENINSULA, AKITA PREFECTURE*

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Abstract. *Stratigraphy:* A brief geological summary of Late Cenozoic sediments of the Oga Peninsula in northeast Japan is given as the basis of paleontological study. The Anden and Katanishi Formations are redefined and the wide distribution of the Anden Formation is indicated. Lithological and paleontological evidence indicates six cycles of sedimentation within Upper Pleistocene deposits. Each cycle consists of four units, unit-A to unit-D. *Ostracoda:* Individual numbers of ostracods per unit volume of sediment vary cyclically in response to lithologic changes. The occurrence of poorly preserved carapaces is confined to the uppermost and lowermost horizons of unit-C sediments. It is probable that some environmental changes might have caused decalcification of those carapaces, because EDTA treatment of well preserved carapaces produced the state of preservation similar to that observed on the poorly preserved specimens. The observed species are assumed to have belonged to shallow marine faunae because the fossil assemblages have species in common with Recent offshore ostracod communities occurring at depths of about 25 m and 50 m, off the Oga Peninsula. The ostracod faunae characterized by cold-water species are replaced by those containing warm-water species responding to the cyclic sequences of lithofacies and probable environmental changes, especially an increase in water temperature. The degree of mixtures of communities is discussed by comparing the structure of fossil assemblages with Recent communities and assemblages. Finally, two new species, *Finmarchinella hanaii* and *F. nealei*, are described.

Introduction

A cyclic change of environments during the glacial age must have profoundly affected organic communities. From this point of view, a cyclically repeated sedimentary sequence of the Late Pleistocene age of the Oga Peninsula offers various interesting information on the glacial age fauna, and the repetitious fossiliferous units provide clues useful in paleontological research. Many contributions have been made on the Pleistocene fauna of this area. For example, KANEHARA (1942), KOTAKA (1954), and TAKAYASU (1962) treated mollusks, ASANO (1948) and TAKAYANAGI and OBA (1966) foraminifers, and KOIZUMI (1968) diatoms. These works contributed much toward improving the taxonomy, paleoecology and biostratigraphy of the Pleistocene fauna of this area. However, they have not paid any attention to the cyclic sedimentation as one of the factors which affected the composition of the fossil assemblages. In this paper, Upper Pleisto-

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* Received March 28, 1979; read Jan. 22, 1977 at Koganei.

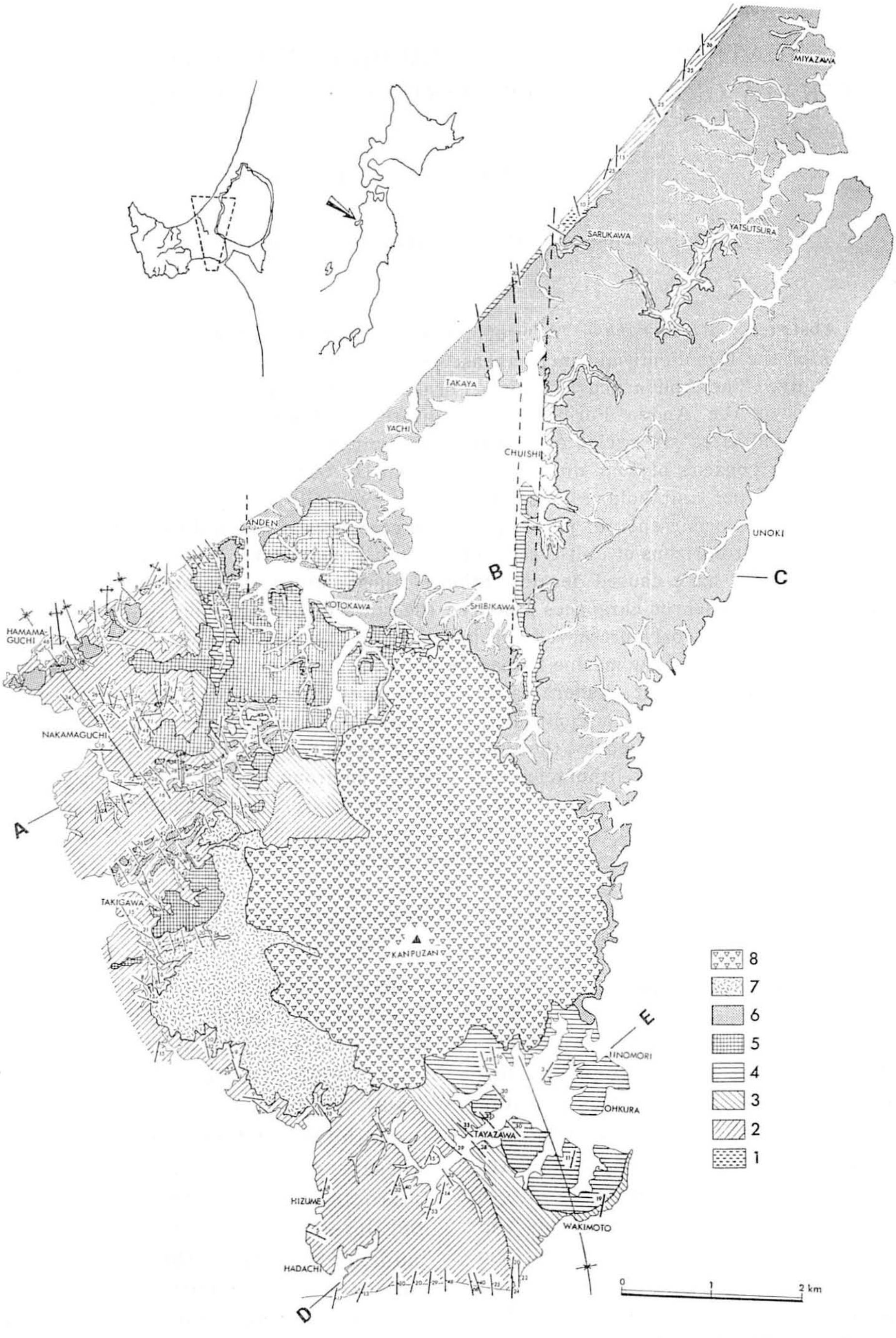

Fig. 1. Index map and geological map. 1, Funakawa Formation. 2, Kitaura Formation. 3, Wakimoto Formation. 4, Shibikawa Formation. 5, Anden Formation. 6, Katanishi Formation. 7, Kampuzan Volcanic Detritus. 8, Kampuzan Lava.

cene ostracods of the Oga Peninsula are reported for the first time and their occurrences are discussed with the framework of this cyclic sedimentation.

Before going into the discussion of ostracod fauna, a brief summary of geology, with special emphasis on the cyclic sedimentation, will be given. The cyclic sedimentation is interpreted in this paper quite differently from that given by KATO and WATANABE (1976).

Geological Setting

Late Cenozoic sediments which constitute the Funakawa Group (Late Miocene

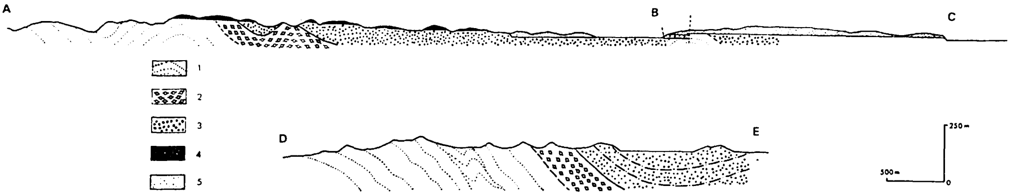

Fig. 2. Cross section. 1, Kitaura Formation. 2, Wakimoto Formation. 3, Shibikawa Formation. 4, Anden Formation. 5, Katanishi Formation. The places indicated by A, B, C, D and E are shown in Fig. 1.

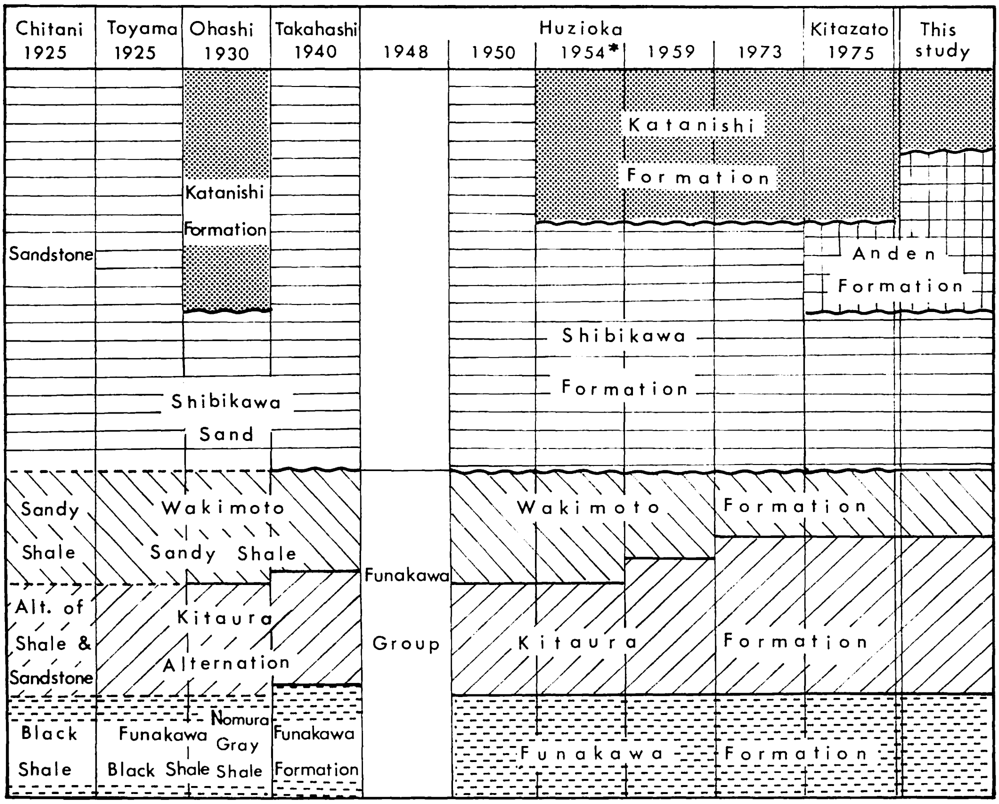

Fig. 3. Comparison of the stratigraphic unit boundaries established by various workers. (1954* indicates Huzioka et al., 1954)

to Early Pleistocene) and the Shibikawa, Anden and Katanishi Formations (Late Pleistocene) are well exposed in the Oga Peninsula, northeast Japan (Fig. 1). They have long been considered a standard of reference stratigraphic section for the Neogene on the Japan Sea side of Japan. The Funakawa Group is characterized by fine-grained, off-shore marine sediments, whereas the overlying formations consist mainly of sandy sediments. In general, ostracods are rare in the Funakawa Group, but they are abundant in the younger formations. Since this study is concerned primarily with ostracods, the author's field survey was confined mainly to those formations younger than the Funakawa Group.

Funakawa Group. HUZIOKA (1948, 1959, 1973) presented a detailed description of lithology of this group. This group includes the Onnagawa, Funakawa, Kitaura and Wakimoto Formations in upward sequence.

Onnagawa and Funakawa Formations. OHASHI named and defined both of them in TOYAMA (1925). These formations are not exposed in the studied area, except for a small restricted exposure near Sarukawa on the north coast, where a massive grey silt intercalated with a number of acidic fine tuff and scoriaceous tuff beds forms an anticlinal structure trending in a N-S direction. This unit had been considered to be a member of the Wakimoto or Kitaura Formation (HUZIOKA, 1959, 1973) until KITAZATO (1975) correlated it with the uppermost part of the Funakawa Formation. In this paper, KITAZATO's correlation is adopted.

Kitaura Formation. The name was given by TOYAMA (1925) and its definition by HUZIOKA (1973). HUZIOKA (1959) tried to draw the upper boundary of this formation at the horizon of the first appearance of *Globorotalia inflata* d'ORBIGNY. However, since formations in general should be defined on the basis of their lithology, the latest definition of HUZIOKA (1973) is adopted here.

Wakimoto Formation. The name was given by TOYAMA (1925), and its definition by HUZIOKA (1973). Exposures of this formation along the coast near

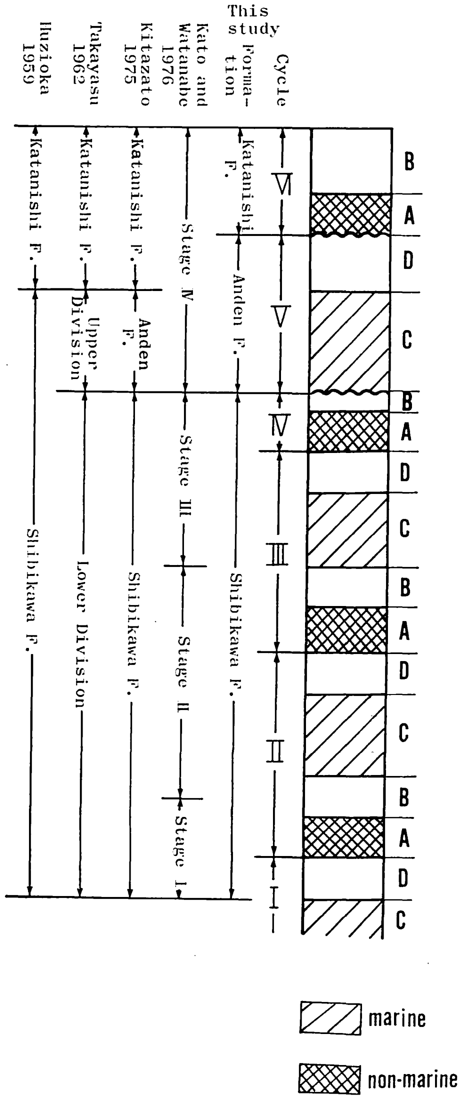

Fig. 4. Cycles and stratigraphic units. A, B, C and D indicate units in the cycles.

