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MULTIDISCIPLINARY RESEARCH IN THE UPPER CRETACEOUS OF THE MONOBE AREA, SHIKOKU

Compiled by

Tatsuro MATSUMOTO and Masayuki TASHIRO

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CONTENTS

PREFACE

The Monogewa valley, i.e. a narrow basin along the River Monobe, in central Shikoku, has been well known since the works of Yehara (1926) and Yabe (1927). It has been especially celebrated for the study of the Lower Cretaceous. Later a fraction of the Upper Cretaceous was recognized on the evidence of a few fossils by Katto and Suyari (1956), without, however, further improvement of knowledge for about 25 years.

In 1973, Takeshi Kozai, a teacher in the Elementary School of Odochi, Monobe-mura, happened to find several molluscan fossils from the strata exposed along the river banks not far from the school. As the material was useful for the educational purpose, further hunting has been made with some pupils of higher classes. The pure and deep interests of a teacher and young children in the nature have brought forth fresh discovery of numerous fossils at various levels of the Cretaceous sequences exposed continuously along the river streams. Kozai took contact with Professor Jiro Katto and Masayuki Tashiro of Kochi University to carry on a palaeontological study as well as to improve the field work. On the other hand, Mr. Keiji Nakano, who was doing independently a geological field work in this area, under the supervision of Prof. Katto and Dr. Tashiro, found some micro-fossils from certain parts of the same sequences. Tashiro took contact with Matsumoto and also with Professor Y. Takayanagi for developing the study further on.

Meanwhile, a cooperative study of the Cretaceous System of Japan had been undertaken for the purpose of international correlation by a working group of about 40 persons under the leadership of Professor Yokichi Takayanagi (Tohoku University) with a grant-in-aid of the Ministry of Education, Science and Culture [*Monbusho*] since April 1978. Naturally the biostratigraphic study of the Cretaceous of the Monobe area was taken into a part of this cooperative work. In other words, the fossils from the Monobe area have been studied by the members of the working group in accordance with their taxonomic category: —for instance, Lower Cretaceous cephalopods by Matsumoto and Obata, Upper Cretaceous ammonites by Matsumoto, bivalves (other than inoceramids) by Tashiro and Kozai, inoceramids by Matsumoto, Noda and Kozai, echinoids by K. Tanaka, foraminifera by Takayanagi, Yasuda and Shimakura, radiolaria by K. Nakaseko, M. Okamura and K. Nakano, calcareous nanno-planktons by Okamura and land plants by H. Matsuo.

In addition to the biostratigraphic aspects, the Cretaceous System of the Monobe area is interesting from the viewpoints of structural geology, sedimentology and palaeotectonics. These aspects have been studied by S. Hada, T. Ikuma, H. Mitsushio, S. Higashi and A. Taira, with the aid of M. Tashiro.

In this volume the results of the multidisciplinary study on the Upper Cretaceous of the Monobe area are assembled. The results of the study on the Lower Cretaceous will be published separately, Echinoids, for instance, have already been published by Tanaka and Kozai (1982), in which an Upper Cretaceous species is included.

We should appreciate highly the cooperative contributions by the authors of individual papers whose names are shown in the title page of this volume as well as in

the contents. Thanks are especially due to Mr. Takeshi Kozai of the Odochi Elementary School, the starter of this study, with whom the following pupils coworked joyfully in hunting and observing fossils in the field:

Messrs. Yutaka Ogasawara, Yutaka Kamiike, Susumu Wada,
Kenshi Nakawaki, Moto Iwai, Hiroshi Nobusaki, Satoru Takahashi,
Hideaki Kuroiwa, Harunori Ozasa and Sunao Morita.

Thanks are likewise extended to Professor Jiro Katto of Kochi University, who have endeavoured to develop the study, and also to Messrs. Toshio Komatsu and Hisafumi Akashi, the former and the present Masters of the Odochi Elementary School, who gave generously the facility for this study.

It should be recorded with gratitude that the present study is an outcome of a more comprehensive project which was supported by the Science Research Fund (No. 334043) of the Ministry of Education, Science and Culture and that its publication in Special Papers No. 25 of the Palaeontological Society of Japan is facilitated with a subsidy from the same Ministry. We owe much on Professor Tsugio Shuto, Editor of the Special Papers, in setting forth the assembled manuscripts into this publication. Finally the result of this paper is partly a contribution to the International Geological Correlation Programme [IGCP] Project No. 58 "Mid-Cretaceous Events" [MCE].

June 16, 1982

Tatsuro Matsumoto
Masayuki Tashiro

I. STRATIGRAPHY OF THE UPPER CRETACEOUS IN THE MONOBE AREA, SHIKOKU

By

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Abstract

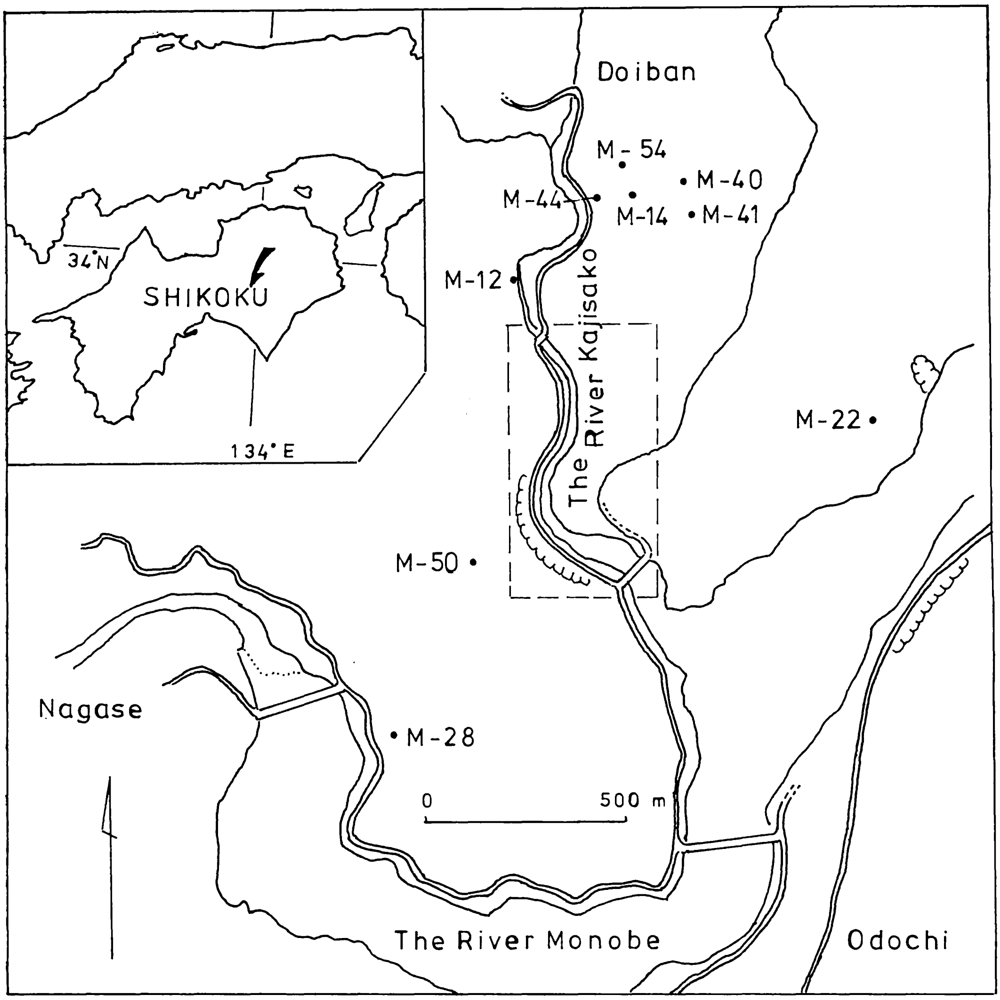
This paper deals with the outline of litho- and biostratigraphy of the Upper Cretaceous System in the Monobe Area, Shikoku. The Nagase (lower) Formation is composed mainly of sandstone. Several ammonites and many shallow marine bivalves, rarely a few brackish water bivalves commonly occur at several horizons of the formation. The Kajisako (upper) Formation is composed of sandstone rich facies in its lower and uppermost parts, and of muddy facies in its middle and upper parts. Many acidic tuff or tuffaceous mudstone beds are found in the lower part. The lower part is characterized by the occurrence of many species of ammonites, inocerami, and other bivalves. In the middle and upper parts, several species of ammonites, inocerami, a few bivalves and abundant planktonic foraminifera and radiolaria occur in the dark gray siltstone and shale.

Introduction

The Upper Cretaceous System of the Monobe Area north of Odochi, Kochi Prefecture is distributed narrowly, as shown in the geological map (see, Text-fig. 1 of the next article). This was discriminated at first by Katto and Suyari (1957) from the Lower Cretaceous Kaminiro Formation (Huzita, 1943) of the Monobegawa Group (Yabe, 1927). It was divided to the Gyliakian Nagase Formation and the Urakawan Kajisako Formation, on the basis of litho-stratigraphy and the evidence of fossils. The species of the Upper Cretaceous ammonites and bivalves were, however, very few.

Recently fossils of mollusca, echinoids, radiolaria and foraminifera, have been collected abundantly from the two formations, and the biostratigraphical and lithostratigraphical investigations have been carried out by a number of authors, with a result reported in this volume. In this article the stratigraphy of the Upper Cretaceous System in this area is described.

