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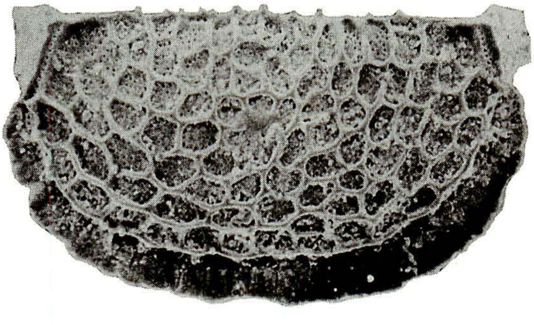

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The ostracod carapace on the cover is an adult specimen of *Manawa konishii* NOHARA (Suborder Palaeocopina, Family Punciidae) from the East China Sea. (photo by K. ABE, x190)

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A STORY OF THE BELEMNITE — AN APPROACH BASED ON THE METHOD OF INVENTING AUXILIARY ASSUMPTIONS IN PALEONTOLOGY

(Presidential address, Palaeontological Society of Japan, 1983)

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In the last presidential address (Hanai, 1982), I made an attempt to offer an explanation for the biological meaning of the furrow observed in the venter of the belemnite rostrum. This time I would like to present full particulars of my study on belemnites with numerous small pits, which occur in Cretaceous deposits of the Miyako district, Iwate Prefecture, with special reference to the bearing that these pits have on the belemnites.

Frankly speaking, when I described *Neohibolites miyakoensis* in 1953, I did not pay much attention to these imperfect belemnites spoiled with small pits. In fact, it was not before reading a paper by Seilacher (1968, p. 279—285) on swimming habits of the belemnites recorded by boring barnacles of the order Acrothoracica, that I first took an interest in *Neohibolites* with small pits. He distinguished two kinds of disposition of borings that differed in distribution and orientation. Borings of one kind are usually patchy in distribution and in general do not show any preferred orientation. The other kind of borings are even in distribution covering the entire rostral surface and show preferred orientation nearly parallel to the rostral axis but inclined on either side of the rostrum towards the posteroventral direction.

In order to explain the regularity in the disposition of the borings of the latter type, Seilacher invoked knowledge of the fact that modern barnacles tend to align their cirral nets towards the water current to feed. He pursued his argument quite logically, following the procedure of his "experimental paleontology", an approach that is actually "the method of hypothesis" i.e. "by inventing hypothesis as tentative answers to a problem under study and then subjecting these to empirical test" (Hempel, 1966, p. 17). If the hypothesis that the borings were produced after the death of the belemnites when they came to rest on the sediments, and the auxiliary assumption that the barnacles tend to orient towards the water current are true, then these borings must be patchy and inconstant in their orientation owing to the restriction of the exposed section of the rostral surface and to the random direction of the current at the place where the belemnites came to rest. Contrary to expectation, observation shows that the borings are evenly distributed and have preferred orientation. Therefore, either the hypothesis or the auxiliary assumption must be false. However, the observation of modern barnacles shows the auxiliary assumption to be true, thus the hypothesis must be false. This reasoning takes the form of modus tollens, and if all the premisses are true, the conclusion must be deductively valid. Thus he concluded that these borings are not post-mortal, and therefore pre-mortal, and that the barnacles aligned themselves with their cirral net facing towards the current, while the belemnites were keeping their horizontal posture and swimming. Further, the preferred

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* This is the English translation of the presidential address delivered at the Annual Meeting of the Society, held at University of Tokyo, Tokyo, on 22 January, 1983.

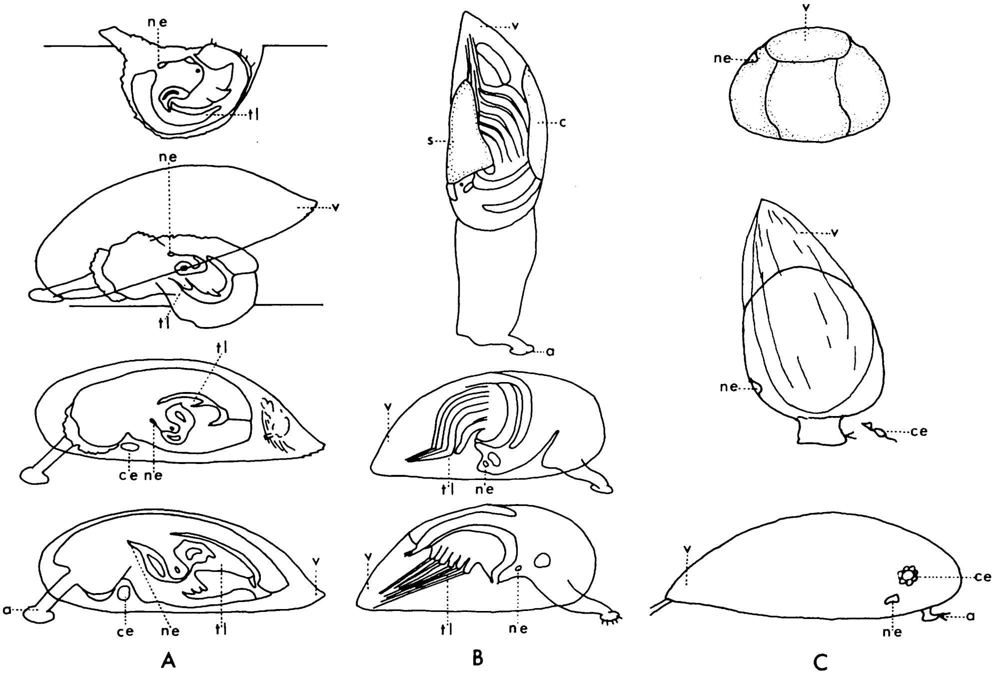
orientation may have been modified slightly by the effects of gravity. However, what is actually rejected is the hypothesis that the borings were produced when the belemnites came to rest on the sediment, and so it is still quite possible that the borings are post-mortal.

Provided that the borings are pre-mortal, what phenomena should be observed on the rostrum? The question is, what is the thickness of the mantle which secretes the rostral layers? Seilacher argued as follows. If the hypothesis that the rostrum was covered by mantle when it was bored by Acrothoracican larvae, and the auxiliary assumption that the mantle will interfere with the commensal living of Acrothoracica on the belemnites are both true, then pathologic irregularities, e.g. irregular growth of rostral layers, that results in swellings or hardenings will occur around the openings of the borings to attest to the presence of the mantle. This test implication is not supported by the observed evidence, and further each boring preserves its complete form with a narrow and slit-like opening as can be seen in solid shell surfaces exposed on the present day sea floor. The reasoning is presented again in the form of modus tollens, and is deductively valid. Thus the rostrum was not always covered by mantle, and therefore was exposed in the observed cases, or if it was covered, the thickness of the mantle was insignificant being "a fraction of millimeter" (Seilacher, 1968, p. 282). Further, because the rostrum will not grow without a covering of mantle epitherium, uncovering of rostrum had to have happened in the last stages of rostral growth.

Reasoning from the pre-mortal interpretation of the borings and assuming an exposed rostrum in the adult stage, Seilacher extended his ideas further into an inquiry into the swimming direction of the belemnites. He asserted, based on the orientation of the borings, that head-on movement of the belemnites occurred in the opposite direction to the direction of streamlining of the rostrum.

His reasoning seems to have gone through the following steps: If the belemnites swam towards the posterior direction as is suggested by their streamlined shape when they were infested by Acrothoracica, and if the orientation of Acrothoracica is adjusted with their cirral nets facing towards the direction of the current, then the Acrothoracica must have strongly preferred orientation nearly parallel to the rostral axis with the anterior end of the aperture pointing towards the apex of the rostrum, so that the Acrothoracica face with their cirral nets towards the current streaming from the apex of the rostrum. The observed evidence proved that the borings were aligned in the opposite direction to that predicted above. Therefore, the hypothesis of backward swimming was falsified and as far as the observed samples were concerned the belemnites swam in the anterior direction. This reasoning is again referable to modus tollens and is deductively valid, if all the premisses are true.

Refutation of the auxiliary assumption about the orientation of Acrothoracica was presented by Cirripedia specialist Petriconi (1971, p. 137—146). He traced the same logic as Seilacher employed for reasoning that the borings were pre-mortal and the rostrum was uncovered in the adult stage of the belemnite. But as to the swimming direction of belemnites, he presented a diametrically opposed conclusion. He noticed that Seilacher's auxiliary assumption on the orientation of Acrothoracica is not consistent with present knowledge on modern Acrothoracica and other barnacles. When the cypris larva of barnacles attaches to the hard surface of the substrate by its first antennae, orientation of the final attachment of cypris larva will determine the orientation of the borings. Attachment of cypris larva is accompanied by weak negative rheotaxy. Then, during their metamorphosis after fixation, cypris larva of barnacles stands on the first antennae, i.e. on the attached point, so that the cirral net will face towards the water current. In the metamorphosis of Acrothoracica, however, the cypris larva turns its body round 180 degrees twisting its first antennae in order to bore the hard substrate scrapping with its dorsal surface. Therefore, the borings will align so as to have the back of the cirral net



Text-fig. 1. The relation between the orientation of attachment of cypris larvae and the orientation of adult barnacles. A. *Trypetesa* sp. B. *Lepas* sp. C. *Balanus* sp. based on Turquier (1971); Colman (1909); Crisp and Stubbings (1957), respectively. a, antennular sucker; c, carina; ce, compound eye; ne, naupliar eye; s, scutum; tl, thoracic legs; v, valve of cypris larva or valve rudiments.

to the water current (Text-figure 1).

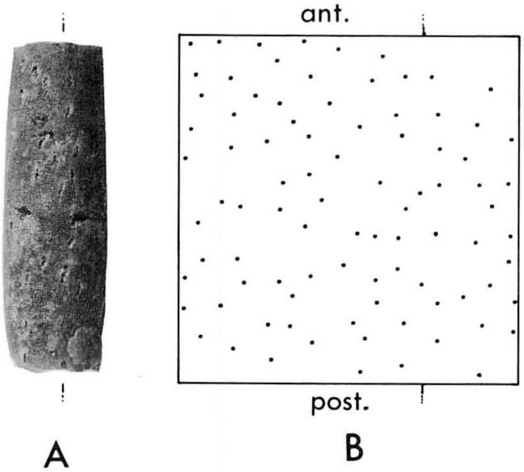
There was no room left for doubt that the cypris larva attached to the rostrum of the belemnites so as to point with its posterior end towards the apex of the rostrum. Such being the case, the inferred direction of water current indicates backward movement of the belemnites. Thus Petriconi (1971, p. 143—146) concluded that the belemnites generally swam by means of a rocket principle as is suggested by their streamlined shape. At the same time, however, his reasons led to the inference that Acrothoracica had the back of their cirral nets toward the direction from which the water current presumably was coming. Though the direction of their cirral nets faces in the reverse direction, this seeming contradiction no more impedes his reasoning, for his observations on the behavior of modern Acrothoracica revealed that they are able to twist their cirral nets 180 degrees to face towards any direction of current from wherever it comes. Further, another group of boring barnacle species without distint cirral nets pump water into the mantle cavity with the aid of expansion and contraction of the muscular mantle sack. So if this type of barnacles were attached to the belemnite, the direction of their cirral nets is no longer relevant to that of the food supply. For details of behavior of boring barnacles refer to the observations of Tomlinson (1955, p. 112). In conclusion, the belemnites were set forward by Seilacher and backward by Petriconi, and seem finally to have been driven into a tight corner.

Things seem to go quite well in this world. Hölder (1973, p. 60—62) found scars on the rostrum of a Jurassic belemnite *Passaloteuthis* from Germany which are interpreted as the traces of pointed teeth left on the rostrum by a fish of prey when the belemnite moved to make a quick escape from the mouth of the predator. Scars suggested the ability of belemnites to move forward and backward and, in case they need, to change direction promptly. Jordan, Scheuermann and Spaeth (1975, p. 334–338) found bilaterally symmetrical color patterns on the dorsal and lateral surface of the adult rostrum of Jurassic belemnites, belonging to the genus *Megateuthis* from Germany. Borings of fungi or algae were also found on the dorsal patterned area of the rostrum. Thus they inferred that, in this genus, the rostrum was covered by a thin and translucent epitherium or even uncovered in the adult stage.

A few years prior to the publication of these papers, I noticed while beachcombing that driftwood and other flotsam including the cuttlebone of *Sepia* when washed ashore are quite commonly infested by barnacles. This experience made me hit upon a hypothesis that the belemnites, whose soft bodies were completely removed by rapid decay shortly after death, might be suspended perpendicularly in the water by buoyancy of air in the phragmocone, like a slender quill with the rostrum as a sinker. And the belemnites might be infested with the Acrothoracica during this period of flotation or suspension. I became satisfied with this inference, because all the observed facts on the borings of the belemnites seemed to be explainable with this hypothesis. Thus I read a paper on this hypothesis at the regular meeting of the Society in 1973 (Hanai, 1974, p. 235; 1975, p. 1). At this point of time, Seilacher's logical sequence of arguments starting from pre-mortal borings on the rostrum, passing through uncovered rostrum, and ending with the swimming direction of the belemnites were broken up in my notion into three independent statements. In other words, if my hypothesis holds, no matter whether the belemnites exposed their rostrum in the adult stage or not, and swam forward or backward, infestation of Acrothoracica will result in borings with uniform distribution and preferred orientation on the rostrum of the belemnites.

Once a hypothesis is devised and proposed, a test implication inferred from the hypothesis must be checked by observation and experiment. The setting behavior of cypris larvae when they attach to the solid substrate provides a basis for such a test. Fortunately, research on the fouling of ships by barnacles provides us with the results of many excellent studies. Nauplius larvae of most barnacles are known to be dispersed during their planktonic life. Cypris larvae, however, have the ability to swim and look about for a solid surface suitable for attachment. This searching behavior leads to the gregarious occurrence of cypris larvae (Knight-Jones, 1953, p. 595; Knight-Jones and Crisp, 1953, p. 1110; Crisp and Knight-Jones, 1954, p. 361). After attachment, they walk about on the surface exploring, recognize their own species, and finally settle so as to maintain a certain distance from earlier settlers (Crisp, 1961, p. 435–437). As a result of a combination of this gregarious and territorial behavior, the distribution of barnacles on an even surface is expected to be not random, but at least, to some extent, uniform within the area of barnacle infestation, and this will also be more true on the evenly cylindrical surface of a vertically oriented belemnite rostrum. Borings on the rostrum of *Neohibolites* from Miyako show uniform distribution giving a value of 0.34 for the variance to mean ratio ($S^2/\bar{X}$), much less than 1, which was calculated by dividing the distribution area of 89 borings into a lattice of 5 x 5 quadrats (Text-figure 2).

Cypris larvae show negative rheotaxy, orientating with their posterior end upstream (Crisp, 1955, p. 589). But the orientation in the current is so weak that it occurs only in the absence of other stimuli, or in most cases its influence is not appreciable at all. Experiments on modern barnacles revealed that the attachment of cypris larvae occurs under the stimulation of gentle water movement. If the current flows rapidly, then the cypris larvae will fail to attach, or even detach from the substratum, but once fixed, rapid flow can not detach them (Walton Smith, 1946, p. 69). It is, however, not unlikely that the belemnites could swim very fast so as to escape from unpleasant surroundings before cypris larvae become fixed. After fixation and metamorphosis of the cypris larvae, rotation of the shell during growth occurs at the stage of young barnacles, in order to orient the cirral net towards the current (Crisp, 1953, p. 342; 1955, p.



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5	6	3	2	1
4	4	3	4	3
3	3	4	5	5
6	3	3	3	4
2	4	3	3	3

Text-fig. 2. Uniform distribution of boring barnacles on *Neohibolites miyakoensis*. A. a specimen from the upper horizon of the Tanohata Formation, 8 m below its top, from the northern cliff of Haipe, Tanohata-mura, Shimohei-gun, Iwate Prefecture, on which the testing of uniformity of distribution is based (× 1.6). B. distribution of points of attachment of cypris larvae. Scattered dots represent the points of attachment of the first antennae of cypris larvae, i.e. the anterior end of the slit-like opening. C. number of dots in each quadrat of the 5 × 5 grid.

589; Crisp and Stubbings, 1957, p. 189—193). This is the reason why certain kinds of barnacles orient toward the current (Crisp and Stubbings, 1953, p. 185). But in the case of the Acrothoracica, rotation can not occur after fixation, and therefore, the orientation of the borings is determined by the orientation of the cypris larvae at the time of fixation (Codez and Saint-Seine, 1957, p. 713; Petriconi, 1971, p. 133, 145). In spite of only weak negative rheotaxy, borings on the rostrum show, strangely enough, strongly preferred orientation.

The cypris larvae just before fixation orient towards the light and against gravity, and the dominant importance of light and gravity over currents in taxis has been well established through many observations on modern cypris larvae (Hiro, 1939, p. 594; Crisp and Barnes, 1954, p. 145—149; Uchinomi, 1955, p. 128; Crisp, 1955, p. 586; Crisp and Stubbings, 1957, p. 186—188). Therefore, if the hypothesis of post-mortal flotation of the belemnites is true, and the infestation occurred during the floating period with the belemnites keeping their vertical position, then it is quite likely that strong positive phototaxy and negative geotaxy combined together might produce strongly preferred orientation of cypris larvae in a vertical direction with their anterior ends upwards. To be exact, however, the rostrum will float with its axis of elongation not vertical, but slightly inclined in the plane of bilateral symmetry of the rostrum. This inclination of the rostral axis from a vertical line connecting the center of gravity with that of buoyancy, might produce slight and bilaterally symmetrical deviation of the orientation of borings from the axis of the rostrum. The inclination would certainly be distinct in the case of *Duvalia* whose rostrum swells in its ventral half. These test implications seem to be supported by observation (cf. Seilacher, 1968, p. 281; Seilacher and Wiesenauer, 1978, p. 148). The pro-ostracum which would have an appreciable influence on the floating posture of the belemnite seems to be extremely susceptible to destruction by wave action, as is suggested by its exceedingly rare occurrence relative to that of the phragmocone (Hewitt and Pinkney, 1982, p. 144) and thus it is unlikely to be a factor influencing floating posture of the belemnite.

Another question weighing on my mind is how to explain the fact that borings with preferred orientation have been found so far only on adult rostra. In this regard, it may be significant that "fresh" cuttlebones still covered with an extremely thin layer of sticky decaying organic matter that are commonly found drifting along the coast of the Inland Sea of Japan during the spawning season are mostly adult forms. *Neohibolites* have been found commonly in various facies of marine sediments of the Miyako Cretaceous. However, those infested by boring barnacles occur, with the exception of one sporadic occurrence in an open sea sandstone, exclusively in back reef silty sandstones. This suggests that the belemnites were infested in a relatively calm, shallow and more or less closed embayment near their spawning ground, where cypris larvae might have occurred gregariously. All of the infested belemnites seem to be adult forms having a very narrow range of maximum diameter from 8.82 to 8.95 mm.

The reasoning employed by Seilacher (1968, p. 282) to support the hypothesis of exposed rostrum in the adult stage of the living belemnites can also be applied to the post-mortal floating hypothesis because the soft parts of the belemnites would be removed by rapid decay shortly after death. The evidence to be expected and found includes absence of pathologic traces around the borings, and preservation of the complete form of the boring with its slit-like opening.

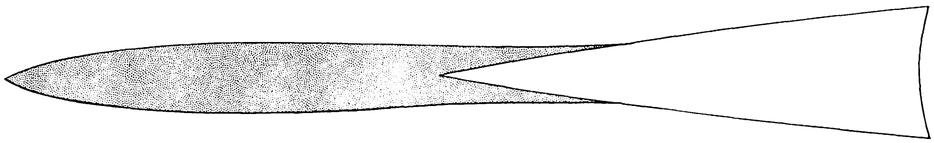
As has been discussed in the foregoing paragraphs, there are two conflicting hypotheses concerning the condition of belemnites at the time of Acrothoracica infestation: One is the pre-mortal swimming hypothesis in which the rostrum must be covered at least proximally by mantle epitherium, and the other is the post-mortal floating hypothesis in which the rostrum must be uncovered because the soft body was removed by rapid decay. If the pre-mortal swimming hypothesis is true, then Acrothoracica should avoid attaching to any area of the rostral surface covered with mantle epitherium of appreciable thickness. Such an area is quite likely to be found in the anterior proximal section of the rostrum and in a surface along the lateral furrows, because the furrows may be interpreted as scars of the posterior extension of the lateral development of the mantle epitherium to improve locomotion. Further, certain evidence seems to support the presence of a soft part covering the entire rostrum at least in certain groups of belemnites. In these cases, no room is left on the rostrum for Acrothoracica to attach. Classical literature has already shown many longitudinally polished sections of deformed rostra in which newly formed rostral layers enveloped and set broken young rostra (Naef, 1922, p. 223; Kabanov, 1967, p. 62). The new finding of loosely linked fragments of proximal sections of the rostrum also suggests the existence of soft parts to connect the fractures bitten off presumably by Ichthyosaurus (Hölder, 1955, p. 62; Seilacher and Wiesenauer, 1978, p. 145; Riegraf and Reitner, 1979, p. 301). On the other hand, if the post-mortal floating hypothesis is true and the rostrum is completely uncovered and suspended in the sea water, then Acrothoracican borings should be distributed over the entire rostral surface with no distinction between proximal and distal, and between ventral, dorsal and lateral sides of the rostrum. Observation has affirmed that this is in fact the case, i.e., borings are distributed over the entire rostral surface.

So far the hypothesis has been tested through Acrothoracican behavior, and we have tacitly taken it for granted throughout the preceding argument that the weight of the rostrum counterbalances the buoyancy of air in the phragmocone, otherwise after death the heavy rostrum of the belemnites would have little chance of floating. A question we must ask then is, "can the belemnite float?" There are two competing hypotheses on the original fabric of the belemnite rostrum, which yield different values for its apparent specific gravity, and this may exert an appreciable influence on the results of buoyancy calculations (Spaeth, 1975, p. 325; Hewitt and Pinckney, 1982, p. 146). In this study, however, the heavier specific gravity of the rostrum is chosen, simply because the heavier the specific gravity the greater the possibility that buoyancy will become critical. Thus a specific gravity of 2.58 for the rostrum is estimated from the specific gravity of the solid rostrum of modern squids, which is one of the heaviest structures found in modern coleoid cephalopods. The volume of the rostrum computed roughly from the curved line shown in Text-figure 3 is 3.7 cm^3, so that the estimated weight of the rostrum is approximately 9.55 g. Thus, more than 5.66 cm^3 of air is needed to counterpoise the weight of the rostrum in sea water. Adopting the shape of the phragmocone restored through extrapolation of the growth rate of the first 18 chambers (cf. Hanai, 1953, pl. 6, fig. 4), it is found that this estimated volume of air corresponds to the volume of a phragmocone 6.3 cm in length and 1.7 cm in largest diameter. Of course, a slightly larger phragmocone with additional air is necessary to accommodate the weight of the wall of the phragmocone itself and the septa and siphuncle as well. Yet the restored size of the phragmocone of *Neohibolites miyakoensis* falls within the range of conceivable size inferred from complete skeletons of belemnites of some other genera reported from classical European localities (Engeser and Reitner, 1981, p. 543; Hewitt and Pinckney, 1982, pl. 1, fig. 1). Post-mortal flotation may, however, only be possible for certain specific genera of belemnites whose phragmocone was durable enough and large enough to retain air to float the heavy rostrum. *Neohibolites* may be one of these genera.

No matter how many tests a hypothesis passes extensive tests still can not conclusively prove the hypothesis, and, of course, the evidence is far from conclusive in the case of the post-mortal flotation hypothesis. Further, so far we have not tested directly the question as to whether the belemnites were alive or dead during the time of infestation by Acrothoracica, rather we have tested the question as to whether or not the rostrum was floating nearly vertically, and exposed or covered by epitherium, and if it was covered, to what extent was it covered. Yet it seems to me that the available evidence provides partial but stronger support for the hypothesis of infestation by Acrothoracica during the time of post-mortal nearly vertical flotation of the belemnites.

Hempel (1966, p. 47) explained in his introduction to the "Philosophy of Natural Science" that a scientific explanation needs to satisfy two interrelated basic requirements. One is the requirement of explanatory relevance in which the explanation should have "a clear, logical bearing on our experience", and therefore "afford good ground for believing that the phenomenon to be explained did, or does indeed occur". The other is the requirement of testability in which the explanation "must be capable of empirical test". Seilacher's explanation fulfilled these requirements perfectly following the procedure of "method of hypothesis". For this reason, Petriconi (1971, p. 143) and the rest of us could pursue the argument further.

We have to admit that paleontology still retains its "old fashioned" constitution (Seilacher, 1968, p. 285). Makiyama (1935, p. 253) deplored the limitations of the studies on the phylogenetic tree of a certain species group of the gastropod genus *Umbonium* using a simile that boasting about one's phylogenetic tree is similar to boasting about the shape of a tree in one's own garden, others are at a loss about what to do, except for just praising it. What he really



Text-fig. 3. Simplified outline of restored *Neohibolites miyakoensis* (x 1). Restoration is based on the specimens figured in Hanai (1953, pl. 6, figs. 4, 5 and 1981, pl. 66, fig. 1).

deplored might be the non-testable aspects of these trees. In connection with this, I have mentioned that "the phylogenetic tree is convenient for summarizing the inferred evolutionary histories of groups of organisms in higher taxonomic categories. However, it may be more injurious than beneficial for illustrating the relationships of descendants at the intra-specific and inter-specific levels, in that it conceals the dynamics of speciation in the dendritic expressions" (Hanai, 1977, p. 85).

Mayr (1963, p. 65) related in his textbook of systematic zoology that "Previously, when asked to explain their theory of classification, taxonomists had been singularly inarticulate". This again leads to the non-testable aspects of classification and may be one of the main reasons why systematic zoology is undergoing excessive decline despite its successes in scientific discoveries and in producing evidence throughout the history of biology, as discussed by Simpson (1962, p. 42). I have once described that a specimen is different from closely similar species in having such and such morphology and therefore the animal should belong to a new species. But now I reflect upon the slightest logical connection between the inference that is to be a new species and such and such a morphological fact, where the explanation was far from meeting the requirements of explanatory relevance and testability.

The aforementioned story of the belemnite as well as the stories on the phylogenetic tree and on classification are all hypotheses with a singular character (Popper, 1957, p. 107), and may be testable at least in principle. In fact, arguments concerning these hypotheses were once a driving force for the study of particular entities (e.g. taxon). The testability of these hypotheses have been maintained through logically linked long sequences of arguments full of auxiliary assumptions that are tacitly assumed to hold true. However, the enlargement of our stock of knowledge easily results in a break somewhere in the logical sequence of these arguments, usually because the auxiliary assumption on which the hypothesis will yield a test implication is no longer consistent with our newly gained experience, as for example in the case of the forward swimming hypothesis for belemnites when Petriconi came across observations on the unique behavior of the cypris larvae of boring barnacles. Without the aid of auxiliary assumptions, the hypothesis easily become virtually non-testable, and, in fact, when Makiyama deplored the non-testability of the phylogenetic tree of *Umbonium*, and when the good old-timers could not give logical explanation of their classification of a particular taxon, these hypotheses (i.e. the phylogenetic tree and classification) could be seen to be virtually non-testable. In many cases in paleontology, it seems long overdue that explanation should have "a clear, logical bearing on our experience" (Hempel, 1966, p. 47), and hence should be testable through "empirical tests" (Hempel, 1966, p. 49). In some respects, paleontology is an unending effort to find a way out of the impasse of the seemingly non-testable aspects of the study of fossils by inventing a new auxiliary assumption or a new series of auxiliary assumptions.

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(In preparing the English translation of this address for publication, I have found the Japanese manuscript in places lacking in sufficient explanation for English translation. Therefore, I have made some additions to give supplementary explanation in the English translation.)

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765. OSTRACODA FROM THE PLIOCENE ANANAI FORMATION, SHIKOKU, JAPAN

— DESCRIPTION —*

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Abstract. Thirty-five out of the samples which Katto *et al.* (1953) studied for fossil foraminifera provided a variable number of ostracode specimens. Systematic studies of those materials led to the discrimination of 79 ostracode species distributed among 42 genera in the Ananai Formation whose occurrence by samples is listed. In addition, seven new species (*Buntonia parascorta*, *B. scorta*, *B. u-carinata*, *Callistocythere ananaiensis*, *C. kattoi*, *Cytherella japonica*, and *Krithe hanaii*) and four unnamed species are described.

The ostracode faunas of the Ananai Formation include more of a variety of elements than have hitherto been reported from the upper Cenozoic of Japan. They include elements of the upper Cenozoic of Taiwan and of such southern regions as the Indo-Pacific, Austral-Tasman, and Nova-Zealand Realms, all as designated by Benson (1964), and have some features in common with those of the shelf area of the East China Sea, particularly its outer portion.

The occurrence of *Bairdoppilata*, *Doratocythere*, and *Jugosocythereis*? represents the first record from the upper Cenozoic of Japan.

Introduction

The Tonohama Group, which is sporadically distributed along the eastern coast of Tosa Bay which abuts the southern border of Shikoku, yields abundant fossil remains, and so has been subjected to indisputable stratigraphical and paleontological studies by many authors since Yabe (1918) investigated the *Operculina*-bearing beds in Japan. The group consists, in ascending order, of the Nobori, Nahari (=Ropponmatsu), and Ananai Formations with the stratigraphic relationships which have been variously assumed among the authors (Katto *et al.*, 1980). The Nahari Formation is of nonmarine origin. The subjacent Nobori Fomration may be of global importance because it represents the type section of *Globorotalia tosaensis* described by Takayanagi and Saito (1962) and is representative of Zone N. 21. This formation yields, however, only scarce ostracode remains which are not suitable for analytical studies of ostracode assemblages. From studies up to this point, it appears that the assemblages are composed mainly of such genera as *Buntonia*, *Cythero-pteron*, *Hirsutocythere? Krithe*, *Palmenella*, and *Palmoconcha*. On the other hand, the Ananai Formation superjacent to the Nahari Formation yields abundant and divesified fossil ostracodes, and most of the samples dealt with, which Katto *et al.* (1953) previously studied for paleontology of foraminiferal remains, yielded a great number

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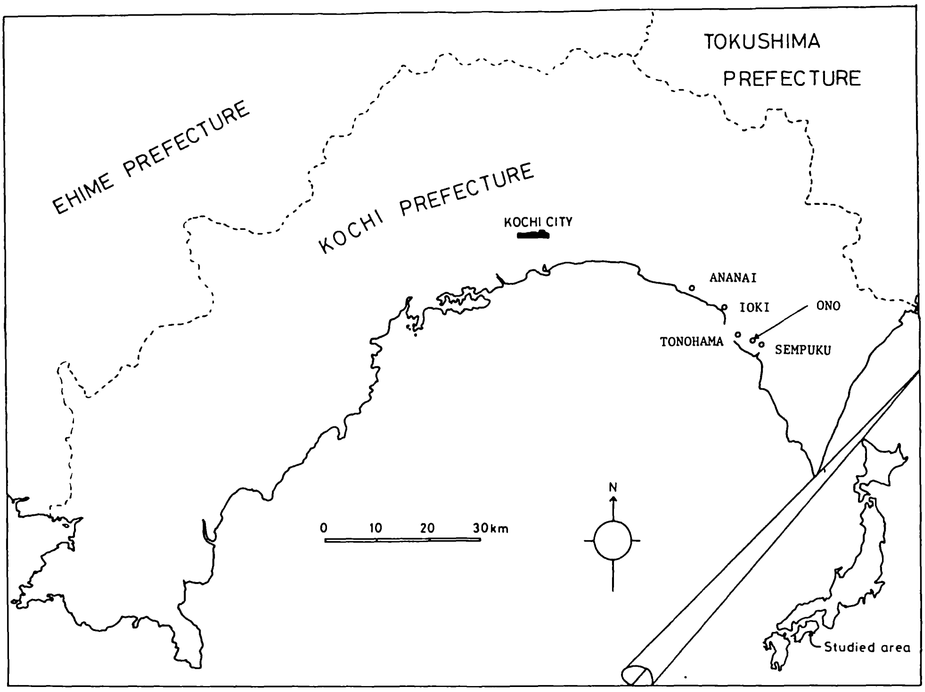
* Received July 13, 1982.