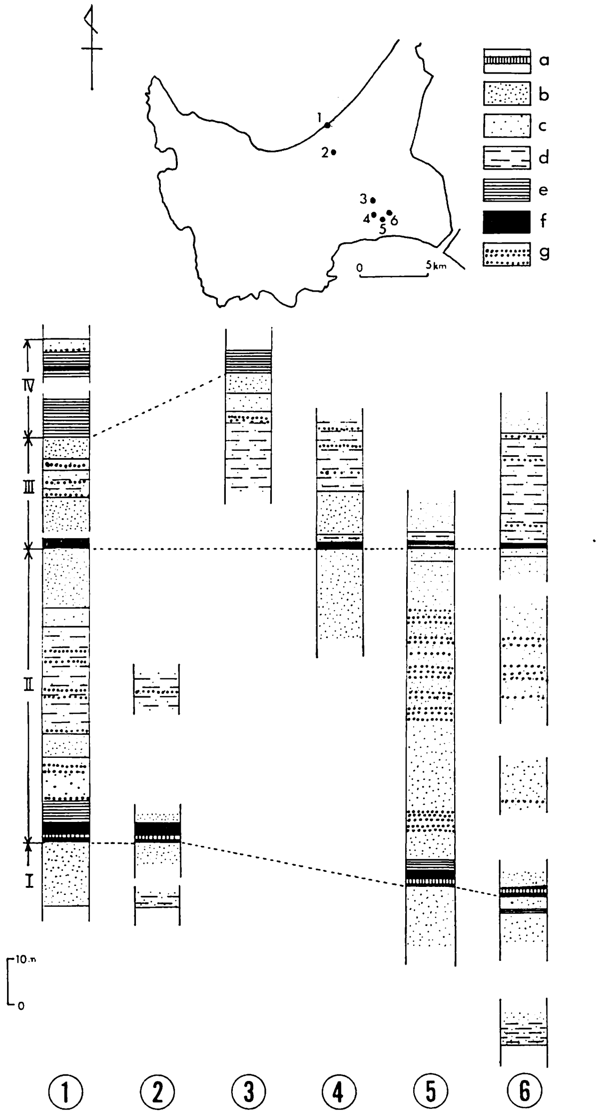

Fig. 5. Columnar sections of the Shibikawa Formation. The cycles-I to IV can be traced on the basis of the continuity of lignite beds, one of which is accompanied with a thick pumiceous tuff bed. In cycle-II, units and subunits of the cycle are sometimes traceable throughout the area, though corresponding sandy sediments are thicker and composed of coarser grains in the south than that in the north. The outcrops are along the southwest coast of Anden (1), at two kilometers south of Anden (2), near Iwakura (3), near Tayazawa (4), at Uchigasaki (5) and from Wakimoto to Iinomori in the east of the synclinal axis (6). a, tuff. b, medium-grained sand. c, fine-grained sand. d, silty sand. e, clay. f, lignite. g, conglomerate.

Anden reveal two diastems in a massive siltstone at two different horizons about 60 m apart. The stratigraphic significance of these two sedimentary breaks has yet to be fully examined in terms of sedimentation cycles.

Younger Formations. Strata overlying the Funakawa Group are called the "Shibikawa Sand" (OHASHI, 1918, in TOYAMA, 1925) and are characterized by a cyclic repetition of shallow-marine and non-marine sediments. They are subdivided into the Shibikawa, Anden, and Katanishi Formations in upward sequence and are separated by unconformities (Fig. 4).

Shibikawa Formation. This formation was named by OHASHI (in TOYAMA, 1925) and, by definition, it corresponds to TAKAYASU's (1962) 'lower division' of the Shibikawa Formation. The type locality was designated by HUZIOKA (1950) at a cliff along the coast to the southwest of Anden village. The formation is also exposed in the environs of Wakimoto. Its thickness is about 120 m at the type locality and increases to more than 230 m near Wakimoto (Fig. 5). The Shibikawa Formation has been considered to lie upon the Wakimoto Formation unconformably (HUZIOKA, 1950, 59, 73, HUZIOKA et al., 1954). However, KITAZATO (1975) did not observe any unconformity. I could neither observe such a distinct lithologic change between the two formations which would suggest the existence of a stratigraphic break. The Shibikawa Formation is characterized by cycles of sedimentation that will be explained in detail in the following chapter. In brief, the formation at the type locality is divisible into the lower 100 m of sandy facies and upper 20 m of clayey facies, on the basis of dominant lithology, namely the sandy units (units-B, C and D of cycles-I, II and III) in the lower facies and the clayey unit (unit-A of cycle-IV) in the upper facies. An erosional surface forming the base of cycle-IV corresponds to the boundary between these two facies. Marine mollusks which occur abundantly in the lower sandy facies are dominated by such cold-water species as *Glycymeris yessoensis* (SOWERBY), *Patinopecten yessoensis* (JAY), *Mercenaria stimpsoni* (GOULD), *Spisula sachalinensis* (SCHRENCK) and *Notoacmea shrenckii* (LISCHKE) according to TAKAYASU (1962).

Anden Formation. The name was given by KITAZATO (1975). The Anden Formation as used herein includes the lower part of the Katanishi Formation as defined

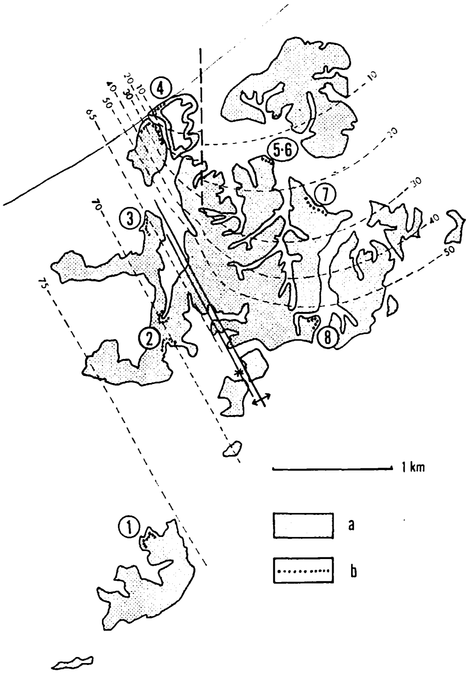

Fig. 6. Distribution of the Anden Formation (a) traced by a key tuff bed (b). Figures beside broken lines indicate the height of the basal plane. Figures in circles are index for Fig. 7. The locations of 5 and 6 correspond to the two adjacent outcrops shown in Fig. 8.

by HUZIOKA et al. (1954), in addition to the Anden Formation of KITAZATO (1975). Its type locality was designated by KITAZATO (1975) at a cliff along the Anden coast.

To the west of the anticlinal axis (Fig. 6), this formation lies nearly horizontal and its base truncates clinounconformably the underlying folded Wakimoto and Kitaura Formations. To the east of the axis, the formation dips gently towards northeast and attains a thickness of 19 m which is about twice as thick as that in the west (Fig. 7). This structure is evident from the distribution of a light purple tuff bed occurring at about 3 m above the basal unconformity.

HUZIOKA et al. (1954), HUZIOKA (1959, 73) and KITAZATO (1975) regarded the pebble-bearing coarse-grained sand con-

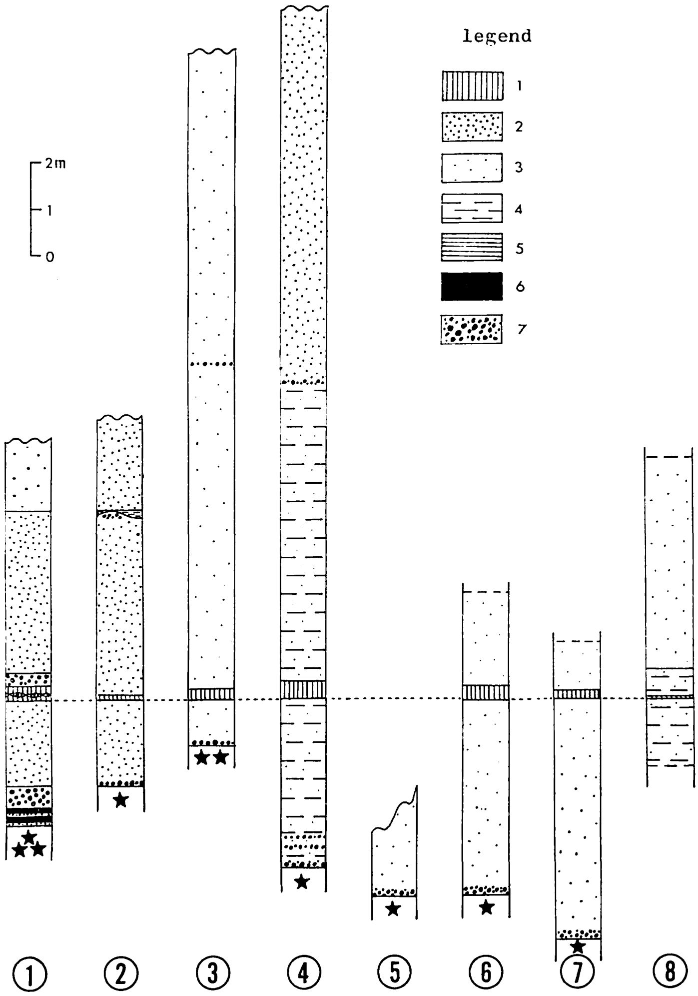

Fig. 7. Columnar sections of the Anden Formation. 1, tuff. 2, medium-grained sand. 3, fine-grained sand. 4, silty sand. 5, clay. 6, lignite. 7, conglomerate. Single star, Shibikawa Formation. Double stars, Wakimoto Formation. Triple stars, Kitaura Formation.

taining abundant *Glycymeris yessoensis, Mercenaria stimpsoni, Patinopecten yessoensis,* and others as a basal conglomerate of the Katanishi Formation. However, the conformable transition from the underlying finer sediments (i. e. silty fine-grained sand) to the overlying coarser sediments (i. e. well sorted medium-grained sand) may possibly be accompanied by very coarse sediments (i. e. pebble-bearing coarse-grained sand) as the result of some environmental changes. This pebble-bearing coarse-grained sand is always found approximately 5 m above the light purple fine-grained tuff bed throughout the area. Furthermore, the well sorted medium-grained sand beds above the pebble-bearing sand are not lake sediments as previously asserted but marine sediments which are indicated by marine fossils including *Glycymeris yessoensis.* And this bed is unconformably overlain by a plant-bearing non-marine clay bed in the Katanishi Formation defined herein (see later). The boundary between the Anden and Katanishi Formations as used in this study occurs at approximately 8 m above the base of the pebble-bearing coarse-grained sand and corresponds to an unconformity separating the marine sand from the non-marine clay. The Anden Formation thus defined is underlain by the Shibikawa Formation clino-unconformably and is unconformably overlain by the non-marine Katanishi Formation. The Anden Formation as defined on the basis of exposures along the Anden coast consists of a lower 10 m of silty fine-grained sand intercalated with a light purple fine tuff bed near its base and of an upper 10 m of a brownish gray, fine-to-medium-grained sand. Marine mollusks are indicative of more or less warm water and include *Acila in-*

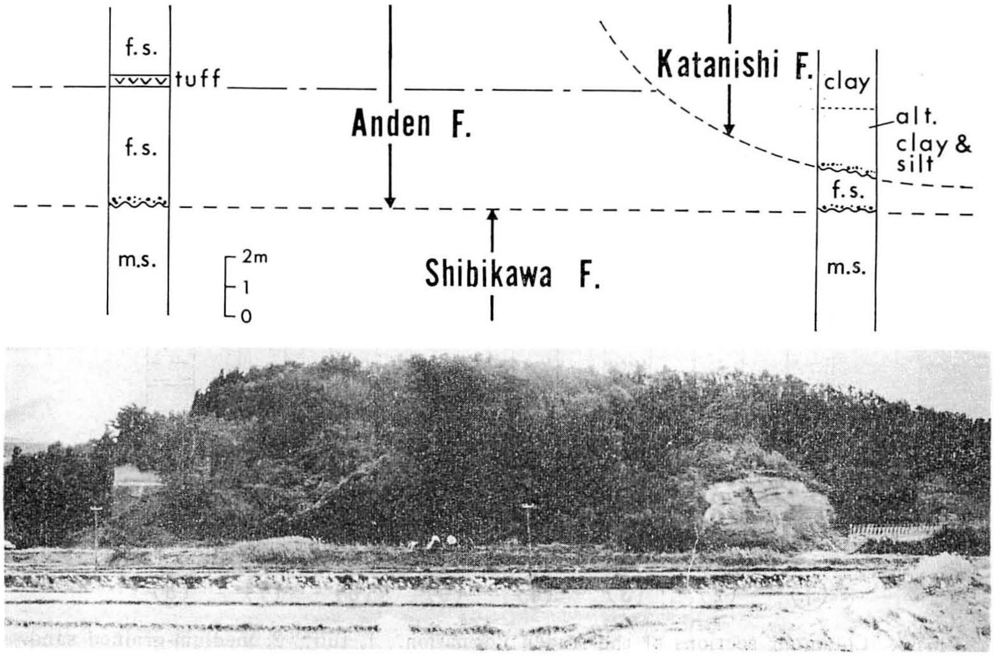

Fig. 8. Two adjacent outcrops showing clear evidence of the unconformity at the base of the Katanishi Formation, near Kotokawa about 500 m southeast of Anden.

signis (GOULD), *Pecten albicans* (SCHRÖTER), *Macoma tokyoensis* MAKIYAMA, *Arcopagia tokunagai* (IKEBE) and *Turritella andenensis* OTUKA according to TAKAYASU (1962).

Katanishi Formation. Named by OHASHI in TOYAMA (1925); its definition will be given herein. The type locality was set by KITAZATO (1975) at Unoki, 5 km east of Anden. The formation is widely distributed to the west of Lake Hachirogata. It lies subhorizontally and a distinct unconformity separates this formation from the subjacent Anden Formation. This unconformity is best exposed at a cliff near Kotokawa located at about 500 m southeast of Anden (Fig. 8), where the Anden Formation is eroded so deeply that the base of the Katanishi Formation reaches a horizon only 2 m above the base of the Anden Formation. This eroded space is filled with a basal clay of the Katanishi Formation. The formation consists of a lower, carbonaceous clay with abundant tube-like burrows (Fig. 10, left bottom) and an upper, medium-grained sand intercalated with lenticular beds of conglomerate. Such plant remains as *Trapa* and *Juglans* and non-marine mollusks including *Corbicula* occur in this lower clay.

Cyclic Sedimentation

The definition of each formation given in the preceding chapter is based on overall lithologic characters and is taking account of the existence of an unconformity. The repetition of marine and non-marine sequences, however, is well displayed in the outcrop along the north coast near Anden, where four formations, the Wakimoto, Shibikawa, Anden, and Katanishi, show evidence of cyclic sedimentation. It thus offers an interesting problem of the relationship between the formational boundaries and the cycles of sedimentation.