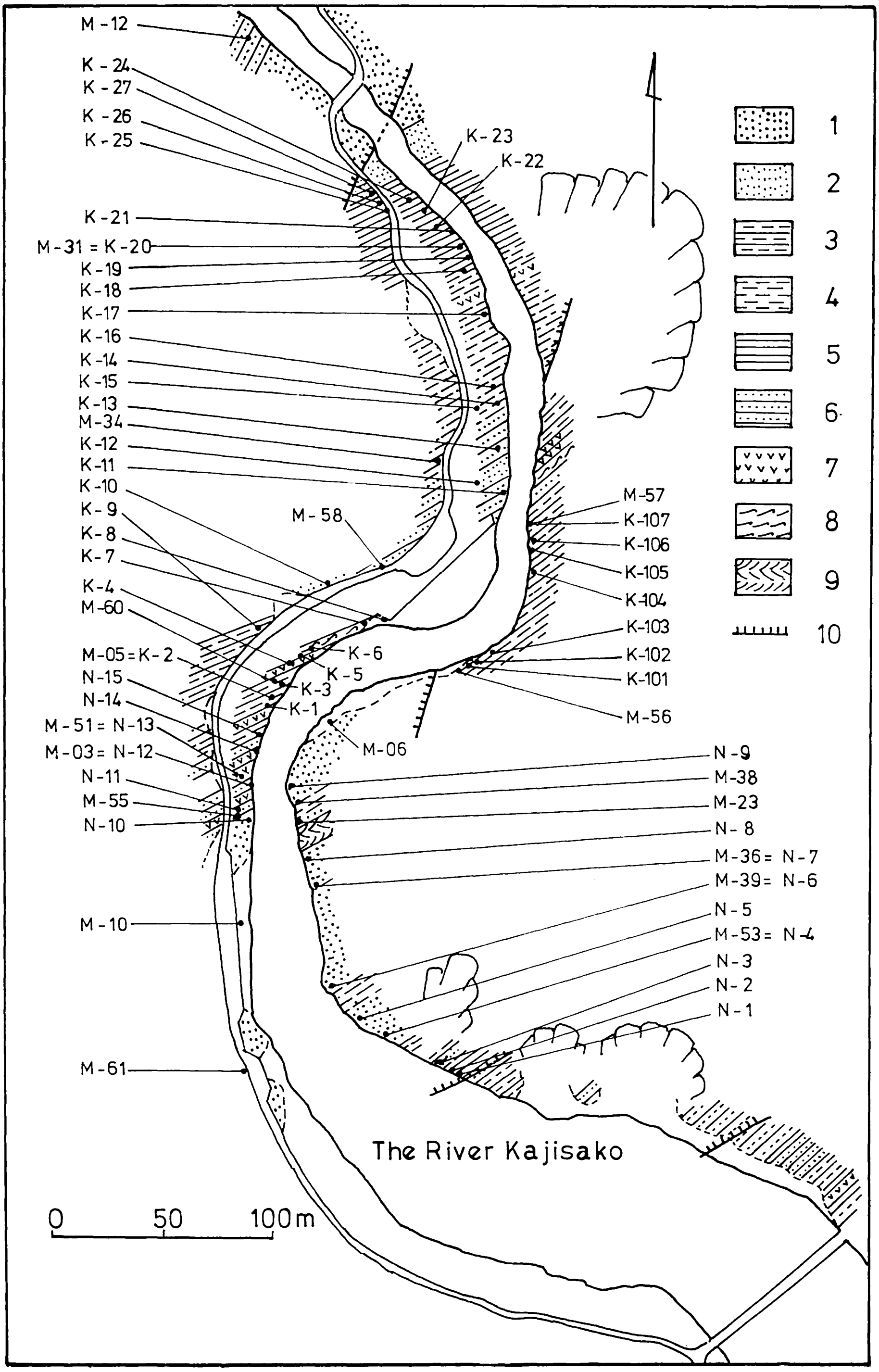
Before going further, we would like to express our hearty thanks to Professor Emeritus Tatsuro Matsumoto of Kyushu University for his continuous guidance, valuable suggestions and critical reading of the manuscript.



Text-fig. 1. Index map showing distribution of fossil localities (M-) of the Upper Cretaceous, Monobe Area.

Stratigraphy

The Upper Cretaceous strata typically crop out on the both right and left banks of the River Kajisako, a tributary to the River Monobe from Doiban (the so-called Mizutani) southward to Odochi, in the Monobe Area, and also on both lateral banks of the Monobe River at and near the Nagase-Dam site, about 1500 m northwest of Odochi. The columnar sections measured along the River Kajisako are shown in Text-figs. 3-4. The sequence which is shown in the columnar sections has been hitheto considered as representing a single formation, the Kajisako Formation (Katto and Suyari, 1957; Katto *et al.*, 1980; Tashiro *et al.*, 1981). On the other hand the type area of the Nagase Formation designated by Katto and Suyari (1957) is at the dam site, located about 600 m southwest from this Kajisako (Mizutani) section (see Text-fig. 1). The lower part of the Kajisako sequence, which is mainly composed of sandy rocks, is undoubtedly cor-



Text-fig. 2. Route map of the exposures along the River Kajisako
1. coarse to medium grained sandstone, 2. fine grained sandstone, 3. alternations of dark-gray siltstone and fine grained sandstone, 4. dark-gray sandy siltstone, 5. dark-gray silty shale, 6. dark-gray shale, 7. acidic tuff or tuffaceous mudstone, 8. slump bedding, 9. cross-laminated sandstone, 10. fault. M-. ammonite and bivalve locality, K- or N-. the locality of the sample for micropalaeontology and lithology.

related with the Nagase Formation of the type exposure, on the grounds of lithological similarity and also on the evidence of the Cenomanian fossils.

1. The Cretaceous System along the River Kajisako (Mizutani)

Nagase Formation

This formation, about 110 m in total thickness, is divided into the lower, middle and upper parts, and is characterized by the occurrence of shallow marine and occasionally brackish water molluscan fossils. The strata take the general attitude of N60°E in strike and about 70° to the north in dip.

The lower part, about 15 m in thickness, is mainly composed of dark gray silty mudstone, but a bed of fine-grained sandstone, about 2.5 m in thickness, is intercalated in the mudstone. On its south (i. e., lower) side this part is in contact with another unit of dark gray siltstone, which is probably Lower Cretaceous and was referred to the 'Hagino' Formation by Katto and Suyari (1957). The contact is a strike fault.

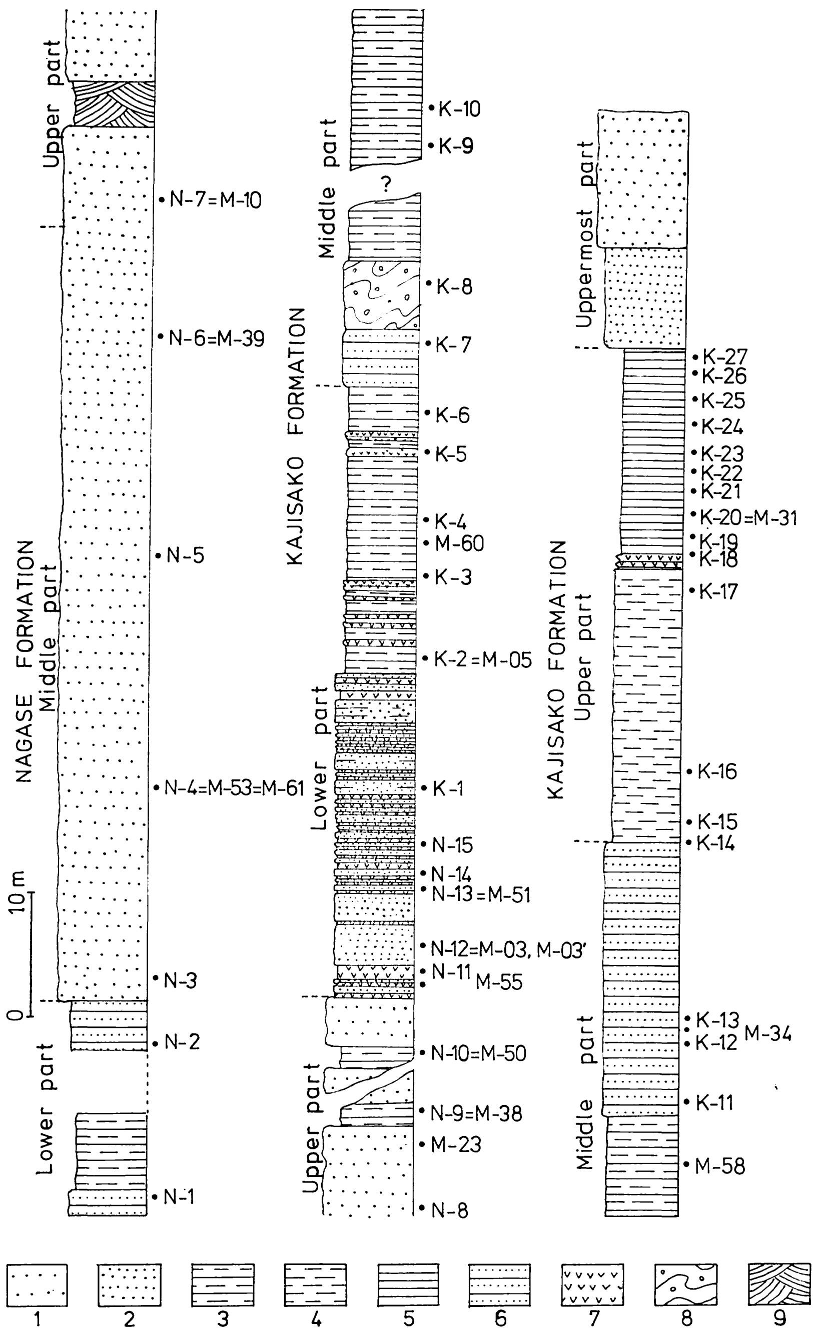
The middle part: This part is composed of medium to coarse grained sandstone, including two molluscan assemblage beds. The lower molluscan bed (loc. M-53, loc. M-61) is marked by the occurrence of ammonites, (*Mantelliceras* spp.), and bivalves (*Pterotrigonia* (*Acanthotrigonia*) *pustulosa* etc.). The upper molluscan bed (loc. M-39) is characterized by abundant shallow-marine bivalves, e. g., several species of *Pterotrigonia, Septifer mifunensis, Cymbophora okadakensis* etc., and occasionally those of brackish water bivalves, *Veloritina mifunensis. Calycoceras* cf. *orientale* is also known from this locality.