Text-fig. 1. Outcrop locations of the Ananai Formation studied.

of ostracode specimens that are sufficient for faunal analysis.

As part of his long range study, Ishizaki (1979) showed the distribution of fossil ostracode assemblages in the Ananai Formation as determined on the basis of the scores of the first three principal components, and suggested plausible depositional environments of the formation. This paper is intended to complement that previous study (Ishizaki, 1979) by giving full descriptions of new and imperfectly known ostracode species detected in the 35 rock samples which were collected at the five isolated localities of Ananai, Ioki, Tonohama, Ono, and Sempuku and by listing the occurrence of ostracode specimens of various taxa by sample.

In recent years, the ostracodes of the marine upper Cenozoic of Japan and those of modern sediments of the adjacent seas have been more intensively investigated than ever by such authors as Ishizaki (1963, 1966, 1973), Hu and Yang (1975), Ishizaki and Kato (1976), Hu (1976, 1977a, b, 1978, 1979), Nohara (1976a, b, 1981b, c), Nohara and Miura (1977), Hu and Cheng (1977), Yajima (1978, 1982), Hu and Yeh (1978), Okada (1979), Malz (1980a-c), Ikeya and Hanai (1982), Frydl (1982), and so forth. These ostracode studies, particularly those by Hu and his collaborators in Taiwan, may make a large contribution toward an understanding of ostracode faunas in such southern areas of Japan as the Ryukyu Islands, Kyushu, and Shikoku which includes the present area under study. In addition, the study of ostracodes in the East China Sea and its adjacent seas, which has recently been accelerated by such authors as Nohara and Tomoyose (1977), Ishizaki (1977, 1981), Wang, Min, and Bian (1978, 1980), Wang, Min, Bian, and Zhang (1979), Kim (1979), Wang, Lu, and Cheng (1980), Wang, Min, and Gao (1980), Nohara (1981a), and others, is another important source of information on ostracodes in those areas of Japan mentioned above.

Samples and Methods

All the samples employed for this study were collected at certain stratigraphic intervals by Katto, one of the cooperative authors of Katto *et al.* (1953) at the five isolated localities of Ananai, Ioki, Tonohama, Ono, and Sempuku (Text-fig. 1, Table 1), and has already been studied by them for fossil foraminifera. According to them, each of the samples having a dry weight of 50 g was disintegrated by using a roller mill for 15 to 30 min., and washed by tap water through a 200 mesh screen.

As far as possible, 200 ostracode specimens were picked at random from the fraction between 12-mesh and 115-mesh screens and examined mainly under a binocular microscope. A systematic study of the ostracode specimens taken from those samples was done through comparative studies with materials described by Brady, deposited at the British Museum (Natural History) and the Hancock Museum, Newcastle-upon-Tyne, and with those described by Hornibrook and Swanson at the New Zealand Geological Survey. Constant reference was also made to the extensive literature, including the recent accounts mentioned in the introduction.

The number of ostracode specimens of various taxa by sample, given in Table 2, represents the larger number of the two valves. The sample numbers of the thirty-five samples which yielded ostracode specimens have letter prefixes which represent particular localities (Table 1). The detailed locations of those localities have been mapped by Katto *et al.* (1953).

In order to perceive which physical agents then prevailed, grain-size analysis was made by Dr. Yoshihiro Tanimura, now of the Department of Paleontology, National Science Museum, Tokyo, of most of the rock samples employed for this study, using an automatic grain-size analyser detailed by Niitsuma (1971). Only the Mdϕ and the mud content are quoted later in the systematics section. The full results of his work will be utilized elsewhere in association with those from the faunal analysis of ostracode assemblages in order to better comprehend depositional environments of the formation.

Overview

The Ananai Formation, the uppermost unit of the Tonohama Group, generally yields abundant remains of fossil ostracodes. Thirty-five out of the samples which Katto *et al.* (1953) studied for fossil foraminifera provided a variable number of ostracode specimens. Systematic studies of those materials resulted in the discrimination of 79 ostracode species distributed among 42 genera, including seven new and four unnamed species. The occurrence of those species by sample is listed in Table 2. That table shows that the ostracode faunas of the Ananai Formation include a variety of elements which have not been found in the upper Cenozoic of Japan, from the Ryukyu Islands up to the areas farther north. As an example, listed below are the species which have been reported by Hu and his collaborators from Taiwan.

Bythoceratina dipleura (=*Monoceratina dipleura* Hu and Cheng, 1977),
Callistocythere ovata Hu, 1976,
Cytheropteron rhombea Hu, 1976,
Doratocythere taiwanensis (=*Basslerites*

Table 1. Sample locations

O: Southern slope, immediately north of Ananai, Aki City, Kochi Prefecture. O1 is 5.5 m above P1
P: The same locality as the above. P3 to P1 in ascending order at an interval of 1.5 m
L: Ioki, Aki City. L1, 5 m above M1, to L4 in ascending order at an interval of 3 m
M: The same locality as the above. M1 is 5 m below L1
K: 150 m north of Tonohama, Yasuda town, Aki County, Kochi Prefecture. K11 to K1 in ascending order at an interval of 1.5 m
H: 80 m west of Ono, Yasuda town, Aki City. H4, 2 m above I1, to H1 in ascending order at an interval of 1 m
I: 110 m west of Ono. I1, 2 m below H4, to I2 in descending order at an interval of 1.5 m
J: 150 m northwest of Ono. J1 is 8 m below I2
G: 150 m west of Sempuku, Nahari town, Aki County. G8 to G1 in ascending order at an interval of 1 m

Table 2. Distribution of ostracode specimens of various taxa by sample.

Samples Specific names	01	P1	P2	P3	L4	L3	L2	L1	M1	K1	K2	K3	K4	K5	K6	K7	K8	K9
1 *Actinocythereis kisarazuensis* Yajima, 1978	-	-	-	2	-	-	-	-	-	1	3	3	2	-	3	3	-	3
2 *Alocopocythere goujoni* (Brady, 1868)	-	1	-	2	-	-	-	-	1	1	1	1	2	2	1	1	2	1
3 *Ambocythere japonica* Ishizaki, 1968	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
4 *Argilloecia hanaii* Ishizaki, 1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
5 *Aurila cymba* (Brady, 1869)	-	-	-	-	-	-	-	-	-	7	3	2	14	11	6	3	-	1
6 *Aurila hataii* Ishizaki, 1968	3	4	9	5	-	2	3	6	4	2	5	5	2	4	3	5	6	3
7 *Aurila munechikai* Ishizaki, 1968	1	12	15	17	17	5	18	18	10	7	9	6	8	8	2	7	7	7
8 *Aurila tosaensis* Ishizaki, 1968	-	1	-	6	-	-	-	-	-	4	1	2	5	5	2	-	-	2
9 *Aurila uranouchiensis* Ishizaki, 1968	2	4	8	4	4	3	8	8	7	8	10	8	5	5	5	5	11	2
10 *Bairdoppilata* sp.	-	-	-	-	2	1	-	10	4	-	-	-	-	-	-	-	-	-
11 *Bicornucythere bisanensis* (Okubo, 1975)	5	16	14	11	2	2	1	1	-	4	-	3	1	-	1	-	5	1
12 *Bradleya albatrossia* Benson, 1972	-	-	-	-	-	-	-	-	-	4	-	-	-	-	3	3	-	-
13 *Bradleya nuda* Benson, 1972	-	-	-	-	-	-	-	-	-	13	6	2	4	11	6	11	11	8
14 *Buntonia hanaii* Yajima, 1978	-	-	-	-	-	-	-	-	-	6	1	3	-	-	3	3	5	4
15 *Buntonia parascorta* n. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 *Buntonia scorta* n. sp.	-	-	-	-	-	-	-	1	-	1	2	1	2	-	4	4	3	1
17 *Buntonia u-carinata* n. sp.	1	2	4	2	4	6	5	2	4	2	-	-	1	-	2	1	1	2
18 *Bythoceratina dipleura* (Hu and Cheng, 1977)	2	1	3	2	-	1	2	5	1	-	-	-	1	1	-	-	-	-
19 *Bythoceratina hanaii* Ishizaki, 1968	1	2	2	1	1	1	4	-	-	-	-	-	-	-	-	-	-	-
20 *Bythoceratina* cf. *orientalis* (Brady, 1869)	-	1	2	-	-	-	1	-	-	1	1	-	-	-	1	1	-	-
21 *Callistocythere alata* Hanai, 1957	-	2	1	1	-	-	2	2	2	2	2	2	4	1	-	-	-	1
22 *Callistocythere ananaiensis* n. sp.	1	1	3	2	8	6	10	6	4	1	12	4	6	6	6	10	4	2
23 *Callistocythere japonica* Hanai, 1957	-	-	-	-	-	1	-	-	-	-	1	-	1	-	1	-	-	-
24 *Callistocythere kattoi* n. sp.	-	2	-	-	8	14	9	4	12	4	4	2	3	5	2	1	1	1
25 *Callistocythere ovata* Hu, 1976	3	1	2	-	1	-	-	2	1	4	1	1	-	1	-	1	1	1
26 *Callistocythere undata* Hanai, 1957	-	3	4	5	1	2	2	2	2	-	2	2	1	2	3	2	1	3
27 *Callistocythere* sp.	1	-	1	-	-	1	-	3	2	1	-	-	-	-	1	-	1	-
28 *Coquimba ishizakii* Yajima, 1978	-	-	3	1	-	-	-	4	3	-	2	2	-	1	2	-	1	2
29 *Cornucoquimba tosaensis* (Ishizaki, 1968)	1	1	2	4	2	3	16	9	6	5	2	3	4	-	7	7	3	6
30 *Cythere lutea omotenipponica* Hanai, 1959	-	2	-	1	2	2	1	2	2	1	2	1	1	-	2	1	3	1
31 *Cytherella japonica* n. sp.	-	-	-	-	-	-	-	-	-	5	-	-	-	-	2	-	-	2
32 *Cytherelloidea hanaii* Nohara, 1976	2	8	2	6	2	4	9	1	3	2	-	1	-	-	2	3	-	2
33 *Cytherelloidea sabahensis* Keij, 1964	1	-	-	-	-	-	-	-	1	3	-	-	-	7	3	2	3	2
34 *Cytherelloidea* cf. *yakenaensis* Nohara, 1976	-	1	1	1	-	-	-	1	-	1	3	3	3	-	1	-	1	-
35 *Cytheropteron miurense* Hanai, 1957	2	5	6	5	4	-	-	-	-	4	10	7	1	2	6	6	3	3
36 *Cytheropteron rhombea* Hu, 1976	-	-	-	-	-	-	-	1	1	2	1	1	6	6	2	4	-	-
37 *Cytheropteron uchioi* Hanai, 1957	-	-	-	2	-	-	1	1	6	13	8	14	2	6	21	7	13	26
38 *Doratocythere taiwanensis* (Hu and Yeh, 1978)	-	-	-	-	1	1	1	2	1	2	3	5	8	1	1	1	1	-
39 *Echinocythereis? bradyformis* Ishizaki, 1968	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40 *Hemicytherura cava* (Hu, 1977)	-	1	-	-	-	-	-	-	1	1	4	1	2	1	1	2	-	2
41 *Hemicytherura cuneata* Hanai, 1957	4	11	8	1	1	2	5	4	1	3	10	3	8	7	3	9	11	7
42 *Hemicytherura kajiyamai* Hanai, 1957	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
43 *Hemicytherura radiata* Hornibrook, 1952	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-	1	1	-
44 *Hirsutocythere? hanaii* Ishizaki, 1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45 *Jugosocythereis* sp.	-	-	2	2	-	-	2	2	2	6	4	9	3	2	4	12	6	4
46 *Kobayashiina hyalinosa* Hanai, 1957	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-
47 *Krithe hanaii* n. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
48 *Krithe producta* Brady, 1880	1	-	-	-	-	-	-	-	-	2	-	-	-	-	3	3	-	-
49 *Lixouria nipponica* Yajima, 1978	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	2	6	3
50 *Loxoconcha hattorii* Ishizaki, 1971	-	1	3	-	2	3	8	4	1	-	-	-	-	-	-	-	1	-
51 *Loxoconcha japonica* Ishizaki, 1968	-	-	2	1	-	-	2	9	1	3	2	1	2	-	-	1	2	2
52 *Loxoconcha kattoi* Ishizaki, 1968	-	8	7	11	10	3	9	18	17	10	10	8	11	13	14	14	14	12
53 *Loxoconcha optima* Ishizaki, 1968	1	1	4	3	1	1	-	1	-	-	4	2	2	2	2	-	-	-
54 *Loxoconcha sinensis* Brady, 1869	3	21	9	11	36	31	12	10	25	19	10	10	8	8	8	8	15	14
55 *Loxocorniculum mutsuense* Ishizaki, 1971	-	-	2	2	-	-	-	-	2	3	-	5	2	1	1	-	-	-
56 *Macrocypris decora* (Brady, 1866)	-	-	-	-	-	-	-	-	-	2	1	2	2	1	1	-	1	-
57 *Munseyella oborozukiyo* Yajima, 1982	2	9	6	7	10	9	6	4	5	1	2	1	2	5	4	3	5	5
58 *Munseyella japonica* (Hanai, 1957)	1	2	1	1	2	1	1	-	1	3	2	1	2	2	1	2	3	1
59 *Mutilus nodulosum* (Hu, 1977)	1	-	-	-	-	-	-	-	-	-	-	-	2	3	1	-	-	-
60 *Neonesidea villosa* (Brady, 1880)	1	1	13	18	1	1	18	21	18	14	9	17	35	14	7	5	13	4
61 *Nipponocythere bicarinata* (Brady, 1880)	-	3	4	1	-	1	4	-	-	1	-	2	-	-	3	2	6	1
62 *Paijenborchella iocosa* Kingma, 1948	-	-	-	-	-	-	-	-	-	2	1	2	2	-	3	2	-	3
63 *Paijenborchella miurensis* Hanai, 1970	2	3	2	2	1	1	2	2	2	3	1	4	-	1	4	4	2	4
64 *Paijenborchella triangularis* Hanai, 1970	-	4	1	3	1	2	-	1	4	1	5	4	-	-	-	-	-	-
65 *Paracytheridea* cf. *bosoensis* Yajima, 1978	-	-	-	4	1	-	1	-	1	-	1	1	-	1	-	-	1	1
66 *Paracytheridea neolongicaudata* Ishizaki, 1966	-	4	2	1	-	-	2	3	1	2	2	-	2	3	1	4	4	4
67 *Parakrithella pseudadonta* (Hanai, 1959)	-	-	3	3	6	2	-	5	3	2	-	1	-	-	-	-	3	-
68 *Pontocythere japonica* (Hanai, 1959)	7	18	12	9	52	79	43	19	11	10	18	22	19	17	12	11	13	12
68 *Pontocythere miurensis* (Hanai, 1959)	-	2	2	3	-	-	1	1	1	1	-	-	-	1	-	1	1	-
70 *Pseudoaurila japonica* (Ishizaki, 1968)	-	1	1	2	-	-	-	-	-	2	1	3	1	3	-	-	2	1
71 *Pterygocythereis scalaris* (Brady, 1880)	-	1	3	-	-	-	-	1	-	2	1	4	-	1	1	5	6	3
72 *Schizocythere kishinouyei* (Kajiyama, 1913)	7	27	10	8	13	5	10	23	13	3	15	8	-	13	13	8	19	15
73 *Semicytherura hanaii* Ishizaki, 1981	-	-	-	2	-	-	1	1	-	1	1	-	-	-	2	-	1	-
74 *Semicytherura henryhowei* Hanai and Ikeya, 1977	1	3	3	4	-	-	1	1	-	1	6	1	4	3	3	4	2	-
75 *Trachyleberis lungkangensis* Hu and Cheng, 1977	-	5	8	12	1	2	10	4	9	7	12	16	22	20	13	18	15	10
76 *Trachyleberis? tosaensis* Ishizaki, 1968	-	1	4	4	-	3	1	1	1	5	12	11	8	8	4	4	1	3
77 *Xestoleberis hanaii* Ishizaki, 1968	1	1	3	3	1	3	4	-	4	4	4	4	6	4	1	-	7	5
78 *Xestoleberis sagamiensis* Kajiyama, 1913	-	-	2	5	1	2	2	5	2	3	5	5	6	4	2	5	5	2
79 *Xestoleberis* sp.	-	-	1	3	1	-	1	1	1	2	1	3	3	-	1	3	-	-
Total number of individuals	58	202	202	207	200	206	239	232	204	230	242	235	244	225	218	230	254	207

	K10	K11	H1	H2	H3	H4	I1	I2	J1	G1	G2	G3	G4	G5	G6	G7	G8
1	1	-	2	1	-	1	1	-	1	-	-	-	2	-	2	-	-
2	4	-	2	3	1	-	1	-	2	-	4	2	-	2	2	-	-
3	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-
4	-	2	1	2	11	5	-	-	1	-	2	6	1	3	4	-	-
5	5	3	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-
6	2	5	5	5	-	3	6	-	9	-	2	9	5	5	9	-	-
7	6	9	6	4	7	4	13	-	7	-	5	8	8	-	7	-	2
8	-	1	-	4	4	1	-	-	2	-	2	-	1	3	2	-	-
9	7	4	1	2	7	4	2	-	4	-	5	4	1	4	8	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	7	5	8	6	1	2	-	1	-	-	5	-	-	-
12	-	6	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
13	2	7	11	3	8	4	1	-	2	-	5	8	3	4	1	-	1
14	1	3	-	-	6	3	-	-	1	-	-	-	-	1	-	-	-
15	-	2	-	5	-	-	-	-	-	-	-	-	-	2	-	-	-
16	1	1	-	4	-	-	2	-	2	-	-	1	-	6	-	-	-
17	1	-	2	3	3	1	3	-	1	-	1	-	2	7	-	-	-
18	-	-	1	-	-	-	-	-	-	1	-	-	2	-	-	-	-
19	-	-	1	-	-	-	-	-	-	-	1	2	-	-	3	1	-
20	-	-	-	-	-	-	-	-	-	-	1	-	2	-	3	-	-
21	5	-	7	3	4	2	2	-	3	-	5	3	7	4	3	-	1
22	5	4	28	15	12	5	13	-	21	-	21	21	17	18	21	2	14
23	-	-	1	1	1	6	-	-	-	-	2	1	1	3	-	-	-
24	6	3	16	1	11	7	11	1	5	-	3	6	8	1	5	1	4
25	-	-	-	-	1	-	2	-	2	-	1	3	4	1	-	-	2
26	3	3	2	-	2	3	-	-	1	-	3	5	-	-	4	-	-
27	1	1	-	-	1	-	1	-	1	1	1	1	2	-	-	-	-
28	-	-	1	-	-	-	2	-	-	-	-	-	1	-	-	-	-
29	2	3	-	-	2	1	-	-	1	-	-	1	2	2	-	-	-
30	-	-	-	2	1	2	1	-	-	-	2	1	5	2	-	1	-
31	-	4	-	1	3	1	-	-	-	-	-	-	-	3	-	-	-
32	2	2	11	1	-	-	1	1	1	-	5	3	6	4	5	-	1
33	-	4	5	-	-	-	1	-	5	-	1	-	6	-	3	-	1
34	3	-	5	3	-	-	-	-	3	-	3	4	3	5	12	-	-
35	3	4	2	1	1	1	2	-	2	-	5	2	5	-	-	-	-
36	7	4	-	4	6	5	3	-	1	-	1	5	6	6	6	1	2
37	2	19	3	8	19	-	6	-	7	-	4	6	2	3	-	-	-
38	1	-	3	-	-	-	2	-	-	-	3	4	1	-	1	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	3	-	-	-	1	-	1	-	-	-	-	1	-	1	1	-	-
41	16	5	13	16	4	2	7	-	13	-	6	13	6	6	10	-	1
42	-	-	-	2	2	-	-	-	2	-	-	-	-	-	1	-	-
43	3	1	-	-	-	-	-	1	-	-	-	2	1	-	-	-	-
44	-	-	-	3	11	1	-	-	-	-	-	-	-	5	-	-	-
45	5	5	-	4	4	3	6	-	2	-	-	3	3	-	3	-	-
46	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
47	-	2	-	7	1	8	-	-	-	-	-	-	-	8	-	-	-
48	-	-	-	5	14	7	-	-	-	-	-	-	-	5	-	-	-
49	-	3	1	1	3	1	-	-	-	-	-	1	1	1	-	-	-
50	-	-	-	-	-	-	-	1	2	-	1	-	-	5	-	-	-
51	-	-	-	1	-	1	-	-	-	-	-	-	-	1	1	-	-
52	14	9	4	4	5	5	14	-	17	-	11	12	8	6	7	-	1
53	1	-	3	3	3	2	2	-	3	-	7	6	3	1	3	1	2
54	5	8	23	8	32	23	20	4	23	-	25	23	8	23	13	1	6
55	-	-	1	-	2	-	1	-	-	-	1	-	1	-	3	-	-
56	1	-	-	-	-	-	-	-	-	2	2	-	1	-	1	-	-
57	6	21	5	11	7	7	12	-	9	-	11	4	8	3	3	-	2
58	2	1	-	1	1	2	-	-	1	-	2	1	-	2	2	-	-
59	-	-	1	-	-	-	1	-	-	-	1	1	-	-	-	-	-
60	11	3	3	12	18	9	-	-	7	8	18	24	8	4	5	-	-
61	-	1	2	6	5	5	1	-	-	-	2	-	-	5	-	-	-
62	3	-	1	1	4	4	-	-	-	-	1	1	-	2	-	-	-
63	4	7	1	-	-	3	1	-	3	-	3	8	2	-	3	1	3
64	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
65	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-
66	-	2	-	-	1	-	2	-	-	-	1	2	1	1	1	-	-
67	-	-	-	-	-	1	5	-	-	-	-	2	-	-	1	-	-
68	18	10	30	32	30	20	39	8	40	-	23	20	20	26	21	3	10
69	1	2	-	-	1	-	1	2	-	-	-	-	-	-	-	-	-
70	2	1	-	-	1	1	1	-	-	-	1	-	-	-	-	-	-
71	-	3	-	2	-	1	1	-	1	-	-	-	-	3	-	-	-
72	16	16	15	8	4	7	14	3	13	-	15	9	21	12	14	1	13
73	1	-	-	-	-	1	-	2	-	-	-	-	1	2	-	-	-
74	4	1	1	1	5	-	1	-	-	-	1	2	-	2	1	-	-
75	10	8	13	11	11	5	8	-	6	-	10	20	8	12	5	-	5
76	3	2	2	11	5	7	3	-	3	-	8	8	2	7	4	-	1
77	-	2	-	-	-	4	-	-	2	-	-	-	1	-	-	-	-
78	2	2	1	4	-	3	1	-	2	-	-	-	-	1	4	-	-
79	2	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-
	203	209	236	237	299	205	225	24	239	12	240	269	207	239	208	13	73

taiwanensis Hu and Yeh, 1978),

Hemicytherura cava (=*Kangarina cava* Hu, 1977),

Mutilus nodulosum (=*Radimella nodulosa* Hu, 1977), and

Trachyleberis lungkangensis Hu and Cheng, 1977.

Of these, four species, *B. dipleura*, *C. ovata*, *C. rhombea*, and *T. lungkangensis* have already been recognized by Ishizaki (1981) in the shelf area of the East China Sea. Herewith, the remaining three species have now also been recognized from the Japonic Realm as described by Benson (1964).

On the other hand, the following eight species discriminated in the Ananai Formation have been reported from the Indo-Pacific, Austral-Tasman, and Nova-Zealand Realms, all as designated by Benson (*op. cit.*):

Alocopocythere goujoni (Brady, 1868),
Bradleya albatrossia Benson, 1972,
Cytherelloidea sabahensis Keij, 1964,
Hemicytherura radiata Hornibrook, 1952,
Krithe producta Brady, 1880,
Macrocypris decora (Brady, 1866),
Neonesidea villosa (Brady, 1880), and
Pterygocythereis scalaris (Brady, 1880).

A. goujoni has been reported in the area west of Carimata between Poulo Condore and Billiton Island, in Hong Kong Harbour, in the Bay of Manila, and in the Pliocene of Timor (Brady, 1868, 1880; Key, 1954; Hanai *et al.*, 1980); *B. albatrossia* in the area off Hong Kong, off Ki (Kai) Island, north of Sarawak, and Batu Island (Benson, 1972; Brady, 1880; van den Bold, 1950); *C. sabahensis* in the area off Sabah, northwest of Borneo (Keij, 1964); *H. radiata* from the upper Eocene to Recent in New Zealand (Hornibrook, 1952); *K. producta* in the area off Sydney, in the Tasman Sea and the Coral Sea (Brady, 1880); *M. decora* along the north coast of Java and Batavia and the west coast of Sumatra (Hanai *et al.*, 1980; van den Bold, 1950); *N. villosa* in the area north of Sumatra, and in Bass' Strait (van den Bold, 1950; Brady, 1880); and *P. scalaris* in Torres

Straits and in the area north of Sarawak (Brady, 1880; van den Bold, 1950).

Except for *B. albatrossia*, whose referable form has been recorded by Nohara (1981c) in the Pleistocene Naha Limestone of Okinawa, all of these species have already been discriminated by Ishizaki (*op. cit.*) as occurring in the shelf area of the East China Sea.

As mentioned above, the ostracode faunas of the Ananai Formation include elements of the upper Cenozoic of Taiwan as well as of such southern regions as the Indo-Pacific, Austral-Tasman, and Nova Zealand Realms, and show a close resemblance to those in the shelf area of the East China Sea, where, particularly in its outer portion, the agency of the Kuroshio Current is sufficient to result in frequent occurrences of those elements.

When using a modern analogue, knowing that the two different settings have such features in common would be very important for understanding depositional environments of the Ananai Formation and the then prevailing oceanography.

In addition to the above-mentioned species, the species described herewith as new are *Buntonia parascorta*, *B. scorta*, *B. u-carinata*, *Callistocythere ananaiensis*, *C. kattoi*, *Cytherella japonica*, and *Krithe hanaii*.

On the generic level, *Bairdoppilata* Coryell, Sample, and Jennings, 1935, *Jugosocythereis* Puri, 1957?, and *Doratocythere* McKenzie, 1967, are initially discriminated in this study as existing in the upper Cenozoic of Japan.

Systematics

The initials "IGPS" used with the type and illustrated specimens stand for the collection of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University, Sendai, Japan. The frequency of each taxon is denoted by the expressions defined by Ishizaki (1981) on the basis of a probability of 0.05 at which no specimen of a certain taxon will be encountered in a sample.

Subclass Ostracoda Latreille, 1806

Order Podocopida Müller, 1894

Suborder Platycopina Sars, 1866

Family Cytherellidae Sars, 1866

Genus *Cytherella* Jones, 1849

Cytherella japonica n. sp.

Pl. 32, Figs. 3, 4, 6, 7

Diagnosis.—Carapace moderate to large, thick-shelled, oblong. Almost entire surface smooth, but four to five subparallel costae along anterior brim, and those in addition to minute granular eminences along posterior brim.

Description.—Carapace moderate to large, thick-shelled, oblong with greatest height near posterior third or anterior terminal of dorsal margin in lateral view, somewhat ventrally deflated at mid-length, and wider posteriorly. Dorsal margin slightly sinuous, more or less concave near anterior third and broadly arched in posterior two-thirds in left valve, but almost straight in right valve. Ventral margin nearly straight, or slightly concave near mid-length. Anterior margin symmetrically and broadly round, merges into dorsal and ventral margins. Posterior margin broadly round slightly below mid-height, meets dorsal margin forming a broadly round corner. Almost entire surface smooth except for narrow anterior and posterior marginal areas; very finely corrugated or four to five subparallel costae discernible in anterior brim, and those in addition to minute granular eminences in posterior brim. No eye tubercle nor ocular sinus discernible. Smaller pores simple, flush, widely spaced. Larger pores, possibly broken sieve-plate pores, rarely found.

In internal view, outer margin overpassed by outline throughout, and slightly concave near mid-length of ventral margin. Inner lamella not well developed. Smooth narrow ridge circumscribes entire outer margin of left valve, and an accommodative groove continuous along inside outer margin of right valve. Right valve more or less widely overlaps left valve near anterior third of dorsal margin. Oval muscle scars field wide, but arrangement of them not very clear due to poor preservation. Internal openings of normal pore canals rarely observable, simple, small.

Type and dimensions.—Paratype, left valve, sample K9 (IGPS 97807, Pl. 32, Figs. 4a, b) 0.80 mm long and 0.49 mm high; paratype, right valve, sample H3 (IGPS 97808, Pl. 32, Figs. 3a, b) 0.70 mm long and 0.48 mm high; holotype, left valve, sample H3 (IGPS 97809, Pl. 32, Fig. 6) 0.83 mm long and 0.49 mm high; paratype, right valve, sample K9 (IGPS 97810, Pl. 32, Fig. 7) 0.81 mm long and 0.51 mm high.

Type-locality.—About 80 m west of Ono, Yasuda town, Aki County, Kochi Prefecture (sample H3).

Remarks.—So far as being known to the writer, forms of the genus *Cytherella* of Japan have only been listed by Nasu and Saito (1958) as *Cytherella* sp. α and *C.* sp. β from the recent silty sand on the shelf off the eastern coast of the Kii Peninsula, Japan (Kumanonada or the Gulf of Kumano).