In the sequence of cyclic sedimentation, there occurs a certain kind of erosional surfaces showing clearly a depositional break such as uneven surfaces with or without burrowing by organisms, and flat surfaces resulted from the truncation of a bed lying below before the deposition of overlying strata. It is noteworthy that, in the latter case, the bed below the flat surface forms a wedge thinning in a westerly direction. Many of these erosional surfaces do not appear to be related to the cyclic change of lithofacies.

In this paper, boundaries of sedimentary cycles are set provisionally at the base of a sequence of non-marin beds. In doing so, four cycles are recognized within the Shibikawa Formation and one in the Anden and Katanishi Formations, respectively. Each cycle consists of the following four units in upward sequence (Fig. 9):

1) Unit-A

This unit consists mainly of non-marine clay with carbonized materials. Lignite beds about 1 m thick are intercalated within cycles-II and III. In cycles-IV and VI, horizons where lignite should occur are actually represented by carbonaceous clay and in some places by a thin alternation of clay and fine-grained sand. This unit contains such freshwater molluscan shells as *Corbicula* as well as seeds of *Trapa*, a floating plant.

Consisting of a carbonaceous clay, this unit is clearly distinguished from the underlying bed of fine-grained sand in each cycle. The planes which bound this unit from the underlying sediments undulate with amplitude and wave-length of approximately 1.5 m and 4 m in cycle-IV and 0.5 m and 2 m in cycle-VI.

In one case, pipe-shaped lebensspuren are observed in unit-A of cycle-VI, the

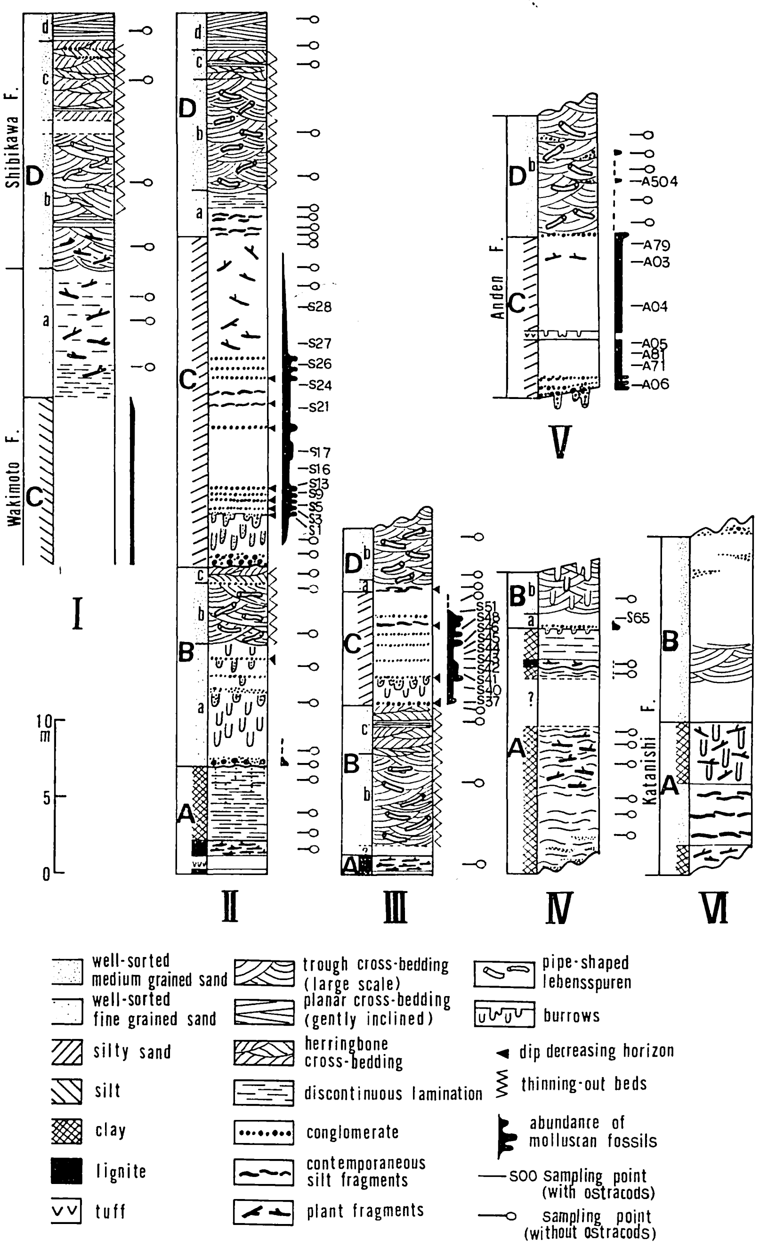
CYCLES

Fig. 9. Cycles. Each column shows the following from left to right: formations, units, subunits, lithology, speciality (bedding and lebensspuren etc.), changes of dip, occurrence of molluscs (wide band means abundant occurrence and broken lines indicate the occurrence of molds), and horizons of sampling for ostracods.

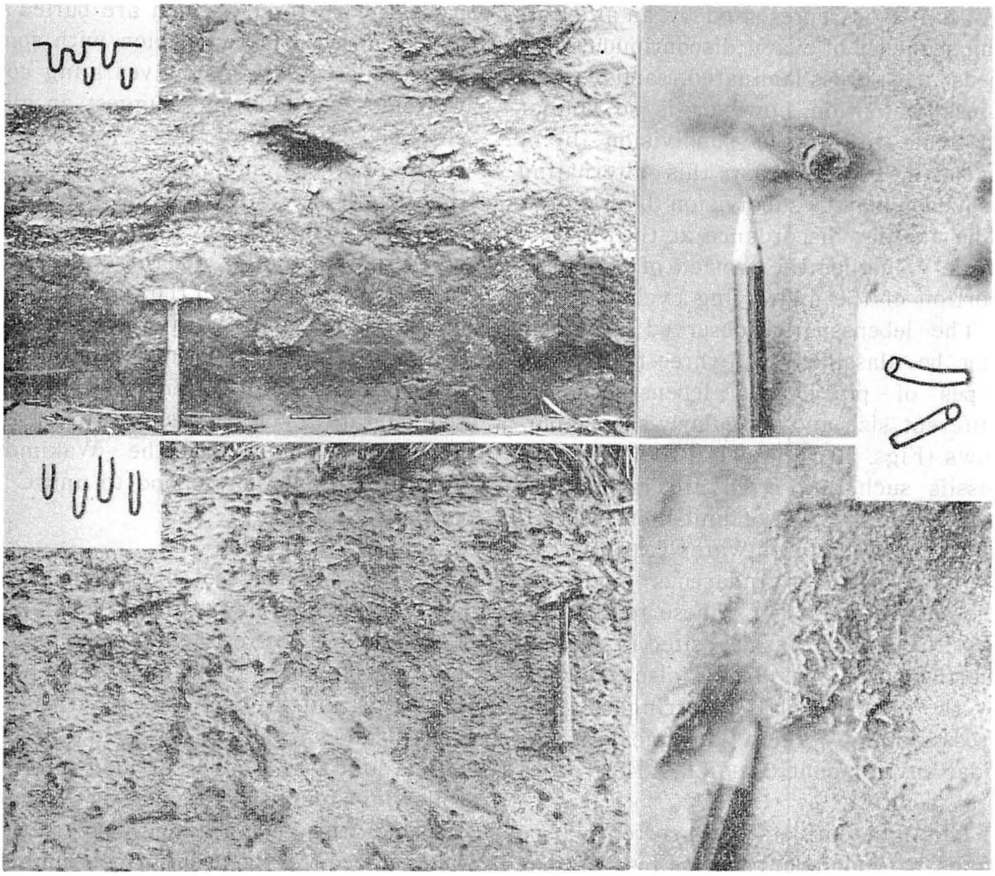

Fig. 10. Burrows and pipe-shaped lebensspurens illustrated in Fig. 9. All photographs were taken at the outcrops along the Anden coast.

uppermost cycle which correspond to the Katanishi Formation (Figs. 9, 10 left bottom).

2) Unit-B

This unit consists of fine- to medium-grained sand characterized by numerous lebensspuren. The transition from unit-A to unit-B is abrupt in cycles-II and IV where numerous irregularly-shaped shallow burrows penetrate the underlying layers to the depth of about 2 cm. In cycle-VI, unit-B is not well represented and indistinguishable from unit-D because of lack of lebensspuren.

Unit-B consists of the following three subdivisions: (a) fine-grained massive sand, (b) fine- to medium-grained sand with gently inclined, trough-type cross-bedding in which poorly developed laminations occur, and (c) medium-grained sand with steeply inclined, herringbone-type cross-bedding, in which well-defined laminations made up of laminae of pumice grains appear. The sand is better sorted higher up in the section.

In cycle-II, all three subdivisions can be observed. In cycle-III, subdivision (a) is concealed beneath a land slide in the Anden section, but its presence is ascertainable in the southern area. In cycle-

IV, unit-B is represented by an alternating sequence of wavy discontinuous clay beds and cross-laminated sands. This cross-lamination, however, is so similar in scale to that of subdivision (b) of cycles-II and III that this alternating sequence may be subdivision (b) of unit-B. The angular discordance at the base of cycle-V implies the erosion of the upper portion of the underlying cycle-IV.

The lebensspuren observed in unit-B can be classified into three types: two types of pipe-shaped lebensspuren of different size and irregularly shaped burrows (Figs. 10 right, 11 II-B-c). Marine fossils such as *Pecten* are rare but do occur near the base of unit-B in cycles-II and IV. A brackish-water fossil, *Ostrea* sp., was found in rudaceous mud near the base in cycle-IV. These fossils suggest that unit-B was deposited in shallow marine conditions. This is also confirmed by the presence of the herringbone-type cross-bedding, which is typical of the tidal environment (SHROCK, 1948).

3) Unit-C

This unit consists of ill-sorted marine sands with abundant marine fossils. The deposit is especially well displayed in cycles-II, III and V. The boundary between unit-B and unit-C is defined clearly by the base of a rudaceous sand, which rests on a very well sorted medium-grained sand of unit-B. The lower horizon of this unit yields marine fossils (Bivalvia, Gastropoda, Echinoidea, Cirripedia, Ostracoda, Foraminifera, etc.). Upwards in the sequence, marine fossils become relatively scarce and fragments of carbonized material gradually become predominant. In general, fossils are scattered in a more or less random orientation in a poorly sorted sand. Frequent occurrences of articulated bivalves indicate autochthonous deposition. Interbedded rudaceous sands are, however, packed with fossils which are buried in a more or less chaotic fashion with some disarticulated larger bivalves lying convex side up. This may suggest an allochthonous origin of these fossils. A study of these mollusks is in progress (for details see SHUTO et al., 1976). Irregularly shaped burrows and pipe-shaped lebensspuren similar to those observed in unit-B also occur in the lower horizon of unit-C together with marine fossils (Fig. 10 left top). The uppermost cycle, cycle-VI, lacks unit-C. In view of the sedimentary cycle, massive silt of the uppermost portion of the Wakimoto Formation may correspond to unit-C in cycle-I.

4) Unit-D

This unit consists of fine- to medium-grained sand similar to that in unit-B. Lebensspuren are restricted to the middle horizon. Changes of lithology from unit-C to this unit are gradual in cycles-I, II and III and are abrupt in cycle-V.

The unit-D is further divided into the following four subdivisions in upward sequence: (a) fine-grained sand, weakly laminated, often containing penecontemporaneous silt fragments, (b) fine- to medium-grained sand characterized by the trough-type cross-bedding, (c) medium-grained sand, characterized by the herringbone-type cross-bedding, (d) well-sorted medium-grained sand, evenly laminated with individual laminae lying generally horizontal or sometimes slightly inclined (Fig. 11, I-D-d and II-D-d). Evenly laminated sand beds of the near-shore environment are explained by REINECK and SINGH (1973) as indicative of accumulation often encountered on beaches just above the high water line. In general, sands of these subdivisions are better sorted higher up in the sequence. The basal part of the Shibikawa Formation below cycle-II corresponds to unit-D in

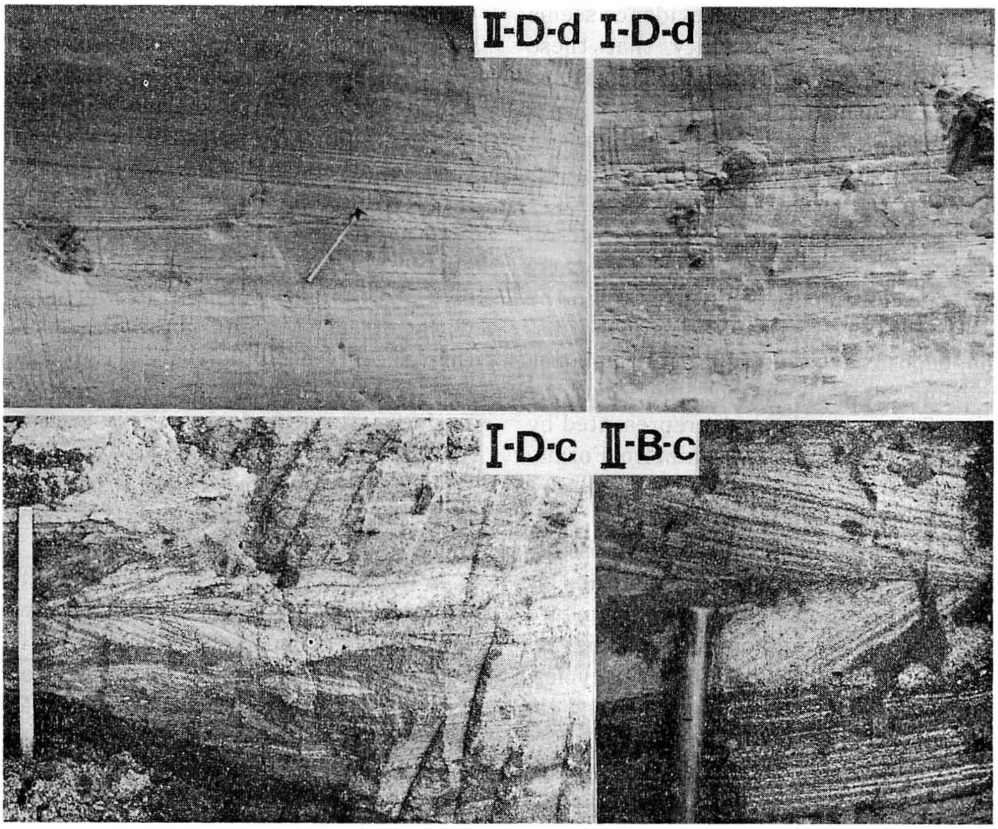

Fig. 11. Cross-bedding illustrated in units-B and D of Cycles-I and II in Fig. 9. The upper two photographs (-d) show even laminae with individual layers usually horizontal or sometimes slightly inclined. The two bottom photographs (-c) display herringbone-type cross-bedding. In II-D-d, the length of the pickax helve is 43 cm. In I-D-d, the hammer helve is 28 cm. In I-D-c, the rod is 30 cm. In II-B-c, the scale on the helve indicates 10 cm. The photographs were taken at the corresponding horizons in the cycles in the outcrops along the southwest coast of Anden.

cycle-I.