The upper part is composed of medium to fine grained sandstone, about 20 m in thickness, with a few inserted layers of silty sandstone, each of which about 1 m in thickness. A bed of cross-laminated sandstone, about 5 m in thickness, is recognized at its midst. There are molluscan beds at three horizons. The lower fossiliferous bed (exposed at loc. M-36, loc. M-10) is characterized by the occurrence of large ammonites, *Calycoceras* aff. *naviculale.* The upper molluscan bed (at loc. M-23) is known by the occurrence of *Acila* (*Truncacila*) *hokkaidoensis.* And the uppermost molluscan bed (exposed at loc. M-38) is formed by abundant specimens of *Glycymeris* (*Hanaia*) cf. *hokkaidoensis*, and known by the rare find of *Inoceramus* aff. *ginterensis* (loc. M-38).

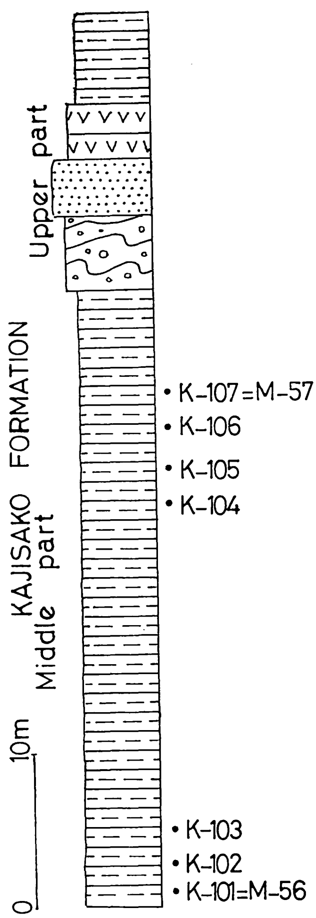
Kajisako Formation

The Kajisako Formation is divided into four parts, i. e., the lower, middle, upper and uppermost parts. The total thickness of the formation is about 180 m.

The lower part: This part is composed of fine grained sandstone and acidic tuff or tuffaceous mudstone in alternation in lower subdivision, and of alternating fine grained sandstone or silty sandstone and thin tuffaceous mudstone in the upper subdivision. Five molluscan beds are recognizable in this part. The lowest bed is known in the basal fine-grained sandstone, in which *Mytiloides* cf. *labiatus opalensis* rarely occurs (loc. M-55). The next bed is represented by loc. M-03. It is characterized by numerous specimens of ammonite, inoceramid and other bivalve species, e. g., *Collignoniceras* cf. *woollgari, Mesopusosia* cf. *indopacifica* etc. (ammonite), *Inoceramus hobetsensis, Mytiloides teraokai, Apiotrigonia* (s. s.) *undulosa, Clisocolus odochiensis* etc. (bivalves). Several



Text-fig. 3. Columnar sections of the Nagase and Kajisako Formations in the route along the River Kajisako. Legend as for Text-fig. 2.



Text-fig. 4. Columnar section of the Kajisako Formation on the left bank of the River Kajisako. Legend as for Text-fig. 2.

echinoids also occur in this bed. The third molluscan bed is characterized by the occurrence of *Inoceramus teshioensis, Apiotrigonia* (s. s.) *undulosa* and several ammonites (loc. M-51). The fourth molluscan bed contains *Inoceramus uwajimensis* and other bivalves (loc. M-05). The matrix of the fossiliferous rock at localities M-55, M-03, M-51 and M-05, is composed of fine-grained sandstone. The uppermost molluscan bed is recognized in the silty mudstone of the upper subdivision. *Inoceramus mihoensis* was collected from this bed (loc. M-60). Some radiolarian fossils are also known nearby this loc. M-60 (loc. K-3, loc. K-4).

The middle part: This part begins with alternating beds of dark-gray siltstone and fine-grained sandstone in the lower subdivision, and overlain by dark-gray siltstone in the upper subdivision. Thickness of the middle part is about 70 m. Several slumping beds including pebbly mudstone are found in the upper 7 m of the lower subdivision. *Inoceramus amakusensis* occurs from the gray siltstone of the lower subdivsion (loc. M-56). *Inoceramus amakusensis* and *I.* cf. *ezoensis* are also known commonly in the dark gray siltstone in the upper subdivision (loc. M-34, loc. M-57). Planktonic foraminifera and radiolarian fossils are recognizable abundantly in the dark gray siltstone (loc. K-101—loc. K-107, loc. K-4—loc. K-16).

The upper part: This part is composed of dark gray siltstone in the lower subdivision and of dark gray shale in the upper subdivision. Its total thickness is 38 m. Two thin beds of acidic tuff are inserted in the basal part of the upper subdivision. Radiolaria and foraminifera are found abundantly at many horizons of this part (loc. K-17—loc. K-27). Calcareous nannoplanktons are also common in this part. The mollusca bearing beds, characterized by *Inoceramus japonicus, Acila* (*Truncacila*) *hokkaidoensis, Ezonuculana mactraeformis* s. s. and *Parvamussium cowperi yubarense,* are intercalated in the upper subdivision (loc. M-31).

The uppermost part: This part is characterized by the fine-grained sandstone in the lower subdivision of about 10 m in thickness and by medium-grained sandstone in the upper subdivision of about 10 m or more in thickness. No fossil has been detected from this part.

Z. The Nagase Formation at and near the Nagase Dam

The Nagase Formation is cropping out on the both banks of the Monobe River at and near the Nagase dam. The stratigraphic sequence is hardly measured in detail at this point, because of the artificial covering of the wall of the Nagase dam which was constructed in 1965. According to the records taken during the construction, it is composed of dark gray mudstone in the lower part, massive sandstone in the main part and dark gray siltstone in the upper part. It is in contact with the Kaminiro (=Hibihara) Formation of the Lower Cretaceous Monobegawa Group on the north side by a fault, called the Kajisakogawa Tectonic Line. On the south side it is conformably underlain by the unnamed formation of the Lower Cretaceous.

Two fossil localities are known in this area. One of them (loc. M-28) is located in the silty mudstone of the lower part. *Mantelliceras cantianum*, *Idonearca ezoensis* s. s., and *Pterotrigonia* (*Acanthotrigonia*) *pustulosa* have been collected there. The other fossil locality (loc. M-50) is characterized by the occurrence of *Matsumotoa* sp., *Glycymeris* (s. l.) sp., *Lopha* sp. and nuculid gen. et sp. indet. It is composed of conglomelatic sandstone which is interbedded in the sandstone of the main part.

3. The Nagase and Kajisako Formations to the south of Doiban

Nagase Formation

The Nagase Formation extends from the vicinity of the Nagase dam northeastward to Doiban. The extention of a part of the formation with about 30 m in thickness, is observable on the roadside exposures to the south of Doiban. Its lower half part is composed of massive sandstone and its upper half consists of dark gray siltstone. Several fragmentary ammonites occur in the siltstone (loc. M-12). The fossiliferous conglomeratic sandstone characterized by certain species of *Matsumotoa*, *Glyccymeris* and *Lopha* is observable in the sandstone of the lower part (loc. M-44).

Kajisako Formation

The fossiliferous dark gray siltstone which is characterized by *Inoceramus japonicus*, *I. amakusensis* and several ammonites, e. g., *Gaudryceras* cf. *striatum*, *Eupachydiscus haradai*, *Polyptychoceras* cf. *subquadratum* etc., is located at about 200 m south of the village of Doiban (loc. M-41, loc. M-40). Radiolarian and foraminiferal fossils occur commonly from the siltstone. The siltstone in this exposure is probably the extention of the Kajisako Formation at Mizutani (Kajisako Stream). It may be correlated with the upper part of the formation, judging from the occurrence of *Inoceramus japonicus*. The Kajisako Formation at this place may be separated from the Nagase Formation mentioned above by a fault of meridional trend.

Concluding remarks

The discussions on the age corrlation of the Upper Cretaceous sequences described above will be given in the last article of this volume. In the present article the basic stratigraphy has been generally explained. For the names of the selected species mentioned in this article, we owe much to the results of Matsumoto (on ammonites), Matsumoto *et al.* (on inoceramids) and Tashiro and Kozai (on other bivalves) which are described respectively in other article of this volume. In the present article the basic data, including the geological and stratigraphical locations of mega-fossils (with prefix

M-), and micro-fossils and lithological samples (with prefix N- or K-) (Text-figs. 1-4), are shown clearly.

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II. GEOLOGICAL STRUCTURE OF THE UPPER CRETACEOUS STRATA IN THE MONOBE AREA, SHIKOKU

By

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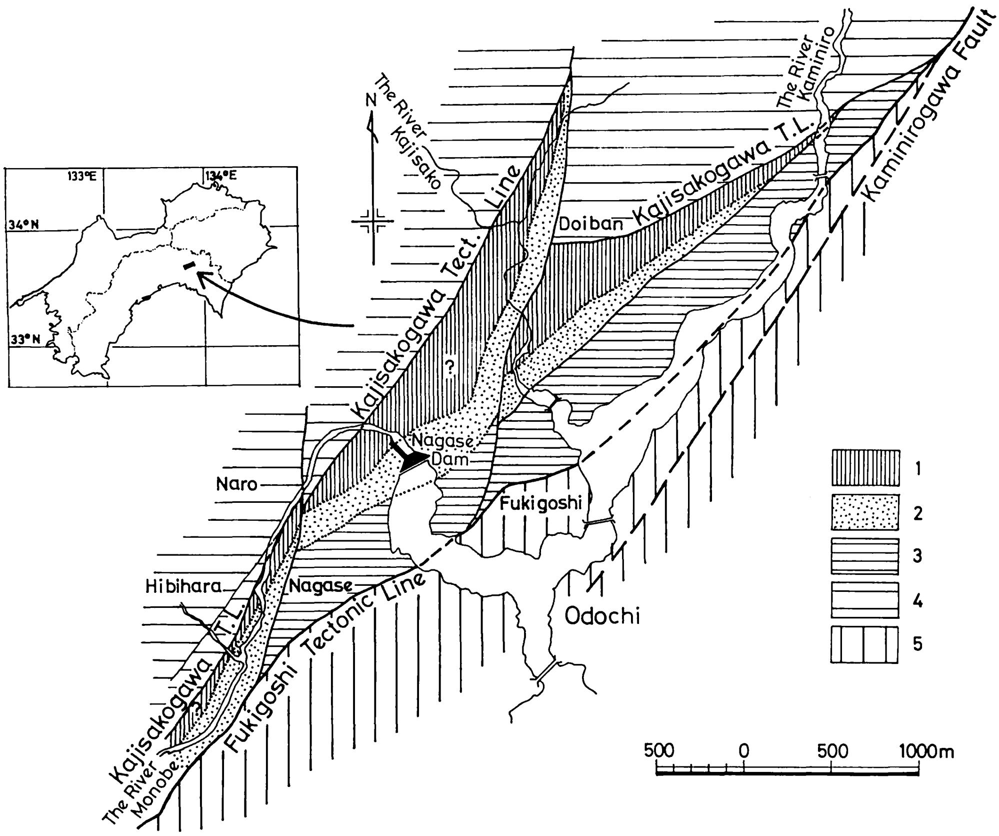
Abstract