Cytherella japonica somewhat resembles *Cytherella* sp. Khosla (1978) from the lower Miocene of Jamnagar and Porbandar districts, Gujarat, India, but differs in that the former is characterized by a shorter and more posteriorly widened carapace.

Occurrence.—Common at K1, K11, H3, and G5 (measured mud content 50.1—68.0%, Mdϕ 3.82—3.94); rare at K6, K9, H2, and H4.

Suborder Podocopina Sars, 1866

Superfamily Bairdiacea Sars, 1888

Family Bairdiidae Sars, 1888

Subfamily Bairdiinae Sars, 1888

Genus *Bairdoppilata* Coryell, Sample, and Jennings, 1935

Bairdoppilata sp.

Pl. 33, Figs. 5, 6; Pl. 34, Fig. 4

Description.—Carapace very large, moderate-shelled, extraordinarily unequal in lateral shape, and widest medially. Right valve subtrapezoid with greatest height in front of mid-length. Dorsal margin rather narrowly arched. Ventral margin sinuous, slightly concave in front of mid-length, and anterior and posterior segments arched. Anterior margin narrowly round well below mid-height. Upper margin long, nearly straight, meets dorsal margin forming a round corner, and merges into dorsal margin. Posterior margin more or less upturns and acuminate well below mid-height. Upper margin sinuous, narrowly concave just above the acumination, the remaining upper margin broadly arched and meets dorsal margin forming a round corner, and merges into ventral margin. Left valve subovate with greatest height slightly before mid-length, and widest medially. Dorsal margin rather narrowly arched. Ventral margin slightly arched. Anterior margin slightly depressed ventrally, and rather narrowly round slightly below mid-height. Upper margin nearly straight, merges into dorsal margin. Lower margin narrowly rounded well below mid-height. Upper and lower margins arched, and merge into dorsal and ventral margins. Surface smooth. No eye tubercle observable.

External openings of normal pore canals simple, flush, moderate in size, widely spaced.

Internally, inner lamella wide in lower half of anterior to ventral marginal areas. A slight vestibule differentiated along lower half of anterior to ventral marginal areas. Selvage distinct along lower half of anterior to ventral margins; concave before mid-length of ventral margin, and stands definitely aside outer margin in anteroventral and posteroventral areas. Selvage in anterior and posterior upper margins becomes thicker and more coarsely crenulate downward. Muscle scars typical of bairdiids. Five or six dorsal scars just below dorsal margin.

Dimensions.—Figured specimens, right valve, sample L4 (IGPS 97815, Pl. 33, Fig. 6) 1.28 mm long and 0.82 mm high; left valve, sample

L3 (IGPS 97816, Pl. 33, Figs. 5a-c) 1.25 mm long and 0.88 mm high; left valve, sample L1 (IGPS 97817, Pl. 34, Fig. 4) 1.26 mm long and 0.81 mm high.

Remarks.—The present report provides the first record of form of the genus *Bairdoppilata* from Japan. This form somewhat resembles *Bairdoppilata alcyonicola* Maddocks (1969) from Nosy Bé, Madagascar, but differs in that the right valve of the former has a posterior terminal much less distinctly upturned and a more shallowly concave ventral margin.

Occurrence.—This form was occurred only from four samples: Abundant at L1 (mud content 61.7%, Mdϕ 3.99); common at M1.

Superfamily Cytheracea Baird, 1850

Family Cytherideidae Sars, 1925

Subfamily Krithinae Mandelstam, 1958

Genus *Krithe* Brady, Crosskey, and Robertson, 1874

Krithe hanaii n. sp.

Pl. 33, Figs. 1-4; Pl. 35, Fig. 9

Diagnosis.—Carapace moderate to large, subovate to oblong with greatest height at posterior third. Dorsal margin broadly rounded, jutting out around posterior third. Surface smooth. Internal openings of normal pore canals very thick, widely spaced.

Description.—Carapace moderate to large, moderate-shelled, subovate to oblong with greatest height at posterior third, and widest at posteromedian area. Dorsal margin broadly round, more or less jutting out near its posterior third. Ventral margin nearly straight, or slightly concave just behind mid-length. Anterior margin symmetrically round, ending at mid-height, and merges into dorsal and ventral margins. Posterior margin depressed ventrally, ends well below mid-height, merges into dorsal margin, and meets ventral margin forming a round acute angle.

Surface smooth. Openings of normal pore canals thick, widely spaced on entire surface. Eye tubercle not distinct.

Internally, outer margin concave near mid-length of ventral margin. Posterior apparent opening distinct. Inner lamella wide along anterior margin, but narrow along the remaining of extracardinal margin. Line of concrescence coincides with inner margin for the most part except for a portion just below mid-height, where narrow but deep vestibule invades into more than half the width of inner lamella to lead to anterior extension of most of radial pore canals in anterior margin. Radial pore canals rather thick, simple, but branch off in some, 16 canals in anterior margin, which are definitely concentrated in a portion just below mid-height. Five simple and thick canals discernible in ventral margin. Hinge pseudoadont. A narrow groove along inside dorsal margin in left valve rather deep, crenulate near its anterior terminal and its posterior half. Muscle scars consists of a vertical row of four adductor scars, of which lowermost one round and small, and upper two scars large, and apparently constricted at their mid-length. An anterior scar appears to be a fusion of three scars. Three scars, at least, discernible above adductor muscle scars. Internal openings of normal pore canals very thick, widely spaced.

Type and dimensions.—Paratype, left valve, sample K7 (IGPS 97811, Pl. 33, Fig. 2) 0.76 mm long and 0.46 mm high; paratype, right valve, sample K7 (IGPS 97812, Pl. 33, Figs. 1a-c) 0.71 mm long and 0.38 mm high; holotype, left valve, sample H2 (IGPS 97813, Pl. 33, Fig. 3, Pl. 35, Fig. 9) 0.90 mm long and 0.51 mm high; paratype, right valve, sample K11 (IGPS 97814, Pl. 33, Fig. 4) 0.77 mm long and 0.41 mm high.

Type-locality.—About 80 m west of Ono, Yasuda town, Aki County, Kochi Prefecture (sample H2).

Remarks.—This species resembles *Krithe producta* Brady (1880) in many respects, but differs in that the former has a smaller and shorter carapace, which projects its posterodorsal margin more strongly.

Occurrence.—Common at H2, H4, and G5 (measured mud content 56.7%, Mdϕ 3.94).

Family Leptocytheridae Hanai, 1957

Genus *Callistocythere* Ruggieri, 1953

Callistocythere ananaiensis n. sp.

Pl. 30, Figs. 4, 5; Pl. 31, Figs. 1-3; Pl. 35, Fig. 2

Diagnosis.—Carapace rather small, thick-shelled, oblong. Surface ornamented with bold anterior and posterior marginal ridges, and two horizontal and vertical ridges.

Description.—Carapace rather small, very thick-shelled, oblong in lateral view, inflated around a horizontal axis at mid-height, and wider posteriorly. Dorsal margin straight. Ventral margin broadly concave in front of mid-length. Anterior margin depressed ventrally, ends slightly below mid-height, and merges into dorsal and ventral margins. Posterior margin more or less narrowly protruded postward below mid-height, merges into dorsal margin in many specimens, but meets it forming a more or less clear cardinal angle in some specimens, and merges into ventral margin. Surface ornamentation is fundamentally characterized by anterior and posterior marginal ridges, two horizontal ridges, two vertical ridges, and an anterior oblique ridge, and a ventral ridge. Anterior marginal ridge very bold and wide along anterior margin from anterior terminal of dorsal margin to that of ventral margin, and branches off a narrower anterior oblique ridge at anterodorsal area, which continues to anteroventral area. Posterior marginal ridge very bold and wide along inside posterior margin from posterior terminal of dorsal margin to that of ventral margin. This ridge widens considerably near lower terminal and becomes obliquely to anteroventral area where it merges into anterior marginal ridge. Upper horizontal ridge more or less sinuous, and prominent, runs slightly above mid-height from anterior oblique ridge to posterior marginal ridge. This ridge crosses two vertical ridges dangling from dorsal margin at an anterior and posterior third of valve length. Lower horizontal ridge short, runs from anteroventral area to median area and intersects anterior oblique ridge and anterior vertical ridge. Anterior vertical ridge bifurcate below upper horizontal ridge and connected with ventral ridge. Posterior vertical ridge branches off into two narrower ridges above upper horizontal ridge, and joins to ventral ridge. Depressions between ridges generally considerably deep except for median area below upper horizontal ridge where partly, irregular reticulation observable. Small pits stud the surface of most of bold ridges. Rimmed pores simple, rather large. Eye tubercle not distinct.

Internally, outer margin widely overpassed by outline posterodorsally. It distinctly concave slightly before mid-length of ventral margin, and narrowly curved at posterior terminal of dorsal margin. Posterior apparent opening distinct at mid-height. Inner lamella wide along anterior and posteroventral margin. Line of concrescence nearly coincides with inner margin. Radial pore canals thick, widely spaced in clusters, and branching off into two or three anteriorly in anterior margin; eight canals along inner margin diverge anteriorly into 22 canals along outer margin. Radial pore canals moderate in thickness, simple, and attain to five and 12, respectively, in posterior and ventral margins. Selvage distinct along inside almost entire extracardinal margin. List more or less distinct along anterior and ventral margins. Hinge entomodont. Median bar in left valve crenulate, thickens and more coarsely denticulate near its terminals. In right valve, anterior tooth small, smooth, and horizontally elongate, and posterior tooth small, smooth, and slightly elongate subvertically. Very small snap-knob observable at concavity of ventral margin of right valve. Central muscle scars consist of a vertical row of four adductor muscle scars, but frontal scars not clear; apparently fused two scars. Internal openings of normal pore canals simple, rather large.

Type and dimensions.—Holotype, right valve, sample H1 (IGPS 97796, Pl. 30, Fig. 4; Pl. 31, Figs. 3a, b), 0.48 mm long and 0.25 mm high; paratype, left valve, sample H1 (IGPS 97797, Pl. 30, Figs. 5a, b), 0.48 mm long and 0.25 mm high; paratype, right valve, sample H1 (IGPS 97798, Pl. 31, Fig. 2; Pl. 35, Fig. 2), 0.48 mm long and 0.24 mm high; paratype, left valve, sample H1 (IGPS 97799, Pl. 31, Fig. 1), 0.45 mm long and 0.25 mm high.

Type-locality.—About 80 m west of Ono, Yasuda town, Aki County, Kochi Prefecture (sample H1).

Remarks.—This species is closely related to *Callistocythere puri* McKenzie (1967) in most respects, but is distinguishable in that the former has much thicker marginal ridges, a more continuous upper horizontal ridge, and two vertical ridges instead of three.

Occurrence.—Abundant at L2, K2, K7, H1-3, I1, J1, G2-6, and G8 (measured mud content 20.5—73.8%, Mdϕ 3.53—4.14); common at P2, L4, L3, L1, M1, K3-6, K8, K10, K11, and H4 (measured mud content 33.4—68.0%, Mdϕ 3.75—4.05).

Callistocythere kattoi, n. sp.

Pl. 31, Figs. 4-7; Pl. 35, Fig. 8

Diagnosis.—Carapace moderate to small, thick-shelled, rectangular. Surface ornamented with marginal ridge, ventral oblique ridge, radial ridges, and coarse reticulation.

Description.—Carapace moderate to rather small, thick-shelled rectangular or subrhomboid in lateral view with greatest height at anterior terminal of dorsal margin, and widest posteroventrally. Dorsal margin almost straight. Ventral margin broadly concave. Anterior margin depressed ventrally, narrowly rounded below mid-height, meets dorsal margin forming a round obtuse cardinal angle, and merges into ventral margin. Lower half of the margin denticulate. Posterior margin more or less vertically truncated, meets dorsal margin forming a broadly or narrowly round cardinal angle, and meets ventral margin forming a narrowly round corner.

Surface ornamented with marginal ridge, ventral oblique ridge, radial ridges, and reticulation. Marginal ridge circumscribes entire margin; broader along anterior margin, and thick and prominent on posteroventral margin. Ventral oblique ridge very prominent and wide from just behind anteroventral area to above mid-height of posterior margin, ornamented with reticulation, and disrupted in posteromedian area. Three narrow radial ridges discernible in mid-anterior area; one extends forward horizontally and the other two run toward anterodorsal area, all joins to marginal ridge at their terminals. Depressions deep in mid-anterior and posteroventral areas. Reticulation rather coarse, covers almost entire surface except for the depressions. Eye tubercle not distinct. Rather large pores simple, open within sola and on muri. Smaller pores also simple, open on muri.

Internally, outer margin overpassed by outline along posterior two-thirds of dorsal and ventral margins, and rather narrowly concave before mid-length of ventral margin. Inner

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Explanation of Plate 28

Figs. 1—4. *Buntonia parascorta* Ishizaki, n. sp.
  1. Adult right valve (Holotype, IGPS 97781; Sample H2).
    a. Lateral view, x 120.
    b. Part of Fig. 1a, showing details of external openings of normal pore canals, x 800.
    c. ditto.
  2. Adult left valve (Paratype, IGPS 97782; Sample H2).
    a. Lateral view, x 120.
    b. Part of Fig. 2a, showing details of external opening of normal pore canal, x 1,600.
  3. Internal view, adult left valve (Paratype, IGPS 97784; Sample H2). x 120.
  4. Internal view, adult right valve (Paratype, IGPS 97783; Sample K11). x 120.

Figs. 5, 6. *Buntonia scorta* Ishizaki, n. sp.
  5. Part of lateral view, showing details of external openings of normal pore canals, adult left valve (Paratype, IGPS 97785; Sample H2). x 1,200.
  6. Part of lateral view, showing details of lateral surface, adult right valve (Paratype, IGPS 97786; Sample G5). x 1,200.

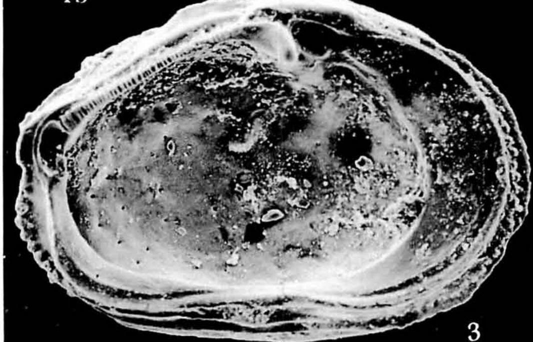

1a


2a


1b


1c


2b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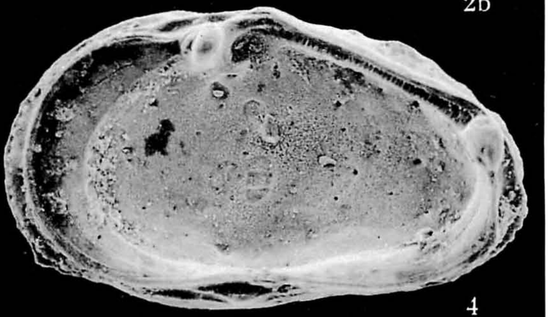
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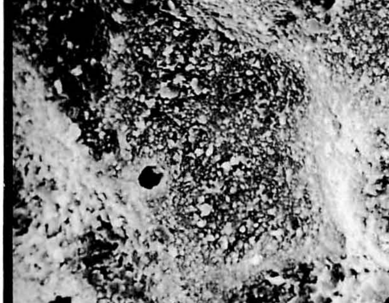
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5

lamella wide along anterior and posteroventral margins. Vestibule very narrow along anterior and posteroventral margins. Radial pore canals thick, widely spaced, often bulbous at anterior fourth of their length, and bifurcate in many cases. Eight canals along inner margin diverge anteriorly into 18 canals along outer margin in anterior margin. Four and 14 canals discernible in posterior and ventral margins, respectively. Selvage distinct along entire extracardianl margin. Hinge entomodont. Median bar in left valve finely crenulate, distinctly thicker and more coarsely denticulate anteriorly, and slightly thickens posteriorly. In right valve, anterior tooth horizontally elongate and trilobate, and posterior tooth round and smooth. A small snap-knob discernible at concavity of ventral margin of right valve. Muscle scars consist of a vertical row of four tightly spaced adductor muscle scars. Fused two scars in front of them. Internal openings of normal pore canals rather thick, widely spaced.

Type and dimensions.—Holotype, left valve, sample H1 (IGPS 97800, Pl. 31, Fig. 5) 0.53 mm long and 0.35 mm high; paratype, right valve, sample H1 (IGPS 97801, Pl. 31, Figs. 4a-c), 0.53 mm long and 0.30 mm high; paratype, left valve, sample H1 (IGPS 97802, Pl. 31, Fig. 6; Pl. 35, Fig. 8), 0.53 mm long and 0.31 mm high; paratype, right valve, sample H1 (IGPS 97803, Pl. 31, Fig. 7) 0.53 mm long and 0.30 mm high.

Type-locality.—About 80 m west of Ono, Yasuda town, Aki County, Kochi Prefecture (sample H1).

Remarks.—In respect of fossae which cover almost the entire surface, this species somewhat resembles *Callistocythere dorsotuberculata* Hartmann reported by Hartmann (1980) from the southeastern coast of Australia, but the former has a rectangular or subrhomboid lateral outline, and a much more prominent and wide ventral oblique ridge.

Occurrence.—Abundant at L3, L2, M1, H1, H3, and I1 (measured mud content 56.8—73.8%, Mdϕ 3.90—4.14); common at L4, L1, K1, K2, K4, K5, K10, K11, H4, J1, G2-4, G6, and G8 (measured mud content 20.5—68.0%, Mdϕ 3.53—3.99).

Callistocythere sp.

Pl. 32, Figs. 1, 2, 5

Description.—Carapace moderate in size, thick-shelled, oblong or subrhomboid with greatest height at anterior cardinal angle in lateral view, and widest posteroventrally. Dorsal margin broadly arched. Ventral margin slightly sinuous, broadly concave in anterior two-thirds, but slightly arched in a posterior third of the length. Anterior margin rather strongly depressed ventrally, narrowly rounded well below mid-height, meets dorsal margin forming a vague obtuse cardinal angle, and merges into ventral margin. Lower section of the margin denticulate. Posterior margin narrowly protruded postward above mid-height, meets dorsal margin forming a more or less distinct cardinal angle, and merges into ventral margin.

Surface fundamentally ornamented with two marginal ridges, as many horizontal ridges, and four vertical ridges. Outer marginal ridge moderate in thickness and circumscribes entire margin. Inner marginal ridge thicker, and runs along inside anterior, ventral, and posterior margins from anterior cardinal angle to before posterior cardinal angle. It deverges for a small distance near anteroventral area and in front of posterior margin. Lower horizontal ridge starts forward from median area to mid-anterior area between outer and inner marginal ridges. Upper horizontal ridge runs postward from anteromedian area to posteromedian area, and then it turns and continues parallel with inner marginal ridge to just before posterodorsal area. Of four vertical ridges, anterior one dangles from anterior cardinal angle to near anterior terminal of upper horizontal ridge; second one from an anterior third of dorsal margin to upper horizontal ridge in median area; third one from mid-length of dorsal margin to the posterior section of upper horizontal ridge in posteromedian area; fourth one from a posterior third of dorsal margin to the posterior section of upper horizontal ridge in posteromedian area. A short ridge crosses between the second and third vertical ridges at a lower third of their length. Eye tubercle not distinct. Smaller pores simple, widely spaced, and flush or low-rimmed on muri and slope of fossae; some come up through warty tubercles on sola. Larger pores equipped with celate sieve plate rarely observed.

In internal view, outer margin rather narrowly concave in front of mid-length of ventral margin, and overpassed broadly by outline along dorsal and ventral margins. Inner lamella wide along anterior and posteroventral margins. Line of concrescence nearly coincides with inner margin. Radial pore canals thick, widely spaced in clusters, diverge into two or three canals anteriorly in anterior margin, but simpler in posterior and ventral margins. Eight canals discernible in inner margin and 21 canals in outer margin of anterior margin, five canals in posterior margin, and 13 canals in ventral margin. Marginal extension of flange distinct along lower two-thirds of anterior margin, which denticulate in well-preserved specimens. Posterior apparent opening distinct at mid-height, whose posterior terminal feebly denticulate. Selvage distinct along entire extracardinal angle. List rather wide, parallel to the inside of selvage.

Hinge entomodont. Median element in left valve finely crenulate narrow bar, whose anterior terminal becomes increasingly thicker and more coarsely denticulate anteriorly. In right valve, anterior tooth obliquely elongate, and trilobate, posterior tooth massive and smooth. Small snap-knob observable at concavity of ventral margin of right valve. Muscle scars consist of a vertical row of four adductor scars. An oblong scar inclined anteriorly in front of them. Internal openings of normal pore canals rather large, widely spaced.

Dimensions.—Figured specimens, left valve, sample G4 (IGPS 97804, Pl. 32, Fig. 2) 0.56 mm long and 0.32 mm high; right valve, sample L1 (IGPS 97805, Pl. 32, Figs. 1a-c), 0.54 mm long and 0.33 mm high; right valve, sample M1 (IGPS 97806, Pl. 32, Fig. 5, Pl. 35, Fig. 5), 0.54 mm long and 0.30 mm high.

Remarks.—Only a few well preserved specimens are available for this study due to the fact that this species only occurred rarely from the most studied samples. This species resembles *Callistocythere undata* Hanai (1957) in some respects, but differs in that the former is basically characterized by regularly spaced distinct vertical ridges. This species is easily distinguished from *Callistocythere alata* Hanai (1957) in the absence of posteroventral spines.

Occurrence.—Common only at L1 (mud content 61.71%, Mdϕ 3.99).

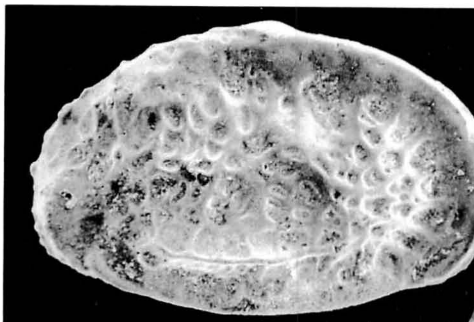
Family Hemicytheridae Puri, 1953

Subfamily Thaerocytherinae Hazel, 1967

Explanation of Plate 29

Figs. 1—4. *Buntonia scorta* Ishizaki, n. sp.
1. Lateral view, adult right valve (Paratype, IGPS 97786; Sample G5). x 120.
2. Lateral view, adult left valve (Paratype, IGPS 97785; Sample H2). x 120.
3. Internal view, adult left valve (Holotype, IGPS 97787; Sample G5). x 120.
4. Adult right valve (Paratype, IGPS 97788; Sample G5).
    a. Internal view, x 120.
    b. Part of Fig. 4a, showing details of central muscle scars. x 240.

Figs. 5—8. *Buntonia u-carinata* Ishizaki, n. sp.
5. Adult right valve (Holotype, IGPS 97789; Sample H3).
    a. Lateral view, x 120.
    b. Part of Fig. 5a, showing details of lateral surface, x 1,200.
6. Adult left valve (Paratype, IGPS 97790; Sample I1).
    a. Lateral view, x 120.
    b. Part of Fig. 6a, showing details of lateral surface, x 1,200.
7. Internal view, adult left valve (Paratype, IGPS 97792; Sample H3). x 120.
8. Internal view, adult right valve (Paratype, IGPS 97791; Sample H3). x 120.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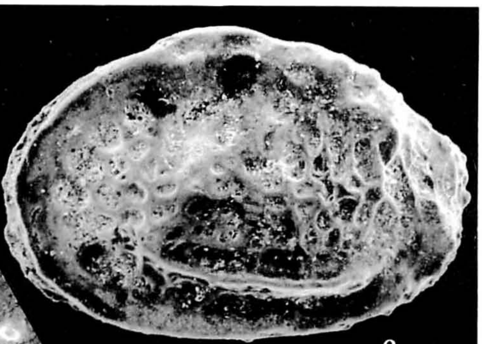
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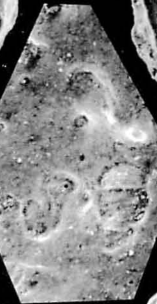
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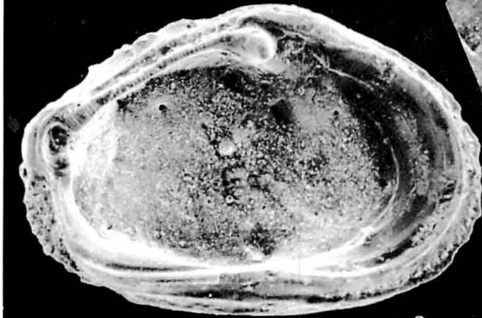
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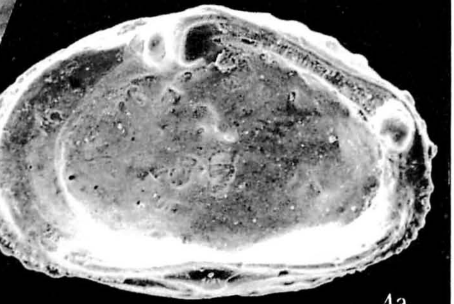
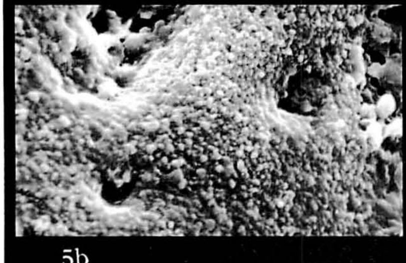

4a


5a


6a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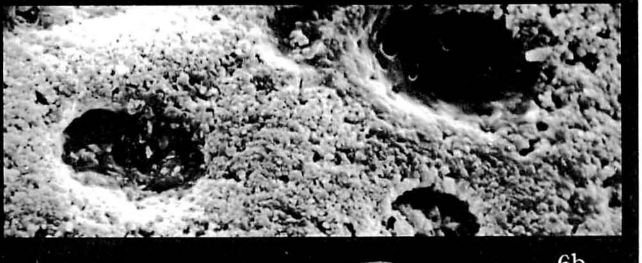
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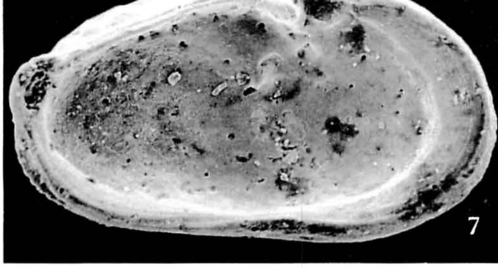
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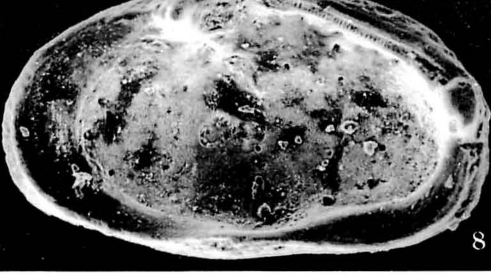
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Genus *Jugosocythereis* Puri, 1957

Jugosocythereis? sp.

Pl. 30, Figs. 1-3; Pl. 35, Fig. 10

Description.—Carapace large, thick-shelled, subtrapezoid with greatest length well below mid-height and greatest height near anterior terminal of dorsal margin, and widest medially, but abruptly deflated posterodorsally forming a flat-relief slope behind a U-shaped posterodorsal ridge. Dorsal margin sinuous, rather narrowly concave behind its anterior terminal, and broadly arched near its posterior third. Ventral margin nearly straight. Anterior margin somewhat depressed, ends below mid-height, meets dorsal margin forming an obtuse cardinal angle, and merges into ventral margin. Flange moderate in width along entire anterior margin. Posterior margin truncated, its lower third distinctly acuminate posteriorly, and its upper two-thirds concave. It meets dorsal margin forming a right-angled cardinal angle, and the lower side of the acumination merges into ventral margin. Several denticles or spines distinct around the acumination.

Surface ornamented with two marginal and many other ridges. Outer marginal ridge continuous along almost entire margin, but very narrow for the most part except along the inside of posterior margin, where it becomes much thicker and runs parallel to the margin. Inner marginal ridge distinct, runs along inside the outer marginal ridge from near anterior cardinal angle to posteroventral area via anterior and ventral margins. It joins posteriorly with the outer marginal ridge at posteroventral area and branches off upward as two distinct vertical ridges at slightly anterior points (branched-off vertical ridges join with the posterior part of a U-shaped posterodorsal ridge). A distinct ridge starts anteriorly from subcentral tubercle to anteroventral area, passing over inner marginal ridge. Four subdued ridges extend posteriorly or posteroventrally from and above subcentral tubercle, and join to or fades before inner marginal ridge. Two other ridges distinct in posterodorsal area united posteriorly with each other to form a U-shaped posterodorsal ridge. A short ridge discernible within U-shaped posterodorsal ridge area. Short radial ridges distinct between outer and inner marginal ridges in anterior marginal area. Several subsidiary ridges observable in front of subcentral tubercle. Most of the above-mentioned ridges compose clear reticulation in association with very narrow traversing ridges in between. Subcentral tubercle moderate mid-length in adult specimen, but in submedian area in immature specimens. Eye tubercle prominent near anterior cardinal angle. Intramural (secondary muri) pores, pores coming up through warty tubercles, and flush pores are simple, rather large.

Internal openings of normal pore canals simple, rather large, widely spaced. Central muscle scars consist of a vertical row of four adductor scars, each of which divided into two as far as observed. Three scars in front of them. Several scars above these scars. Examined immature specimens reveal that radial pore canals simple, regularly spaced in anterior margin, but more widely spaced anterodorsally. Forty-eight in anterior margin, eight in acuminate posterior end, and 25 in posteroventral margin. Vestibule well differentiated, attaining to about a third the width of inner lamella in anterior margin, but much narrower in posterior and posteroventral margins.

Dimensions.—Figured specimens, complete carapace, sample K9 (IGPS 97793, Pl. 30, Fig. 1), 0.90 mm long and 0.50 mm high; immature right valve, sample K2 (IGPS 97794, Pl. 30, Figs. 3a, b, Pl. 35, Fig. 10), 0.67 mm long and 0.40 mm high; immature left valve, sample K2 (IGPS 97795, Pl. 30, Figs. 2a-c) 0.69 mm long and 0.41 mm high.

Remarks.—This form has yet to be examined for its internal characters toward rigorous generic assignment, because only one complete adult carapace is available for this study although a great deal of specimens were found from 24 out of the 35 examined samples.

This form somewhat resembles *Hermanites posterocostatus* Ishizaki (1966), but is distinguishable from the latter in that the former has an inner marginal ridge which runs vertically along inside the outer marginal ridge in the anterior marginal area and branches off upward as two vertical ridges around a posterior fourth of the ventral margin.