All the subdivisions of unit-D can be observed in cycles-I and II. The thickness of subdivision (a) tends to decrease upward from cycle-I to cycle-III. Subdivision (a) is not well represented in cycle-V and subdivisions (c) and (d) seem to have been eroded away in cycles-III and V.

Pipe-shaped burrows of different sizes are observable in subdivision (b). Poorly preserved moulds of mollusks and echinoids occur in cycle-V, suggesting a low possibility of preservation of organic remains in these sandy units. In fact, fossils are generally very rare in these units. In exceptional cases in the same horizon, however, mollusks bearing well-preserved color pattern are found in an outcrop about 300 m south of Anden, and suggest a relatively short period of the subjection of shells to abrasion. Furthermore, the occurrence of *Spisula sachalinensis* has so far been confined within this horizon. The above evidence seems to eliminate the possibility that these fossils were derived from lower horizons.

5) Conclusion

From the foregoing description of the cyclic sedimentation, the following remarks can be made:

1. Cycle-I represents only the late regressive phase of one cycle, the early transgressive phase being masked in the massive silt bed of the Wakimoto Formation, deposited exclusively in deep marine environments. It is possible that the base of the cycle may be represented by a diastem found in the Wakimoto Formation.

2. The marine facies, which is typically represented by unit-C and possibly includes a major part of units-B and D, tends to decrease in thickness in upward sequence, while the non-marine facies represented by unit-A is thicker in cycles-IV and VI than that in cycles-II and III. Furthermore, all the successive units from A to D and their subdivisions are preserved fully only in the lower cycles and are partly missing from the upper cycles.

3. Those units which are absent from a given cycle fall within unconformable surfaces in the cyclic sequence. These surfaces can be classified into the following two categories: (1) surfaces formed in the phase of inundation by the sea. A stable stand of sea level for a certain period of time may be inferred from the development of an extensive abrasion platform. The base of unit-C in cycle-V, which also truncates the inclined Wakimoto and Kitaura Formations, represents this category in having an extensive horizontal erosion surface. It is likely that the seaward extension of this surface merges into relatively off-shore sediments such as unit-C of cycles-II and III. The unit-C of these lower cycles contains many horizons presumably interrupting sedimentary continuity, namely, the basal surfaces of coarser sediments which are separated sharply from finer sediments lying below, surfaces with burrows excavated by organisms, and surfaces with a combination of both features. In other words, the landward extension of these relatively off-shore sediments of unit-C might possibly be correlated with terrace deposits now lying higher than the plane of the Anden Formation in the west of the anticlinal axis. (2) Surfaces formed during a regression. The base of unit-A of cycles-IV and VI, formed after the erosion of a considerable thickness of the underlying sediments, falls in this category.

4. The upper two incomplete cycles, cycles-V and VI, whose upper and lower limits are bounded by unconformities, correspond directly to the Anden and Katanishi Formations, respectively. The upper boundary of the Shibikawa Formation, however, is defined by an unconformity and its lower boundary by a conformable lithological transition. Thus, in general, formational boundaries which are based primarily on differences in overall lithology do not always correspond to boundaries between cycles.

5. There has been a controversy as to whether the transgressions and regressions inferred from the cyclic sediments of the Oga Peninsula were caused by eustatic sea-level changes or by local tectonic movements. The dip of the formations decreases upwards from the Shibikawa Formation to the Katanishi Formation. The stepwise reduction of dip of strata is well demonstrated along the Anden coast. The dip suddenly decreases, at the unconformity at the base of the Anden Formation, at the discordant planes indicated by solid triangles in Fig. 9, and probably in cross-laminated

beds where the angle of dip lessens between the base and top of each bed (indicated by zigzag lines in Fig. 9). These horizons occur independently of the cyclic change of lithofacies, though some of these horizons may have been misunderstood to interpret cycles and used to correlate arbitrarily with glacial cycles by KATO and WATANABE (1976). Furthermore, the amount of tilting is not equal in different horizons and localities, and the direction of tilting varies from place to place. In conclusion, there is no observable correlation between the cyclic sedimentation and the stepwise reduction of dip of strata. The Shibikawa, Anden and Katanishi Formations seem to reflect the up and down movements of sea level as well as local tectonic movements which were independent from glacioeustatic sea-level changes.

Ostracod Fauna

Stratigraphic horizons from which ostracod samples were collected are indicated in Fig. 9. The sample preparation employed in this study is detailed by IKEYA (1971c). For a comparative study, Recent materials were dredged from several stations off the Oga Peninsula using an OCKELMANN type sampler, modified by HANAI in order to obtain semiquantitative samples. The sampler was designed to dredge a veneer of sediments of about 1 cm in thickness just below the water-sediment interface, and over an area of approximately 1 m^2 (5 m×0.2 m). Sampling stations are shown in Fig. 12. For the identification of ostracod taxa, references were made to HANAI (1957a, 1957b, 1957c, 1959a, 1959b, 1970), ISHIZAKI (1966, 1968, 1971), NEALE (1974), and NEALE and HOWE (1975).

1) Abundance of fossil ostracods

As shown in Figs. 9 and 13, ostracods are nearly exclusively confined to unit-C in the cycles of sedimentation. The number of ostracods per one cubic centimeter of sediments varies vertically within each unit-C, that is, it reaches a maximum near the middle of unit-C and then decreases upwards. In general, the

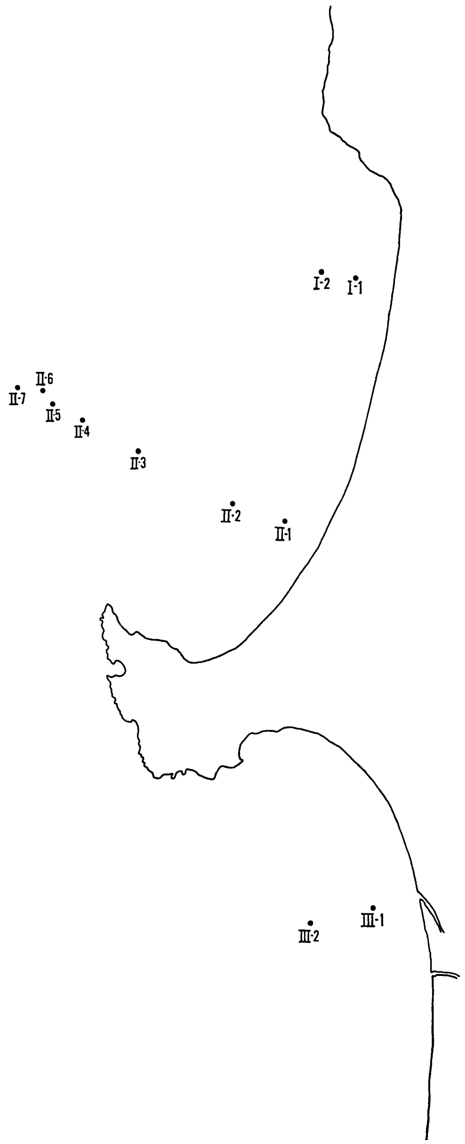

Fig. 12. Sampling stations off Oga Peninsula for Recent ostracods.

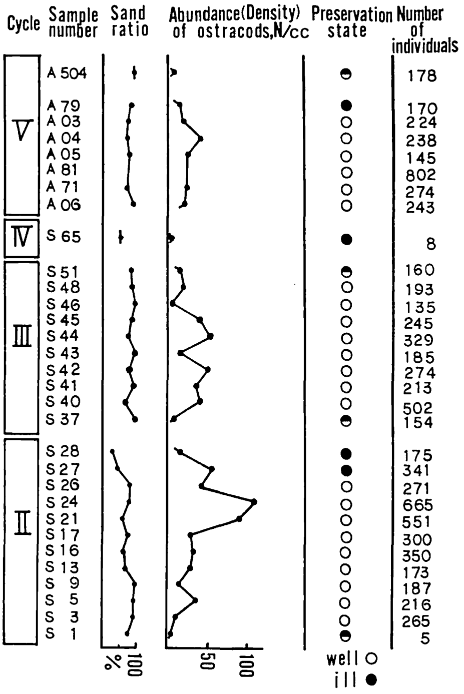

Fig. 13. Vertical changes of ostracod faunae (1) and sand ratio.

abundance of ostracods changes cyclically in accordance with lithological changes.

The ratio of sand fraction per unit volume of sediments is shown in Fig. 13. There is a tendency that the density of ostracods shifts in an inverse relation to the sand ratio throughout the sequence.

2) State of preservation

The state of preservation of fossil ostracods is not the same in all the horizons. Under the binocular microscope, carapaces show two types of appearance: one having a glossy surface showing sculpture clearly and the other with a milky surface showing sculpture obscurely. Most of the specimens from samples S-27, 28, 65 and 79 have a milky surface. Both types of preservation are found in samples S-1, 37, 51 and A-504. The remaining samples contain ostracods with a glossy surface showing clearly defined sculpture. In order to clarify the differences of preservation, *Cythere lutea* with a glossy carapace from sample S-16 and that with a milky carapace from samples S-27 and 28 were examined by means of SEM (scanning electron microscope). Those carapaces with a milky surface (sample S-28) have a more rough and granular appearance than those with a glossy surface (sample S-16) (Fig. 14, Pl. 21, Figs. 1, 2). This observation agrees well with that made by OERTLI (1975). Fine structures such as the surface pits and sieve plates of normal pore canals are hardly preserved in the specimens from sample S-27 and 28. Observations of fractured carapaces from sample S-28 revealed that the thin outer layer (epicuticle) is not clear due to decomposition, and that calcite grains of the middle layer (procuticle) are more sparse than those of glossy surface specimens (Pl. 21, Figs. 4, 7, 8).

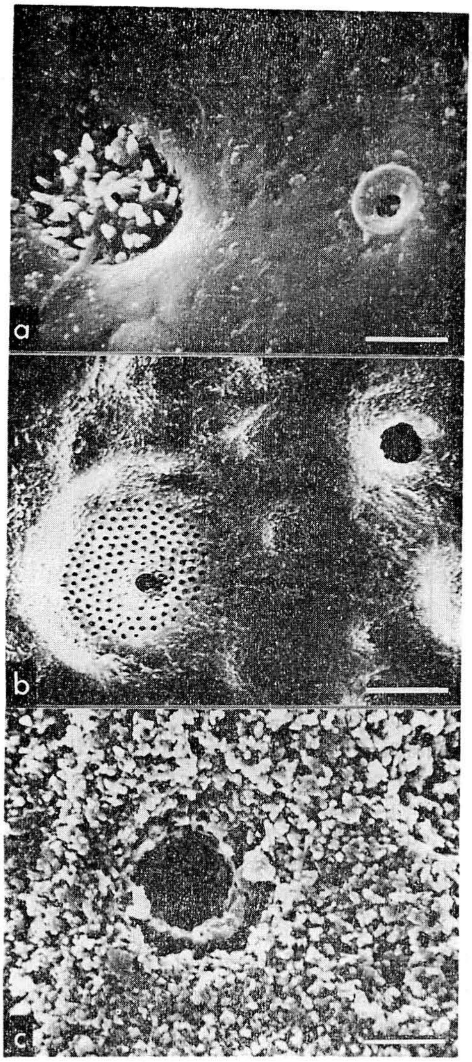

Fig. 14. Different state of preservation of carapace surface of *Cythere lutea*. Compare the microstructures of the surface and normal pore canals, large pores and small pores. a: Recent specimen. b: well preserved fossil. c: poorly preserved fossil lost its sieve plate. Scale 10 μm.

The surface of a glossy carapace from sample S-16, after being decalcified in a solution of neutralized 0.1 M EDTA for 45 seconds, showed an appearance similar to that of the milky carapaces from samples S-27 and 28 (Pl. 21, Figs. 5, 6). Decalcification of the carapaces of living *Cythere lutea* by EDTA resulted in a very different appearance (Pl. 21, Fig. 3) owing to the presence of a stiff outer layer (epicuticle) which might have protected the carapace from the solution of calcite. Therefore, the poorly preserved carapaces are inferred to have been subjected to decalcification after the outer layer was decomposed.

It is interesting to note that the occurrence of poorly preserved carapaces is confined to the uppermost and lowermost horizons of unit-C sediment. Some environmental change seems to have influenced the state of preservation there.

3) Relation of faunal changes to the cycles

As shown in Table 1, ostracod faunas in these cycles are dominated by cold-water genera, and, in generic composition, they somewhat resemble the high latitude marine ostracod faunae of NEALE and HOWE (1975). Fig. 15 shows a vertical change in the frequency of individuals belonging to the genera *Baffinicythere* and *"Urocythereis"* which are known to be distributed in the Arctic Ocean and its neighboring areas. The vertical change in the total frequency of individuals of the cold-water genera including *Baffinicythere*, *"Urocythereis"* *Finmarchinella*, *Hemicythere*, *Howeina*, *Munseyella*, *Schizocythere* and *Semicytherura*, which are known to be distributed mainly in high latitude areas, is also presented in Fig. 15. The frequency of most of these cold-water inhabitants tends to decrease in higher stratigraphic horizons. According to NEALE (1974), *Finmarchinella angulata* (SARS) ranges geographically from about 50° north latitude in the Atlantic to the Arctic Ocean. This species also decreases upwards and is mainly confined to the lower two cycles.