The structure of the Upper Cretaceous strata in the Chichibu Belt of the Monobe area can be interpreted into the tectonic framework of the left-lateral movement on the Kaminirogawa Fault in post-Cretaceous age. The high-angle faults of NE-SW trend, such as the Kajisakogawa and Fukigoshi Tectonic Lines, are considered to be the synthetic strike-slip faults which presumably have the same sense of displacement as that of the Kaminirogawa Fault. On the contrary, the faults of N-S trend are interpreted to be the conjugate strike-slip faults with the opposite sense of right-lateral displacement. The Cretaceous fault belt in the Chichibu Belt as the high-angle faults with strike-slip movement differs from the imbricate thrust belt of the Cretaceous System in the Shimanto Belt in having a narrow zone of the deformed Cretaceous strata with greater degree of basement involvement, and in having presumably different cross-sectional profiles of faults, high-angle versus downward flattening.

Geologic Structure

In general, the Cretaceous strata in the Chichibu Belt are intensely folded and thrust. The fold structure of the Cretaceous strata in the Monobe area has been discussed by Ikuma (1980). The main purpose of this paper is to emphasize the major tectonic lines and their significance. High-angle faults affecting the Cretaceous strata of the area have been known for many years (Hujita, 1943; Kobayashi, 1950; Katto and Suyari, 1956; Ichikawa and Ikuma, 1977; Ikuma and Ichikawa, 1978; Ikuma, 1980). Especially, the narrow distribution of the Upper Cretaceous strata is strongly controlled by the high-angle faults which were termed the Kajisakogawa Tectonic Line, the Fukigoshi Tectonic Line and the Kaminirogawa Fault from the north (Text-figs. 1 and 2).

The Kajisakogawa Tectonic Line (Katto and Suyari, 1956) was originally designated as the boundary fault between the Northern and Middle Subbelts of the Chichibu Belt and the distribution of the Upper Cretaceous strata of the area is restricted to the southern side of the fault (*i.e.* the Middle Subbelt). Although the recent work by



Text-fig. 1. Geological Map of the Monobe area.
1-2 : Upper Cretaceous (1 : Kajisako Formation, 2 : Nagase Formation), 3-4 : Lower Cretaceous (3 : unnamed, 4 : Hibihara Formation (Kaminiro Formation)), 5 : pre-Cretaceous

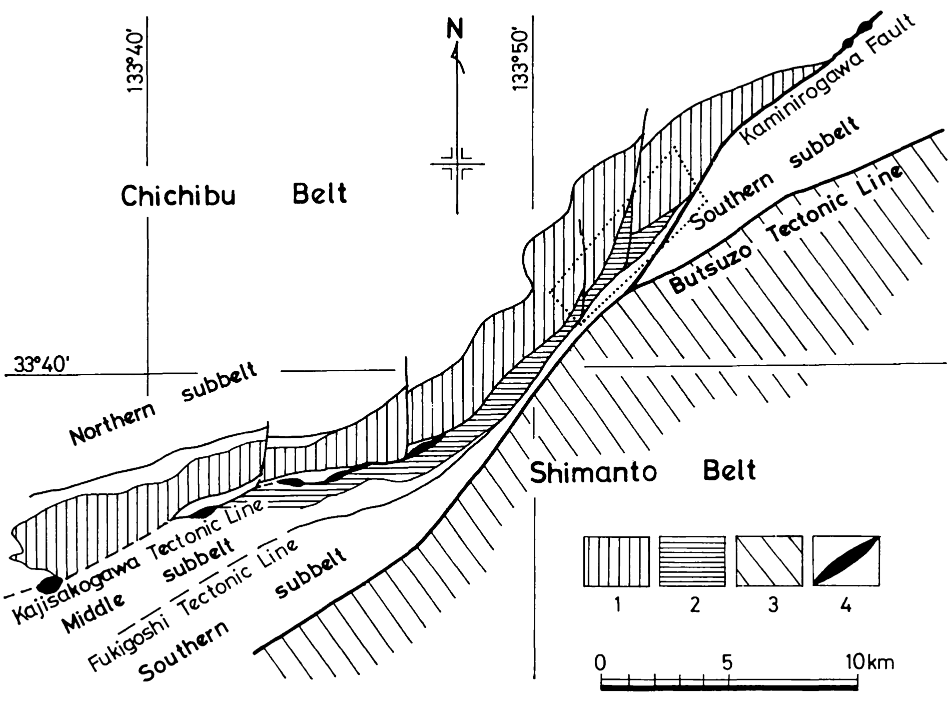
Ikuma (1980) showed a somewhat different interpretation concerning the fault, we applied this term to the fault between the Lower Cretaceous Hibihara Formation of the Northern Subbelt and the Upper Cretaceous Nagase or Kajisako Formations of the Middle Subbelt. The westward extension of the fault is frequently represented by small bodies of serpentinite and the lenticular bodies characterizing the Kurosegawa Tectonic Zone (Text-fig. 2). Complex masses in the zone are considered to be, mostly, tectonic blocks derived from the basement rocks under the Late-Palaeozoic to Mesozoic sediments and consist mainly of regional metamorphic rocks, acidic igneous rocks and the Siluro-Devonian rocks. The Upper Cretaceous strata generally trend east-northeast and dip toward north-northwest. The facing is right-side up. However, the dips of them almost consistently change to southward near the Kajisakogawa Tectonic Line and facing is overturned in this case. The Fukigoshi Tectonic Line (Katto and Suyari, 1956) is the fault between the Middle and Southern Subbelts of the Chichibu Belt. No Cretaceous formation has yet been found from the southern side of the tectonic line, *i.e.* from the Southern Subbelt, in this area. The Kaminirogawa Fault (Hujita, 1943) was originally designated as the fault which provides for the southern limit of the distribution of the Cretaceous System of the Chichibu Belt in the Kaminirogawa area. The Lower Cretaceous Hibihara Formation of the Northern Subbelt occurs in fault contact with the Sambosan Group (Lower Mesozoic) of the Southern Subbelt directly. Serpentinite has been found as small bodies along the eastward extension of the fault (Text-fig. 2).

These faults are all high angled (over 50°) ones with a general trend of NE-SW and dipping southeast or northwestward. Width of the sheared part of these faults ranges several to several tens meters in general (Ikuma, 1980).

The relationship between the Upper Cretaceous Nagase Formation and the Lower Cretaceous strata in the eastern part of the area is inferred to be in fault contact laying on the stratigraphic evidence. Although the fault is exposed at a few localities, the nature of the fault is interpreted as being the same as the faults of NE-SW trend.

The Cretaceous strata of the Northern and Middle Subbelts of the Chichibu Belt and the Kajisakogawa Tectonic Line are cut by faults of north-south trend. These are also interpreted to be high-angle faults according to restricted observations at a few localities. The bed remarkably changes a east-northeast strike to NNE strike near the western side of the faults. The faults of N-S trend have a component of right separation.

Hitherto, the vertical displacement along the high-angle faults has been emphasized rather than the horizontal displacement. Of course, the differential movement with vertical displacement along the high-angle faults is inferred to be important, if we consider the arrangement of the pre-Cretaceous basement. Recently, Ichikawa and Ikuma



Text-fig. 2. Generalized tectonic map of the Monobe-Ryoseki area
1-3 : Cretaceous, 4 : Serpentinite

(1977) and Ikuma & Ichikawa (1978) have discussed the left-lateral strike separation of 10-12 km along the Kaminirogawa Fault which can be mostly attributed to a strike-slip faulting. They regarded that the Kaminirogawa Fault extends for the fault of NE-SW trend branching from the Median Tectonic Line and considered its main activity in post-Cretaceous∼pre-Middle Eocene age (Ikuma & Ichikawa 1978; Ichikawa, 1980). Ikuma (1980) pointed that the Cretaceous strata of this area were finally rearranged by the left-lateral movement of the Kaminirogawa Fault.

The fault pattern and other structural characteristics of the Cretaceous strata in this area are in good agreement with this view. The wrenching causes two sets of intersecting, vertical faults to form in a predicable orientation along the wrench zone. One set is strike-slip faults trending at low-angle to the wrench and has the same sense of displacement as that of the main wrench fault. In contrast, the high-angle set of conjugate strike-slip faults has a displacement sense opposite to that of the wrench. We consider that the high-angle faults of NE-SW trend are the synthetic strike-slip faults which presumably have the same sense of displacement as that of the Kaminirogawa Fault. The Kajisakogawa and Fukigoshi Tectonic Lines of NE-SW trend are the important faults dividing the subbelts of the Chichibu Belt and certainly have a long history dating back to the Late Paleozoic. So the strike-slip movement along these faults in post-Cretaceous is inferred to be the reactivation of the preexisting faults. Whereas the faults of N-S trend are considered to be the conjugate strike-slip faults with the opposite sense of right-lateral displacement.

Besides, axes of the small-scale folds in the Lower Cretaceous Hibihara Formation of the Northern Subbelt of the Chichibu Belt intersect the Kajisakogawa Tectonic Line at an small angle in a clockwise direction. These folds have a tendency to produce left-handed fold set. Left-lateral wrenches produce left-handed fold sets, where a traverse along the axis of any fold to its terminus would turn left to reach the next fold in the en échelon set.