Occurrence.—Abundant at K3 and K7 (mud content 58.6 and 54.1%, Mdϕ 4.05 and 3.99); common at K1, K2, K4, K6, K8-11, H2-4, I1, G3, G4, and G6 (measured mud content 33.0—50.1%, Mdϕ 3.67—3.87).

Family Trachyleberididae Sylvester-Bradley, 1948

Subfamily Buntoniinae Apostolescu, 1961

Genus *Buntonia* H. V. Howe, 1935

Buntonia parascorta n. sp.

Pl. 28, Figs. 1-4; Pl. 35, Fig. 1

Diagnosis.—Carapace moderate in size, thick-shelled, subovate with truncated posterior margin. Six or seven short radial ridges bridge across furrow along inside of anterior margin. Hinge short, about half the length of carapace.

Description.—Carapace moderate in size, thick-shelled, subovate with greatest height just in front of mid-length (at anterior cardinal angle) in lateral view, and slightly inflated around a horizontal axis at mid-height except in a wide compressed zone along anterior margin. Dorsal margin short, nearly straight, and abruptly descends postward. Ventral margin broadly concave at middle, or broadly arched. Anterior margin broadly rounded, meets dorsal margin forming a somewhat distinct anterior cardinal angle, and merges into ventral margin. Marginal extension of flange distinct along anterior margin from before anterior cardinal angle to anteroventral area, where a few marginal denticles often differentiated. Posterior margin truncated ventrally; it meets dorsal margin forming a vague cardinal angle, and merges into ventral margin. Five or more of marginal denticles, generated from a narrow marginal extension of flange, distinct on well-preserved specimens.

Surface ornamented with marginal ridges together with radial, horizontal, and corrugated ridges. Outer marginal ridge distinct, but short, and is confined to posterior margin. Inner marginal ridge, running from before posterior end of dorsal margin to upper terminal of anterior margin via ventral margin, prominent and wide along anterior and ventral margins, and becomes narrower along inside of outer marginal ridge. Inside inner marginal ridge a broad furrow runs along anterior and ventral margins, but it abruptly becomes much narrower along posterior margin. Six or seven short radial ridges bridge across this furrow along anterior margin; some of them extend up to anteromedian area. Dorsal marginal ridge narrow, limited to a posterior half

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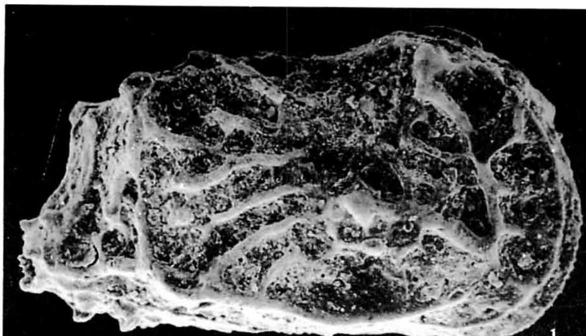
Explanation of Plate 30

Figs. 1—3. *Jugosocythereis?* sp.
  1. Lateral view, adult complete carapace (IGPS 97793; Sample K9). x 80.
  2. Immature left valve (IGPS 97795; Sample K2).
    a. Lateral view, x 80.
    b. Part of Fig. 2a, showing details of external openings of normal pore canals, x 1,200.
    c. Part of Fig. 2a, showing details of lateral surface, x 1,200.
  3. Immature right valve (IGPS 97794; Sample K2).
    a. Internal view, x 80.
    b. Part of Fig. 3a, showing details of muscle scar arrangement, x 230.

Figs. 4, 5. *Callistocythere ananaiensis* Ishizaki, n. sp.
  4. Lateral view, adult right valve (Holotype, IGPS 97796; Sample H1). x 120.
  5. Adult left valve (Paratype, IGPS 97797; Sample H1).
    a. Lateral view, x 120.
    b. Part of Fig. 5a, showing details of lateral surface, x 550.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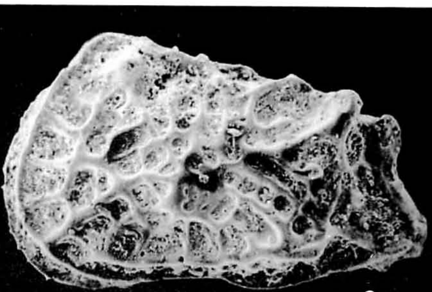
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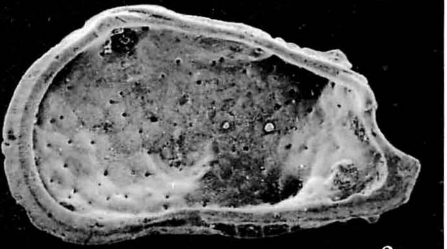
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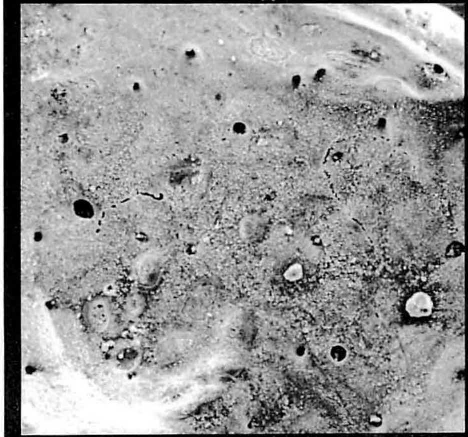
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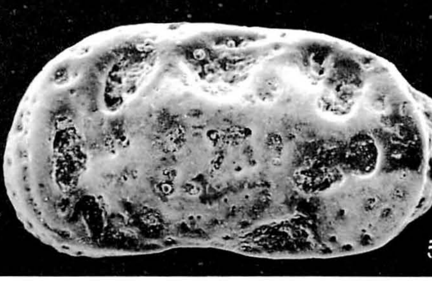
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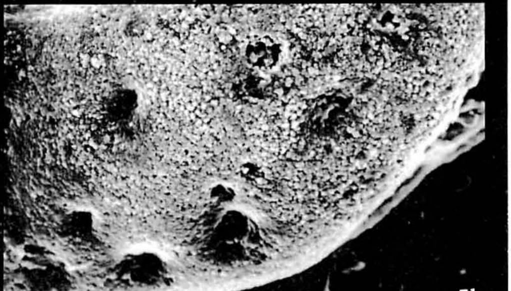
5b

of the margin. Lower horizontal ridge distinct and long along inside the furrow from an anterior third to near posterior end of ventral margin. Upper horizontal ridge much shorter, confined to only posterior part. Both the horizontal ridges connected with each other by a U-shaped junction opening anteriorly. Several corrugated ridges, confined to posterodorsal area, narrow and irregular. Eye tubercle not distinct. Intramural normal pores small, widely spaced. A few rimmed somewhat larger pores observable. In internal view, outer margin broadly concave near mid-length and narrowly curved at posterior terminal of ventral margin and overpassed almost entirely by outline except for posteroventral area in left valve and for near anterior cardinal angle and posteroventral area in right valve.

Hinge holamphidont; median element short, being nearly half the length of carapace, strongly crooks ventrally at the junction of antero- and posteromedian elements. Anteromedian element elongate, smooth, tooth-like process, and posteromedian element distinctly crenulate linear bar in left valve. Anterior tooth prominent, bilobate, protruded laterally, and posterior tooth massive, inclined posteroventrally. Inner lamella moderately wide along anterior margin, an less wide along antero- and posteroventral margins. Vestibule not differentiated. Radial pore canals somewhat sinuous, often bulbous at an anterior third of their length, bifurcate in some, and moderate in number, but more widely spaced anterodorsally. Forty-four along anterior margin and 17 along posterior margin. Selvage, which bounds anterior socket dorsally and posterior socket posteriorly and runs along the upper side of median element of hinge, distinct along entire outer margin in left valve. A shallow furrow, an accommodation to the selvage in left valve, discernible along extracardinal outer margin except for concavity near mid-length of ventral margin in right valve. A somewhat elongate snap-knob discernible below mid-length of ventral margin in right valve. Muscle scars consist of a vertical row of four very small and tightly spaced adductor scars; anterior scars not distinct. A few dorsal scars are in an arched line, starting from above adductor scars up to near anterior terminal of dorsal margin. Internal openings of normal pore canals thick, widely spaced.

Type and dimensions.—Holotype, right valve, sample H2 (IGPS 97781, Pl. 28, Figs. 1a-c), 0.56 mm long and 0.35 mm high; paratype, left valve, sample H2 (IGPS 97782, Pl. 28, Figs. 2a, b), 0.54 mm long and 0.33 mm high; paratype, right valve, sample K11 (IGPS 97783, Pl. 28, Fig. 4) 0.58 mm long and 0.34 mm high; paratype, left valve, sample H2 (IGPS 97784, Pl. 28, Fig. 1, Pl. 35, Fig. 1), 0.57 mm long and 0.38 mm high.

Type-locality.—About 80 m west of Ono, Yasuda town, Aki County, Kochi Prefecture (sample H2).

Remarks.—This species is rather closely related to *Buntonia hanaii* Yajima (1978), but is distinguishable from the latter in having distinct horizontal ridges and short radial ridges which bridge across the furrow along the inside of the anterior margin. *Buntonia parascorta* also resembles *B. scorta* n. sp. in many respects, but the former has a larger non-reticulate carapace and two distinct horizontal ridges which are posteriorly connected with each other by a U-shaped junction.

Occurrence.—In addition to the common occurrence at the type locality, this species was rarely found from K11 and G5.

Buntonia scorta n. sp.

Pl. 28, Figs. 5, 6; Pl. 29, Figs. 1-4; Pl. 35, Fig. 3

Buntonia sp. Ishizaki, 1981, p. 48, 49, pl. 9, fig. 11, pl. 10, figs. 4a, b, 5, pl. 15, fig. 9.

Diagnosis.—Carapace moderate to rather small, thick-shelled, subovate. Compressed peripheral zone broad. Horizontal ridge distinct along ventral margin. Hinge short, about half the length of carapace.

Description.—Carapace moderate to rather small, thick-shelled, and subovate in lateral view. Compressed peripheral zone broad along the inside of outline except for posterodorsal area. Dorsal margin short, rather narrowly arched, and ends anteriorly near mid-length of carapace where anteromedian element of hinge structure is divided from posteromedian element. Ventral margin broadly arched. Anterior margin symmetrically rounded, merges into dorsal and ventral margins. Posterior margin more narrowly rounded, merges into dorsal and ventral margins. Marginal extension of flange discernible along entire extracardinal outer margin. Several short marginal denticles, generated from a very narrow marginal extension of flange, distinct along posterior margin of well-preserved specimens.

Surface ornamented with reticulation except for compressed peripheral zone. In addition, marginal, horizontal, and corrugated ridges distinct. Marginal ridge wide, continuous from anterodorsal area to above mid-height of posterior margin via ventral margin, and forms a wide compressed peripheral zone without distinct reticulation, which decreases in width postward. Horizontal ridge runs along ventral margin from above anteroventral margin to a point above posteroventral margin, and then turns and fades upward. Corrugated ridges particularly distinct in posterodorsal area, where they strengthen muri vertically. An anteriorly inclined depression distinct just below anterodorsal margin. Eye tubercle not so distinct. External openings of normal pore canals moderate in size, flush, widely spaced. A few celate pores also observable on apophyses.

In internal view, outer margin broadly concave near mid-length and narrowly curved at posterior terminal of ventral margin, and widely overpassed almost entirely by outline except for posteroventral and posterodorsal areas in left valve and for near anterior cardinal angle, in addition, in right valve. Hinge holamphidont. Median element short, being nearly half the length of carapace, sharply crooks ventrally at the junction of antero- and posteromedian elements. Anteromedian element round, smooth, and tooth-like process, and posteromedian bar narrow but somewhat thickens near its terminals, straight, and distinctly crenulate in left valve. Anterior tooth smooth, and narrowly protruded laterally, and posterior tooth slightly incised ventrally in right valve.

Inner lamella moderately wide along anterior margin, and less wide along antero- and posteroventral margins. Vestibule not differentiated. Radial pore canals somewhat sinuous, often bulbous at an anterior third to near anterior end of their length, bifurcate in some, and moderate in number, but more widely spaced anterodorsally: Forty-three along anterior margin and 12 along posterior margin. Selvage, which bounds anterior socket dorsally and posterior socket posteriorly, distinct along entire extracardinal outer margin in left valve. Two lists observable along anterior margin. A round snapknob discernible below mid-length of ventral

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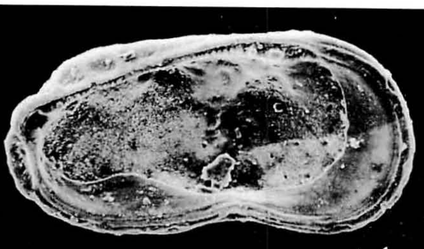
Explanation of Plate 31

Figs. 1—3. *Callistocythere ananaiensis* Ishizaki, n. sp.
  1. Internal view, adult left valve (Paratype, IGPS 97799; Sample H1). x 120.
  2. Internal view, adult right valve (Paratype, IGPS 97798; Sample H1). x 120.
  3. Adult right valve (Holotype, IGPS 97796; Sample H1).
    a. Part of lateral view, showing details of lateral surface, x 1,200.
    b. Part of lateral view, showing details of external opening of normal pore canal, x 2,400.

Figs. 4—7. *Callistocythere kattoi* Ishizaki, n. sp.
  4. Adult right valve (Paratype, IGPS 97801; Sample H1).
    a. Lateral view, x 120.
    b. Part of Fig. 4a, showing details of lateral surface, x 800.
    c. Part of Fig. 4a, showing details of external openings of normal pore canals, x 800.
  5. Lateral view, adult left valve (Holotype, IGPS 97800; Sample H1). x 120.
  6. Internal view, adult left valve (Paratype, IGPS 97802; Sample H1). x 120.
  7. Internal view, adult right valve (Paratype, IGPS 97803; Sample H1). x 120.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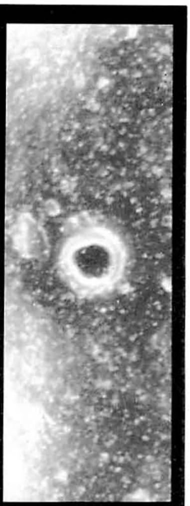
3a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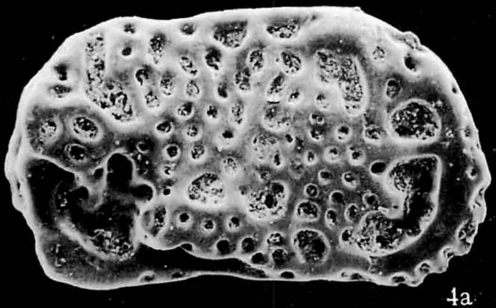
4a


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4b


4c


6


7

margin in right valve. Muscle scars in subcentral area consist of a vertical row of four very small and tightly spaced adductor scars. Two small scars in front of them fused to form a united J-shaped scar. Internal openings of normal pore canals small and widely spaced, but a few of them distinctly thicker.

Type and dimensions.—Paratype, left valve, sample H2 (IGPS 97785, Pl. 28, Fig. 5, Pl. 29, Fig. 2) 0.51 mm long and 0.35 mm high; paratype, right valve, sample G5 (IGPS 97786, Pl. 28, Fig. 6, Pl. 29, Fig. 1) 0.52 mm long and 0.33 mm high; holotype, left valve, sample G5 (IGPS 97787, Pl. 29, Fig. 3, Pl. 35, Fig. 3) 0.51 mm long and 0.35 mm high; paratype, right valve, sample G5 (IGPS 97788, Pl. 29, Figs. 4a, b) 0.51 mm long and 0.33 mm high.

Type-locality.—About 150 m west of Sempuku, Nahari town, Aki County, Kochi Prefecture (sample G5).

Remarks.—This species is closely related to *Buntonia parascorta* n. sp. in many respects, but is distinguishable from the latter in having a more regular reticulation except in a broad compressed peripheral zone, vague short radial ridges which bridge across the anterior peripheral zone, and by lack of an upper horizontal ridge.

Occurrence.—Common at K6-8, H2, and G6 (measured mud content 44.2—50.0%, Mdϕ 3.84—3.99).

Buntonia u-carinata n. sp.

Pl. 29, Figs. 5-8; Pl. 35, Fig. 4

?*Ambocythere* sp. Hu, 1978, p. 146, pl. 3, fig. 25, Figs. 19A, B.

Diagnosis.—Carapace moderate in size, thick-shelled, suboblong with truncated posterior end. Posterior half reticulate, ornamented with two horizontal ridges which connect with each other to form a U-shaped junction.

Description.—Carapace moderate in size, thick-shelled, suboblong with greatest height at or somewhat before mid-length in lateral view, and inflated around a horizontal axis at mid-height except in compressed peripheral zone along anterior margin. Dorsal margin short, being confined to posterior half of carapace, nearly straight or slightly arched, and gradually descends postward. Ventral margin nearly straight or broadly arched. Anterior margin symmetrically round, meets dorsal margin forming a more or less discernible cardinal angle at mid-length, and merges into ventral margin; marginal extension of flange discernible from an upper part of anterior margin to anterior terminal of ventral margin. Posterior margin ends below mid-height, narrowly round, and merges into dorsal and ventral margins in right valve, but it is more or less strongly truncated, meets dorsal margin forming a distinct cardinal angle at posterior terminal of dorsal margin (due to the wall bounding posterior socket), and merges into ventral margin in left valve; marginal extension of flange observable, from which several denticles are differentiated along a margin below cardinal angle in left valve.

Surface ornamentation with distinct reticulation is confined to a posterior half. Marginal ridge of high relief rather narrow, but continuous, starting from upper terminal of anterior margin to near mid-height of posterior margin via ventral margin, and then fades upwards. A deep furrow distinct along inside marginal ridge except for near posterior end where reticulation makes it intermittent. Two horizontal ridges, confined to a posterior half, are more distinct than marginal ridge, and are connected with each other forming a U-shaped junction. Eye tubercle not distinct. External openings of normal pore canals flush, large or small, widely to moderately spaced on ridges or elevated portions, but small, rather closely spaced in some sola.

In internal view, outer margin almost entirely overpassed by outline except for posterior and near anterior terminals of dorsal margin, slightly concave near mid-length. It narrowly curves at posterior terminal of dorsal margin in left valve. Hinge holamphidont; median element slightly longer than half the length of carapace, crooks ventrally near the junction of antero- and posteromedian elements. Anteromedian element rather small, elongate, smooth, protruded laterally as a tooth, and posteromedian element distinctly crenulate linear bar which thickens toward posterior terminal in left valve. Anterior tooth prominent, protruded laterally, and posterior tooth massive, somewhat larger than anterior tooth, incised anteroventrally. Inner lamella moderately wide along anterior margin, and less wide along antero- and posteroventral margins. Line of concrescence apparently coincides with inner margin. Radial pore canals relatively thick, somewhat sinuous, bifurcate in some, bulbous in many at or before an anterior third of their length, and relatively few in number, and more widely spaced anterodorsally. Forty along anterior margin and 14 along posterior margin. Selvage distinct along almost entire outer margin. A distinct list runs along anterior margin. Muscle scars in subcentral area consist of a vertical row of four small and tightly placed adductor scars. An oblong scar in front of them inclined anteriorly. A large and several small scars observable as dorsal scars. Internal openings of normal pore canals thick, widely spaced.

Type and dimensions.—Holotype, right valve, sample H3 (IGPS 97789, Pl. 29, Figs. 5a, b) 0.53 mm long and 0.28 mm high; paratype, left valve, sample I1 (IGPS 97790, Pl. 29, Figs. 6a, b) 0.52 mm long and 0.29 mm high; paratype, right valve, sample H3 (IGPS 97791, Pl. 29, Fig. 8, Pl. 35, Fig. 4) 0.54 mm long and 0.31 mm high; paratype, left valve, sample H3 (IGPS 97792, Pl. 29, Fig. 7) 0.53 mm long and 0.30 mm high.

Type-locality.—At about 81 m west of Ono, Yasuda town, Aki County, Kochi Prefecture (sample H3).

Remarks.—This species is related to *Buntonia parascorta* n. sp. in many respects, but is distinguishable from the latter in having a distinct reticulation in the anterior half of carapace and by lack of distinct radial ridges which bridge across a compressed peripheral zone along anterior margin. *Buntonia u-carinata* also resembles *Buntonia scorta* n. sp. in some respects, but the former has two distinct horizontal ridges which are connected with each other by a U-shaped junction and by lack of a distinct reticulation in the anterior half of carapace.

Occurrence.—Common at P2, L2-4, M1, H2, H3, I1, and G5 (measured mud content 49.5—73.8%, Mdϕ 3.82—4.14).

Family Xestoleberididae Sars, 1928

Genus *Xestoleberis* Sars, 1866

Xestoleberis sp.

Pl. 34, Figs. 1-3; Pl. 35, Fig. 6

Xestoleberis sp. B Ishizaki, 1968, p. 42, pl. 6, fig. 16.

Explanation of Plate 32

Figs. 1, 2, 5. *Callistocythere* sp.
  1. Adult right valve (IGPS 97805; Sample L1).
    a. Lateral view, x 120.
    b. Part of Fig. 1a, showing details of lateral surface, x 800.
    c. Part of Fig. 1a, showing details of external opening of normal pore canal, x 800.
  2. Lateral view, adult left valve (IGPS 97804; Sample G4). x 120.
  5. Internal view, adult right valve (IGPS 97806; Sample M1). x 120.

Figs. 3, 4, 6, 7. *Cytherella japonica* Ishizaki, n. sp.
  3. Immature right valve (Paratype, IGPS 97808; Sample H3).
    a. Lateral view, x 80.
    b. Part of Fig. 3a, showing details of lateral surface, x 1,600.
  4. Adult left valve (Paratype, IGPS 97807; Sample K9).
    a. Lateral view, x 80.
    b. Part of Fig. 4a, showing details of external opening of normal pore canal, x 2,400.
  6. Internal view, adult left valve (Holotype, IGPS 97809; Sample H3). x 80.
  7. Internal view, adult right valve (Paratype, IGPS 97810; Sample K9). x 80.


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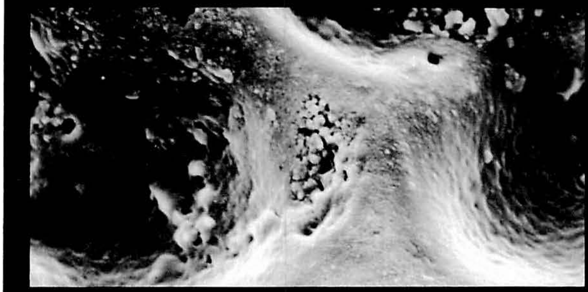
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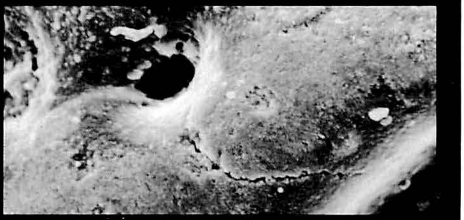
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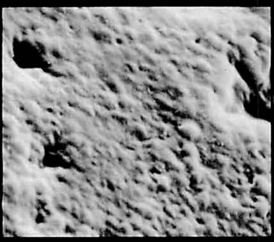
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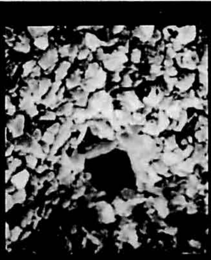
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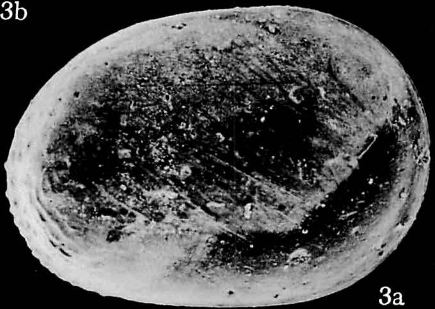
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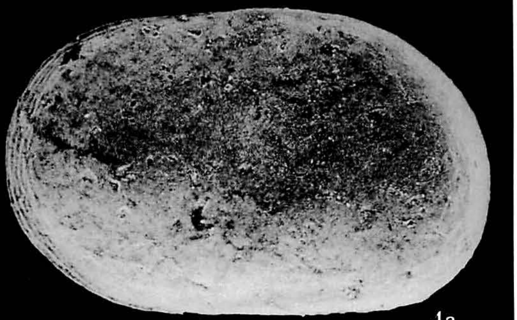
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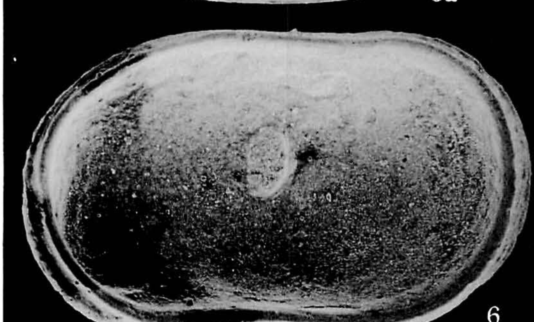
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Description.—Carapace moderate in size, subtrapezoidal or subpentagonal with greatest height slightly behind mid-length in lateral view, and widest around just above a posterior third of ventral margin. Ventral absolutely flat. Dorsal margin distinctly arched, more narrowly protruding slightly behind mid-length. Ventral margin nearly straight. Anterior margin asymmetrical, narrowly rounded well below mid-height, merges into dorsal margin, and meets ventral margin forming a narrowly rounded corner. Posterior margin truncated, ends slightly above posterior terminal of ventral margin, meets dorsal margin forming a more or less distinct cardinal angle, and ventral margin at rounded right angles.

Surface smooth entirely. Eye spots not observed. Sieve-plate pores with setose pores almost flush, widely spaced.

Internally, outer margin broadly concave slightly before mid-length of ventral margin, and its posteroventral area overpassed to a certain extent by outline. Inner lamella moderate in width only in anteroventral area, where a narrow but deep vestibule attains to about three-fourths the width of inner lamella, and much subdued in the remaining portion of extracardinal margin. Radial pore canals simple and numerous in anteroventral and ventral margins, but more widely spaced in anterior and posterior margins. About forty canals in anterior to anteroventral area, four in posterior margin, and 28 in ventral margin. Selvage distinct along entire outer margin. Hinge merodont. Anterior tooth narrow, elongate, and crenulate, and posterior tooth thicker, elongate, slightly arched, and polylobate, and median groove finely crenulate in right valve. Internal openings of normal pore canals simple, rather large.

Dimensions.—Figured specimens, left valve, sample K4 (IGPS 97818, Pl. 34, Fig. 3) 0.61 mm long and 0.33 mm high; right valve, sample K4 (IGPS 97819, Pl. 34, Figs. 1a, b) 0.53 mm long and 0.28 mm high; right valve, sample K4 (IGPS 97820, Pl. 34, Fig. 2, Pl. 35, Fig. 6) 0.59 mm long and 0.31 mm high.

Remarks.—This form is definitely conspecific with *Xestoleberis* sp. B Ishizaki (1968) reported from Uranouchi Bay, Kochi Prefecture, Japan, but is still to be examined for its internal features because only a few relatively well-preserved adult specimens are studied in this work. *Xestoleberis suetsumuhana* Yajima (1982) resembles this form. It is, however, distinguished in that the latter has an anterior vestibule much narrowly confined to the ventral side and the longest axis placed more ventrally.

Occurrence.—Common at P3, K3, K4, and K7 (measured mud content 33.4—58.6%, Mdϕ 3.77—4.05).

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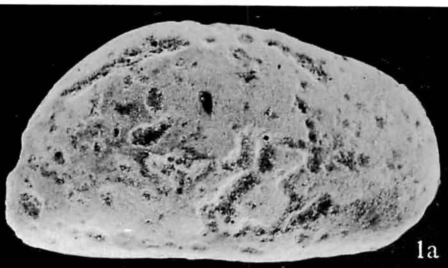
Explanation of Plate 33

Figs. 1—4. *Krithe hanaii* Ishizaki, n. sp.
1. Adult right valve (Paratype, IGPS 97812; Sample K7).
   a. Lateral view, x 80.
   b. Part of Fig. 1a, showing details of lateral surface, x 1,200.
   c. Part of Fig. 1a, showing details of external opening of normal pore canal, x 1,200.
2. Lateral view, adult left valve (Paratype, IGPS 97811; Sample K7), x 80.
3. Internal view, adult left valve (Holotype, IGPS 97813; Sample H2), x 80.
4. Internal view, adult right valve (Paratype, IGPS 97814; Sample K11), x 80.

Figs. 5, 6. *Bairdoppilata* sp.
5. Adult left valve (IGPS 97816; Sample L3).
   a. Lateral view, x 55.
   b. Part of Fig. 5a, showing details of lateral surface, x 800.
   c. Part of Fig. 5a, showing details of external openings of normal pore canals, x 800.
6. Lateral view, adult right valve (IGPS 97815; Sample L4), x 55.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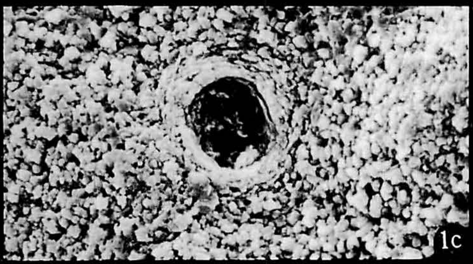
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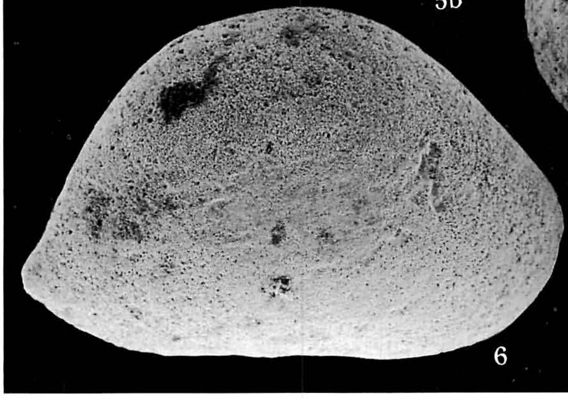
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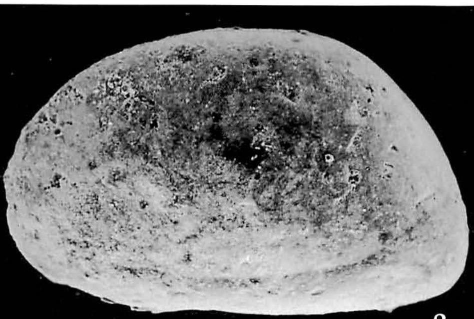
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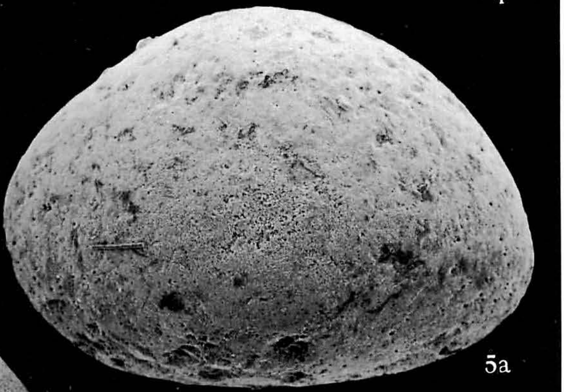
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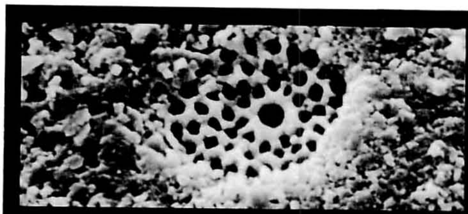
Explanation of Plate 34

Figs. 1—3. *Xestoleberis* sp.
  1. Adult right valve (IGPS 87819; Sample K4).
    a. Lateral view, x 120.
    b. Part of Fig. 1a, showing details of sieve-plate pore, x 3,500.
  2. Inner view, adult right valve (IGPS 97820; Sample K4). x 120.
  3. Lateral view, adult left valve (IGPS 87818; Sample K4). x 120.