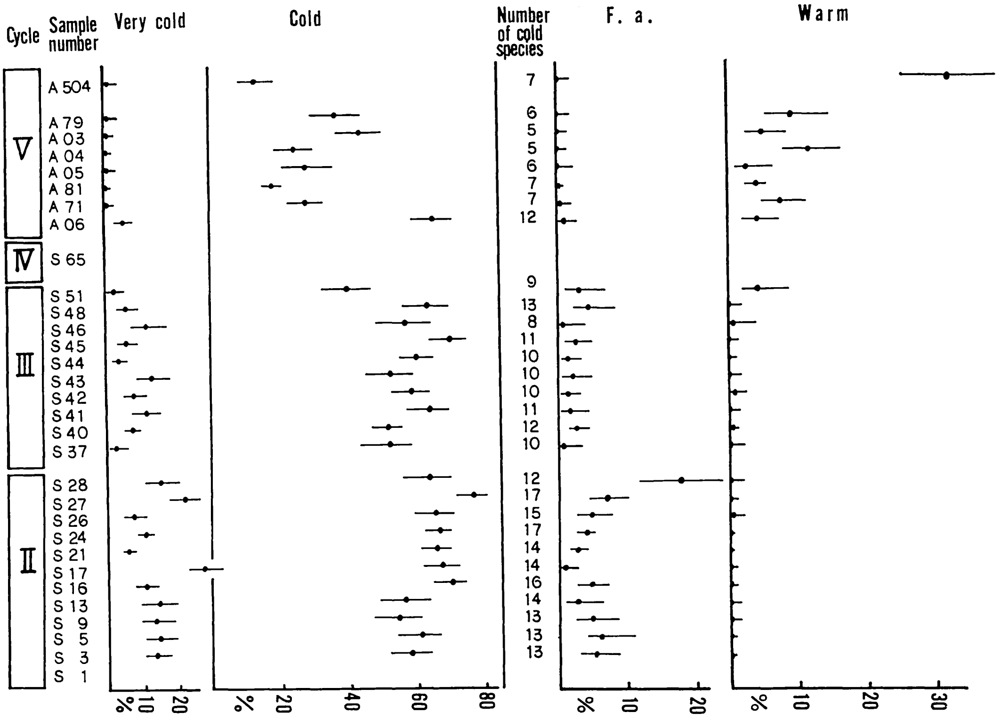

Fig. 15. Vertical changes of ostracod faunae (2). Ratio of individuals belonging to *Baffinicythere* and "*Urocythereis*" (Very cold) ; to *Baffinicythere*, "*Urocythereis*", *Finmarchinella*, *Hemicythere*, *Howeina*, *Munseyella*, *Schizocythere*, and *Semicytherura* (Cold) ; to *Finmarchinella angulata* (F. a.) ; to *Loxoconcha optima*, *Cytheromorpha acupunctata*, *Proteoconcha tomokoae*, *Trachyleberis scabrocuneata*, *Echinocythereis bradyformis*, and *Ruggieria bisanensis* (Warm). The bar indicates the range of 95% confidence.

In contrast to the cold-water species, seven species which are known to inhabit warm current areas near Japan today occur nearly exclusively in the uppermost cycle. They are *Loxoconcha optima* ISHIZAKI, *Cytheromorpha acupunctata* (BRADY), *Proteoconcha tomokoae* (ISHIZAKI), *Trachyleberis scabrocuneata* (BRADY), *Echinocythereis bradyformis* ISHIZAKI, and *Ruggieria bisanensis* (OKUBO). Therefore, the faunae characterized by cold-water species were replaced by those comprising warm-water species in the cyclic sequence of lithofacies.

Recent ostracods inhabiting depths ranging from 25 m to 800 m off the Oga Peninsula were dredged (Fig. 12). The fossil assemblages were found to have several species in common with the modern ostracod communities living at depths of about 25 m and 50 m (Table 1). Therefore, the observed species in these cycles are interpreted to have lived in shallow seas not deeper than 50 m, and the range of sea level fluctuations might also have been confined within this depth.

Throughout the cycles, the number of fossil species in common with the Recent ostracod fauna living at a depth of 25 m is nearly equal to that at 50 m. So it is difficult to conclude that the environment

Table 1. Faunal list of ostracods.

		II											III										V							
		S3	S5	S9	S13	S16	S17	S21	S24	S26	S27	S28	S37	S40	S41	S42	S43	S44	S45	S46	S48	S51	A06	A71	A81	A05	A04	A03	A79	A504
A	Pectocythere pseudoamphidonta							*		*	*	6																		
	Microcytherura sp.	1	1	2		*		*	1	1																				
	Semicytherura leptocytheroidea					3	1	2	1	*	1	1																		
	Hemicythere sp.								2		2	2																		
	Munseyella hokkaidoana	1	*	1		*		*		1	*			*							1									
	Cytherura sp.B				1	1	*	*	2		1			2								1				1				
	Howeina camptocytheroidea				3	8	6	6	5	5	7	6	2										*							
	Baffinicythere sp.B					1	1	1	3		6			1	*															
	Baffinicythere sp.C				1	5			2	2	6	2											*							
	Urocythereis sp.A	5	3	4					*	*											1									
B	Munseyella hatatatensis	3	5	5	9	3	2	3	1	*	*	2		1	1	1	1	1	1		3	8	2							
	Callistocythere setanensis	2	6	4	4	3	1	2	1	1	*	2		*		1	2	2	1	4	1	1		*				*	2	
	Callistocythere undulatifacialis	10	10	12	9	1	5	3	2	5			6	9	7	2	5	3	2	4	1	6	5	4	5	3	3	2	1	
	Schizocythere okhotskensis	9	8	9	13	18	15	14	17	12	21	11	5	5	5	7	4	5	4	4	5	5	2	1	*	1	1		1	1
	□○Semicytherura henryhowei	2	1	4	1	6	1	5	3	6	5	18	2	5	3	3	1	2	1		3	4	1		2	1	3	*	2	
	Howeina higashimeyaensis	7	13	9	6	8	8	11	7	5	3	10	25	11	2	4	1	3	1	1	3	1	4	4	2	3	2	5	2	1
	□ Hemicythere gorokuensis	4	1	2	2	2	1	4	5	3	4	2	1	*	*	1	1	*	*	2	2	2	1	4		4	1	*		1
	Baffinicythere sp.A	9	8	4	3	1	4	*	1	*	*	5	1	3	3	4	3	2	2	3	2	3	2	*				2	1	1
	Baffinicythere sp.D				6	11	4	3	3		3						3		1	4	1									
	Finmarchinella angulata	5	7	3	3	5	1	3	4	5	7	18	1	3	2	1	2	2	2	1	5	3	1	*	*					
	Finmarchinella nealei	6	3	2	2	1	2	3	3	7	3		3	4	2	1	3	2	*		3	5	*	1	1	1			1	1
	Urocythereis gorokuensis	3	3	6	4	3	8	2	2	4	6	9	1	1	7	3	10	2	3	8	3		2		*					1
	Hemicytheridae sp.	7	8	6	2	5	4	3	4	3	11	2	3	3	3	2	2	1	3	3	2	1								3
C	□○Cushmanidea sp.A	1					1				*		1	*	1	*		1			2	1	1	2	*	10	7	1	9	10
	Cushmanidea sp.B			1							*			1		1		*			1	6		2	*	4	1	3	8	7
	Callistocythere subjaponica						1	*	*					*		*		*	1					1	1	3	1	1		17
	□ Spinileberis sp.	3	*	1	1		4	1		*			1	1							1		*	3	5	4	*		1	
	○Cytherura sp.A			2	1	*	*	1	1	1			1	1		1	1		*	1	1	3	1	2	5	1	2			
	□ Hemicytherura kajiyamai		*		*			*						1				1	*			3	1	1	1	1	*			
	□ Cytheropteron sawanense	1	4		1		2	1	2	*	2	1	1	7	2	4	3	4	2		2	8	5	8	9	12	4	3	4	
	○Loxoconcha optima													*		1						3	2	1	1			3	1	9
	Loxoconcha sp.A												1	1		1	1	2	*	1			11	2	6	8	8	4	2	1
	Finmarchinella hanaii	3	8	5	3	6	5	11	8	14	1		11	17	36	32	24	43	54	34	54	3	49	20	9	18	28	36	31	10
	Aurila sp.B						3	1	1	1		1	10	4	*	1	5	2	2	3	1		3	4	5	6	3	4	5	5
	□○Muellerina sp.	2	5	1			*	1	*				3	1	3	1	1	2		1	2	3	3	3	1	10	3	2	2	1
	□○Trachyleberis scabrocuneata												1							1			*	3	2	1	5	1	5	1
	Coquimba sp.												1	1		*	1	1	*	1	1	1		3	7	2	1			
D	□ Schizocythere sp.																								*	1				
	Cytheromorpha acupunctata																							*		1	*	*		
	○Proteoconca tomokoae																							*	*		1	*	3	23
	○Echinocythereis bradyformis																							1	1		*			
	Ruggieria hisanensis																						2	1	*				1	
E	Paracypris sp.							1	*												2	3		*					1	
	Neonesidea sp.	1		1	1			1	1	1			1	1	3	1	3	3	2	3	2	1	1	1		1	2		3	1
	□○Cythere lutea	1		2	2	11	1	2	6	2	3	3	2	*			1	*			4	2	*	3	4	2	4	3	2	6
	Paijenborchella miurensis												1	1	1	2		*												
	□ Paijenborchella triangularis		*				2	*	*					1							1			*						
	Loxoconcha sp.B				2			1	2					*		1		1				1		*	1				1	
	□○Loxoconcha sp.C	1	2	1		3		3	4	3	2		3	*	*	*			*		1		2		3	1	3	2	2	
	Loxoconcha sp.D			2		1	1				1			1												3	*	*	1	
	Aurila sp.A	3	1	5	9	2	1	3	4	9	*		4	4	9	12	18	11	8	16	10	6	4	3	4	6	6	7	4	
	Cornucoquimba moniwensis	3	1	4	6	1	2	1	*	1			7	5	3	3	7	3	4	1	2	3		1	*	10	2	2	3	1
	Hermanites sp.					*	3	2	1	1	2	1		1	2	*	3	*	2	1	2	3	1	1	*					3
	Trachyleberididae sp.														*			*	1		1									
	□ Bythoceratina hanaii		*	1	1		1	*					2	*		*			1					1		1		1		
	○Xestoleberis sp.A				1	*	1	1	1		*		1			1		1		1		1		1	*	4	1		1	
F	Cushmanidea sp.C												1						*											
	Eucythere sp.									*																				
	□○Cythere japonica							*		1																	*			2
	Palmenella limicola	1									*																			
	Paracytheridea sp.																	1												
	Cytherura sp.C	1		1																				*	1					
	Cytherura sp.D								*																1					
	Cytheropteron sp.A					1		1	1	1				*			1	*	*		1			*			*		1	
	○Cytheropteron sp.B			1				*					1						*					*	1					
	Loxocorniculum kotoraformum	1																*				1								
	Cytheromorpha sp.														1									*		1	*	*		
	Urocythereis sp.B																						*							
	Cornucoquimba sp.				1	1		1						*		*														
	Hirsutocythere nozokiensis							*																						
	△Acanthocythereis sp.						1											*												
	Buntonia sp.A																		*											
	Buntonia sp.B													*										*						
	Xestoleberis sp.B	*	*	1				*	*					*		*		*				1							1	
	Xestoleberis sp.C							1	*	1					*	1	1					2	1							
	Xestoleberis sp.D			1																	1									
	□○Cytherois sp.		1					*															1	*		1	*	*	1	
	Sclerochilus sp.					*		2			1	1								1	1									

Figures indicate the ratio of each species within a sample in percent, and * indicates existence of species less than 0.5 percent. The SEM photographs of all species are shown in OKADA (1977). Species found in Recent sea, at the depth of 25 m(○), 50 m(□), and 75 m(△) are also shown. The cycle numbers are indicated by II, III and V, beside of which sample numbers are shown. The species are classified into six types: A) species mostly confined to the lowest cycle, B) species gradually decreasing in individual numbers towards upper levels, C) species gradually increasing in individual numbers upwards, D) species confined to the uppermost cycle, E) species without any particular tendency in stratigraphic distribution, and F) species too rare to show any tendency.

of the upper cycle was significantly different in depth from that of the lower cycle.

The distribution pattern of a typical cold-water species, *Baffinicythere* sp. may give us information about the change of water temperature. According to HAZEL (1970), the maximum depth in which living *B. emarginata* (SARS) can be found decreases equatorwards from 200 m to 38 m as the species is probably governed by winter bottom temperatures lower than about 5°C which are needed for reproduction. So the disappearance of such cold-water species as *B.* sp. throughout the sediment column may indicate an increase in bottom water temperature during winter time greater than the low winter temperature needed for reproduction of the species. Furthermore, vertical changes of water temperature at depths less than 50 m are not significant, when compared with the extent of seasonal changes (Central Meteorological Observatory, 1967-1969).

In conclusion, the gradual changes of ostracod faunae as mentioned above are probably not the direct result of changes in the depth of seas. It is very likely that the average sea-water temperature, especially in winter, rose from lower cycles to upper cycles.

In terms of stratigraphic occurrences, the species can be classified into the following six types (Table 1): A) species mostly confined to the lowest cycle, B) species gradually decreasing in numbers towards higher stratigraphic levels, C) species gradually increasing in individual numbers upwards, D) species confined to the uppermost cycle, E) species without any particular tendency in stratigraphic distribution, and F) species too rare to show any particular tendency.

The distribution of some species listed in Table 1 is known, while the geographic ranges of other species have as yet to be determined. The results as described above, however, may become useful in estimating their geographic ranges, because these four groups (from A to D) are considered to have originated from their differing temperature preference. For example, the range of *Finmarchinella hanaii* n. sp. would be different from that of *F. nealei* n. sp. which would be similar to that of *F. angulata*.

Howeina higashimeyaensis ISHIZAKI exhibits morphologic variations and the relative abundance of different morphotypes changes through the sequence, especially from one cycle to another and also at some horizons within unit-C where rudaceous silty sands are succeeded by rather massive silty sands. This poses many interesting paleontological problems.

4) Structure of ostracod assemblages

There are many studies on the structure of Recent communities and fossil assemblages ; e. g. on fossil lake chydorids (Cladocera) by WHITESIDE and HARMSWORTH (1967) and TSUKADA (1967), on Recent marine benthonic foraminifers by BUZAS and GIBSON (1969) and IKEYA (1970, 1971a, 1971b), and on Recent marine decapods by ABELE (1974). It is well known that the structure of a community depends upon its surrounding environment. Investigation of the structure of fossil assemblages is said to be useful in obtaining information on environmental changes.