Concluding Remarks

To sum up the above observations and considerations, it should be emphasized that the structure of the Upper Cretaceous strata in the Monobe area can be attributed to the wrench tectonics in post-Cretaceous age. This structural characteristics of the Upper Cretaceous strata in the Chichibu Belt differs markedly from the structure of the Cretaceous System in the Shimanto Belt which has been attributed mainly to compression, now related to subduction process (Kanmera and Sakai, 1975; Hada *et al.*, 1979; Suzuki and Hada, 1979). The Shimanto Belt is characterized by the imbricate thrust structure and the existence of tectonic mélange (Suzuki and Hada, 1979). The interpreted high-angle fault profiles of the Upper Cretaceous in the Chichibu Belt contrast with the downward flattening thrust profiles of the Shimanto Belt. The imbricate thrust structure would be caused in the compressional stress field which lies closer to the subduction zone. On the contrary, the high-angle fault belt of the Upper Cretaceous strata in the Chichibu Belt presumably occurs in the area landward of the compressional zone,

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III. PALAEOTECTONIC SETTING OF THE NAGASE AND KAJISAKO FORMATIONS (UPPER CRETACEOUS), SHIKOKU

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Abstract

The Late Cretaceous geotectonic analysis of Southwest Japan indicates that it was a part of an arc-trench system. The Upper Cretaceous Nagase and Kajisako Formations of the Monobe area in Shikoku was a part of strike-slip basins in the Kurosegawa tectonic zone which occupied the outer zone of non-volcanic frontal arc. These formations compose a fining-upward depositional cycle representing a transgressive facies which changes from a nearshore sand facies to an offshore mud facies. Biostratigraphic data suggest that they show an extremely low rate of sedimentation in an order of a few centimeters per one thousand years. This unusual sedimentation rate might be explained by a special sedimentary setting of more or less submerged frontal arc ridge; sediments from the continental margin area were either trapped in the forearc basin or by-passed to the trench area leaving the frontal arc area in a state of almost nondepositional condition.

Introduction

The lithofacies and spatial arrangement of the Cretaceous rocks of Southwest Japan strongly suggest that they were a part of an ancient arc-trench system from volcanic arc to subduction complex. The overall geotectonic framework of this arc-trench system seems to have been controlled by two major strike-slip mobile zones which occurred along the inner and outer side of the non-volcanic frontal (outer) arc. Within the outer strike-slip mobile zone (Kurosegawa tectonic zone) there is a series of elongated and fault-bounded local clastic basins of Early Cretaceous to partly Late Cretaceous age. The Nagase and Kajisako Formations (Tashiro *et al.*, Art. I, this volume) occupy one of such Upper Cretaceous sequences in which rather unusual record of sedimentation is preserved. These formations are composed of sandstone and shale attaining 290 m of total thickness. Biostratigraphic analysis (papers in this volume), however, indicates that they range from Cenomanian to possibly Lower Campanian in age giving the sedimentation rate in an order of 1–2 cm per one thousand years, a rate comparable to pelagic to hemipelagic accumulation. This paper considers a possible explanation of this observation with a broad context of arc-trench palaeo-tectonics.

Cretaceous arc-trench system of Southwest Japan

The Cretaceous geologic provinces of Southwest Japan form five major belts (Fig. 1, Tanaka, 1977; Taira, 1979). They are: (A) a belt of andesitic and rhyolitic extrusives and terrestrial sediments associated with contemporaneous granitic intrusives, (B) a narrow, elongate belt of Upper Cretaceous marine clastic basins along the Median Tectonic Line, (C) a belt of uplift, (D) a belt of scattered small basins of mainly Lower Cretaceous and partly Upper Cretaceous nonmarine to shallow marine sediments along the Kurosegawa tectonic zone, and (E) an outermost belt (Shimanto Belt) consisting of thick flysch-melange complex in which metabasalts and cherts occur.

These geologic provinces were interpreted as parts of ancient arc-trench system (Taira, Katto and Tashiro, 1979; Taira, 1979; Taira *et al.*, 1981). There are some lines of evidence that the Median Tectonic Line during Cretaceous time was left-lateral slip fault (Ichikawa, 1980). Furthermore, Otsuki and Ehiro (1978) indicated that many faults in Japan show dominantly left-lateral motion during Cretaceous time. The reconstruction of the Kula and Pacific plate indicates that it moved northerly direction possibly oblique to the "Shimanto trench" (see reconstruction by Uyeda and Miyashiro, 1974;

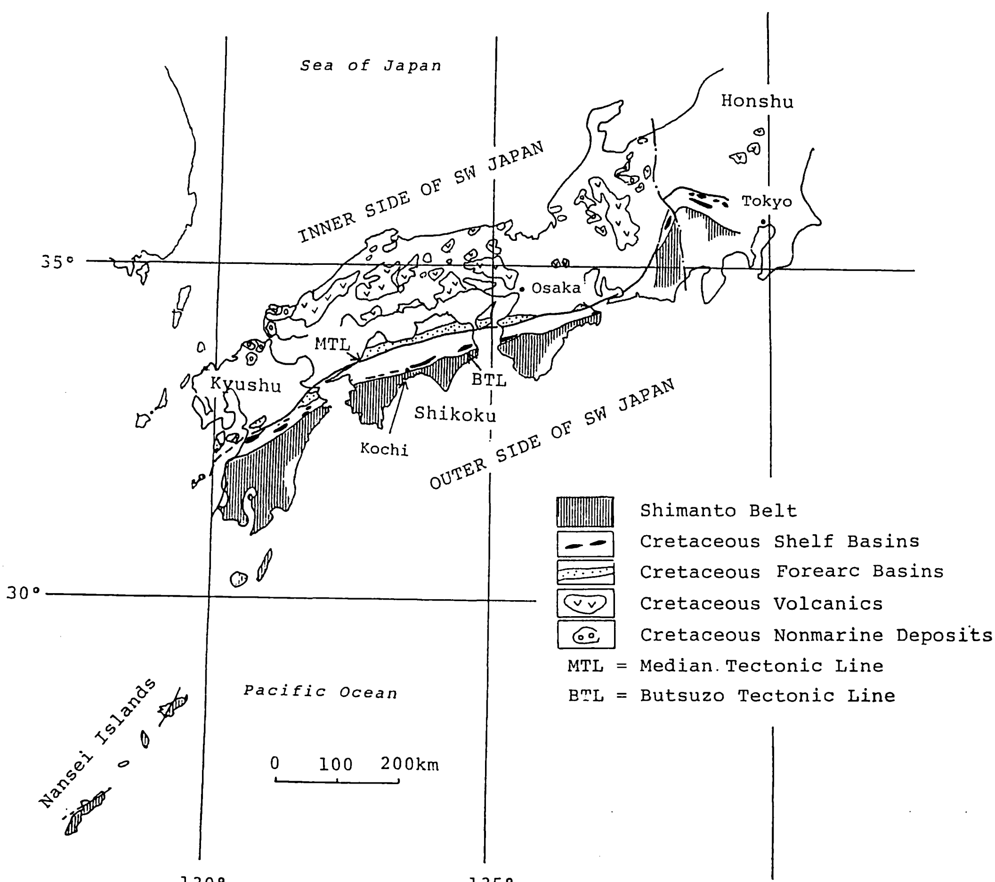

Fig. 1. Cretaceous rocks of Southwest Japan. Adapted from Taira *et al.* (1980).

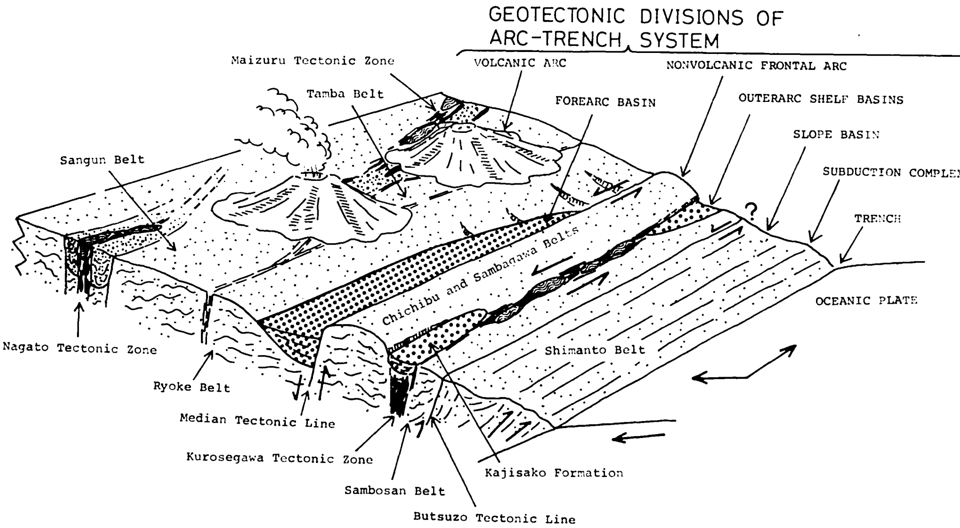

Fig. 2. Late Cretaceous geotectonic reconstruction of arc-trench system in Southwest Japan. After Taira, Saito and Hashimoto (1981).

Hilde *et al.*, 1977). With these data, Taira, Saito and Hashimoto (1981) showed a model of oblique subduction margin at the time of Late Cretaceous in the Southwest Japan (Fig. 2). In this model, two major left-lateral strike-slip mobile zones, the Kurosegawa tectonic zone and the Median Tectonic Line bound the frontal non-volcanic arc. Along these strike-slip mobile zones, sedimentary basins which were apparently controlled by lateral tectonic movement had been formed.

Forearc basins

The belt which is composed of marine clastic basins along the Median Tectonic Line (see Fig. 1) lies between the magmatic arc and the non-magmatic frontal arc and is called the forearc basin (the term "intra-arc basin" was used by the author preveously e. g. Tashiro, Taira and Matsumoto, 1980, but "forearc basin" is adapted in the present article following the terminology by Dickinson and Seely, 1979).

During Late Cretaceous time, a series of succesive forearc basins was formed in Kyushu, Shikoku and Kinki districts; they are the Goshonoura, Mifune, Ohnogawa [=Onogawa], Himenoura and Izumi basins. These basins show the following features in common.

(1) These basins were formed along the strike-slip mobile zones.

(2) Geologic structure is a syncline (or synclinorium) with its axis generally parallel to the arc trend, but the each individual fold pattern often shows *en echelon* arrangement.