Fig. 4. *Bairdoppilata* sp.
  Inner view, adult right valve (IGPS 97817; Sample L1). x 55.

Figs. 5—8. *Munseyella oborozukiyo* Yajima, 1982.
  5. Adult right valve (IGPS 97821; Sample P1).
    a. Lateral view, x 160.
    b. Part of Fig. 5a, showing details of lateral surface, x 550.
    c. Part of Fig. 5a, showing details of external openings of normal pore canals, x 1,200.
  6. Lateral view, adult left valve (IGPS 97822; Sample P1). x 160.
  7. Inner view, adult left valve (IGPS 97824; Sample P1). x 160.
  8. Inner view, adult right valve (IGPS 97823; Sample P1). x 160.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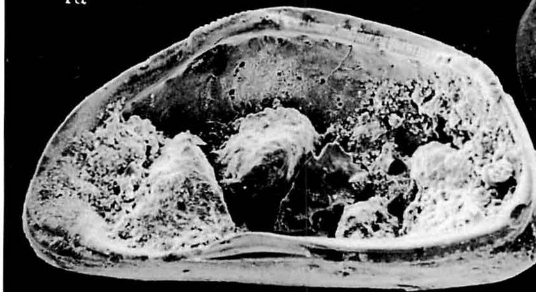
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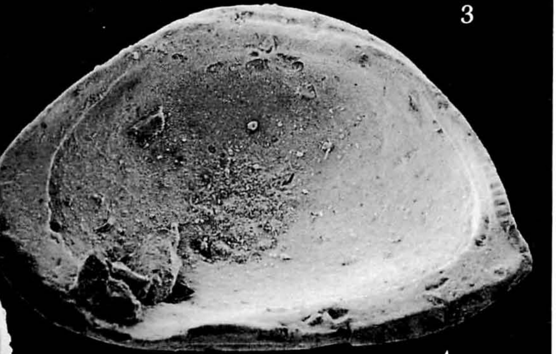
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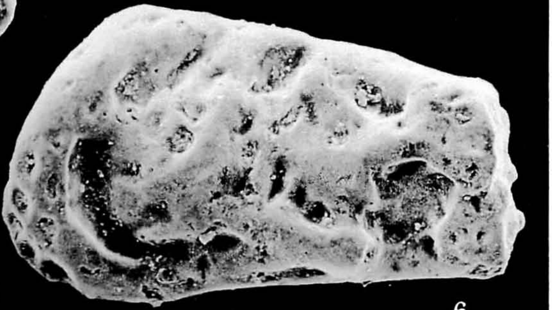
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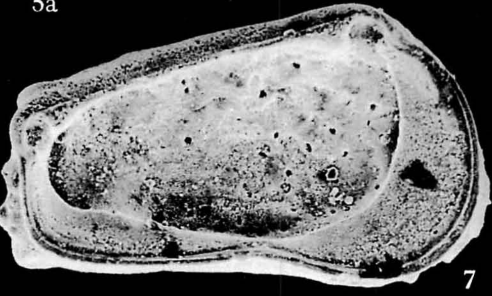
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鮮新統穴内層（四国）の貝形虫—記載—：甲藤ほか（1953）が有孔虫の研究に用いたもののうちの35試料から貝形虫化石を検出した。それらの分類学的検討の結果，穴内層より42属79種の貝形虫種を識別し，それらの産出を表示するとともに，7新種（*Buntonia parascorta, B. scorta, B. u-carinata, Callistocythere ananaiensis, C. kattoi, Cytherella japonica, Krithe hanaii*）および4未命名種を記載した。

穴内層の貝形虫群集は，本邦の上部新生界より従来報告されているものに比して多様で（台湾の上部新生界の要素や Benson (1964) のインド—太平洋界，オーストラリア—タスマニア界，ニュージランド界等の要素を含む），東シナ海陸棚上（とくにその外縁部）の群集と共通した特徴を示している。

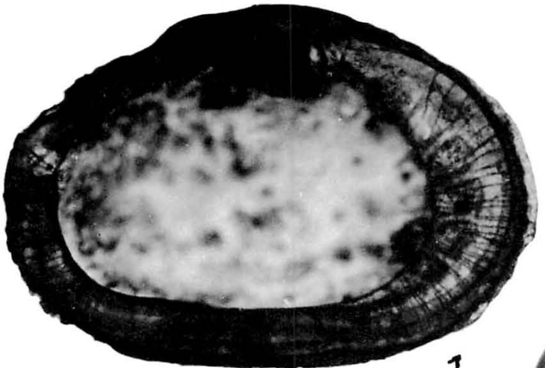
Bairdoppilata, Doratocythere, Jugosocythereis？の3属の本邦上部新生界よりの産出は初めての報告である。

石崎国熙

Explanation of Plate 35

Inner view by transmitted light

Fig. 1. *Buntonia parascorta* Ishizaki, n. sp.
Adult left valve (Paratype, IGPS 97784; Sample H2). x 123.
Fig. 2. *Callistocythere ananaiensis* Ishizaki, n. sp.
Adult right valve (Paratype, IGPS 97798; Sample H1). x 123.
Fig. 3. *Buntonia scorta* Ishizaki, n. sp.
Adult left valve (Holotype, IGPS 97787; Sample G5). x 123.
Fig. 4. *Buntonia u-carinata* Ishizaki, n. sp.
Adult right valve (Paratype, IGPS 97791; Sample H3). x 123.
Fig. 5. *Callistocythere* sp.
Adult right valve (IGPS 97806; Sample M1). x 124.
Fig. 6. *Xestoleberis* sp.
Adult right valve (IGPS 97820; Sample K4). x 124.
Fig. 7. *Munseyella oborozukiyo* Yajima, 1982.
Adult right valve (IGPS 97823; Sample P1). x 167.
Fig. 8. *Callistocythere kattoi* Ishizaki, n. sp.
Adult left valve (Paratype, IGPS 97802; Sample H1). x 121.
Fig. 9. *Krithe hanaii* Ishizaki, n. sp.
Adult left valve (Paratype, IGPS 97813; Sample H2). x 61.
Fig. 10. *Jugosocythereis*? sp.
Immature right valve (IGPS 97794; Sample K2). x 127.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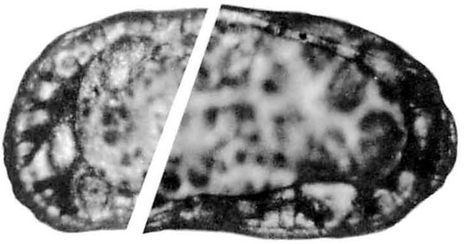
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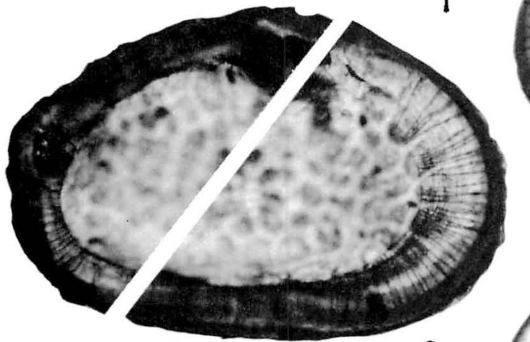
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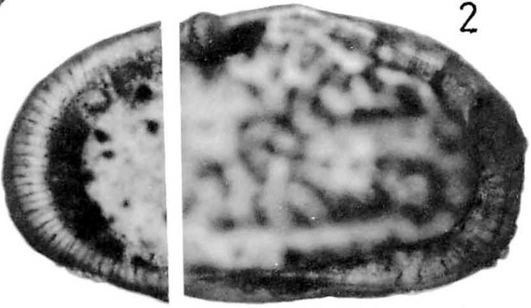
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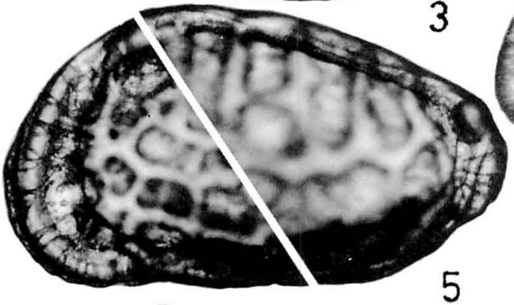
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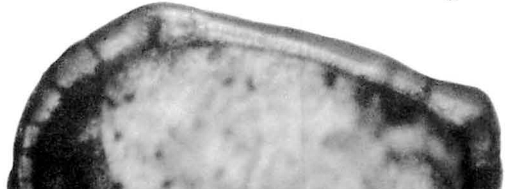
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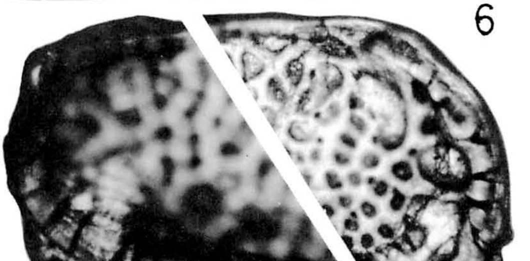
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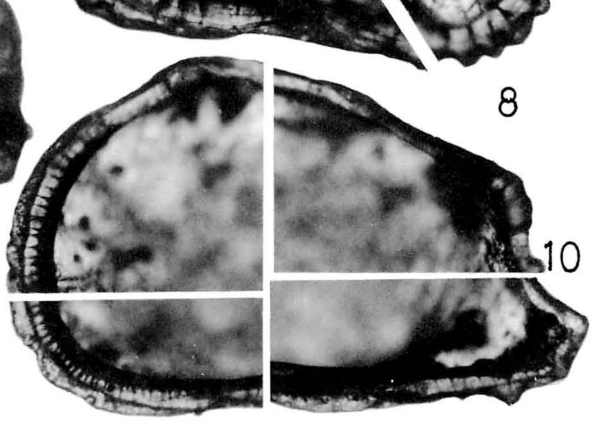
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Trans. Proc. Palaeont. Soc. Japan, N. S., No. 131, pp. 159—167, September 30, 1983

766. OXYGEN AND CARBON ISOTOPIC COMPOSITION IN THE SKELETON OF AN AHERMATYPIC SCLERACTINIAN CORAL, *DENDROPYLLIA JAPONICA* Rehberg*

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Abstract. The variation in oxygen isotope ratio ($^{18}O/^{16}O$) shows the periodicity within a given corallite of an ahermatypic scleractinian coral, *Dendrophyllia japonica* Rehberg, which was collected at the depth of 140 m in the Toyama Bay, Central Japan. The variation in $^{13}C/^{12}C$ ratio, however, is little observed in the same portion of the corallite. The annual growth rate of the corrallite in this area is estimated to be 23—24 mm, the distance from peak to peak in the periodicity, on the bases of the temperature dependence of the $^{18}O/^{16}O$ ratio in ahermatypic coral skeletons and of the seasonal change in local sea water temperature.

The distal part of the same corallite denotes much lower $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios than those in the other parts. This observation suggests that metabolic oxygen and carbon are vigorously incorporated into the skeleton at the front of the growth of coral and that the proportion of skeletal CO_3^{2-} derived from metabolic CO_2 to those from inorganic HCO_3^- taken from sea water is apparently varied in the process of skeletal calcification.

Introductory Notes

Despite the widespread abundance in marine environment, the skeletons of scleractinian corals were not noted for a fairly long time with respect to the oxygen and carbon isotopes after the work of Epstein *et al.* (1951), by the reason of the isotopic disequilibrium with the ambient sea water. In the 1970's, studies on isotopic composition of scleractinian corals became active little by little, and then some noteworth results have been reported one after another.

Weber and Woodhead (1970, 1972a, 1972b) and Weber (1973) examined the coelenterates from many places in respect to the stable isotope ratios of their skeletons. In a series of their research, they reached a conclusion that the most important factors causing isotope ratio variations in the skeletal carbonate of corals are temperature and zooxanthellar activity. Moreover, they showed that the $\delta^{18}O$ value versus temperature curves for various hermatypic scleractinian genera are parallel or nearly parallel to the isotopic paleotemperature scale determined by Epstein *et al.* (1953) and later modified by Craig (1965). In the case, the scleractinian curves are displaced toward more negative $\delta^{18}O$ values. Such a temperature dependence of $\delta^{18}O$ value in hermatypic genera was lately proved for *Montastrea annularis* from several locations by Emiliani *et al.* (1978) and Fairbanks and Dodge (1979). Weil *et al.* (1981) also substantiated the temperature dependence of coral skeletal $\delta^{18}O$ values by their careful experiments on two hermatypic coral species, *Pocillopora damicornis* and *Montipora verrucosa*, which were cultured under various controlled temperature and light conditions. Meanwhile, carbon isotope ratios ($\delta^{13}C$ values) in the skeleton of hermatypic

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* Received Aug. 14, 1982; read Jan. 26, 1980 at Tsukuba.

corals have been considered to change as a function of water depth (Weber *et al.*, 1976; Fairbanks and Dodge, 1979), because $\delta^{13}C$ values are chiefly controlled by the activity of the symbiotic zooxanthellae which is associated with change in light intensity.

Developing the idea of Weber and Woodhead (1970), Goreau (1977) thought out a theoretical model to explain oxygen and carbon fractionation in process of the calcification of hermatypic corals, and then Erez (1978) verified experimentally the mechanism by which lighter carbon and oxygen isotopes (^{12}C and ^{16}O, respectively) were selectively enriched into the skeleton of hermatypic corals.

Deep-sea ahermatypic corals have been known to be generally less depleted in ^{13}C and ^{18}O than hermatypic corals and to be temperature dependent for $\delta^{18}O$ value of their carbonate skeletons (Weber, 1973). Emiliani *et al.* (1978) also discussed the possibility of a small-sized solitary coral *Bathypsammia tintinnabulum* as a temperature indicator, based on the fact that both oxygen and carbon isotopes in the distal part of corallite which was fully matured approached the equilibrium value with sea water.

The main aim of this study is to estimate the annual growth rate of an ahermatypic scleractinian coral *Dendrophyllia japonica* Rehberg by using the cyclic variation of $\delta^{18}O$ value within a given corallite. The change of $\delta^{18}O$ value must be periodical in the adequate part of the same corallite growing in the region where sea water temperature varies seasonally. Because little is known about their growth rate, this attempt may be significant to discuss the skeletal calcification rates of ahermatypic corals without any symbiont, which are living over the entire temperature range of present-day ocean as compared with the relatively narrow temperature range of hermatypes.

Material Studied

During the KT-75-6 Cruise of the R/V "Tansei-maru", an ahermatypic scleractinian coral, *Dendrophyllia japonica* Rehberg, was dredged at six locations in the Toyama Bay (Fig. 1). Most of all specimens were broken branches and it was rarely the case that the basal part was recovered. The bright yellowish-colored polyps were adhered originally to the distal part of each corallite and their color changed to dark brown after the collection, while some organisms encrusted compactly to the proximal part of branches.

It was the specimens collected at the locality named St-26 that were used in the present study, for the reason that the largest quantity of *Dendrophyllia* corallum were dredged with a lot of other benthos. The St-26 was situated at the depth of 140 m, about 10 km off Domi, Nanao City, Ishikawa Prefecture. Only the portion of the skeleton associated with the polyp was

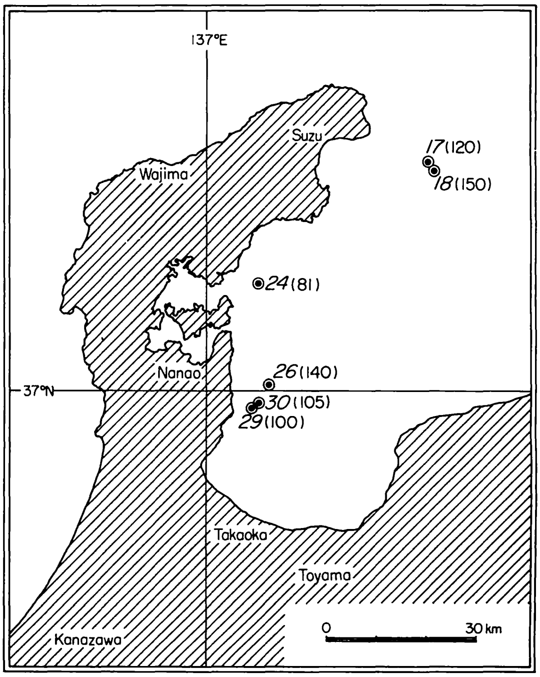

Fig. 1. Index map showing the localities where *Dendrophyllia* corallums were collected during the KT-75-6 Cruise of the R/V "Tansei-maru".
(Italic and parenthesized numbers represent the station number and water depth, respectively.)

analyzed for the purpose of determining the average isotopic composition of *Dendrophyllia* skeleton and of comparing the average isotopic composition between *Dendrophyllia* and shell samples. The shell samples used here were two species of molluscs, *Pycnodonte musashiana* (Yokoyama) and *Chlamys jousseaumei* Bavay, and one of brachiopod, *Terebratulina peculiaris* Hatai. These shell samples were entirely composed of calcite and were 16 mm in length and 15 mm in height, on the average.

A curved but the longest (about 19 cm) *Dendrophyllia* branch was selected in order to examine the variation in both oxygen and carbon isotope ratios within a corallite. The straight part was 6.3 cm in length from the tip. Soft tissues were attached to the distal part up to 14.2 mm in length. Some changes in diameter of the corallite could be observed but did not show any systematic periodicity. This corallite was elliptical in outline, and the maximum diameter attained 21.5 mm. The septa were in five complete cycles, arranged in the hexameral plan.

Experimental Methods

The main portion of septa was took away with a dentist's drill, after removal of polyp by immersion in 10% sodium hypochlorite solution. That is, only wall part of the corallite was used for examining the variation in isotope ratios. Because it was actually impossible to scrape along the isochronal surface inside of septa and special care was exercised to avoid the contamination of younger skeletal materials to older ones. The scraping of the specimen was carried out by use of a flat-shaped and fine-grained file. Both specimen and file were cleaned by blowing the compressed air as often as one sample was cut off. Each sample was finally ground to about 250 mesh (62 μ in diameter).

The powdered sample was roasted at 470°C for 30 min. in an atmosphere of flowing helium. Carbon dioxide was evolved under vacuum by reaction with 100% phosphoric acid and subsequently extracted and purified as described before (Omura, 1977). Measurements were made on powder ranging in weight from 15 through 20 mg. The sample gas was extracted by standard techniques using trichloroethylene and liquid nitrogen cooled traps. The standardized analytical procedure involved a reaction time of about 15 hours and an extraction period of 20 min.

Isotope ratios were determined with the McKinney type mass spectrometer in which sample and standard gases were alternately compared up to six times for 3 min. intervals. Isotope ratios are reported in the widely used delta notation with respect to PDB standard CO_2 as:

$$\delta^{18}O = \frac{Rx - Rs}{Rs} \times 1{,}000 \ (‰, \text{per mil})$$

where R is the $^{18}O/^{16}O$ (or $^{13}C/^{12}C$ for $\delta^{13}C$) ratio, and x and s refer to sample and standard, respectively. The reproducibility of the measurement was less than 0.18 per mil for $\delta^{18}O$ and about 0.11 per mil for $\delta^{13}C$. The isotopic composition of a working standard (CK-13) used in this study has already established with respect to PDB standard through interlaboratory calibration with H. A. Lowenstam and S. Epstein of the California Institute of Technology and R. N. Clayton of the Chicago University (Nakamichi *et al.*, 1969).

Results and Discussion

(1) Composition of *Dendrophyllia* skeleton versus shell samples.

The mean isotope ratios ($\delta^{18}O$ and $\delta^{13}C$ values) of *Dendrophyllia* skeleton and shell samples are summarized in Table 1.

The mean $\delta^{18}O$ and $\delta^{13}C$ values of three species of shell samples are +0.91 (±0.55) and +2.15 (±0.27) per mil, respectively. However, δ values of shell samples examined here cannot be used for the precise comparison with those of *Dendrophyllia* samples, because they are composed of the different mineral phase with each

Table 1. Mean oxygen and carbon isotope ratios of *Dendrophyllia japonica* Rehberg and three shell samples.

Sample	$\delta^{18}O$*	$\delta^{13}C$*
Dendrophyllia japonica	- 2.48(0.79)10	- 6.53(0.90)10
Terebratulina peculiaris	+ 0.67(0.33)5	+ 1.95(0.21)5
Chlamys jousseaumei	+ 0.70(0.63)5	+ 2.42(0.08)5
Pyenodonte musashiana	+ 1.36(0.30)5	+ 2.10(0.22)5

*Format for data: mean delta value(standard deviation) number of specimens analyzed.

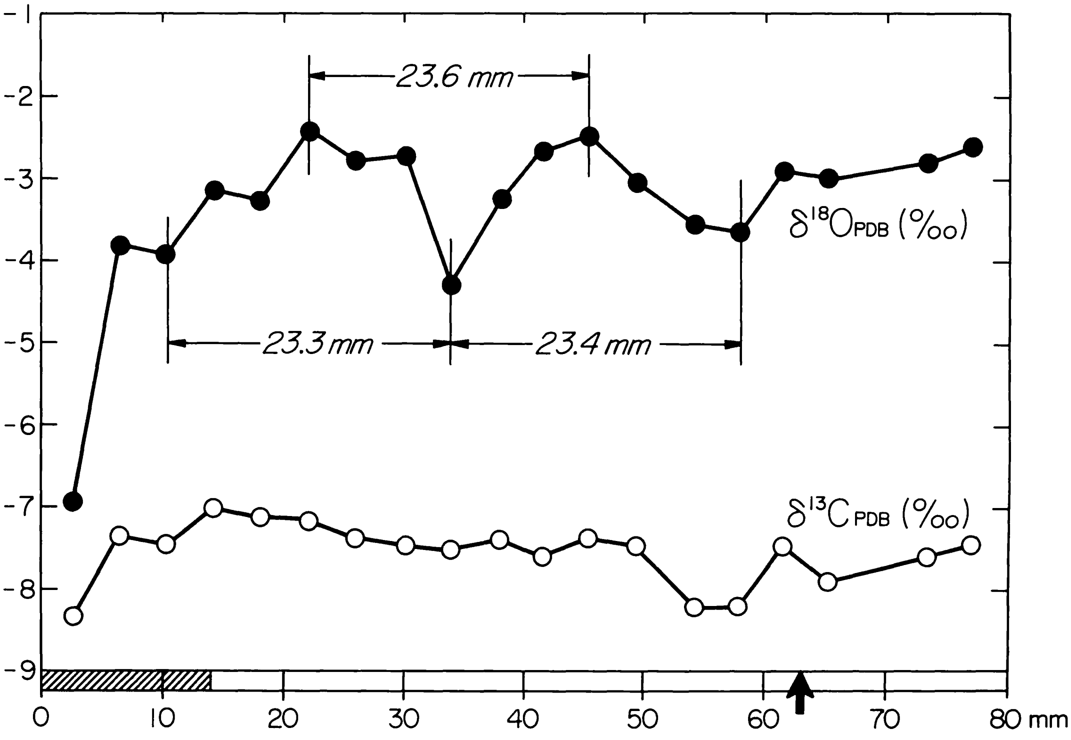

Fig. 2. Variations in $\delta^{18}O$ and $\delta^{13}C$ values within a corallite of *Dendrophyllia japonica* Rehberg. (Shaded part denotes the region where polyp was attached; the arrow shows the curvature point of the corallite.)

other. It is possible to estimate the δ value of the aragonitic material in isotopic equilibrium with sea water. Such an aragonite is expected to give the δ^{18}O value of +1.8 per mil relative to the PDB standard, by using the equation of Horibe and Oba (1972). Accordingly, *Dendrophyllia* skeleton is thought to be approximately 4.3 per mil lower in δ^{18}O value than the aragonite in isotopic equilibrium with sea water. Depending on the data of Weber and Woodhead (1972a), the difference in δ^{18}O value between skeletons of hermatypes and the aragonite in isotopic equiilibrium is not exceeding 3 per mil at a given temperature. Therefore, it can be conclusively said that the above observations support the strong "bital effect" of ahermatypic corals, as mentioned by Weber (1973).

(2) Variations in δ^{18}O and δ^{13}C values within a corallite.

Variations in oxygen and carbon isotope ratios within a given corallite are illustrated in Fig. 2.

δ^{13}C value does not vary systematically and its variation is characterized by the limited ranges, particularly in the straight-elongated part of the corallite. On the other hand, Fig. 2 denotes clearly the cyclic variation of δ^{18}O value in the corallite up to about 6 cm in length from the tip. The range of variation in δ^{18}O value is 1.17 to 1.91 per mil. The distance from peak to peak in the periodicity is 23 to 24 mm.

If the salinity of the ambient sea water changed seasonally, apparent δ^{18}O and δ^{13}C values alike should be influenced and show the same pattern of their variations. The limited range in variation of δ^{13}C value suggests that the chemistry of the sea water is little varied by the seasonal change in influx of fresh water. If the variation in δ^{18}O value within the corallite depends substantially on temperature curve is parallel or nearly parallel to the paleotemperature scale, as pointed out by Weber and Woodhead (1972a), the variation from 1.17 to 1.91 per mil in δ^{18}O value means that the seasonal change in sea water temperature is approximately 5 to 8°C at the sampling location. So far some data at the location tell us about the change in temperature and salinity of the sea water through the year (Figs. 3 and 4). Such data seem to support that the temperature range of 5 to 8°C is not irrelevant as the seasonal variation in sea water temperature even at the depth of 140 m near the location where the samples analyzed were collected.

For those reasons, the cyclic variation in δ^{18}O value is considered to be caused by the seasonal change of sea water temperature. In other words, the distance from peak to peak seen in the periodicity is regarded as an annual growth rate of *Dendrophyllia japonica* Rehberg. The *Dendrophyllia* specimen used here was a broken branch, and hence it is quite hard to infer what part in a dendroid corallum was examined. It may, however, be said that the

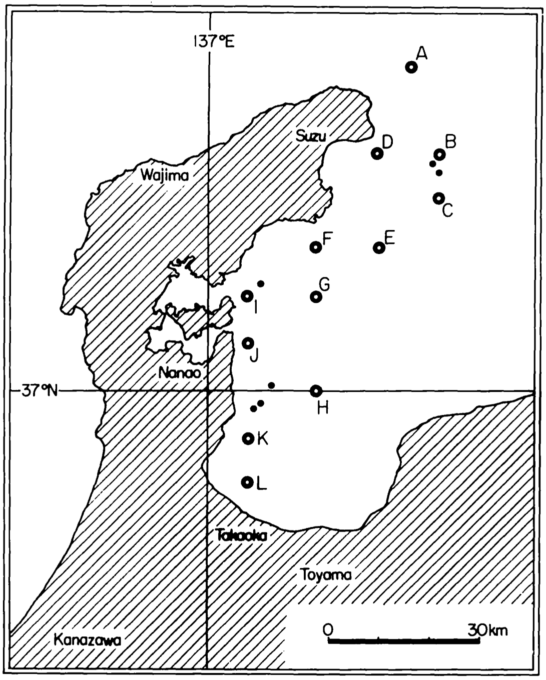

Fig. 3. Map showing some locations where fixed point observation is carried out for temperature and salinity of sea water by the Fisheries Experiment Station of Toyama Prefecture.
(Small black circles show the localities where *Dendrophyllia* corallums were found to inhabit at present.)

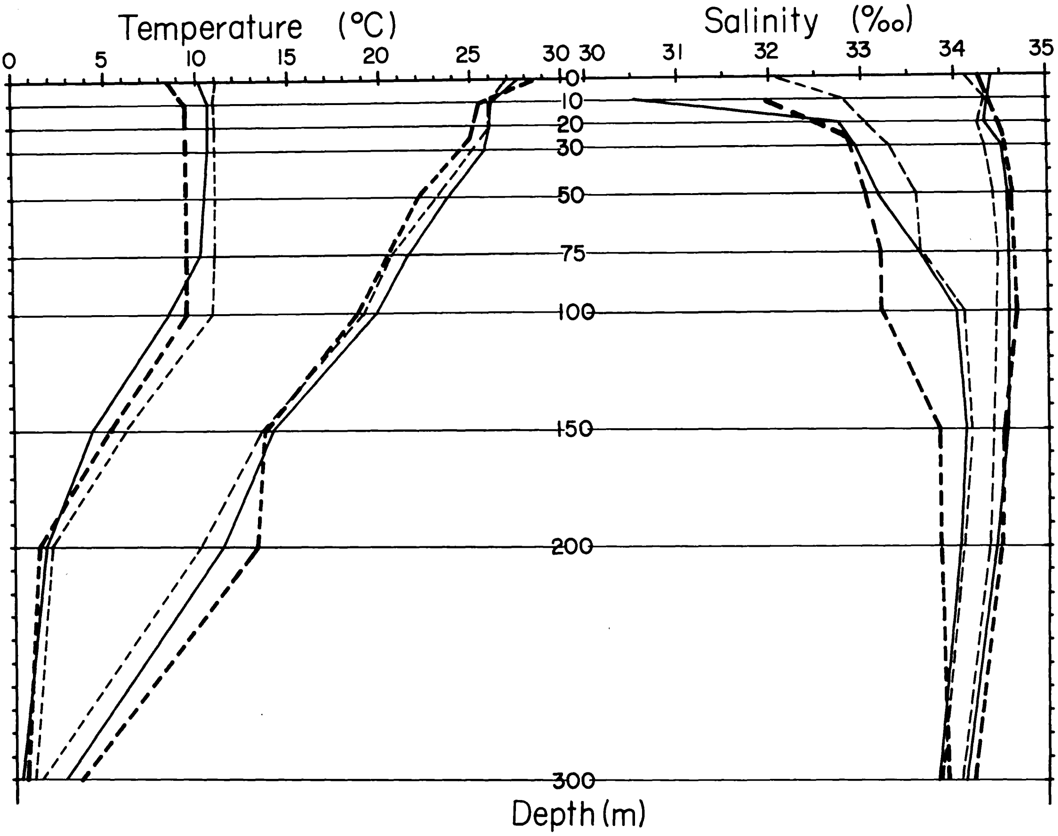

Fig. 4. The range of variation in temperature and salinity of sea water in the Toyama Bay. (Thick dotted lines are drawn on fifty data at twelve locations from points A to L, from April, 1953 through March, 1958: while thin solid and dotted lines on ten data from November, 1978 through November, 1979, at twelve locations and point H, respectively.)

partial annual growth rate of *Dendrophyllia* corallum attains 23 to 24 mm at this place. It has often been said that growth rates of ahermatypic corals are much lower than hermatypes. Because they do not have a favorable influence upon the symbiotic zooxanthellae in their calcification process. Further elucidation on the cyclic variation in $\delta^{18}O$ value will require more detail observations. The growth rate of *Dendrophyllia* should be reconfirmed with a radiochemical technique by use of short-lived radioactive isotopes.