The structure of fossil assemblages is shown in Fig. 17. Numbers of individuals of each species are plotted in log scale on the ordinate, against respective species in the sequence from the most to the least abundant, on the abscissa. Most assemblages are arranged non-linearly, each line consisting of a steeper segment

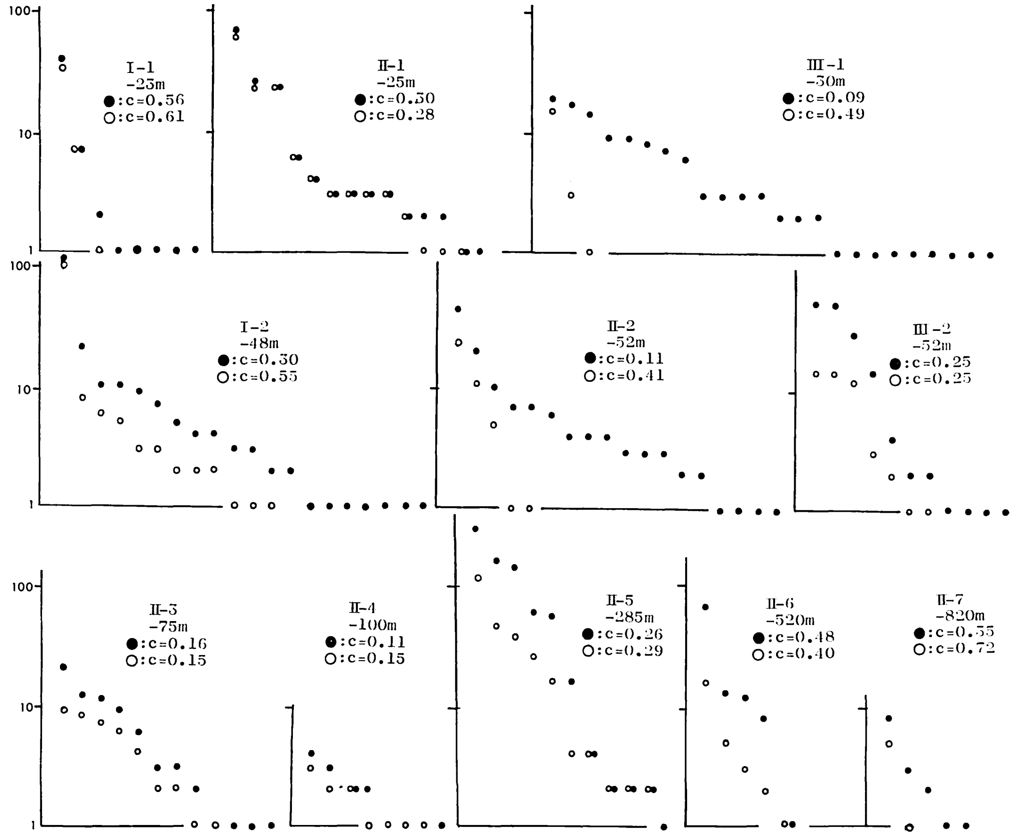

Fig. 16. The structure of Recent living communities (○) and total assemblages (●). Numbers of individuals of each species in log scale on the ordinate. Species sequence from the most to least abundant on the abscissa.

and a more gently declining segment. The inclination of the latter is nearly constant at most horizons. The steeper segment is readily identifiable at some horizons but cannot be easily recognized at others. The inclination of the lines, which as a whole represents the diversity of the samples, is much lower than that of reported communities of living animals. This is also shown by extremely high values of diversity index H' (Fig. 18). The conspicuousness of steeper segments can be expressed by the index of concentration $c=\sum(n_i/N)^2$ of SIMPSON (1949), where N is total number of individuals in an assemblage and n_i is the number of individuals of i'th species in the sequence. Then the value of c shows significant changes through the cycles (Fig. 18). In cycle-II, c remains very low. On the contrary, c often rises to higher value in cycles-III and V. This suggests the environment of cycles-III and V differs from that of cycle-II.

According to IKEYA's (1970) study on Recent foraminifers, total assemblage which consists of living and dead foraminifers is arranged in a bent line when it is a mixture of different communities. The same may be said of the Recent

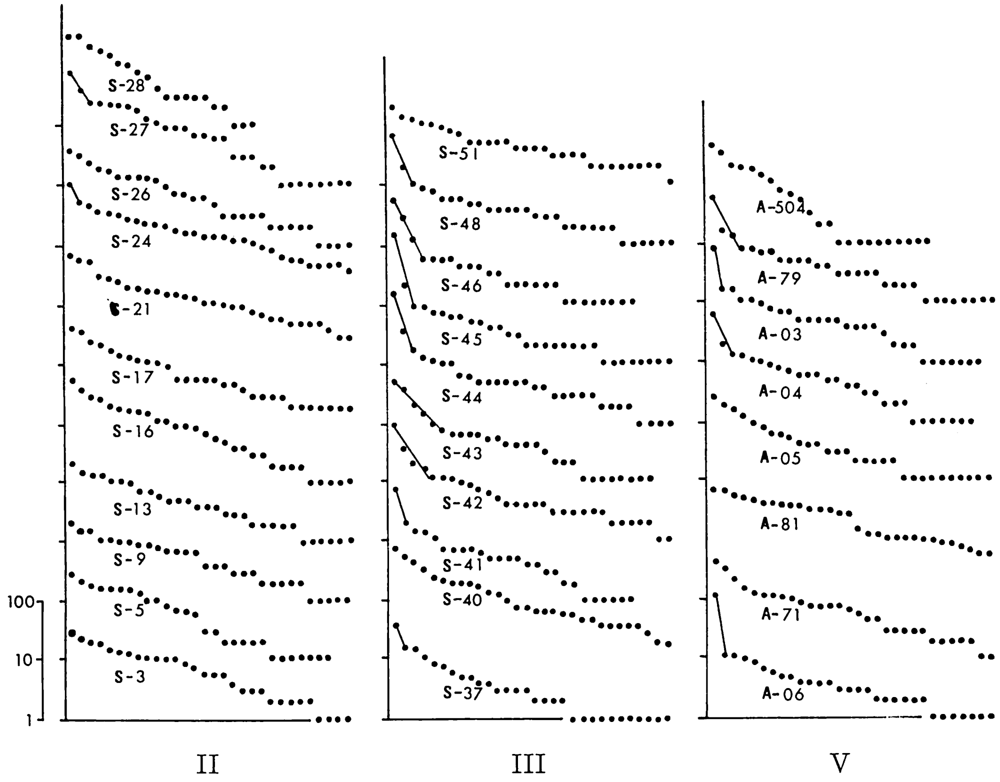

Fig. 17. The structure of fossil assemblages. Numbers of individuals of each species on the ordinate. Species sequence from the most to least abundant on the abscissa. Scale marks on the ordinate also indicate the origin of the samples. Forming gentle slopes by dots, every assemblage shows high diversity. When the steeper segment of a bent line is conspicuous, their marginal dots are connected by a straight line to clarify the steepness. II, III and V correspond to cycle numbers.

ostracod samples off the Oga Peninsula (Fig. 16). Good examples are II-2 and III-1 from shallow marine environment. Each of the living communities fits onto a straight line, whereas the respective total assemblages deviate considerably from the lines. In II-2, owing to the addition of dead ostracods from different communities to the living community at the place, the total assemblage becomes arranged in a sharply bent line. In III-1, because of extreme mixing of dead ostracod carapaces, the steeper segment is no longer obvious and the inclination of the line becomes quite gentle. In other samples, resulting from the addition of fewer dead ostracods, the total assemblages retain low diversity.

Therefore, the sharply bent lines and the high diversity of the fossil assemblages probably resulted from mixing of communities. Obscureness of steeper segments may reflect the degree of mixing. IKEYA (1970, p. 186) considered assemblages to be "a sum of successive generations of living populations adapted respectively to such environmental fluctuations as seasonal and annual, and fur-

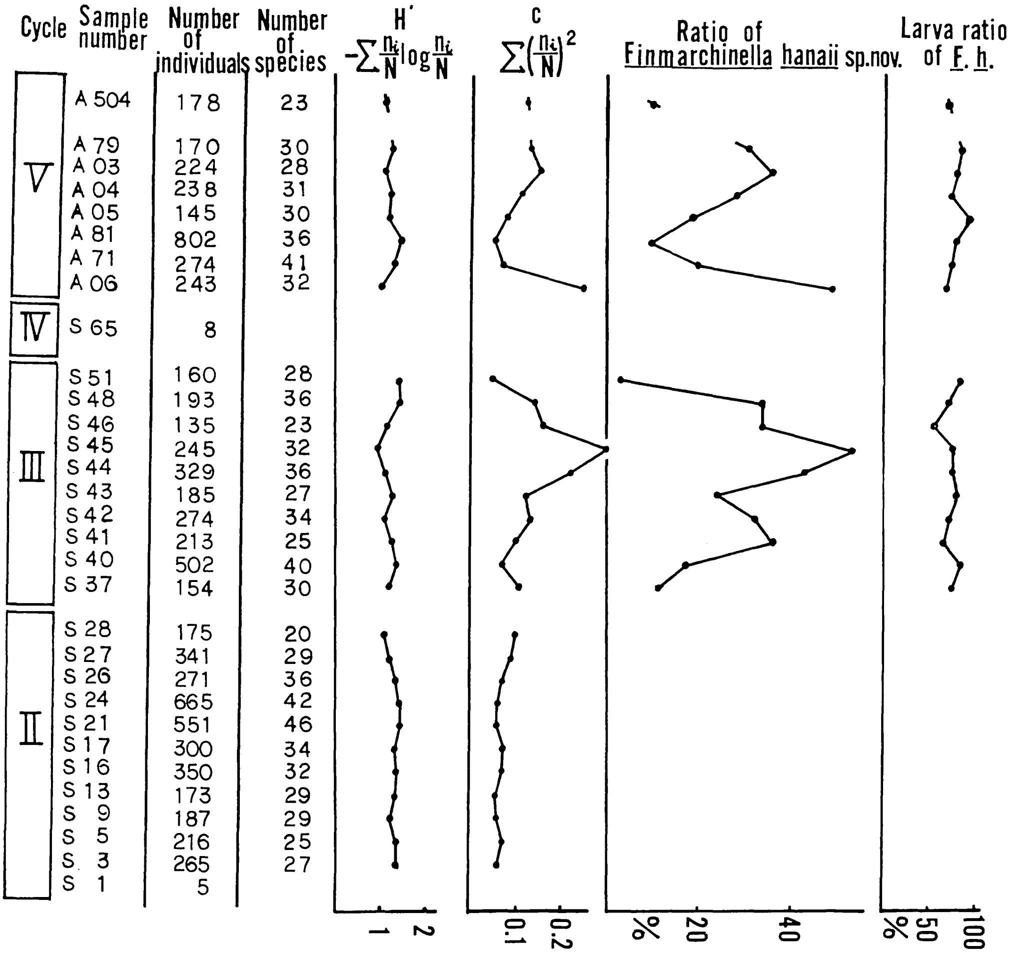

Fig. 18. Vertical changes of ostracod faunae (3). The values of diversity index (H′) are constantly high. The conspicuousness of steeper segments (in Fig. 17) is expressed by the index of concentration (c). N is total number of individuals in an assemblage and n_i is the number of individuals of i'th species in the sequence.

ther modified by transportation of dead tests by currents". In other words, the mixture is expected to occur in an unstable environment and/or in a violent environment with high transportation energy. So the change in value of c in the fossil assemblages may suggest that the environment became more or less stable and/or mild towards upper cycles.

Both shapes and size are different between larval valves and adult ones of *Finmarchinella hanaii* n. sp., which is the dominant species through cycles-III and V. So possibly they may have been moved independently by the sorting agent. The ratio of the larvae to total number of valves of *F. hanaii* is almost constant and does not show any correlation with the value of c. So it would be difficult to confirm the idea that the steeper segments (in Fig. 17) depend on the species which were concentrated by sorting effect. Furthermore, no significant correlation was observed between the value of c and the sand ratio of the respective samples. This result also stands against the idea.

The dominant species through each cycle are *Schizocythere okhotskensis* HANAI, *Howeina higashimeyaensis* and *Callistocythere undulatifacialis* HANAI in the lowest cycle, *Finmarchinella hanaii* and *Aurila* sp. A in the middle cycle, and *Finmarchinella hanaii* and *Cytheropteron sawanense* HANAI in the uppermost cycle. The middle and the upper cycles resemble each other with regard to dominant species. This may mean that the environment of cycle-III resembled more that of cycle-V than that of cycle-II. The dominant species itself frequently changes within the lowest cycle, which may indicate the instability of the environment. In cycles-III and V, it remains unchanged throughout unit-C except for the lowest and uppermost horizons. This fact, together with the value of c, suggests that the environment became more stable from the lower cycle to the upper cycles.

Systematic Descriptions

Depository and Abbreviations.—Holotypes and paratypes are deposited in the collection of the University Museum, University of Tokyo (UMUT), Japan. Numbers of these specimens are prefixed CA for Cenozoic Arthropoda.

The following abbreviations are used in the systematic section:

S: Sex (M for male and F for female)
Sp: Specimen measured (L, R, C for left valve, right valve, carapace)
Me: Measurement in mm (L for length, H for height, W for width)
N: Number of observations
$\bar{X}$: Arithmetic mean
s: Standard deviation
V: Coefficient of variation
a: Coefficient of regression of reduced major axis
OR: Observed range

Order Podocopida SARS, 1866

Superfamily Cytheracea BAIRD, 1850

Family Hemicytheridae PURI, 1953

Subfamily Hemicytherinae PURI, 1953

Genus *Finmarchinella* SWAIN, 1963

Subgenus *Barentsovia* NEALE, 1974

Finmarchinella (*Barentsovia*) *hanaii* sp. nov.

Pl. 22, Figs. 1-13

Diagnosis.—A species of *Finmarchinella* (*Barentsovia*) with weak anterior marginal ridge, notched caudal process, crescent posterodorsal rib and overall reticulation. Reticulation weak, consisting of shallow polygonal fossae surrounded by fine muri and accompanied with second-order reticulation. Hinge line arches abruptly near anterior and posterior terminals.