(3) They had an extremely high rate of sedimentation.

(4) Each basin is a "graben-like" trough and had a life span of about 10 m. y.

In the eastern Kyushu, the Kurosegawa tectonic zone tends to diverge forming two separate systems, and within this divergent zone, an enormously thick Turonian to Santonian sediments (Ohnogawa Group) were accumulated. The Ohnogawa Group shows the 20,000 m thick, laterally deposited clastic sediments which were fed from NE direction now dipping toward the same NE direction (Teraoka, 1970). This pattern is quite similar to the previously reported examples of strike-slip basins in California (Ridge basin, Crowell, 1974) and in Norway (Hornelen basin, Steel, 1976).

The diverged two tectonic zones enclose the Sambagawa and Chichibu belts separating these from the Ryoke belt to the north and Sambosan and Shimanto belt to the south in the Island of Shikoku. The northern branch is the Median Tectonic Line. A large lateral as well as vertical displacement has been estimated along this fault. Along this, a narrow Campanian to Maastrichitian clastic basin (Izumi basin) was formed. The Izumi Group shows structural and sedimentary pattern similar to the Ohnogawa Group. The strata show some 40,000 m thick lateral accumulation, dipping to the east with *en echelon* synclinal structures, and the sediment was fed from the east to west direction (Suyari, 1973). This pattern, again, is quite similar to the preveously documented examples of the strike-slip basins (see Reading, 1980 for summary).

Outer-arc shelf basin

To the south of Median Tectonic Line lies the pre-Cretaceous rocks of Sambagawa and Chichibu belts which have been interpreted as Jurassic subduction complex by Taira, Saito and Hashimoto (1981). The Chichibu belt is uncomformably overlain by Lower Cretaceous clastic rocks. Therefore, during most of the Cretaceous time at least a part of the Chichibu belt remained as a belt of uplift. The time of exposure of the Sambagawa belt is considered to have occured between the Late Cretaceous and the Early Paleogene (Katto and Taira, 1979). Thus, the Sambagawa belt also formed a belt of uplift since the Late Cretaceous. These belt of uplifts have been interpreted as a non-magmatic frontal (outer) arc in the sense of Karig and Sharman (1975).

Along the Kurosegawa tectonic zone which extends in the southern margin of this belt of uplift, there are various elongated basins in which relatively thin fluvio-brackish to shallow marine sediments were deposited during most of the Cretaceous time. These sediments yield abundant molluscan fauna and land-plant flora. This belt can be interpreted as a series of outer-arc shelf basins.

The Kurosegawa tectonic zone contains the tectonic lenses of Silurian to Devonian limestone and shale associated with rhyolitic tuffs (Yoshikura and Sato, 1976). It also contains such rocks as metabasalts, barroisite-bearing schist, rodingite, jadeite-glaucophene schist, garnet amphibolite and sheared granite as tectonic blocks (Nakajima and others, 1978). These anomalous and exotic rocks are surrounded by serpentinite being described by Maruyama (1981) as "serpentinite melange". Within this belt, there are Triassic to Cretaceous shallow marine sediments in highly complex manner, often bounded by faults.

The Cretaceous sediments show a distinctive fining-upward depositional megacycle. The cycle starts on an unconformity with the basal, fluvial or nearshore conglomerates grading up into tidal to shelf sandstones which are overlain by offshore mud deposits. At least three correlative Lower Cretaceous cycles are recognized. There is another cycle in Upper Cretaceous represented by the Nagase and Kajisako Formations.

Sedimentation of the Nagase and Kajisako Formation

The exposures of the Nagase and Kajisako Formations are quite limited so that the lateral facies relationship and the areal extent of lithologic units are virtually unknown. Because of this, the interpretation of depositional environments of these formations should be inferred from the investigation of one representative section along the Nagase River. This limitation leaves the interpretations quite speculative. However, there are several lines of evidence which might help to construct a workable hypothesis.

Nagase Formation

The Nagase Formation represents a lower sandstone facies of a major fining-upward depositional cycle. The sandstone is medium-grained and grain shape is subangular (Fig. 3A). The rock is strongly indurated with silica cement which shows syntaxial overgrowth (Fig. 3B). The bedding characteristics are quite obscured showing rather "massive" type bedding. The following observations may aid in the environmental interpretation. (1) A general thickening-upward bedding trend is observed in the lower part of the Nagase Formation. Bed thickness ranges from 50 to 100 cm in the lower part and reaches 200 to 300 cm in the upper part of the cycle. In the upper part, a lens of molluscan shells is observed. (2) In the upper part of the formation, a trough cross bed with about 40 cm amplitude (Fig. 4B) is observed suggesting that this sandstone

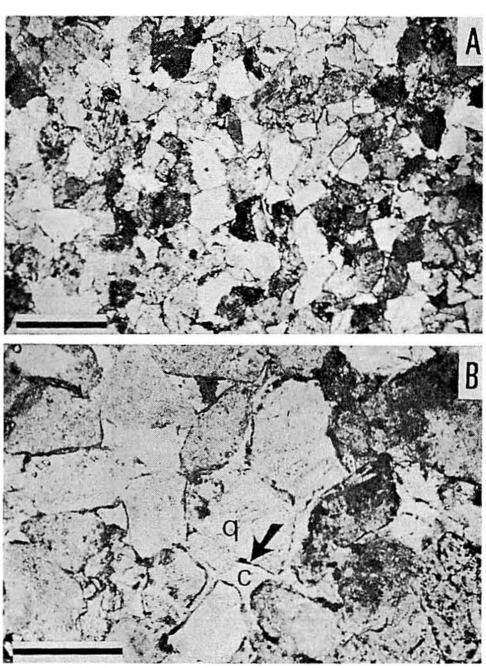

Fig. 3. Photomicrographs of sandstones of the Nagase Formation. A.) Scale bar is 600 microns. B.) q=quartz grain, c=silica cement overgrowth; dust ring indicated by an arrow. Scale bar is 300 microns.

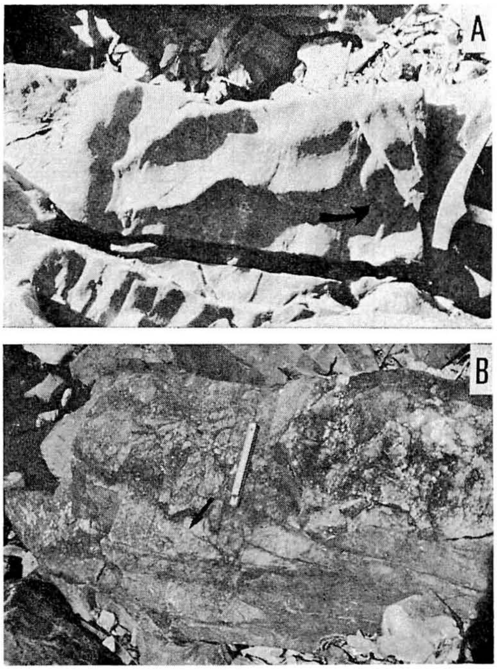

Fig. 4. A.) Ripple mark and burrow (indicated by an arrow) on the surface of sandstone bed. Nagase Formation. B.) Trough cross lamination (indicated by an arrow) in the sandstone of Nagase Formation.

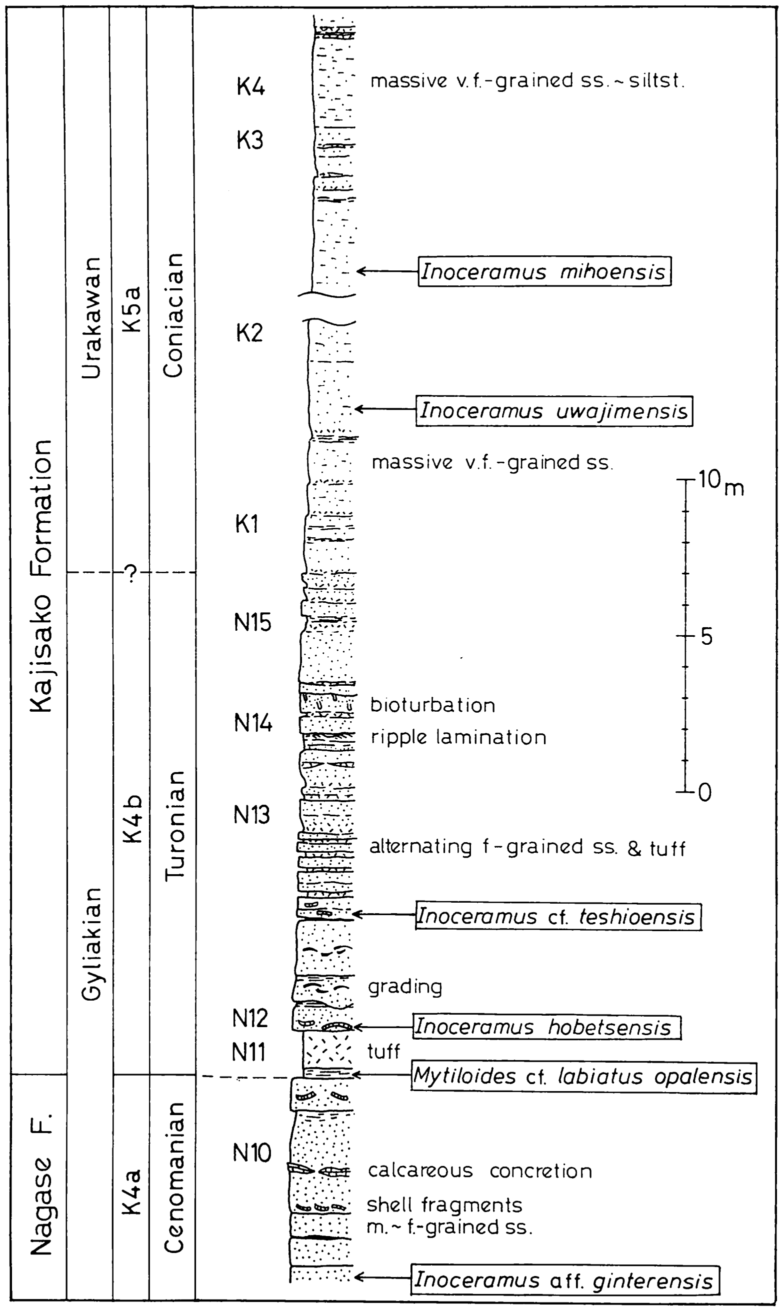

Fig. 5. Stratigraphic columnar section of the sequence at the Nagase-Kajisako boundary. Inocerami biostratigraphy adapted from Matsumoto *et al.* (1982, in this volume).

bed was laid under a current flow. Asymmetric ripples with spacing of 10 to 20 cm and branching burrows similar to *Ophiomorpha* which are oriented more or less parallel to the bedding plane are also recognized (Fig. 4A). (3) Molluscan fauna also suggests a transgressive nature: shallow marine to brackish condition in the middle part of the formation and somewhat deeper condition in the upper part (Tashiro et al., 1980, 1982, Art. I of this volume).