(3) Oxygen and carbon isotope ratios at the tip of a corallite.

Another interesting result was obtained in the variation of oxygen and carbon isotope ratios within a corallite. It is the low $\delta^{18}O$ and $\delta^{13}C$ values observed at the tip of the corallite (Fig. 2). In order to make sure whether such an extremely low δ value is a characteristic common to all of *Dendrophyllia* corallite, only the wall part of three portions in a corallite was taken out from the other four corallite specimens as shown in Fig. 5 and were examined for isotopic composition.

As a result, it is clear that all of the examined corallite show the same pattern without exception (Table 2). Because metabolic carbon is some 12 to 17 per mil lighter and metabolic oxygen is some 10 per mil ligher than those derived from HCO_3^- in sea water (Weber and Woodhead, 1970; Land *et al.*, 1975; Goreau, 1977; Emiliani *et al.*, 1978), it is very likely that metabolic carbon and oxygen are vigorously incorporated into the skeleton which is secreted at the front of growth. That is, the proportion of skeletal CO_3^{2-} derived from metabolic CO_2 to that from inorganic HCO_3^- taken from sea water seems to vary in the process of the skeletal calcification by hermatypic scleractinian coral. Such an apparent variation in isotopic composition is summarized in Fig. 6. In the case of *Dendrophyllia* skeletons, it does never approach the value in isotopic equilibrium with sea water, as shown for a small-sized solitary coral *Bathypsammia tintinnabulum* by Emiliani *et al.* (1978). These facts is suggestive the followings: (1) *Dendrophyllia* grow infinitely at the same growth rate if circumstances permit, whereas ahermatypic simple corals like *Bathypsammia* cannot exceed certain limit in size: (2) The higher δ values in a corallite except the tip may be resulted from reformation of the isotopic composition due to the secondary thickenning or the secondary deformation of fine skeletal structure during the life time of scleractinian coral as observed in rugosa by Kato (1963).

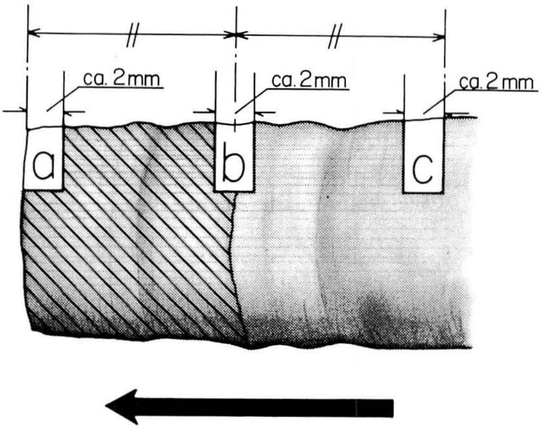

Fig. 5. Simplified sketch of *Dendrophyllia* specimen showing three portions to examine the variation in $\delta^{18}O$ and $\delta^{13}C$ values within a corallite.
(Shaded part and black arrow represent the limit of adherent polyp and growth direction, respectively.)

Corallite No.	a		b		c	
	$\delta^{18}O_{PDB}$	$\delta^{13}C_{PDB}$	$\delta^{18}O_{PDB}$	$\delta^{13}C_{PDB}$	$\delta^{18}O_{PDB}$	$\delta^{13}C_{PDB}$
1	- 6.94	- 8.35	- 3.13	- 7.00	- 2.81	- 7.38
2	- 7.45	- 8.63	- 2.48	- 7.10	- 2.84	- 7.37
3	- 6.04	- 8.06	- 3.00	- 6.18	- 4.25	- 5.82
4	- 6.06	- 7.81	- 3.31	- 5.74	- 3.53	- 6.20
5	- 4.66	- 8.79	- 3.63	- 7.33	- 3.43	- 7.04
Mean delta value	- 6.23	- 8.36	- 3.11	- 6.67	- 3.37	- 6.76
Standard deviation	(±1.06)	(±0.41)	(±0.42)	(±0.68)	(±0.59)	(±0.71)

Table 2. $\delta^{18}O$ and $\delta^{13}C$ values in different three portions within the same corallite.
(See Fig. 5 for the portion analyzed.)

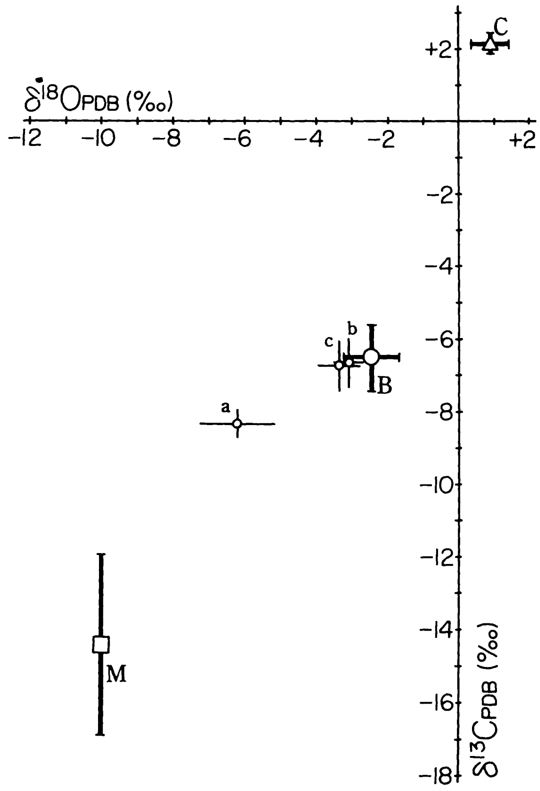

Fig. 6. $\delta^{18}O$ versus $\delta^{13}C$ diagram of the samples examined in this study.
(B and C show mean δ values of bulk *Dendrophyllia* skeleton and shell samples, respectively; a, b and c, mean δ values of three portions illustrated in Fig. 5; M, δ value of metabolic carbon and oxygen in coral skeleton, mentioned by Weber and Woodhead, 1970; Land *et al.*, 1975; Goreau, 1977; and Emiliani *et al.*, 1978.)

Acknowledgments

I wish to thank Prof. K. Konishi of the Department of Earth Sciences, Faculty of Science, Kanazawa University, for his continuous encouragement throughout this study. Coral and shell samples used in this work were identified by Drs. K. Mori and K. Ogasawara of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University. My thanks are also due to the KT-75-6 crew of the R/V "Tansei-maru" of the Ocean Research Institute, University of Tokyo, for collecting the samples and to members of the Fisheries Experiment Station of Toyama Prefecture for their permission to cite the data on temperature and salinity of sea water in the Toyma Bay.

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非造礁性サンゴ *Dendrophyllia japonica* Rehberg 骨格中の酸素・炭素同位体組成：石川県七尾市百海東方約 10 km・水深 140 m の地点からドレッジされた非造礁性サンゴの一種 *Dendrophyllia japonica* Rehberg 骨格中の酸素・炭素同位体比（$^{18}O/^{16}O$・$^{13}C/^{12}C$）を求めた。その結果，炭素同位体比の変動がほとんど見られないのに対し，同一 corallite の成長方向に沿って酸素同位体比の周期的変動が明らかになった。$\delta^{18}O$ 値の変動巾は 1.2～1.9‰ で，周期性にみられる各ピーク間の距離は 23～24 mm であった。このことは，非造礁性サンゴ骨格中の酸素同位体比の温度依存性から，生息環境における水温の季節変化を示すと考えられ，周期性にみられた各ピーク間の距離から採集地付近の同種のサンゴの成長率が 20 mm/yr 以上に達すると結論できる。

また，corallite の最先端部における酸素・炭素同位体比がともに上記の周期性にみられた変動巾をこえて，著しく低い δ 値を示すことが明らかになった。この事実から，とくに成長の最前線でサンゴ固有の代謝作用で作られる，いわゆる metabolic な酸素および炭素がさかんに取込まれていること，またサンゴ骨格の石灰化過程で，導入される酸素・炭素のうち，海水中の重炭酸イオン（HCO_3^-）由来のものと metabolic なものとの割合が変化するように思われる。

大 村 明 雄

Trans. Proc. Palaeont. Soc. Japan, N. S., No. 131, pp. 168–176, pls. 36, 37, September 30, 1983

767. LOWER TRIASSIC RADIOLARIA FROM THE KANTO MOUNTAINS, CENTRAL JAPAN
PART 1: PALAEOSCENIDIIDAE*

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Abstract. Abundant and well-preserved Lower Triassic Radiolaria occurs from the Ogamata Formation, Kanto Mountains, Central Japan. This radiolarian assemblage contains Palaeoscenidiidae and many other spumellaria. Three genera and five species of Palaeoscenidiidae were discriminated from the chert beds intercalated in this formation. This spicular radiolarian assemblage is quite similar to that of Paleozoic, and is very important to investigate the relationship between Paleozoic and Mesozoic spicular Radiolaria. In this paper, I described the following five species of Palaeoscenidiidae; *Archaeosemantis venusta* Sashida, n. sp., *Archaeosemantis* sp., *Parentactinia nakatsugawaensis* Sashida, n. sp., *Archaeothamnulus ramosus* Sashida, n. sp., and *Archaeothamnulus*? sp.

Introduction and Acknowledgments

Since the method of individual separation by the acid treatment was established, our knowledge of the Triassic radiolarian fauna has been accumulated by Kozur and Mostler (1972, 1978, 1979, 1981), Wever et al. (1979), Pessagno et al. (1979), Dumitrica (1978a, b, 1982) and Dumitrica et al. (1980) etc. Also, in Japan, Nakaseko and Nishimura (1979) clarified a part of the Upper Triassic radiolarian fauna with the detailed description. Moreover, biostratigraphical and paleontological studies of Triassic radiolarians have been worked out by Yao et al. (1982), Matsuda and Isozaki (1982), Mizutani and Koike (1982) and others. According to these contributions, the Triassic radiolarian biostratigraphy and the zonation based on the short ranged genera and species will be possible to establish. The Triassic Radiolaria is very important to investigate the relationship between Paleozoic and Middle to Upper Mesozoic radiolarian assemblages.

Based on many thin sections, Fujimoto (1933) discriminated two types of radiolarian assemblage, "Paleozoic-type" and "Mesozoic-type" in chert formations distributed in the Kanto Mountains and brought the "Argument of Radiolaria" in Japan. However, since then, no comprehensive study of radiolarian fossils of chert formations has been made in the Kanto Mountains. I have been studying the Mesozoic and Paleozoic Radiolaria from the Kanto Mountains, and the present study deals with the Lower Triassic Palaeoscenidiidae from chert beds embedded in the Ogamata Formation distributed in Okuchichibu.

I will express my sincere thanks to Professor Hisayoshi Igo of the University of Tsukuba for his continuous guidance in various ways and critical reading of this manuscript. I am also very much indebted to Professor Tadashi Sato and Dr. Shigeru Takizawa of the University

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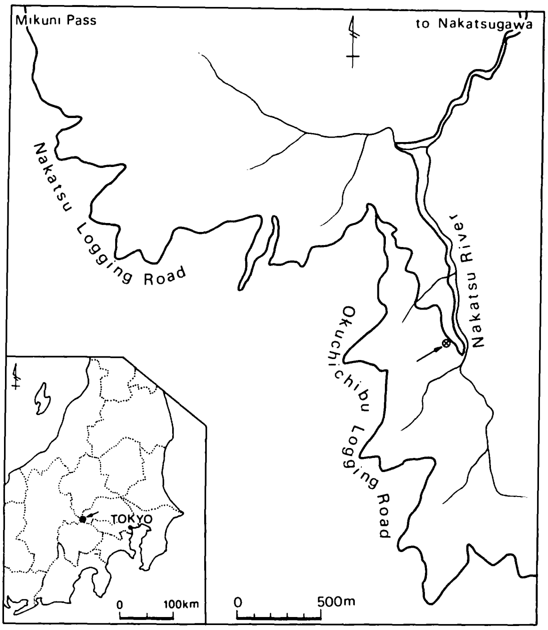
Geological Setting

The Lower Triassic Radiolaria was discriminated from the Ogamata Formation typically exposed in the upper reaches of the Nakatsu River in Saitama Prefecture (Text-fig. 1). The geology of this area was summarized by Fujimoto et al. (1950), Fujimoto et al. (1957) and Ishii (1962). Recently, Ishii and Matsukawa (1980) restudied the stratigraphy and geologic structure of this formation. However, Sato et al. (1981), Sashida et al. (1982) discriminated Jurassic Radiolaria from the shale beds of this formation and discussed the necessity of revision of stratigraphy and geologic structure. The following stratigraphic units are recognized in the Ogamata Formation, near the type section, in descending order (Text-fig. 2):

7: Medium- to fine-grained sandstone; including volcanic breccia and alternation of sandstone and mudstone — more than 30 meters thick.
6: Fine-grained sandstone; intercalating shale in the lower part and conglomerate with pebbles of various kinds of sedimentary origin and basic rocks in the upper part — about 100 meters thick.
5: Shale; including sandstone blocks of about three meters in maximum diameter — about 15 meters thick.
4: Chert; — about 60 meters thick.
3: Medium- to fine-grained sandstone; frequently including shale beds in the lower and upper parts — about 20 meters thick.
2: Black shale; with sandstone blocks of 10 meters in diameter and discontinuous chert beds — about 20 meters thick.
1: Fine-grained sandstone; with intercalation of shale beds in the lower and middle parts — 40 to 50 meters thick.

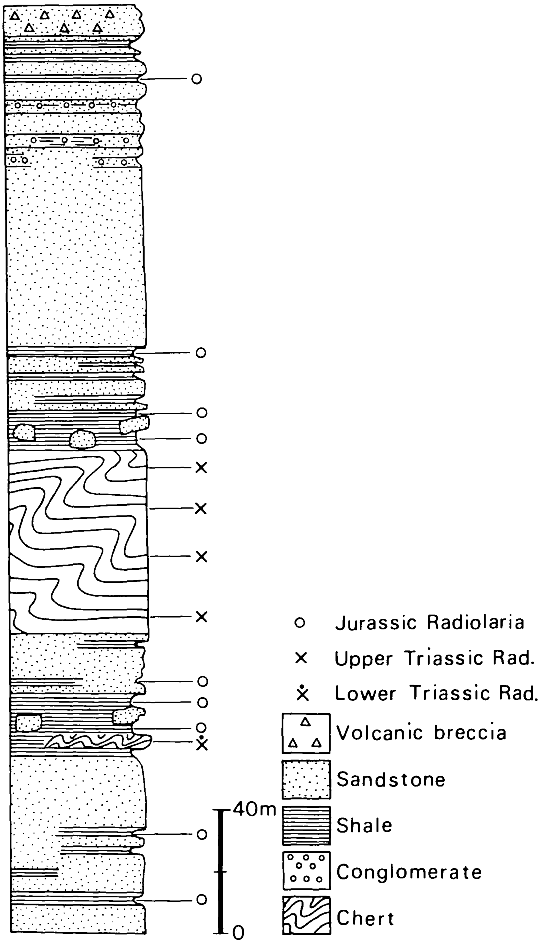


Text-fig. 1: Map showing the locality of the Lower Triassic Radiolarians.

The Lower Triassic conodont, *Neospathodus* sp., and the present radiolarian fauna occur from lower chert beds of unit 2. This chert is usually dark gray to black and interbedded with tuffaceous films. The Upper Triassic conodonts, *Epigondolella postera* and others and also well-preserved radiolarians were discriminated from the upper chert beds of unit 4. Jurassic Radiolaria was obtained from all of shaly facies of this formation.

Note on the Family Palaeoscenidiidae

Deflandre (1953) first introduced the spicular Radiolaria with four basal spines under the name of *Palaeoscenidium* from the Lower Carboniferous deposits of Montagne Noire, France. Subsequently, Radiolaria with the same basal skeletons has been reported from the Upper Devonian of the Ohio Shale (Foreman, 1963) and South Ural (Nazarov, 1975), and from the Silurian of Cornwallis Islands (Holdsworth, 1977). On the other hand, Dumitrica (1978b) reported the spicular Radiolaria with four basal spines which resembles Paleozoic Palaeoscenidiidae from the Lower Ladinian of Italy and Rumania. Dumitrica proposed the Subfamily Pentactinocarpinae to



Text-fig. 2: Generalized columnar section of the Ogamata Formation, near the type section.

the Triassic Palaeoscenidiidae that has four basal spines and one apical spine, and the spumellarian skeleton was covered by globular cortical shell. Moreover, he introduced a new genus *Parentactinia* to the Family Entactiniidae having similar basal skeletons to *Palaeoscenidium*, but this genus shows bar-centered spine and has globular shell connected with basal spine. Recently, Dumitrica (1982) described many Middle Triassic spicular radiolarians, some of which he had included in Palaeoscenidiidae and Entactiniidae from the same samples. He discussed possible relationship among these radiolarians and some Paleozoic and Cenozoic taxa.

Furutani (1982, 1983) discussed the construction and phylogeny of Paleozoic and Mesozoic Palaeoscenidiidae. According to his study, Palaeoscenidiidae is composed of Palaeoscenidiinae and Pentactinocarpinae. Palaeoscenidiinae is characterized by having the skeleton of two to four apical spines and four basal spines with median bar. On the other hand, Pentactinocarpinae consists of one apical spine and four basal spines. He suggested that Pentactinocarpinae was derived from Palaeoscenidiinae by extinction of three minor apical spines, and discriminated seven genera in Palaeoscenidiinae and five genera in Pentactinocarpinae. Takemura and Nakaseko (1982a, b) investigated the skeleton of the Jurassic palaeoscenidiids from manganese ore deposits in the Mino Belt, Central Japan. They distinguished two types of Palaeoscenidiidae belonging to Nassellaria, and discussed the relationship between the Paleozoic and Jurassic palaeoscenidiids. Moreover, they pointed out the revision of definition of the Family Palaeoscenidiidae.

Lower Triassic Palaeoscenidiidae from the Kanto Mountains is usually well-preserved and abundantly occurs. Three genera and five species of Palaeoscenidiidae were discriminated. *Archaeosemantis venusta* Sashida, n. sp. basically consists of four basal spines and four apical spines (Text-fig. 3), and this species resembles closely *Palaeoscenidium cladophorum* described by Deflandre (1953), Foreman (1963) and Nazarov (1975). It is also similar to *Archaeosemantis pterostphanus* Dumitrica (1978b) and *Archaeosemantis cristianensis* Dumitrica (1982) that have peculiar morphology and broad variations. *Parentactinia nakatsugawaensis* Sashida, n. sp. having four, long straight basal spines and basket-like shell, is comparable to *Parentactinia* with palaeosceniid skeletons as shown in Text-fig. 5. However, this species is easily distinguishable from *Parentactinia* of Dumitrica in having long and straight basal spines that do not show eccentric feature. The ill-preserved specimens without shell of this species (Pl. 2, Figs. 2, 6, 7) are quite similar to Paleozoic Radiolaria, *Bissylentactinia rudicula* Nazarov and *Haplentactinia rhinophusa* Foreman. Moreover, Middle Triassic spicular Radiolaria *Palhindeolithus paululus*, *Tandarnia arachnoconcha* and *Tandarnia recoarense* which were described by Dumitrica (1982), resemble ill-preserved specimens of *Parentactinia nakatsugawaensis*. *Archaeothamnulus ramosus* Sashida, n. sp. resembles *Archaeothamnulus verticillatus* introduced by Dumitrica (1978b, 1982), but usually its preservation is not complete.

Systematic Description

Subclass Radiolaria Müller, 1858

Order Polycystina Ehrenberg, 1838, emend. Riedel, 1967

Suborder Spumellaria Ehrenberg, 1875

Family Palaeosenidiidae Riedel, 1967, emend. Holdsworth, 1977

Genus *Archaeosemantis* Dumitrica, 1978

Archaeosemantis venusta Sashida, n. sp.

Pl. 36, Figs. 1-9

Diagnosis.—Spicular skeleton with commonly six to eight stout spines arising from ends of very short median bar. Three or four of them are longer, and other spines commonly shorter and straight.

Description.—Commonly, four, long, delicate, rod-like basal spines and four, rod-like tapering apical spines. The basal spines with rugged external surface, divergent and curved inward on a half, and distally tapering. Each of the basal spines forms an angle of 55—60 degrees with its neighbours. The divergent apical spines are generally short, about a third to a fourth of the basal spines, and some of them gently curved downwardly.

Dimensions.—Length of basal spines 115—200 microns, apical spines 25—75 microns (generally 30—70 microns), based on nine illustrated specimens.

Remarks.—The present species resembles *Palaeoscenidium cladophorum* originally described from Montagne Noire (Deflandre, 1953) Ohio Shale (Foreman, 1963), and South Ural (Nazarov, 1975). However, the former species is distinguished from the latter by having straight basal spines, with numerous spinules approximately at right angles to the spine. Moreover, *Palaeoscenidium cladophorum* described by Foreman, has lamellar quadrangular cup. Dumitrica (1982) introduced *Archaeosemantis cristianensis* from the Lower Ladinian of the Buchenstein Limestone of Italy. His two illustrated specimens (pl. 3, fig. 11, pl. 7, fig. 3) of this species rather resemble those of *Archaeosemantis venusta*. However, the former species is easily distinguishable from the latter by having two laterally directed apical spines and the basal spines with spinules. Dumitrica (1982) also described *Archaeosemantis longivirga* from the same limestone. This species has four apical and basal spines. However, it is distinguishable from *Archaeosemantis venusta* by rather long median bar and thorny spines.

The species name is from Latin, *venustus*, beautiful.

Reg. nos. IGUT 5800 (Holotype), 5801—5808 (Paratypes).

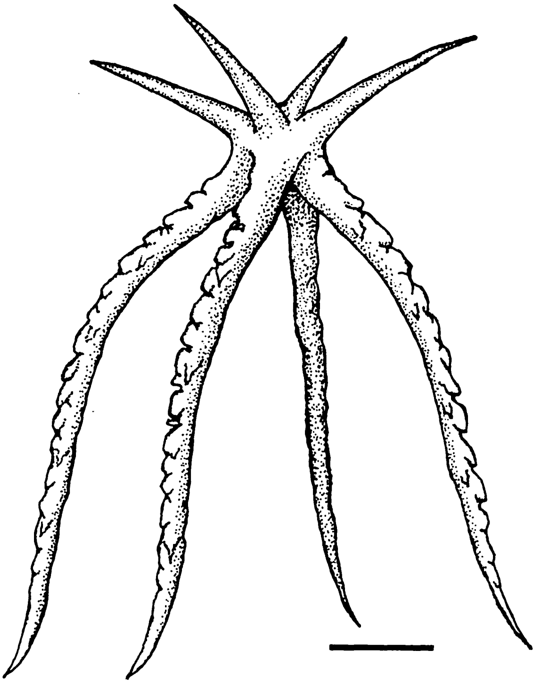
Archaeosemantis sp.

Pl. 36, Fig. 10

Description.—Four to five sturdy basal spines and one to two tapering apical spines. The basal spines with the remainder of numerous thorny spinules, straight, divergent, and tapering. Each of basal spines forms an angle of 30—70 degrees. The apical spines shorter than one half to one third of the basal spines, rod-like, and have rugged surface.

Dimensions.—Basal spines 100—120 microns, and apical spines 60 microns based on illustrated specimen.

Remarks.—Two specimens are obtained. The present species resembles *Archaeosemantis venusta* in having similar basal skeletons. However, it is distinguishable from the latter by



Text-fig. 3: *Archaeosemantis venusta* Sashida, n. sp. (scale = 25 microns)

having stout straight basal spines with remainders of spinules. The basal skeleton of this species is similar to *Palhindeolithus pulcher* reported by Deflandre (1973) from Montagne Noire, but it differs from the latter in the number and surface feature of the basal spines.

Reg. no. IGUT 5815.

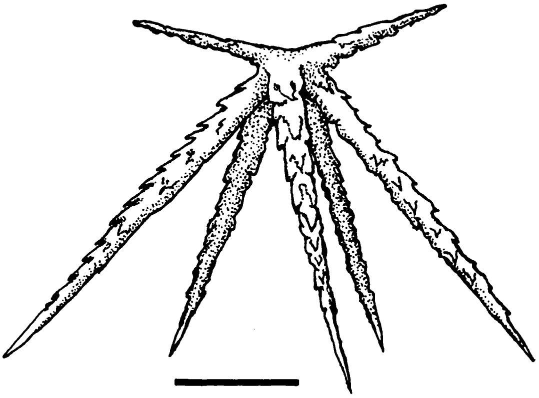
Genus *Parentactinia* Dumitrica, 1978

Parentactinia nakatsugawaensis Sashida, n. sp.

Pl. 37, Figs. 1-9

Diagnosis.—Generally, spicule consisting of a short median bar and eight stout spines, of which four spines are long and constitute base of an incomplete single globular shell.

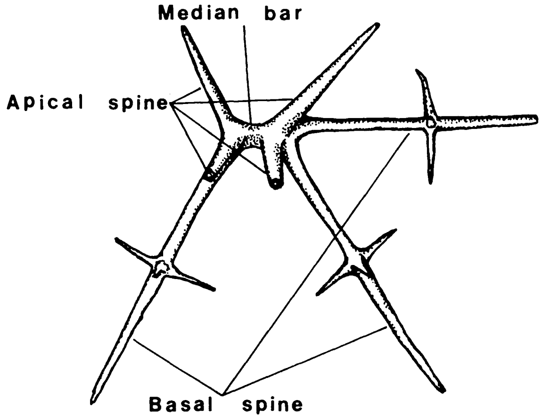
Description.—Four apical spines conical, obliquely directed, two of them rather long, rodlike, tapering and two others short. Four basal spines cylindrical, long, stout, straight and divergent. They connected with a rather loose hemispheric shell having irregular shaped pores resulted by intersection of bars with various angle. Four stout spinules approximately at right angles to the basal spines, connected with these bars and sustains this hemispheric shell. The shell is not complete in apical region. The basal spines seem to be not covered by shell but remains as ridges.



Text-fig. 4: *Archaeosemantis* sp. (scale = 50 microns)

Dimensions.—Basal spines 165—225 microns, long apical spines 80—115 microns and short apical spines 25—50 microns based on 9 specimens.

Remarks.—The present species abundantly occurs, however, the well-preserved specimens with shell are rare. The basal skeleton of this species as shown in Text-fig. 5, has palaeonscenidiid affinities (Furutani, 1982), and is related to *Parentactinia* of Dumitrica (1978b). This species resembles *Parentactinia pugnax* described by Dumitrica (1978b). Especially his illustrated specimen (pl. 4, fig. 5) is quite similar to *Parentactinia nakatsugawaensis*. However, *Parentactinia nakatsugawaensis* has long straight basal spines and more incomplete shell compared with *Parentactinia pugnax*. The basal skeletons without hemispheric shell also resemble Paleozoic spicular Radiolaria, such as *Haplentactinia rhinophyusa* Foreman, *Bissylentactinia rudicula* Nazarov and others. *Tandarnia recoarensis* and *Tandarnia arachnoconcha*, spicular Nassellaria of Middle Triassic (Dumitrica, 1982), are similar to ill-preserved *Parentactinia nakatsugawaensis*. However, the



Text-fig. 5: Basal skeleton of *Parentactinia nakatsugawaensis* Sashida, n. sp.

former two species are easily distinguishable from the latter by the disposition of its spines. Reg. nos. IGUT 5817 (Holotype), 5818–5825 (Paratypes).

Genus *Archaeothamnulus* Dumitrica, 1982

Archaeothamnulus ramosus Sashida, n. sp.

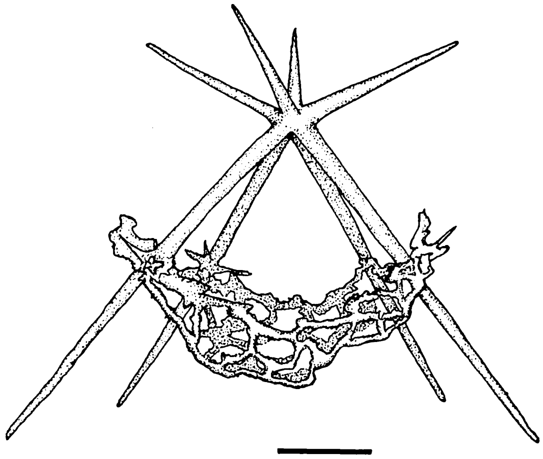
Pl. 37, Figs. 10-12

Diagnosis.—Skeleton formed of long spicule with five sturdy spines arising from center. Commonly four of them diverge obliquely downward and bear a vertical, and the other spine arises apically and bears a vertical of short spinules.

Description.—Siliceous spicule consisting of a straight axial spine and four slightly curved basal spines. The four basal spines make an angle of 80–90 degrees with close vicinity of the center, consisting of three spines convex inward. At first joint, a stout rod-like tapering spine branches to make an angle of about 120 degrees with its neighbours, and two or three spinules divergent at the second joint. Both the spines and basal spines of the whole skeleton are cylindrical.

Dimensions.—Axial length 30–50 microns, total length of the preserved basal spines probably 500–600 microns. Maximum diameter of main spines 7–12 microns.

Remarks.—Five specimens have been recorded from the Ogamata Formation. The present species is closely related to *Archaeothamnulus verticillatus* reported by Dumitrica (1978b, 1982) from the Lower Ladinian of the Buchenstein Limestone, Recoaro, Italy. However, the latter species has longer basal spine and one branching near the center. Deflandre (1973) reported *Xiphocladiella cuja* from the Lower Carboniferous in Montagne Noire. This species has four to five basal spines and long axial spines with complicated branching spinule at middle part. The basal skeleton of this species slightly resembles *Archaeothamnulus ramosus* Sashida, n. sp.