Description.—Valves in lateral view rounded-rectangular of typical *Finmarchinella* shape. Anterior margin round, dorsal margin straight in male and scarcely convex in female, posterodorsal margin angularly convex, posterior margin protruding into a caudal process with two weak notches. In dorsal view rounded, subhexagonal. Eye tubercle and subcentral tubercle well-developed. Anterior marginal ridge weak. Ornamentation of overall reticulation consisting of polygonal fossae with second-order reticulation and accented by a rib developed in posterodorsal area. Fossae very shallow, often obscure and surrounded by fine muri. The rib runs posteriorly near dorsal margin from about two-thirds of the length of the valve, curves ventrally at about five-sixths of the length, and ends at about two-thirds of the height. There are two weak nodes near anterior margin at about two-thirds and one-third of the height. The upper node is connected with an eye tubercle by a short ridge in right valve, separated in left valve. Hinge merodont, 5-6 teeth in anterior and posterior hinge area respectively. The anteriormost and posteriormost teeth are largest and scarcely separated from adjacent teeth, near which hinge line curves ventrally, while the other teeth are clearly separated from each other. Normal pore canals consisting of large and small pores. Large one is sieve type either with or without an apparent setal opening. Small pore with secluded obscure inner structure. Marginal pore canals nearly straight without branching; approximately 45 anteriorly and 15 posteriorly. Anterior and posterior vestibules narrow. Muscle scar pattern typical of the genus consisting of a vertical row of four adductor scars with three scars anteriorly. The middle two adductor scars quite clearly divided. Sexual dimorphism marked, the males being lower, in proportion to their length, than the females. Juvenile forms show more prominent tubercles and ridges, and narrower vestibules.

Table 2. Measurements (in mm) of *F. hancii* from cycles-II, III and V.

S	Sp	Me	Cycle	N	$\bar{X}$	s	V	OR	$a(s_H/s_L)$
F	L	L	II	14	0.714	0.0184	2.58	0.68-0.74	0.737
			III	41	0.737	0.0232	3.15	0.69-0.79	0.553
			V	23	0.713	0.0220	3.08	0.66-0.75	0.492
	L	H	II	14	0.361	0.0136	3.75	0.33-0.38	
			III	41	0.379	0.0128	3.39	0.35-0.40	
			V	23	0.367	0.0108	2.95	0.34-0.39	
	R	L	II	21	0.720	0.0283	3.93	0.66-0.76	0.530
			III	56	0.728	0.0264	3.63	0.66-0.77	0.475
			V	17	0.702	0.0218	3.10	0.65-0.74	0.571
	R	H	II	21	0.356	0.0150	4.21	0.33-0.38	
			III	56	0.367	0.0126	3.42	0.33-0.40	
			V	17	0.355	0.0124	3.50	0.33-0.37	
	C	W	III	7	0.370			0.35-0.39	
			V	1				0.37	
M	L	L	II	20	0.630	0.0175	2.77	0.59-0.66	0.704
			III	32	0.634	0.0194	3.05	0.60-0.67	0.513
			V	26	0.615	0.0169	2.75	0.59-0.66	0.524
	L	H	II	20	0.297	0.0123	4.14	0.28-0.33	
			III	32	0.298	0.0099	3.33	0.28-0.31	
			V	26	0.295	0.0089	3.00	0.28-0.32	
	R	L	II	15	0.611	0.0233	3.82	0.55-0.65	0.552
			III	30	0.640	0.0179	2.79	0.61-0.69	0.407
			V	25	0.607	0.0197	3.24	0.56-0.64	0.457
	R	H	II	15	0.281	0.0129	4.59	0.24-0.30	
			III	30	0.297	0.0073	2.45	0.28-0.31	
			V	25	0.285	0.0090	3.16	0.27-0.31	
	C	W	III	5	0.302			0.29-0.31	

Affinities and Differences.—This species is most closely related to *F.* (*B.*) *angulata.* Both species lack any rib connecting the ventral end of the posterodorsal rib with the subcentral tubercle. It is easily differentiated from *F.* (*B.*) *angulata* by the weak anterior marginal ridge, shallow fossae and fine muri. In dorsal view its outline is more rounded and smooth than *F.* (*B.*) *angulata.* Hinge line is clearly curved near its margins and teeth of anterior and posterior hinge area are clearly separated in this species, whereas in *F.* (*B.*) *angulata* from the Oga Peninsula, hinge line is almost straight at the anterior margin of the hinge.

Types.—Holotype, UMUT-CA 9614, a left valve (Pl. 22, Fig. 2); Figured paratypes, UMUT-CA 9615-9626.

Occurrence.—This species occurs from all the horizons of cycles-II, III, V as listed in Table 1. The ratio of number of individuals within each sample increases towards upper horizons.

Finmarchinella (*Barentsovia*) *nealei* sp. nov.

Pl. 23, Figs. 1-5

Diagnosis.—A species of *Finmarchinella* (*Barentsovia*) with a well-developed anterior marginal ridge, weak posterodorsal rib, and overall reticulation. Its ventrolateral surface hangs downward in such a manner to hide the posterior part of the ventral contact margin in lateral view. Hinge line gently arches near the anterior margin.

Description.—In lateral view, valves rounded-rectangular having a typical *Finmarchinella* shape. Anterior margin round, dorsal margin slightly concave in males and barely convex in females, posterodorsal margin gently convex, posterior margin protruded a little by a rather smooth caudal process. Ventrolateral surface hanging downward to hide posterior part of ventral contact margin at about three-fourths of the length, where the carapace bulges most. In dorsal view rounded subhexagonal. Eye tubercles well-developed and subcentral tubercle gently convex. Anterior marginal ridge well developed. Ornamentation of overall reticulation consisting of finely pitted round fossae and weak costation. A weak rib runs posteriorly near dorsal margin from about the middle of the valve

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Explanation of Plate 21

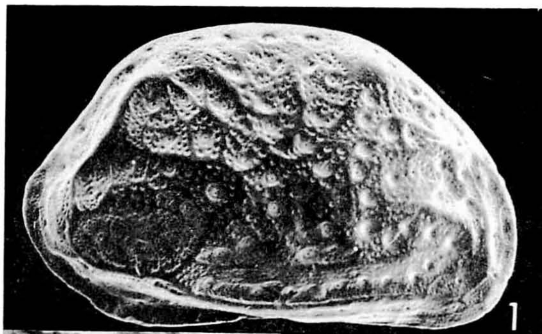
Fig. 1. *Cythere lutea* from sample S-16. Lateral view of male right valve. An example of well preserved fossil ostracod. ×89.

Fig. 2. *Cythere lutea* from sample S-27. Lateral view of male right valve. An example of poorly preserved fossil ostracod. ×89.

Figs. 3-8. Structure of the carapace of *Cythere lutea,* shown by fractured samples.

3. Recent sample from the Hayama Beach with EDTA treatment. ×1300.
4. Well preserved fossil from sample S-16 without EDTA treatment. ×1400.
5-6. Well preserved fossils from sample S-16, with EDTA treatment. 5: ×1300. 6: ×1400.
7-8. Poorly preserved fossils from sample S-28, without EDTA treatment. 7: ×1450. 8: ×1400.

c: procuticle consists of many calcite granules. de: denatured (fossilized) epicuticle. di: denatured inner membraneous layer. dis: denatured inner membraneous layer at sieve plate. ep: epicuticle. im: inner membraneous layer. lp: large normal pore canal with sieve plate. os: outer surface. p: pit. s: small normal pore canal without sieve plate. sp: sieve plate with numerous pores. st: seta.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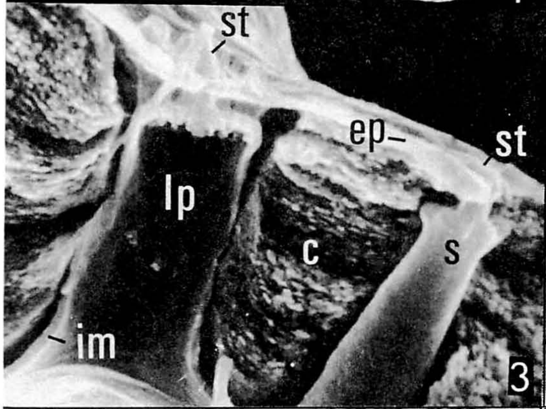
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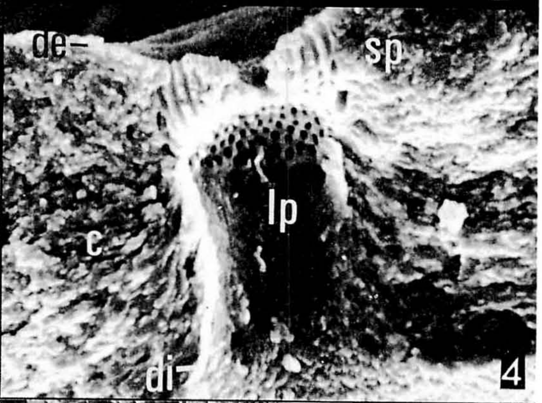
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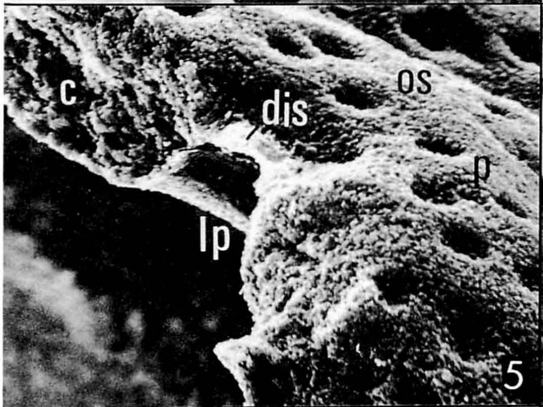
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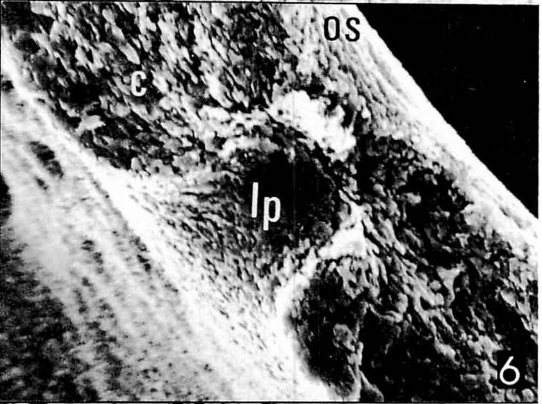
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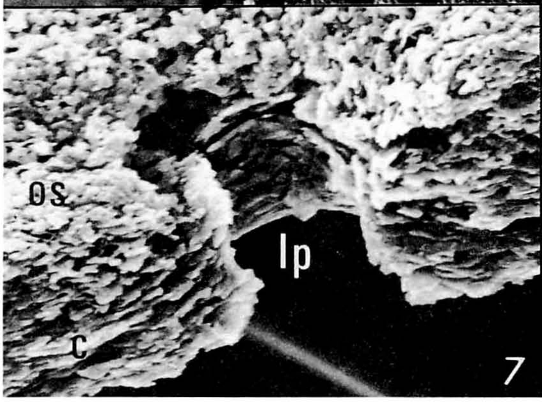
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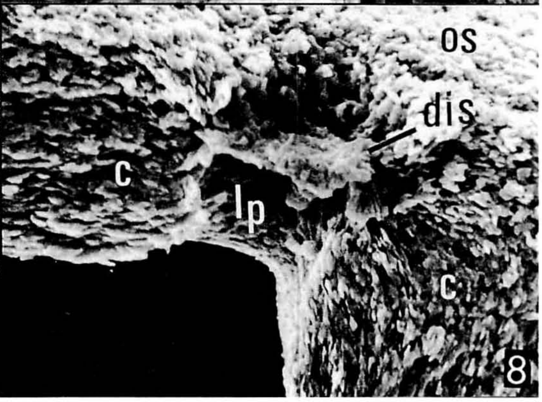
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length, curves ventrally at about five-sixths of the length, where it is most prominent, and becomes obscure at about two-thirds of the height. Hinge antimerodont, 5-6 teeth in anterior and posterior hinge areas respectively, anteriormost and posteriormost teeth are largest. The first, forth, and fifth teeth from the posterior end are subdivided into two toothlets. Anteriormost tooth and its adjacent tooth are also subdivided. Each tooth and toothlet is separated merely at the dorsal side. Hinge line arches gently at anterior hinge area and curves abruptly near posterior end. Normal pore canals consisting of large sieve-type pores either with or without an apparent setal opening, and small pores with secluded obscure inner structure. Marginal pore canals nearly straight without branching; approximately 40 anteriorly and 25 posteriorly, concentrated anteroventrally. Anterior and posterior vestibules narrow. Muscle scars consisting of a vertical row of four adductor scars with two apparent scars anteriorly. The middle two adductor scars are very clearly divided. Sexual dimorphism marked, the males being lower, in proportion to their length, than the females.

Affinities and Diffeernces.—This species is closely related to *F.* (*B.*) *angulata.* Both species lack any rib connecting the ventral end of the posterodorsal rib with the subcentral tubercle. It is easily differentiated from *F.* (*B.*) *angulata* by the weak central tubercle, the lack of posterior node and downwards hanging ventro-

Table 3. Measurements (in mm) of *F.* (*B.*) *neclei* from cycles-II, III and V.

S	Sp	Me	Cycle	N	$\bar{X}$	s	V	OR	$a(s_H/s_L)$
F	L	L	II	24	0.675	0.0281	4.17	0.63-0.74	0.947
			III	11	0.679	0.0394	5.80	0.63-0.75	0.949
			V	4	0.658	0.0130	1.98	0.65-0.68	0.522
	L	H	II	24	0.373	0.0195	5.22	0.34-0.41	
			III	11	0.373	0.0234	6.28	0.33-0.41	
			V	4	0.362	0.0083	2.29	0.35-0.37	
	R	L	II	24	0.675	0.0233	3.45	0.64-0.74	0.788
			III	15	0.682	0.0410	6.01	0.62-0.73	0.980
			V	1				0.67	
	R	H	II	24	0.368	0.0118	3.20	0.35-0.40	
			III	15	0.372	0.0256	6.89	0.34-0.41	
			V	1				0.36	
	C	W	II	4	0.360			0.34-0.38	
			III	4	0.373			0.33-0.39	
M	L	L	II	9	0.589	0.0120	2.03	0.57-0.61	0.482
			III	6	0.580	0.0208	3.59	0.56-0.62	0.264
	L	H	II	9	0.306	0.0068	2.24	0.30-0.32	
			III	6	0.312	0.0121	3.89	0.29-0.32	
	R	L	II	4	0.590			0.57-0.61	
			III	2	0.570			0.56-0.58	
			V	1				0.57	
	R	H	II	4	0.303			0.29-0.31	
			III	2	0.290			0.28-0.30	
			V	1				0.30	

lateral surface. In dorsal view, its outline is more smooth than that of *F.* (*B.*) *angulata*. Hinge line near anterior margin curves gently in this species, whereas it is almost straight in *F.* (*B.*) *angulata*. The ribs of this species are so weak that it seems also to be related to *F.* (*Finmarchinella*) *finmarchica* (SARS). It is, however, easily differentiated from *F.* (*F.*) *finmarchica* by the existence of a rib and a well-developed anterior marginal ridge. In lateral view, *F.* (*B.*) *nealei* is very similar to *Hemicythere nana* SCHORNIKOV, though *H. nana* has amphidont type hinge, weaker anterior marginal ridge, and more rounded outline.