With these data, it can be suggested that the Nagase Formation may represent a shallow marine sand facies such as sand bar or nearshore sand shoal deposits.

Kajisako Formation

The Kajisako Formation is a transgressive facies overlying the Nagase Formation (Fig. 5). The lowermost part is a 130 cm thick tuff and shale bed (N11, Fig. 5). Above this bed lies a 100 cm thick sandstone bed (N12, Fig. 5) which shows a marked difference from the sandstone bed of the Nagase Formation. The composition of this sandstone shows abundant tuffaceous material including glass shards (Fig. 6A, B) and chloritic shale fragments with rich fine-grained matrix. The sandstone also contains abundant micaceous grains together with microfossil remains such as foraminifera, radiolaria (Fig. 7A-D) and molluscan shell fragments. The bedding show massive nature and locally the grading in the lower part of the sandstone bed is observed. On the bottom surface, shells of *Inoceramus hobetsensis* (Fig. 8) are observed. The lower part of the bed show apparant erosional scour. The upper part of the bed show a thinner layer of parallel lamination and ripple lamination.

The overlying sandstone beds (to K4, Fig. 5) intercalate frequently with tuffs and silty mudstones which show extensive bioturbation (Fig. 9). This part as a whole indicates apparant fining- and thining-upward depositional trend. Within this 30 m thick sequence, *Mytiloides* cf. *labiatus opalensis* to *Inoceramus mihoensis* zones are recognized in successive order suggesting that the presence of the Upper Gyliakian to Lower Urakawan (Turonian to Coniacian) (Matsumoto *et al.*, 1982, Art. VI, this volume). Especially, in the lower 10 m of the sequence, the complete K4b (Turonian) inocerami biozones are present. This correlation indicates that the sedimentation rate within this part is unusually slow, about a few milimeters per one thousand years, a rate comparable to pelagic seciments.

The age of abundant tuff beds in this part of sequence also coincides with the

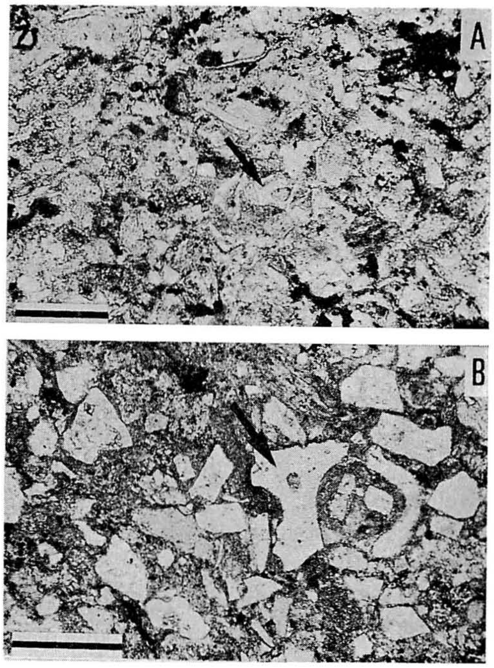

Fig. 6. Photomicrographs of sandstones of the Kajisako Formation. Volcanic glass indicated by arrow. A.) Scale bar is 600 microns. B.) Scale bar is 300 microns.

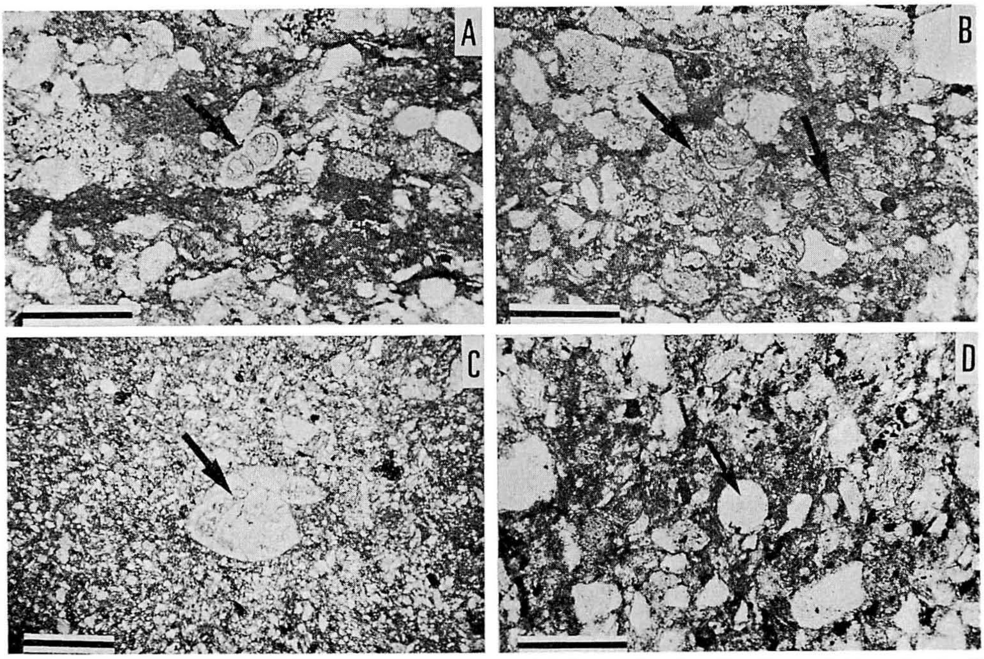

Fig. 7. Photomicrographs of sandstones containing microfossils (foraminifera in A, B and C, radiolaria in D). Scale bar is 300 microns for A, B and D, 600 microns for C. Kajisako Formation.

Fig. 8. Casts of *Inoceramus hobetsensis* on the bottom surface of the bed N12 (see Fig. 5) of the Kajisako Formation.

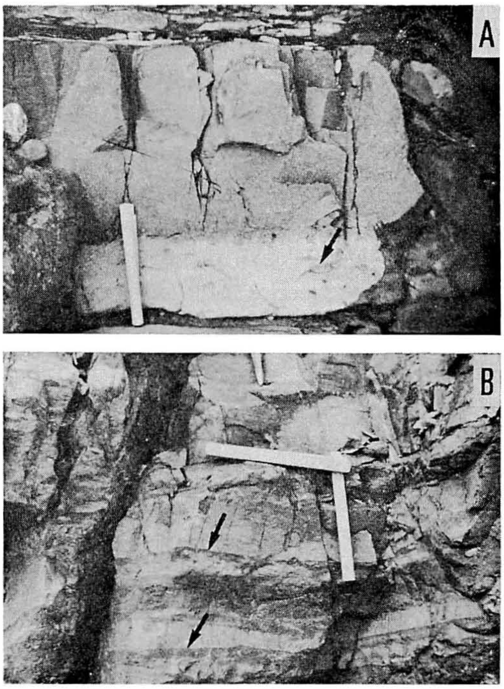

Fig. 9. Tuff beds in the Kajisako Formation. A.) Bioturbation within a tuff bed indicated by an arrow. B.) Note that the basal tuffaceous part grades upward to sandy part.

main cluster of radiometric dating of volcanoplutonic rocks in the Kyushu and Chugoku districts, 95 to 85 m. y. B. P. (Nozawa, 1970).

Toward the upper part, shales become predominated with a minor amount of tuff intercalations. In the transition zone from the alternating sandstone and shale to shaly facies, a few horizons of slump bed are present. The upper shale facies show "massive" appearance and intercalations of sandstone or tuff beds are not abundant. Microfossils are rich within shale facies.

The Kajisako Formation apparantly show a deeper facies than the Nagase Foration. The bedding characteristics and rather "mixed" compositional nature of sand grains may suggest that the sandstone beds are re-sedimented origin such as by turbidity currents.

Depositional Setting

The overall depositional trend of the Nagase and Kajisako Formations can be interpreted as a major transgressive sequence starting from the shallow marine sand deposits (Nagase Formation) to the possible resedimented sandstones of the lower part of Kajisako Formation and finally the deeper water shale facies of the upper part. The problem, however, arose from the fact that the transgression took place in about 10 million years while only 30 meters of sandy sediments were accumulated. A close inspection of the outcrop suggests that there is no particular break or hiatus in lithology.

Considering the palaeogeographic setting of the Turonian to Coniacian arc-trench system of Southwest Japan, it is evident that an enormously thick sediments were accumulated in the forearc basin (Ohnogawa basin). Also sedimentation of sandstone and shale took place in the Shimanto belt. It may be possible that the drainage from the continental area supplied the majority of sediments to Ohnogawa trough and to the "Shimanto trench" by-passing the frontal arc area. The areal extent of the outer-arc at that time is not known, but, considering the present area of the Chichibu and Sambagawa belts, the total area might not be significant. With progress of marine transgression, it might bearly be an island chain or subsided ridge with very little potential as a sediment source area. The characteristics of composition of sandstone in the Kajisako Formation suggest that it was deposited within a place where shallow marine elements and offshore elements were mixed, such as shelf-slope break. The modern examples of sediments from the shelf break area show such characteristecs as observed in the Kajisako Formation; sand mixed with microfossils, abundant mica flakes, shell fragments and sand-mud facies change (Southerard and Stanley, 1977). The presence of slumping in the Kajisako Formation may suggest the presence of "slope" setting. With these data, I have interpreted the Kajisako Formation as the transgressive shelf break facies which overlied the relict shallow marine sand facies of the Nagase Formation.