Text-fig. 6: *Parentactinia nakatsugawaensis* Sashida, n. sp. (scale = 30 microns)

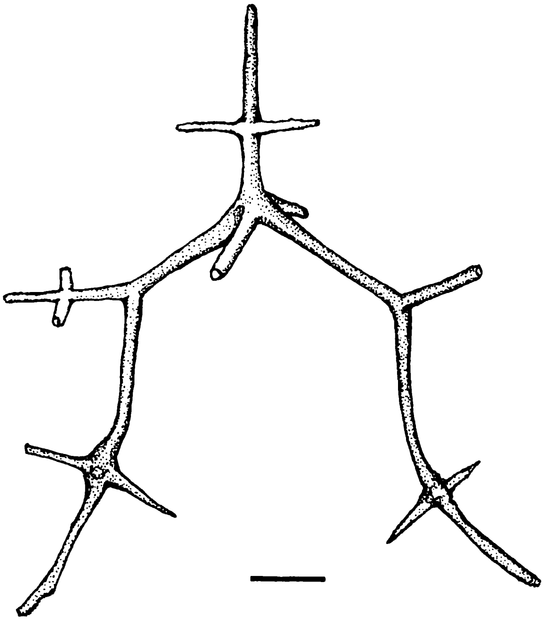
The species name is from Latin, *ramus*, branching.

Reg. nos. IGUT 5827 (Holotype), 5828 and 5829 (Paratypes).

Archaeothamnulus? sp.

Pl. 36, Figs. 11-13

Description.—Four, long, slender, rod-like basal spines, one or two rather short tapering apical spines. The basal spines with smooth surface, divergent to draw an arch, but some of them straight and tapering ends usually curved inward. The apical spines shorter than a third to a fourth of the basal spines, and gently curved downward.



Text-fig. 7: *Archaeothamnulus ramosus* Sashida, n. sp. (scale = 25 microns)

Dimensions.—Basal spines 350—580 microns, apical spines 100—140 microns? based on three specimens.

Remarks.—Dumitrica (1982) introduced many Middle Triassic spicular Nassellaria from the Buchenstein Limestone. Among them, *Tandarnia simplicima* is rather similar to the present species. However, *Archaeothamnulus*? sp. can be distinguishable from *Tandarnia simplicima* and other spicular Nassellaria by the disposition of its spines. This species also resembles Paleozoic spicular Radiolaria *Palacantholithus stellatus* described by Deflandre (1973) from Montagne Noire in having long arched basal spines. However, the latter has spinule at right angles to the basal spines.

Reg. nos. IGUT 5810 (Holotype), 5811 and 5812 (Paratypes).

All specimens described herein are stored in the collections of Institute of Geoscience, the University of Tsukuba (IGUT).

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Explanation of Plate 36

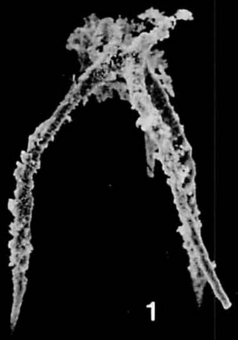
Figs. 1—9: *Archaeosemantis venusta* Sashida, n. sp.

1.	holotype, x250	IGUT. 5800
2.	paratype, x340	IGUT. 5801
3.	paratype, x440	IGUT. 5802
4.	paratype, x280	IGUT. 5803
5.	paratype, x320	IGUT. 5804
6.	paratype, x320	IGUT. 5805
7.	paratype, x280	IGUT. 5806
8.	paratype, x320	IGUT. 5807
9.	paratype, x320	IGUT. 5808

Fig. 10: *Archaeosemantis* sp.
x250 IGUT. 5815

Figs. 11—13: *Archaeothamnulus*? sp.

11.	x150	IGUT. 5810
12.	x170	IGUT. 5811
13.	x200	IGUT. 5812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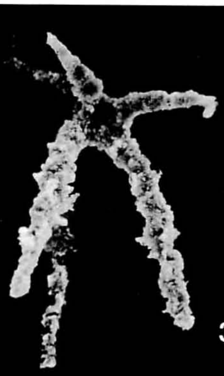
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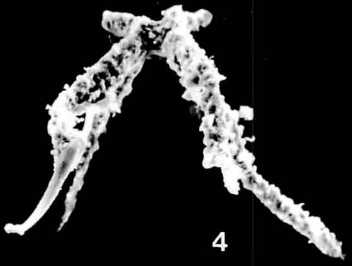
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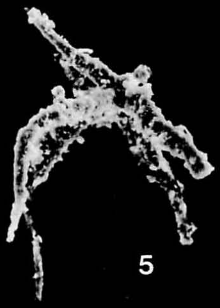
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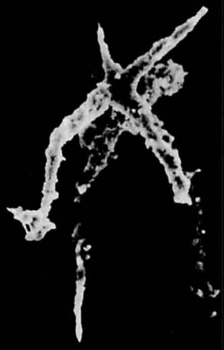
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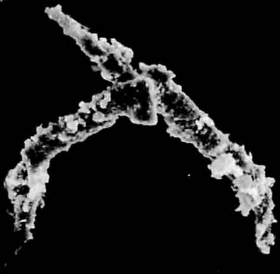
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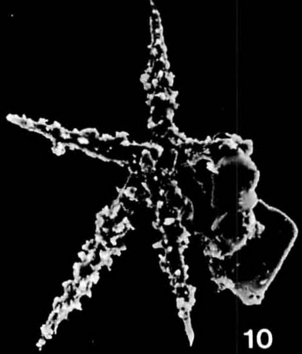
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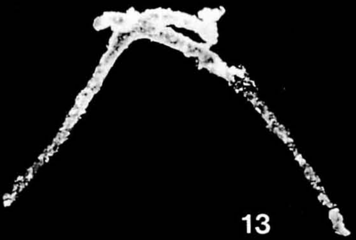
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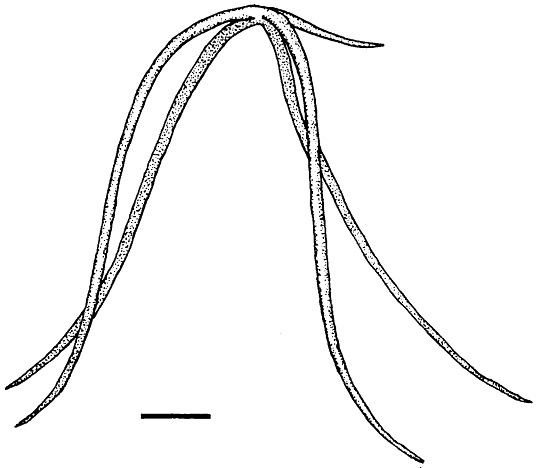

Text-fig. 8: *Archaeothamnulus*? sp. (scale = 50 microns)

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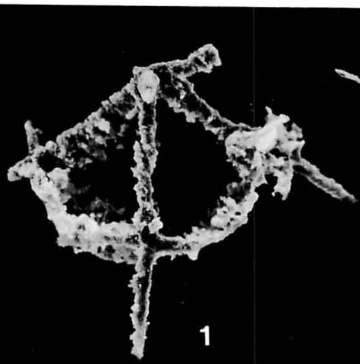
関東山地より産する下部三畳系放散虫化石その1 Palaeoscenidiidae：関東山地奥秩父に分布する大ガマタ層から，豊富で保存良好な下部三畳系放散虫化石を産する。この放散虫化石群集には Palaeoscenidiidae をはじめ多くの Spumellaria が含まれ，現在まで3属，5種の Palaeoscenidiidae が識別されている。ここでは，次のような Palaeoscenidiidae 5種（内，3種は新種）を記載した。*Archaeosemantis venusta* Sashida, n. sp., *Archaeosemantis* sp., *Parentactinia nakatsugawaensis* Sashida, n. sp., *Archaeothamnulus ramosus* Sashida, n. sp., *Archaeothamnulus* ? sp.

指 田 勝 男

Explanation of Plate 37

Figs. 1—9: *Parentactinia nakatsugawaensis* Sashida, n. sp.
1. paratype, x350 IGUT. 5818
2. paratype, x200 IGUT. 5819
3. holotype, x200 IGUT. 5817
4. paratype, x260 IGUT. 5820
5. paratype, x250 IGUT. 5821
6. paratype, x280 IGUT. 5822
7. paratype, x200 IGUT. 5823
8. paratype, x300 IGUT. 5824
9. paratype, x230 IGUT. 5825

Figs. 10—12: *Archaeothamnulus ramosus* Sashida, n. sp.
10. paratype, x250 IGUT. 5828
11. holotype, x250 IGUT. 5827
12. paratype, x250 IGUT. 5829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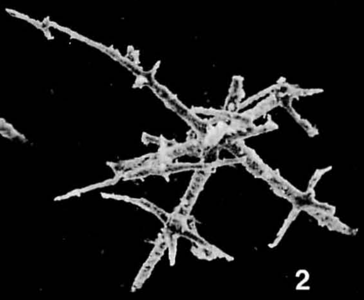
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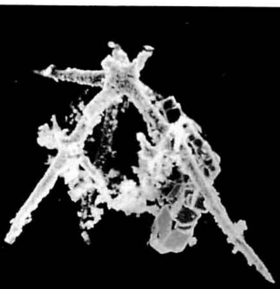
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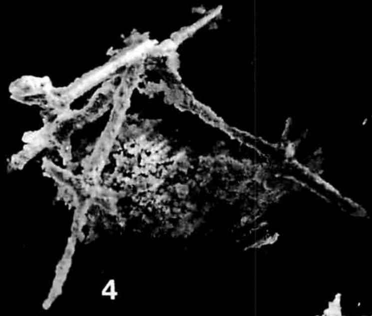
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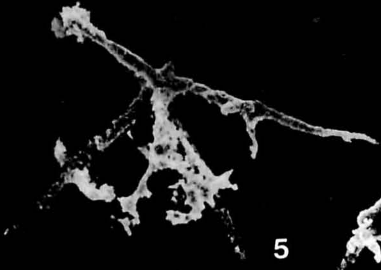
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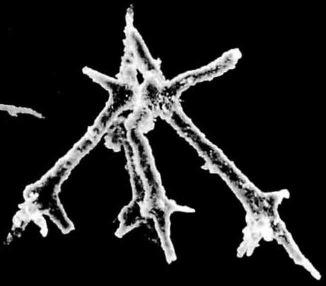
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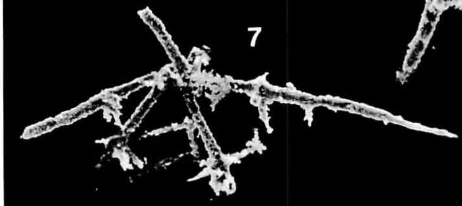
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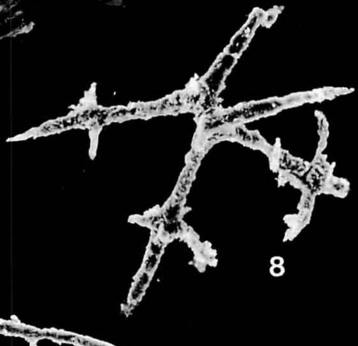
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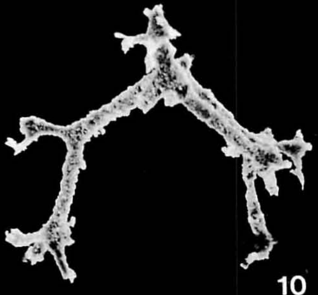
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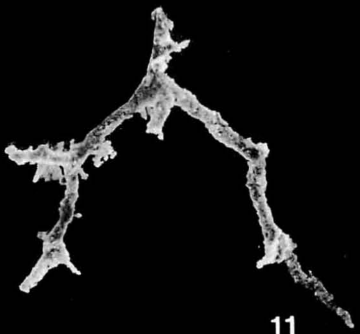
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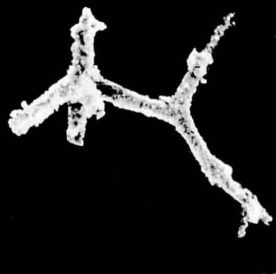
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Trans. Proc. Palaeont. Soc. Japan, N. S., No. 131, pp. 177—190, pls. 38—40, September 30, 1983

768. ON THE SUBGENUS *WAKINOA* (CRETACEOUS NON-MARINE BIVALVIA) FROM GYEONGSANG GROUP, KOREA*

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Abstract. In genus *Trigonioides* (s.l.), the subgeneric difference can be read on the median V-ribs angle and the length ratio and the strength of the pseudocardinal hinge teeth, not the number of hinge teeth. Considering the stratigraphic sequence as well as the taxonomic characters, *Wakinoa* is thought as transitional form between *Koreanaia* and *Trigonioides* (s.s.). In addition, this paper contains description of two species of *Wakinoa* and a new species of *Trigonioides* (s.s.) from lower Gyeongsang Group, Korea.

Introduction and Acknowledgements

Wakinoa has been known as an important and interesting member in non-marine fauna of the Mesozoic Asia together with *Trigonioides* (s.s.), *Plicatounio*, *Nippononaia*, and *Koreanaia* since it was erected by Ota (1963) on "*Nippononaia*" *wakinoensis* from Japan. *Wakinoa* possesses several common characters with other trigonioidid genera or subgenera. However, its taxonomic relation and stratigraphic positions are not clearly grasped yet, because the fossil localities have been found in separate basins, and the fossil preservation is not sufficiently good.

This paper is to make clear the taxonomic characters of *Wakinoa*, discussing its relationships with other relevant subgenera, and to describe two species of *Wakinoa* and a new species of *Trigonioides* (s.s.) from Korea.

Acknowledgements.—I would like to express my sincere gratitude to Emeritus Professor Tatsuro Matsumoto of Kyushu University for his continuous encouragement during my study and critical reading of the typescript of this paper. I would like also to thank Dr. Minoru Tamura of Kumamoto University for his friendly help including a guidance to fossil localities in the Mifune group, and Mr. J. W. Kim of Kyungpook National University for his support in field and laboratory works.

This study was financially supported by the Korean Traders Scholarship Foundation.

Relationship of *Wakinoa* with other Subgenera of Genus *Trigonioides*

At present, the genus *Trigonioides* contains four subgenera, *Trigoniodes* (s.s.), *Wakinoa*, *Koreanaia*, and *Kumamotoa*. These subgenera possess common characters in both of the surface ornamentation and the internal structures. On the surface ornamentation, the subgenera are characterized by the V-shaped median ribs and reversed V-ribs on both the anterior and posterior parts. As to the internal structures, the two subequal adductor scars and the minute

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* Received September 29, 1982; read October 3, 1981, at Hiroshima.

pedal scar as well as the hinge teeth, 5, 4, 3, 2/PII, PIII, PIV are in common in all the subgenera.

The subgeneric difference can be read in both the median V-ribs angle and the hinge structure. As previously mentioned (Yang, 1974, 1976, 1979), the median V-ribs angle is larger than 35 degrees in *Koreanaia*, about 30 degrees in *Wakinoa*, and less than 20 degrees in *Trigonioides* (s.s.) and *Kumamotoa*.

Before discussing the subgeneric difference in the hinge structure, the synopsis on the dental formulae can be shown as follows:

Koreanaia;

$$\begin{array}{ccccccc} 5 & & 3 & & & \mathrm{PIII} & \\ \hline & 4 & & 2 & \mathrm{PII} & & \mathrm{PIV} \end{array}$$

Wakinoa;

$$\begin{array}{cccccccc} 5 & & 3 & & (1) & & \mathrm{PIII} & \\ \hline & 4 & & 2 & & \mathrm{PII} & & \mathrm{PIV} \end{array}$$

Trigonioides (s.s.);

$$\begin{array}{ccccccccc} 5 & & 3 & & 1 & & & \mathrm{PIII} & \\ \hline & 4 & & 2 & & (1') & \mathrm{PII} & & \mathrm{PIV} \end{array}$$

(*T. kodairai*)

$$\begin{array}{ccccccccccccc} & 5 & & 3 & & 1a & & 1b & & 1c & & \mathrm{PIII} & \\ \hline (6) & & 4 & & 2 & & 1'a & & 1'b & & \mathrm{PII} & & \mathrm{PIV} \end{array}$$

(*T. paucisulcatus*)

Kumamotoa;

$$\begin{array}{ccccccccc} 5 & & 3 & & 1a & & & \mathrm{PIII} & \\ \hline & 4 & & 2 & & (1'a) & \mathrm{PII} & & \mathrm{PIV} \end{array}$$

(*Ku. suzukii*)

$$\begin{array}{cccccccccccc} & 5 & & 3 & & 1a & & 1b & & & \mathrm{PIII} & \\ \hline (6) & & 4 & & 2 & & 1'a & & (1'b) & \mathrm{PII} & & \mathrm{PIV} \end{array}$$

(*Ku. mifunensis*)
(*Ku. matsumotoi*)

On account of the number of hinge teeth, there must be a problem in the classification of subgenera as pointed out by Tamura (1981). That is, *T. kodairai* and *Kumamotoa suzukii* would not be discriminated from each other, and *Kumamotoa mifunensis* and *Kumamotoa matsumotoi* would be also considered as members of *Trigonioides* (s.s.). In addition to the above dental formulae, considering the hinge structure of a new species of *Trigonioides* (s.s.) (described below), the number of the pseudocardinal teeth is gradually increased with upward stratigraphic sequence. Therefore the number of the pseudocardinal teeth cannot be considered as subgeneric taxonomic character.

However, the subgeneric difference can be found on other hinge characters such as the transverse crenulations, the relative length of the pseudocardinals and the morphology of hinge plates. The transverse crenulations on the hinge teeth are also the important common character in the present genus except some of the *Koreanaia* spp. (*K. cheongi* and *K. yunnanensis*). But the crenulations on the pseudocardinals are very fine in both of *Wakinoa* and *Koreanaia* but fairly strong and rather stout in *Kumamotoa*. In *Trigonioides* (s.s.), they are also regular but of intermediate intensity between the above two. Furthermore, there is a difference in the relative length of the pseudocardinals between the subgenera. That is, the ratio of 1a to 3 is less than 0.3 in *Trigonioides* (s.s.) but larger than 0.6 in *Kumamotoa* (Yang, 1974). In other words, the submedian pseudocardinals 1a and 1b are fairly long in *Kumamotoa*, but rather short and weak in *Wakinoa* and *Trigonioides* (s.s.). And the hinge plate of *Kumamotoa* is wider than that of any other subgenera. For these comparisons, Text-figure 1 and Figures 8—20 of Plate 39 are shown.

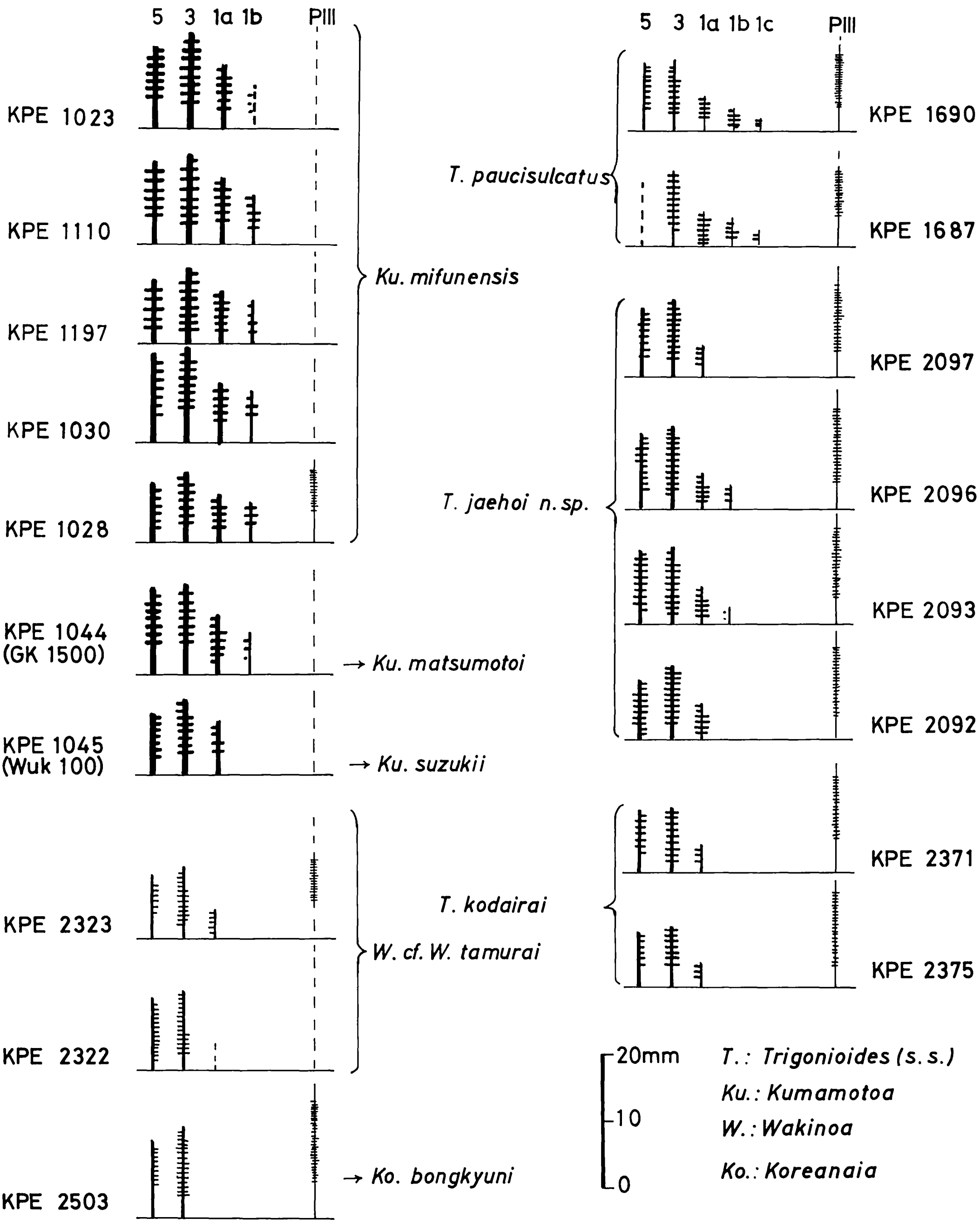
Considering the stratigraphic horizons of the fossils as well as the taxonomic characters, *Wakinoa* is regarded as a transitional form between *Koreanaia* and *Trigonioides* (s.s.).

Incidentally, *Trigonioides kodairaiformis* Martinson, 1965, from southeastern Fergana, U.S.S.R., is considered to be referred to *Wakinoa* rather than to *Trigonioides* (s.s.) in its surface ornamentation (Martinson, 1965, pl. 1, figs. 1—5) and hinge teeth.

Systematic Description

Superfamily Unionacea

Family Trigonioididae Cox, 1952



Text-figure 1. Comparison of the subgeneric differences in hinge teeth of the genus *Trigonioides*.
Crenulation: illustrated by short horizontal lines,
Tooth length: expressed by vertical line.

Genus *Trigonioides* Kobayashi and Suzuki, 1936

Subgenus *Wakinoa* Ota, 1963

Type-species.—"*Nippononaia*" *wakinoensis* Ota, 1959.

Subgeneric diagnosis (emend.).—Shell medium in size, suboval to subelliptical in outline, subequilateral and equivalve. Umbo moderately high and prosogyrous, located at about two fifth of the shell length from the anterior extremity. Hinge plate moderate in breadth, provided with the short pseudocardinal teeth and long posterior lateral ones, the pseudocardinals two or three on right valve, two on left valve, and the posterior lateral ones one on right valve, two on left valve, forming the following dental formula:

$$\begin{array}{cccccccc} 5 & & 3 & & (1) & & \text{PIII} & \\ \hline & 4 & & 2 & & \text{PII} & & \text{PIV} \end{array}$$

where 4, 3 and PIII: with fine transverse crenulations on both sides, 5 and PII: with fine transverse crenulations on posterior (or dorsal) side only, (1) and PIV: with fine transverse crenulations on anterior (or ventral) side only, and 2 crenulated on both sides or anterior side only. Both muscle scars well defined, the anterior one accompanied with a minute pedal scar. Inner ventral margin crenulated. Surface ornamented with numerous V-shaped ribs in the median part and the reversed V-ribs on both of the anterior and the posterior sides, the angle of the median V-ribs about 30 degrees.

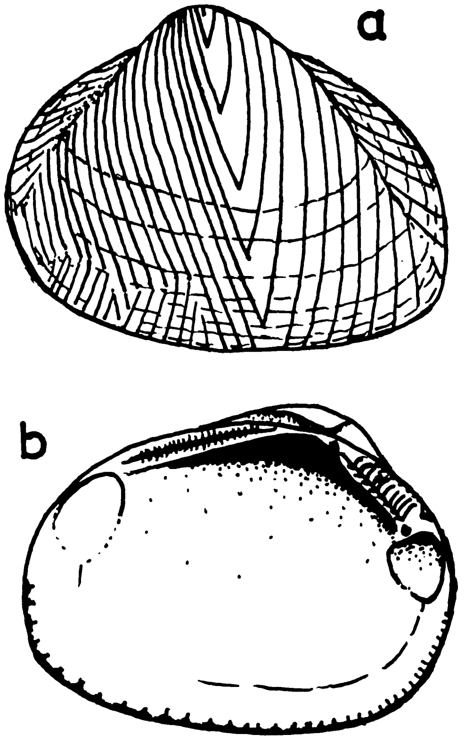
Trigonioides (Wakinoa) sp. cf. *T. (W.) tamurai* Yang, 1976

Pl. 38, Figs. 1-15, Text-fig. 2

Material.—Thirty four specimens (KPE 2311—33, 2348—56, 2364—65) collected from the light grey siltstone and greenish grey greywacke of the upper Middle Hasandong Formation, Nagdong Subgroup, Gyeongsang Group, Korea (Coll. S. Y. Yang).

Measurements (in mm) of *Trigonioides (Wakinoa)* sp. cf. *T. (W.) tamurai*

Specimens	L	H	L/H
Conjoined (KPE 2311)	59.2	45.3	1.31
Left valve (KPE 2312)	35.6++	27.9	
Left valve (KEP 2314)	42.5++	38.9	
Left valve (KPE 2315)	25.3+	15.8+	
Left valve (KPE 2316)	—	34.1	
Left valve (KPE 2317)	23.6	15.0	1.57
Right valve (KPE 2319)	—	31.6	
Right valve (KPE 2348)	40.3++	32.2+	
Conjoined (KPE 2352)	42.2	34.6	1.22
Conjoined (KPE 2364)	49.7+	42.6	1.17+



Text-figure 2. *Trigonioides (Wakinoa)* sp. cf. *T. (W.) tamurai* Yang, 1976.
a: surface ornamentation and outline of the left valve,
b: internal structures of the left valve.

Description.—Shell medium in size (about 20—60 mm in length), generally suboval in outline; subequilateral and equivalve; anterior margin well rounded, posterior one rather straight and obtusely angulate at the postero-ventral corner, ventral margin broadly arcuate; umbo fairly prominent, slightly prosogyrous, placed at about two-fifths of shell length from the anterior extremity, and projected slightly above the hinge line. Test moderate in thickness.

Surface ornamented with numerous V-shaped ribs in the median part and the reversed V-ribs on both of the anterior and the posterior sides. The antero-ventral half occasionally ornamented with multiple V-ribs on some specimens. The angles of the median V-ribs about 30 degrees and those of the reversed V-ribs on both sides about 45—60 degrees. The subradial ribs and grooves on the posterior half much stronger and wider than those on the anterior half. The subradial median ribs number more than 18 on the anterior half and more than 12 on the posterior half on the adult large specimens. The whole surface ornamented also with fine numerous concentric growth-lines of irregular interval and prominence. Posterior ridge running from the umbo down to the postero-ventral corner.

Hinge plate moderate in breadth, provided with opisthocline pseudocardinal teeth and postero-lateral teeth; the pseudocardinal ones two or three on the right valve, two on left valve; the postero-lateral teeth one on the right valve, two on the left valve, forming the following dental formula:

$$\frac{5\quad 3\quad (1)\qquad \mathrm{PIII}\qquad}{\quad 4\quad 2\qquad \mathrm{PII}\qquad \mathrm{PIV}}$$

where 5: narrow and elongated, with fine transverse crenulations on the ventral (lower) side only, parallel to the antero-dorsal margin,

3: largest and highest in the right valve, with fine transverse crenulations on both sides, subparallel to the antero-dorsal margin,

1: smallest and low in the right valve, occasionally indistinct, with a few fine transverse crenulations on the anterior side only, nearly vertical,

PIII: longest in the right valve, with very fine transverse crenulations, rather striations, on both sides on the crest of the tooth, parallel to the postero-dorsal margin,

4: elongated highest in the left valve, with fine transverse crenulations on both sides, subparallel to the antero-dorsal margin,

2: moderately elongated, sloping obliquely toward the antero-ventral side, crenulated wholly on the antero-dorsal side, but only in upper part on the posterior side,

PII: narrow and elongated, with very fine transverse crenulations on the dorsal (upper) side only, parallel to the postero-dorsal margin,

PIV: narrow and elongated, with very fine transverse crenulations on the ventral (lower) side only, parallel to the postero-dorsal margin.