Types.—Holotype, UMUT-CA 9627, a left valve (Pl. 23, Fig. 1); Figured paratypes, UMUT-CA 9628-9631.

Occurrence.—This species occurs from almost all the horizons of cycles-II, III, V listed in Table 1. The ratio within each sample decreases towards upper horizons.

Acknowledgments

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Explanation of Plate 22

Figs. 1-13. *Finmarchinella* (*Barentsovia*) *hanaii* OKADA, n. sp., from sample S-45.
All figures ×78 unless otherwise stated.

1. Female right valve (Paratype, CA 9615).
2. Female left valve (Holotype, CA 9614).
3. Male right valve (Paratype, CA 9616).
   a. External lateral view.
   b. External view of large normal pore canal with sieve plate and setal opening. ×1700.
   c. External view of small normal pore canal. ×3500.
4. Male left valve (Paratype, CA 9617).
5. Larval instar, right valve (Paratype, CA 9618).
6. Larval instar, left valve (Paratype, CA 9619).
7. Male right valve (Paratype, CA 9620).
8. Female right valve (Paratype, CA 9621).
   a. Internal lateral view.
   b. Anterior part of hinge. ×205.
   c. Posterior part of hinge. ×205.
   d. Adductor muscle scars with three scars anteriorly. ×260.
9. Larval instar, right valve (Paratype, CA 9622).
10. Male complete carapace (Paratype, CA 9623).
11. Female complete carapace (Paratype, CA 9624).
12. Larval instar, complete carapace (Paratype, CA 9625).
13. Anterior marginal area of female left valve (Paratype, CA 9626), showing radial pores. ×118.


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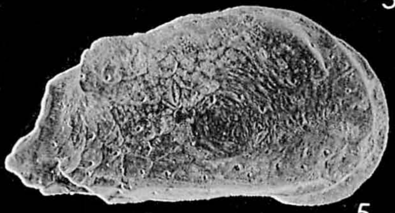
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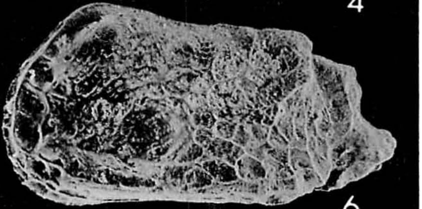
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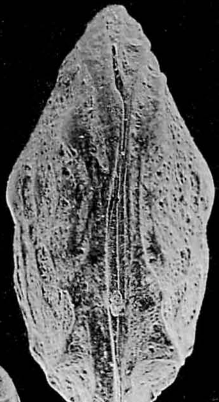
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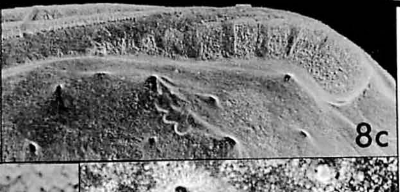
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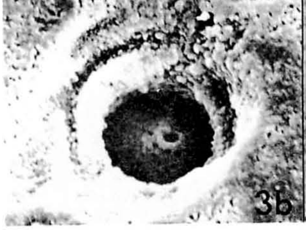
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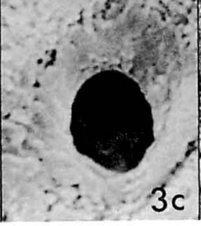
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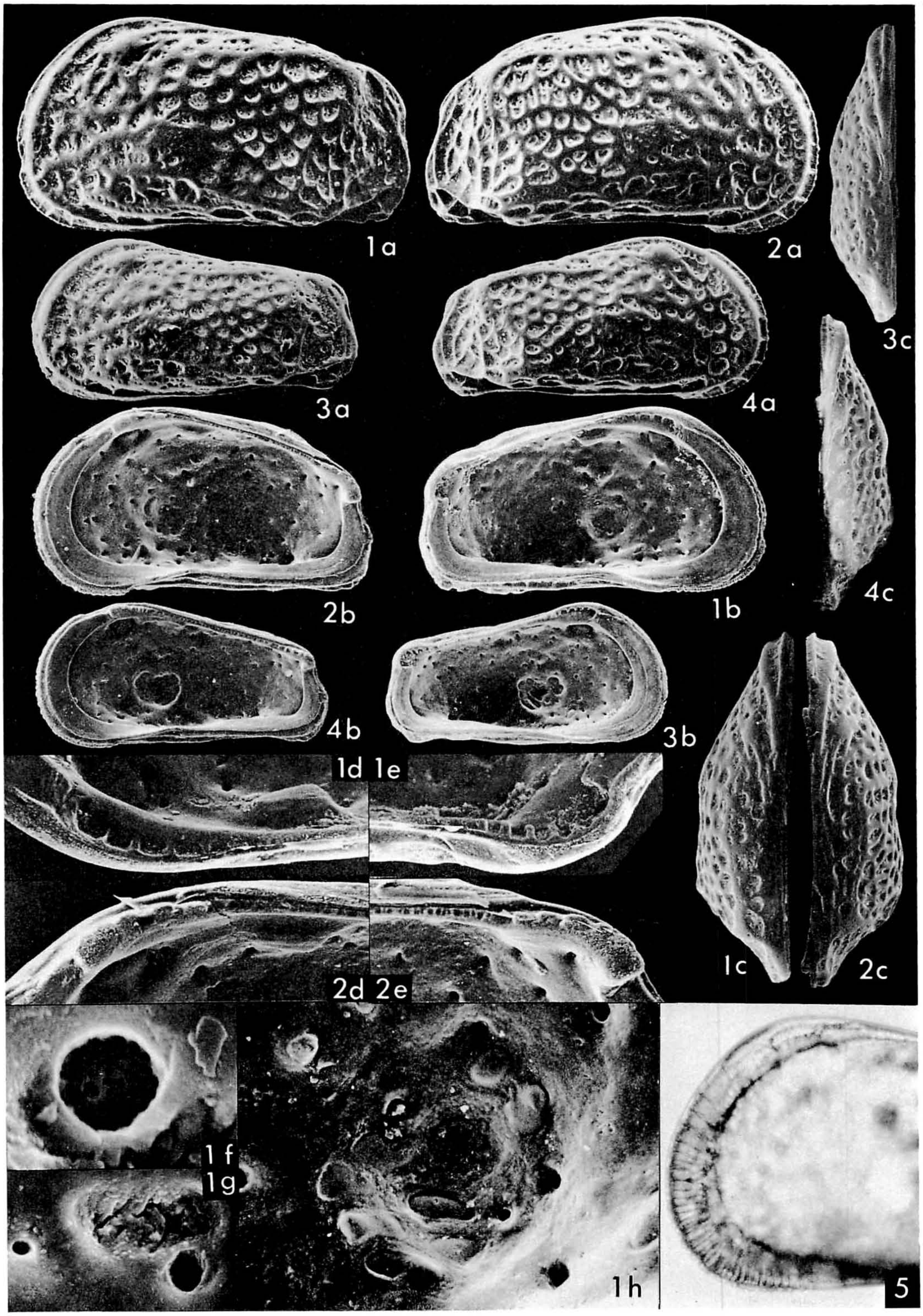
Explanation of Plate 23

Figs. 1-5. *Finmarchinella* (*Barentsovia*) *nealei* OKADA, n. sp., from sample S-24.

a. External lateral view. ×88.
b. Internal lateral view. ×76.
c. External dorsal view. ×76.
d. Anterior part of hinge. ×220.
e. Posterior part of hinge. ×220.
f. External view of large normal pore canal with sieve plate and setal opening. ×2600.
g. External view of large and small pore canals. ×1200.
h. Adductor muscle scars with two scars anteriorly. ×350.
1. Female left valve (Holotype, CA 9627).
2. Female right valve (Paratype, CA 9628).
3. Male left valve (Paratype, CA 9629).
4. Male right valve (Paratype, CA 9630).
5. Female left valve (Paratype, CA 9631). Anterior marginal area showing radial pores. ×118.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Postscript: Recently, Yamanoi (1978) reported to have confirmed the unconformity with vast time gap between the Wakimoto and Shibikawa Formations by examining pollen. However, because most samples were taken from non-marine sediments in the Shibikawa Formation, and from marine sediments in the lower formations, the pollen evidence cannot be regarded as conclusive.

秋田県男鹿半島上部新生界の層序と介形虫：

〔層序〕男鹿半島上部新生界の層序を要約して記載した。この中で，不整合に基づいて，安田層と潟西層を再定義した。また，安田層の広範な分布がピンクタフ鍵層（北里，1975）の追跡により明らかにされた。鮪川層，安田層，潟西層を通じて，岩相および化石の産状はサイクリックに繰返して変化している。各サイクルを unit-A, B, C, D に区分し，記載した。〔介形虫〕介形虫の産出密度はサイクルに対応して変化し，その産出は unit-C にほとんど限られているが，その中でも密度の低い unit-C 最上部及び最下部に保存の悪い殻が見られる。これらの殻と微細構造の類似した殻が，保存の良い殻を EDTA で脱灰することにより得られた。フォーナとしては，男鹿半島沖の現生種ソリネットサンプルとの比較により，50 m 以浅の浅海性フォーナと推定した。また，下部のサイクルには北極海周辺にも分布する寒流系の種が多く含まれるが，これらの占める割合は上部へ向けて減少する。一方，日本近海の暖流域で生息が知られている種の占める割合が上部のサイクルで増加している。これらの変化は海水温の上昇によると思われ，海進海退をサイクリックに繰返しながらも浅海域の海水がしだいに暖かくなったことを示していると思われる。現生群集，遺骸混合群集および化石混合群集の構造の比較解析により，群集の混合度を論じ，これにより下部のサイクルから上部のサイクルへ向けて環境がしだいに安定化したと推論した。最後に，代表的な属である *Finmarchinella* の2新種 *F. hanaii* と *F. nealei* を記載した。

岡田　豊

日本学術会議第12期会員選挙について

このことにつき日本学術会議中央選挙管理会より本会会員各位に周知していただくように依頼がありましたのでお知らせします。（以下，日本学術会議月報20巻7号より転載）

新たに有権者の登録を希望する方々に　昭和55年11月25日に日本学術会議第12期会員選挙が行われます。会員を選挙し，会員に選挙されるためには，日本学術会議の有権者名簿に登録された者（以下「有権者」という）でなければなりません。新たに有権者としての登録を希望する方（第11期の有権者で，日本学術会議中央選挙管理会（以下「管理会」という）から新しく登録用カードの提出を求められた方を含みます）は，管理会に成規の登録用カード用紙に所要の事項を記入提出し，管理会の資格審査を受けなければなりません。

登録用カード用紙は「登録用カード用紙請求書」（様式は下記参照）により管理会に請求すれば無料で送付します。

登録用カードの受付は，いつでも行っていますから，早めに提出してください（なお，第12期会員選挙の有権者になるためには，登録用カードは昭和55年3月31日までに管理会に到着していなければなりません）。

有権者の方々に　第11期の有権者の方々は，管理会で保管してある登録カードにより，資格審査が行われ，このうち，引き続き有権者と認定された方々は，有権者名簿に登録されますから改めて登録用カードを提出する必要はありません。有権者名簿の縦覧は昭和55年7月1日から10日の間に行われます。

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住　所（郵便番号）

注）用紙は，B5判ですが，「はがき」を用いても差し支えありません。

有権者異動届

昭和　年　月　日

日本学術会議中央選挙管理会　御中

第　部　学　地方区

（ふりがな）
氏　名　　　　　　　㊞

下記のとおり異動がありましたからお届けします。

事　項	（新）	（旧）※
（ふりがな）※※ 1 氏名		
2 本籍		
3 住所 （郵便番号）		
4 勤務機関 及び職名		
5 勤務地 （郵便番号）		
6 博士の学位	①学位の種類　②授与大学 ③授与年 昭和　年	
7 名誉教授	大学 高専	8 所属学会

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2 ※※印は改姓，改名のときのみ記入すること
3 ※印，※※印以外の欄は現状を記入する
ただし，旧と同一の場合は「同右」と記入すること

〈届け先〉
〒106 東京都港区六本木7—22—34
日本学術会議中央選挙管理会

なお，有権者の資格や選挙方法などにつき不明の節は日本学術会議中央選挙管理会または本会庶務係にお問合せ下さい。

行事予定

	開催地	開催日	講演申込締切
第124回　例会	名古屋大学	1979年10月20日	1979年8月20日
1980年総会・年会	筑波大学	1980年1月25・26日	1979年11月25日
第125回　例会	高知大学	1980年6月	1980年4月

講演申込先：〒113　東京都文京区弥生2-4-16　日本学会事務センター　日本古生物学会行事係

第124回例会の終了後，古生物研究所計画懇談会（世話人：高柳洋吉・速水　格）が予定されている。

お知らせ

今春から常務委員などの役割分担が一部変更になりました。会務の円滑を期するため，1979―80年度の本会関係の連絡先を用務別に記しておきますのでよろしく御協力下さい。

○会費の払込　お送りしている銀行振込用紙で日本学会事務センター

○会費に関する問合せ　会計係：浅間一男（科学博物館分館地学部）

○本会の常務委員会への連絡一般　庶務係：鎮西清高・山口寿之（東京大学・理学部・地質学教室）

○住所変更・入退会申込・報告紀事バックナンバー購入申込　日本学会事務センター内日本古生物学会

○講演申込　日本学会事務センター，または行事係：浜田隆士（東京大学・教養学部・宇宙地球科学教室）

○報告紀事への投稿　なるべく書留便で日本学会事務センター内日本古生物学会，または編集係：速水格（東京大学・総合研究資料館）（原稿コピーと投稿カードを同封または別送して下さい）

○報告紀事編集に関する問合せ　編集委員会：速水格（同上），斎藤常正（山形大学・理学部・地学教室），小沢智生（東京大学・理学部・地質学教室）

○特別号に関する問合せ・購入申込　特別号編集委員会：首藤次男・柳田寿一（九州大学・理学部・地質学教室）（郵送によらない直接販売は東大・総合研究資料館，科学博物館でも取扱います）

○"化石"に関する問合せ・投稿・購入申込　化石編集部：高柳洋吉・石崎国熙（東北大学・理学部・地質学古生物学教室）

○各種の賞に関する問合せ，推薦依頼　賞の委員会：猪郷久義（筑波大学・地球科学系）（79年度のみ）

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