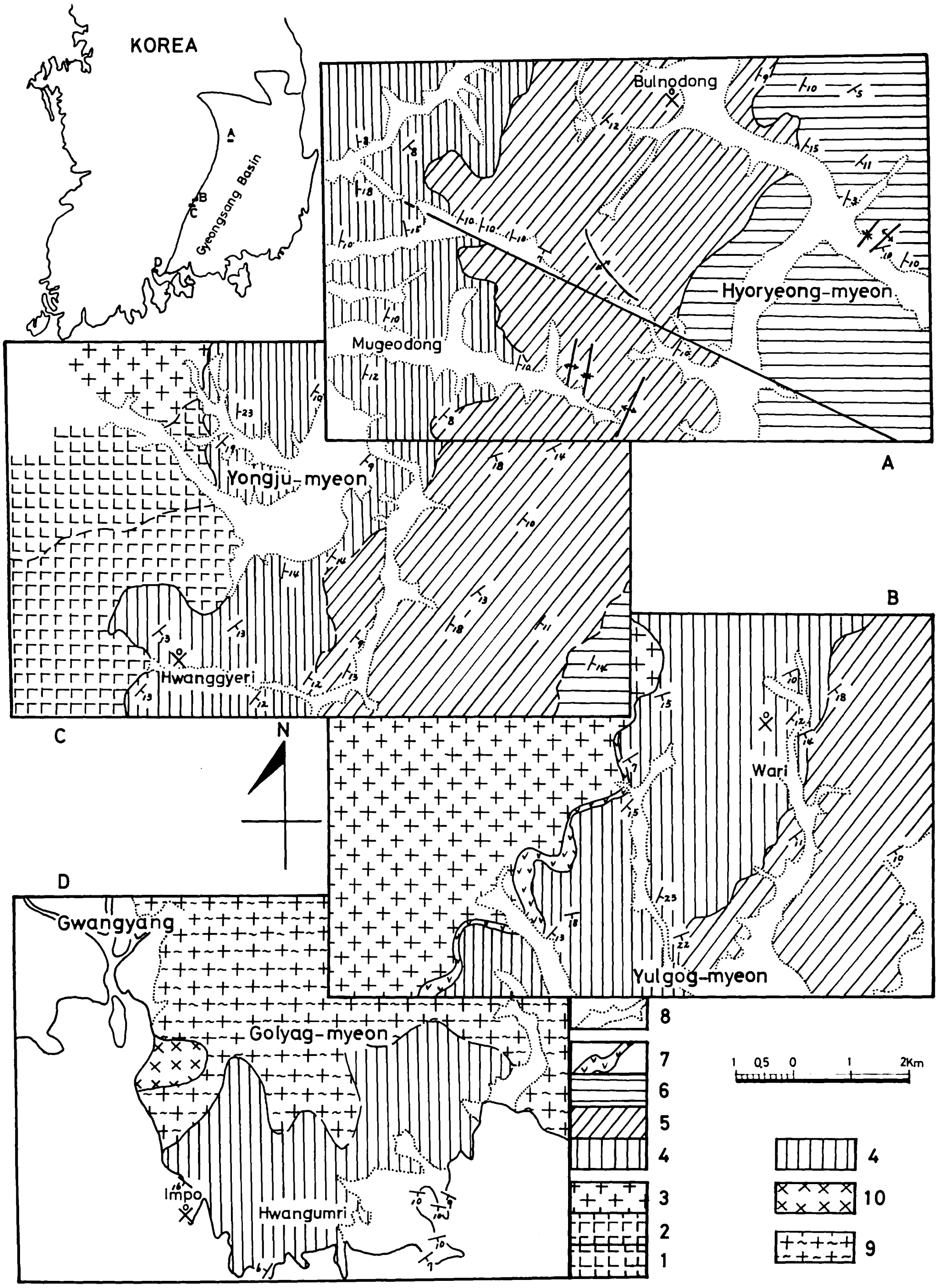
Two adductor scars subequal in size, the anterior one strongly impressed, accompanied with a minute pedal scar, the posterior one somewhat larger but not so distinct. Pallial line simple. Inner ventral margin crenulated. Umbonal cavity moderate in depth.

Observation.—The specimens are fairly well preserved, but severely deformed except for several of them. Among the thirty four specimens, there are eleven conjoined ones, thirteen right valves and ten left valves. The tests are in general well preserved, and so the internal structures are observed on the five internal moulds artificially made with dilute hydrochloric acid.

Occurrence.—The specimens were collected from the light grey siltstone and greenish grey greywacke at Bulnodong, Hyoryeong-myeon, Gunwui-gun, Gyeongsangbug-do, Korea (see Text-figure 3-A). The fossiliferous bed contains plenty of the molluscan fossils besides the present species; *Plicatounio* (s.s.) spp., *Nagdongia soni*, and *Viviparus* sp.

Remarks.—The specific name, *Wakinoa tamurai* was proposed for the specimens, *Wakinoa tetoriensis* of Tamura (not Maeda's *Trigonioides tetoriensis*, 1963) on the differences of the surface ornamentation and the hinge teeth by Yang (1976).

The present specimens are most similar to *Wakinoa tamurai* in surface ornamentation and



Text-figure 3. Geological maps around the fossil localities of *Trigonioides (Wakinoa)* cf. *tamurai* Yang and *T. (W.) wakinoensis* Ota.
1. Gneissose dioritic rocks, 2. Gneissose syenite, 3. Gneissose granite, 4. Yeonhwadong Formation, 5. Hasandong Formation, 6. Dongmyeong Formation, 7. Acidic dike, 8. Alluvium, 9. Metamorphic rocks, 10. Intermediate to basic plutonic rock.

hinge teeth, but precise comparison is difficult because of the insufficient preservation of the specimens from Japan. However, it can be safely said that the present specimens are more similar to *Wakinoa tamurai* than any other species referred to *Wakinoa* on the development of the submedian hinge tooth (1), and the multiple V-sculptures on the antero-ventral half. And it can be also safely discriminated from the species of *Trigonioides* (s.s.) and *Kumamotoa* on the fairly large angle of the median V-sculpture and the fine crenulations of the hinge teeth. In the latter subgenera, the angles of the V-ribs are generally less than 20 degrees and the crenulations on the hinge teeth are regular and prominent. And it is also discriminated from the species of *Koreanaia* on the smaller angles of the V-ribs on the median part in which the angles are 35—45 degrees.

Trigonioides (*Wakinoa*) *wakinoensis* (Ota), 1963

Pl. 39, Figs. 1-7

1936. *Trigonioides kodairai* Kobayashi and Suzuki, *Japan. Jour. Geol. Georgr.*, vol. 13, nos. 3—4, pl. 29, fig. 13.
1941. *Trigonioides kodairai* Kobayashi and Suzuki, *Bull. Geol. Inst. Manchoukuo*, no. 101, figs. 1—4.
1959. *"Nippononaia" wakinoensis* Ota, *Trans. Proc. Palaeont. Soc. Japan*, N. S., no. 34, p. 107, 108, pl. 11, figs. 1—7, 11.
1959. *"Nippononaia" sengokuensis* Ota, *Ibid.*, p. 108, pl. 11, figs. 8—10.

Material.—Eight specimens (KPE 2401—5, 2671—2, 2410) collected from the light grey siltstone of the lower to middle Yeonhwadong Formation, Gyeongsang Group, Korea. (KEP 2401—5; Coll. K. H. Chang: KPE 2671—2, 2410; Coll. S. Y. Yang).

Occurrence.—Among the specimens, KEP 2401—5 are collected from the lower Yeonhwadong Formation at Hwanggyeri, Yongju-myeon, Habcheon-gun Gyeongsang nam-do, Korea (see Text-figure 3-C). At this locality, the present species is associated with *Nagdongia soni*, and *Viviparus* sp. Two specimens (KPE 2671—2) are collected from the lower Yeonhwadong Formation at Impo, Hwangumri, Golyag-myeon, Gwangyang-gun, Jeonranam-do, Korea (see Text-figure 3-D). Here, the present species is associated with *Plicatounio* sp. and *Pseudohyria* sp. And the other one (KPE 2410) is collected from the middle Yeonhwadong Formation at Wari, Yulgog-myeon, Habcheon-gun, Gyeongsangnam-do, Korea (see Text-figure 3-B). At this locality, *Nagdongia soni*, *Nippononaia ryosekiana*, *Viviparus* sp. and dinosaur's bones are associated with the present species.

At the above three localities, the specimens of the present species are severely deformed and quite poorly preserved as minority of the faunas. Therefore, the outline and the internal structures can not be clearly defined on these specimens. However, the surface ornamentation such as V-sculptures and the angle of the Vs can be safely identified with that of *W. wakinoensis* from Japan.

Subgenus *Trigonioides* Kobayashi and Suzuki, 1936

Type-species.—*Trigonioides kodairai* Kobayashi and Suzuki, 1936.

Subgeneric diagnosis (emend.).—Postero-lateral hinge teeth two on left valve, one on right valve, forming the following dental formula:

	5		3		1a		(1b)		(1c)		PIII	
(6)		4		2		(1'a)		(1'b)		PII		PIV

The other characters same as in my previous descriptions (Yang, 1974, p. 396—398; Yang, 1978, 341—342).

Included species.—*Trigonioides kodairai* Kobayashi and Suzuki, 1936; *Trigonioides paucisulcatus* (Suzuki), 1940; *Trigonioides tetoriensis* Maeda, 1963; *Trigonioides jaehoi*, sp. nov. (described below).

Trigonioides (Trigonioides) jaehoi, sp. nov.

Pl. 39, Figs. 9-10; Pl. 3, Figs. 1-16, Text-fig. 4

Etymology.—This species is dedicated to Mr. Jaeho Oh of the Korea Institute of Energy and

Resources who discovered the fossil locality and kindly introduced me to the locality and helped in sampling.

Measurements (in mm) of
Trigonioides (Trigonioides) jaehoi

Specimens	Length	Height	L/H
Right valve (KPE 2001)	43.8	31.8	1.38
Conjoined (KPE 2002)	46.4	33.2	1.40
Left valve (KPE 2004)	40.0	26.2+	1.53−
Conjoined (KPE 2005)	44.8	32.1	1.40
Left valve (KPE 2006)	44.2	33.1	1.34
Conjoined (KPE 2007)	44.9	31.4+	1.43−
Conjoined (KPE 2009)	46.1	31.6	1.46
Left valve (KPE 2011)	38.6	29.0	1.33
Right valve (KPE 2013)	37.3	26.3	1.42
Conjoined (KPE 2014)	44.0	30.3	1.45
Conjoined (KPE 2016)*	45.5	33.3	1.37
Left valve (KPE 2019)	39.6	30.6	1.29
Right valve (KPE 2022)	38.3	28.3	1.35
Left valve (KPE 2025)	43.3	30.2	1.43
Conjoined (KPE 2031)	34.1+	27.4	1.25
Conjoined (KPE 2036)	41.3	32.9	1.26
Conjoined (KPE 2041)	37.8+	28.7	1.32+
Left valve (KPE 2042)	43.0	31.7	1.36
Right valve (KPE 2052)	39.0	29.3	1.33
Left valve (KPE 2057)	48.2	37.0	1.30
Left valve (KPE 2058)	59.2	40.3	1.47

Conjoined valve (KPE 2016)*: holotype.

Material.—Holotype (KPE 2016, Pl. 40, Fig. 14) and one hundred and one paratypes (KPE 2001–2102) collected from the grey calcareous siltstone of the upper horizon of the Hasandong Formation, Nagdong Subgroup, Gyeongsang Group, Korea (Coll. S. Y. Yang).

Description.—Shell medium in size (about 40–60 mm in length), equivalve and subequilateral; suboval in outline, with ratio of L/H about 1.35; anterior margin well rounded, posterior one subquadrate, ventral margin broadly arcuate; umbo somewhat prominent, projected slightly above the hinge line, slightly prosogyrous and placed at about two-fifths from the anterior extremity; moderate in inflation; escutcheon and lunule both present.

Surface ornamented with V-shaped ribs on the median part and reversed V-ribs on both of the anterior and posterior parts. The angles of the median V-ribs about 10–15 degrees and those of the reversed V-ribs on both sides about 50–60 degrees. The subradial median ribs on the anterior side finer and weaker but denser than those on the posterior side. The ribs on the antero-ventral part generally effaced, becoming indistinct. The median ribs number 13 to 19 in the anterior half and 10 to 12 in the posterior half, the ribs sloping obliquely toward outer dorsal sides number more than 10 on the antero-dorsal side and 18 on the postero-dorsal side; the whole surface ornamented also with numerous concentric growth-lines of irregular interval and prominence.

Hinge plate moderate in breadth, provided with opisthocline pseudocardinal teeth and postero-lateral teeth, the pseudocardinal teeth three or four on both valves, and the postero-lateral ones one on right valve, two on left valve, forming the following dental formula:

$$\frac{5\quad 3\quad 1a\quad (1b)\qquad PIII}{(6)\quad 4\quad 2\quad 1'a\qquad PII\qquad PIV}$$

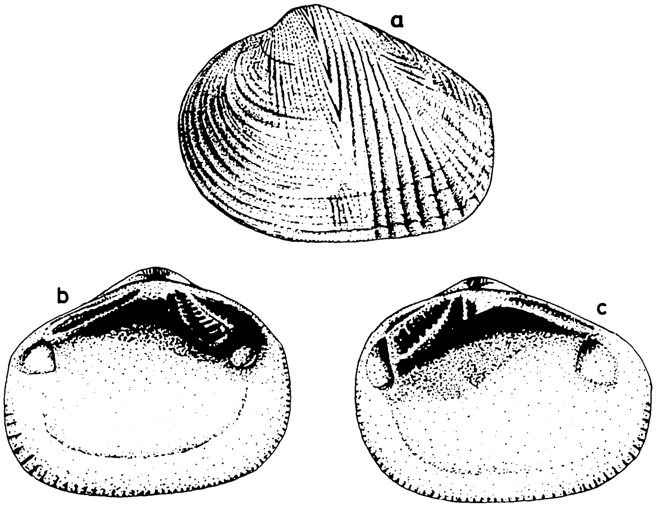
where 5: narrow and elongated, with regular transverse crenulations on both sides or ventral (lower) side only, parallel to the antero-dorsal margin,

3: most prominent and largest in the pseudocardinal teeth of the right valve, crenulated on both sides, subparallel to the antero-dorsal margin,

1a: low and short, crenulated on both sides, obliquely downward to the antero-ventral margin,

1b: smallest in the right valve, sometimes indistinct, crenulated on anterior side only, nearly vertical,

PIII: prominent and elongated, with fine transverse crenulations on both sides, parallel



Text-figure 4. *Trigonioides (Trigonioides) jaehoi*, sp. nov.
a: surface ornamentation of the left valve.
b: internal structures of the left valve.
c: internal structures of the right valve.

to the postero-dorsal margin,

6: narrow and elongate, sometimes indistinct, crenulated lower side only, parallel to antero-dorsal margin,

4: largest pseudocardinal tooth in the left valve, crenulated on both sides, subparallel to the antero-dorsal margin,

2: moderate and elongated, sloping obliquely toward the antero-ventral side, crenulated wholly on the antero-dorsal side, but only on the upper part on the posterior side,

1'a: smallest in the left valve, crenulated on both sides, nearly vertical,

PII: narrow and elongated, with fine transverse crenulations on the dorsal (upper) side only, parallel to the postero-dorsal margin,

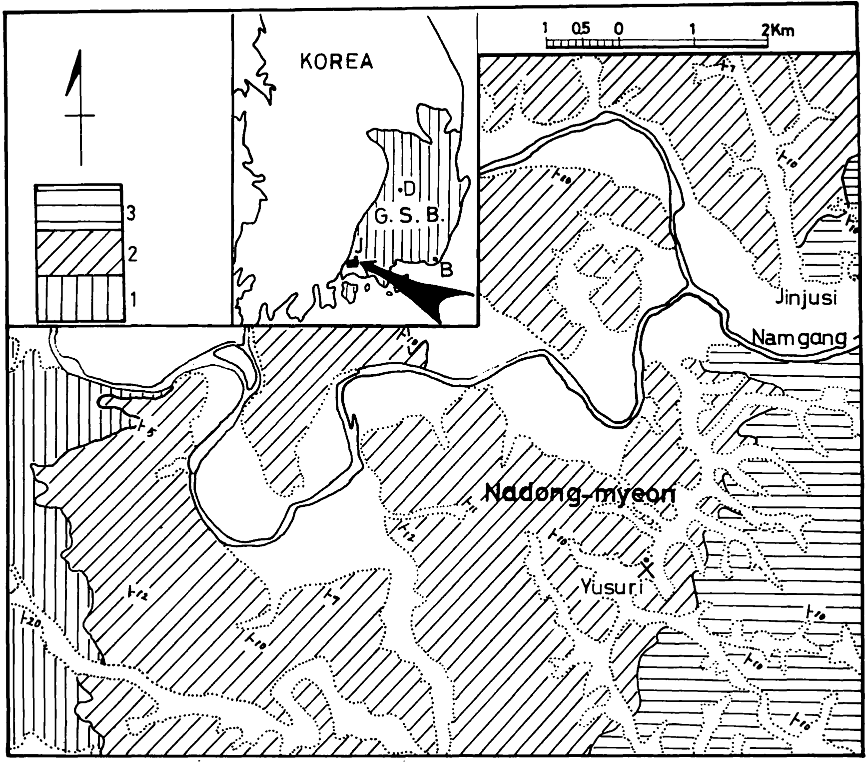
PIV: narrow and elongated, more or less shorter than PII, with fine transverse crenulations on the ventral (lower) side only, parallel to the postero-dorsal margin.

Two adductor scars subequal in size and form, anterior one subcircular, strongly impressed, accompanied with a distinct minute pedal scar; posterior one also subcircular and more or less larger, but not so distinct; shell margin crenulated internally; pallial line simple and distinct on the anterior half, but indistinct on the posterior half; umbonal cavity moderately deep.

Observation.—The holotype (KPE 2016) is a conjoined valve, 45.5 mm in length and 33.3 mm in height. Among the 102 type-specimens, 42 are conjoined, 31 right valves and 29 left valves. Most of the specimens are well preserved but secondarily deformed. It is notable that even the ligaments are well preserved on some of the specimens (Pl. 3, Figs. 1, 2a, 3a). The subradial ribs on the median part are fairly effaced on the anterior half of the most specimens. The internal structures have been observed on the ten adult specimens about 40 mm in length from which the tests were dissolved out with dilute hydrochloric acid.

Occurrence.—The fossils occur separately here and there not gregariously. Of the conjoined specimens, the commissure planes are generally posed vertically and the antero-posterior axes inclined to stratification. Among the collection, the conjoined specimens occupy a relatively large number (about 41.2%). And all show no severe destruction besides secondary deformation. These facts may suggest that the fossils have been preserved in situ.

The fossil locality is at a river channel near



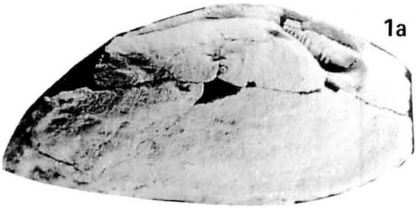
Text-figure 5. Geological map around the fossil locality of *Trigonioides (Trigonioides) jaehoi*, sp. nov.
1. Yeonhwadong Formation, 2. Hasandong Formation, 3. Dongmyeong Formation.
In index map, B: Busan, J: Jinju, D: Daegu, G.S.B.: Gyeongsang Basin.

Explanation of Plate 38

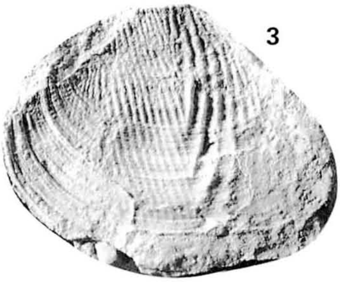
Figures 1—15. *Trigonioides (Wakinoa)* sp. cf. *T. (W.) tamurai* Yang, 1976

1. Right valve (KPE 2322), 1a; internal mould, 1b; rubber cast, showing the hinge teeth.
2. Left valve (KPE 2324), 2a; internal mould, 2b; rubber cast, showing the hinge teeth.
3. Right valve (KPE 2320), external mould, showing the multiple V-sculpture on the anterior part faintly.
4. Right valve (KPE 2323), 4a; internal mould, 4b; rubber cast, showing the hinge teeth.
5. Left valve (KPE 2317), slightly compressed and anterior side somewhat broken out.
6. Right valve (KPE 2313), posterior part broken out.
7. Left valve (KPE 2315), posterior part broken out and slightly compressed vertically.
8. Left valve (KPE 2314), strongly compressed antero-posteriorly.
9. Left valve (KPE 2312), showing the multiple V-sculpture on the antero-ventral part, the postero-ventral part broken out.
10. Left valve (KPE 2354), showing the reversed V-ribs on the antero-dorsal part.
11. Right valve (KPE 2319), showing the multiple V-ribs on the anterior part, the posterior part broken out.
12. Right valve (KPE 2348), posterior part broken out.
13. Left valve (KPE 2316), the posterior part broken out.
14. Left valve (KPE 2318), the antero-ventral part broken out.
15. Conjoined valve (KEP 2311), 15a; left valve, 15b; right valve, compressed laterally.

All figures are approximately of natural size. Locality; see Text-figure 3-A.


1a


2a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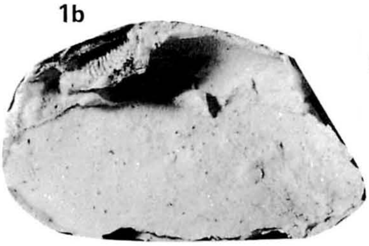
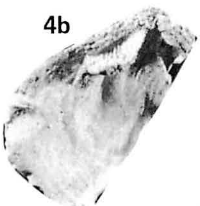
2b


1b

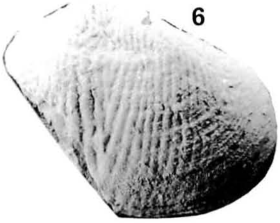

5


4a


4b


8


7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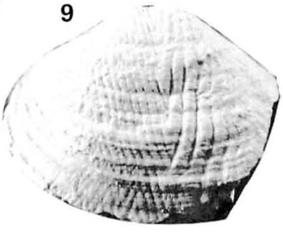
10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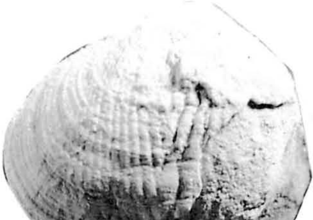
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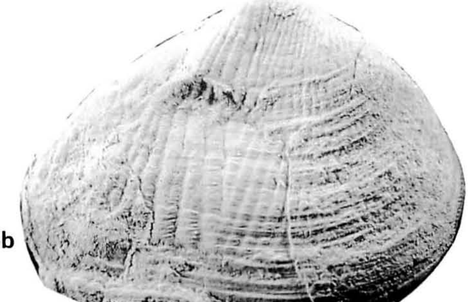
11


12


14


15a


15b

Yusuri, Nadong-myeon, Jinyang-gun, Gyeongsangnam-do, Korea (see Text-figure 5). The associates of the present species at the locality are *Plicatounio (P.)* spp. and *Viviparus* sp.

Comparison.—Trigonioides (s.s.) *kodairai* and the present species are much alike each other in surface ornamentation and outline. However, examining in more detail, specific differences can be grasped. In the present species the riblets on the antero-dorsal side are fewer, and on the postero-dorsal side more numerous than in *T.* (s.s.) *kodairai*, respectively. And except a few specimens, the species described here is ornamented with the subradial ribs on the umbonal area and the posterior half, but the ribs are gradually effaced towards the antero-ventral margin. This effacement is also observed on the specimens of *T.* (s.s.) *kodairai*, but more distinctly in the present species. With this respect, the present species is intermediate between *T.* (s.s.) *kodairai* and *T.* (s.s.) *paucisulcatus*. A similar transitional feature is seen in the hinge teeth, *T.* (s.s.) *kodairai* possesses pseudocardinal teeth, three on the right valve and two or three on the left valve, and *T.* (s.s.) *paucisulcatus* has five on the right valve and four or five on the left valve of large adult specimens, even though ontogenetic variation is observed. While the present species possesses three or four on both valves. In the number of the pseudocardinal hinge teeth, the present species is fairly similar to *Kumamotoa* spp., but easily discriminated from the latter in the ratio of the length of the teeth and the strength of the transverse crenulations.

In the stratigraphic sequence, the present species also falls in the intermediate position between *T. kodairai* and *T. paucisulcatus.*

References

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Explanation of Plate 39

Figures 1—7. *Trigonioides (Wakinoa) wakinoensis* (Ota), 1963.

1. Left valve (KPE 2672), dorsal part not preserved, compressed laterally.
2. Right valve (KPE 2403), strongly compressed antero-posteriorly.
3. Right valve (KPE 2402), umbonal part only.
4. Right valve (KPE 2405), strongly compressed and the ventral part broken out.
5. Left valve (KPE 2671), strongly compressed and the median part only.
6. Conjoined valve (KPE 2401), 6a; left valve, 6b; right valve, strongly compressed.
7. Left valve (KPE 2410), inner view, anterior part broken out, external mould shown.

Loc.: (KPE 2671) (KPE 2672); see Text-figure 3-B.
(KPE 2401-5); see Text-figure 3-C.
(KPE 2410); see Text-figure 3-D.

Figure 8. *Trigonioides (Wakinoa)* sp. cf. *T. (W.) tamurai* Yang, 1976. Right valve (KPE 2323), internal mould, showing the hinge teeth. Loc.: see Text-figure 3-A.

Figures 9—10. *Trigonioides (Trigonioides) jaehoi*, n. sp.

9. Left valve (KPE 2094), internal mould, showing the internal structures.
10. Right valve (KPE 2098), internal mould, showing the hinge teeth.

Loc.: (KPE 2094, 98); Yusuri, Nadong-myeon, Jinyang-gun, Gyeongsangnam-do, Korea (see Text-figure 5).

Figures 11—12. *Trigonioides (Trigonioides) paucisulcatus*, Suzuki, 1940.

11. Right valve (KPE 1687), internal mould, showing the hinge teeth, the specimen strongly compressed antero-posteriorly.
12. Right valve (KPE 1690), internal mould, showing the hinge teeth.

Loc: (KPE 1687, 90); at a point about 1.5 km northeast from Geoncheonri, Seo-myeon, Weolseong-gun, Gyeongsangbug-do, Korea (see Yang, 1978).

Figures 13—19. *Trigonioides (Kumamotoa) mifunensis* Tamura, 1970.

13. Right valve (KPE 1023), 13a; internal mould, showing the internal structures, antero-dorsal part only, 13b; rubber cast.
14. Rubber cast of right valve (KPE 1110), antero-dorsal part only, showing the internal structures.
15. Left valve (KPE 1198), showing the hinge teeth.
16. Right valve (KPE 1028), 16a; internal mould, showing the internal structures, 16b; rubber cast.
17. Left valve (KPE 1022), internal mould, showing the hinge teeth.
18. Left valve (KPE 1199), internal mould, showing the internal structures.
19. Right valve (KPE 1197), internal mould, showing the hinge teeth.

Loc.: (KPE 1022, 23, 28, 1110, 1197—99); at about 500 m southeast from Tashiro, Kosa town, Kumamoto, Japan (the type-locality of *T. (K.) mifunensis*).

Figure 20. *Trigonioides (Kumamotoa) matsumotoi* Kobayashi and Suzuki, 1941.
Rubber cast (KPE 1044) of the GK 1500, showing the internal structures.

All figures are approximately of natural size.


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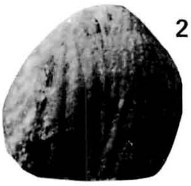
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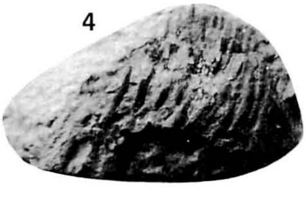
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13a


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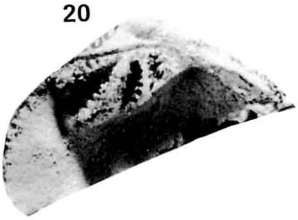
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韓国下部慶尚層群産 Wakinoa 亜属について：*Wakinoa* を含む *Trigonioides* 属の亜属の分類学的形質を検討した結果と *Wakinoa* の二個種と新種 *Trigonioides* (s. s.) *jaehoi* を報告する。*Trigonioides* 属の亜属分類には pseudocardinals 数だけを考慮する場合は，Tamura (1981) が指摘したように問題がある。しかし，pseudocardinals 数だけでなく，それらの長さの比率，crenulation の強さ及び hinge plate の形態等で亜属段階の分類が可能である。層序的位置と分類的形質で *Wakinoa* 亜属は *Koreanaia* と *Trigonioides* (s. s.) 間の transitional form と思われる。
梁承栄

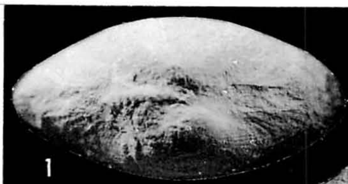
Bulnodong	不老洞	Jinjusi	晋州市
Geoncheonri	乾川里	Jinyang-gun	晋陽郡
Golyag-myeon	骨若面	Mugeodong	黙語洞
Gunwui-gun	軍威郡	Nadong-myeon	奈洞面
Gwangyang-gun	光陽郡	Nagdong	洛東
Gyeongsang	慶尚	Seo-myeon	西面
Habcheon-gun	陜川郡	Namgang	南江
Hasandong	霞山洞	Wari	互里
Hwanggyeri	黄渓里	Weolseong-gun	月城郡
Hwangumri	黄金里	Yeonhwadong	蓮花洞
Hyoryeong-myeon	孝令面	Yongju-myeon	龍洲面
Impo	林浦	Yulgog-myeon	栗谷面
Jeonranam-do	全羅南道	Yusuri	柳樹里

Explanation of Plate 40

Figures 1—16. *Trigonioides (Trigonioides) jaehoi*, sp. nov.

1. Conjoined valve (KPE 2005), dorsal view, showing the lunule and the ligament.
2. Conjoined valve (KPE 2001), 2a; dorsal view, showing the lunule and the ligament, 2b; left valve side view, compressed laterally.
3. Conjoined valve (KPE 2014), 3a; dorsal view, showing the lunule and the ligament, 3b; left valve side view.
4. Left valve (KPE 2004), slightly compressed vertically.
5. Conjoined valve (KPE 2031), right valve side view, somewhat compressed laterally.
6. Left valve (KPE 2024), posterior part broken out.
7. Right valve (KPE 2022), posterior part broken out.
8. Right valve (KPE 2013), posterior part broken out.
9. Conjoined valve (KPE 2002), left valve side view, compressed laterally.
10. Conjoined valve (KPE 2009), left valve side view, posterior part broken out and compressed laterally.
11. Conjoined valve (KPE 2041), right valve side view.
12. Left valve (KPE 2019), side view.
13. Conjoined valve (KPE 2007), left valve side view, slightly deformed.
14. Conjoined valve (KPE 2016), left valve side view.
15. Left valve (KPE 2011), side view.
16. Left valve (KPE 2006), side view.

KEP 2016 (Figure 14) is the holotype and the others are the paratypes.
All figures are approximately of natural size.
Loc.: Yusuri, Nadong-myeon, Gyeongsangnam-do, Korea (see Text-figure 5).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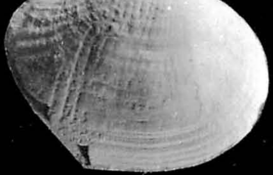
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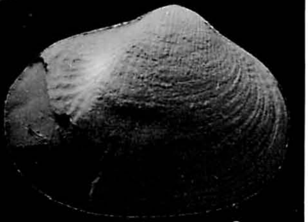
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2b


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行事予定

	開催地	開催日	講演申込締切
第132回 例会	熊本大学	1983年10月23日	1983年8月23日
1984年 年会・総会	京都大学	1984年1月21，22日	1983年11月21日

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日本学会事務センター 日本古生物学会 行事係

お知らせ

○日本学術会議第13期会員選挙の全国区第4部地質学候補者として本会より特別会員大森昌衛君を推薦した。

誤植訂正

編集係のミスにより本誌130号の表紙に次の誤植がありましたのでおわびして訂正します。

Errata for No. 130

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Cover	bottom	July 15	July 30
Back cover	3	July 15	July 30
	6	Plio-Pleistocene	Plio-pleistocene
	8	of	fo
	10	MATSUMOTO	MATUMOTO

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