Conclusion

Considering the overall paleogeographic setting and with some sedimentological evidence, the Nagase and Kajisako Formations are interpreted as a part of outer-arc shelf to shelf break facies. The sediments supplied to this area had been very limited because the majority of sediments were either trapped within the forearc basin and/or by-passed to the trench environments. This hypothetical interpretation suggests that within the arc-trench system, a shallow marine sediment venier of extremely low rate of sedimentation can be formed on the outer non-volcanic ridge when the transgression shut off the supply of sediments. In order to verify this conclusion, it is necessary to investigate further the sediments accumulated in a similar setting.

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(JE) in Japanese with English abstract.
(J) in Japanese.

IV. CLAY MINERALS OF THE UPPER CRETACEOUS OF THE MONOBE AREA

By

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Abstract

Clay minerals of the Upper Cretaceous Nagase and Kajisako Formations of the Monobe area have been studied by X-ray method. Identified minerals are illite and chlorite, and the former shows mixed-layering with small amount of montmorillonite. The Nagase Formation is characterized by a larger content of clay components as compared to the Kajisako Formation, although the clay mineral assemblage is unchanged throughout both formations.

Introduction

In the preceding papers, the Upper Cretaceous System of the Monobe area has been studied from viewpoints of stratigraphy and sedimentology. We have attempted to investigate clay minerals in this area in order to get some information for supporting some sedimentological data. The purpose of the present paper is to outline the clay mineralogy of the Upper Cretaceous Kajisako and Nagase Formations in this area.

We would like to express our sincere thanks to Professor Emeritus Tatsuro Matsumoto of Kyushu University and Professor Masayuki Tashiro of Kochi University for kind arrangement of affording us the opportunity of this study and also for critical reading of the manuscript.

Analytical Method

28 sedimentary rock samples were collected effectively from the Upper Cretaceous Nagase and Kajisako Formations to cover various horizons by Tashiro *et al.* The Nagase Formation is composed mainly of sandstone, and the Kajisako is mainly of mudstone and partly sandstone and tuff. All the samples are not affected by weathering, and their clay mineral components were examined by X-ray diffraction method.

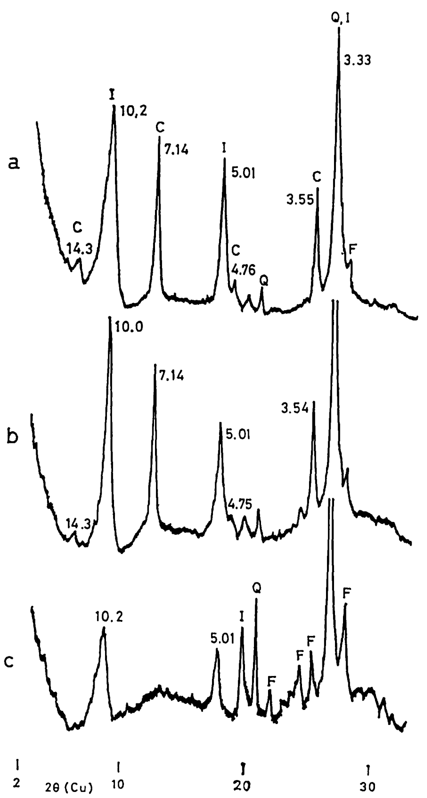
About 20 grams of the rock samples were ground in a stainless mortar, and the powdered material was mixed with distilled water at a ratio of 1 : 20. After adequate dispersion using a ultrasonic beam, less than 2 micron fraction was separated by sedimentation method. Centrifugal suspension was dropped on a slide glass, and then dried at room temperature.

Thus prepared air-dried oriented specimens of all the samples were initially analysed. Some samples were also run after treatments with ethylene glycol and HCl in order to detect montmorillonite and to confirm chlorite, respectively. X-ray diffraction pattern was recorded with a Rigaku diffractometer under the following conditions: Ni-filtered CuKα radiation, scanning speed of 2° per minute and scanning range of 2–34° (2θ).

Result and Discussion

It has been revealed that clay minerals constituting the Upper Cretaceous of the Monobe area are illite and chlorite. Non-clay minerals in clay-size fraction are quartz and feldspar.

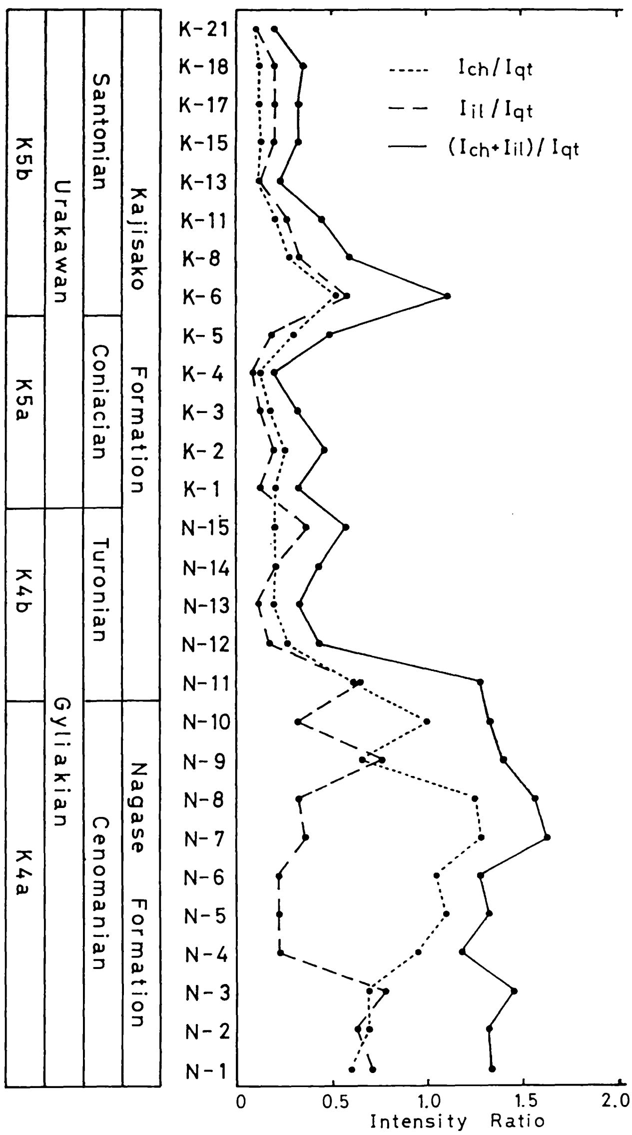
Text-fig. 1a shows the X-ray diffraction pattern of a representative sample in air-dried state, where the basal reflections of illite (a 10 Å sequence) and those of chlorite (a 14 Å sequence) are observed. The first order reflection spacing (10.2 Å) of illite is slightly larger than that of normal illite (10.0 Å). By ethylene glycol solvation, this reflection yields noticeable decrease in spacing and resulting sharpness in profile as shown in Text-fig. 1b, which is interpreted as mixed-layering with small amount of montmorillonite layer (Hower and Mowatt, 1966; Shirozu and Higashi 1972). Mixed-layering nature is commonly recognized in illite from the Monobe area, and is particularly outstanding at the lower horizons of the Kajisako Formation in which tuffaceous sediments predominate. The term of illite in this paper is used to indicate mica clay minerals including illite-montmorillonite mixed-layer mineral.



Text-fig. 1. X-ray diffraction patterns of sample N-1: illite (I), chlorite (C), quartz (Q), feldspar (F). a. Untreated. b. Treated with etylene glycol. c. Treated with HCl.

As for chlorite, this material gives reflections at 14.3 Å and its exact integral submultiples with exclusively high intensity of the second and fourth orders (Text-fig. 1a and 1b), and the mineral is identified as Fe-rich chlorite (Shirozu, 1978). As clearly shown in Text-fig. 1c, the chlorite is dissolved away when treated with HCl, which confirms the identification. The diffraction patterns of chlorite from the Monobe area are all identical. All the samples contain only illite and chlorite as clay components, which are comparable to the results of the Upper Cretaceous-Paleogene marine sediments in Kyushu by Miki (1978).

Estimation of the content of two clay minerals was made on the X-ray patterns. Intensity ratios of illite (10 Å) and chlorite (7 Å) to quartz (3.3 Å) are plotted along with stratigraphical succession in Text-fig. 2, in which the values are considered to



Text-fig. 2. Intensity ratios of illite (10 Å) and chlorite (7 Å) to quartz (3.3 Å) showing variation of clay contents in 28 samples from the Monobe area.

mean the relative abundance of these components.

Biostratigraphical and sedimentological studies made by Tashiro *et al.* (in this volume) and Taira (in this volume) in the present special issue indicate that the Upper Cretaceous System of this area is divided into two Formations, Nagase and Kajisako, and they have demonstrated a possibility that the sedimentation rate was very slow in the lower part of the Kajisako Formation, *i.e.* in the Turonian.

As is clear in Text-fig. 2, the "total clay content" curve shown by a solid line decreases abruptly around the horizon of N-11, which corresponds approximately with the boundary of the two Formations. Namely, the Nagase Formation composed mainly of coarse-grained sediments shows large content of clay components, particularly chlorite, whereas the Kajisako Formation has small contents of both illite and chlorite. In the lower part of the Kajisako Formation, no particular feature in clay mineralogy is detected which could be related with the slow sedimentation. It is, however, noticed that the illite in some samples from this part is mixed-layered with relatively large amount of montmorillonite layer as mentioned above. This nature may be attributed to the original tuffaceous material since volcanic glass is subjected to transformation from montmorillonite to illite through illite-montmorillonite mixed-layer by diagenetic alteration (Oinuma, 1979). Additional X-ray examination on some samples from the lower part of the Kajisako Formation gives no sign of glauconite, Fe-rich micaceous mineral, that is usually known as a product in a shallow marine environment with slow sedimentation rate.

Generally, reverse transformations, *i.e.*, aggradation process by diagenesis and degradation process by weathering must be taken into consideration in regard to the genesis of clay minerals in sedimentary rocks. Therefore more detailed clay mineralogical studies of individual clay component are required to discuss critically the problem of sedimentary environment in this area.

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V. UPPER CRETACEOUS AMMONITES FROM THE MONOBE AREA, SHIKOKU

By

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Abstract

Only a few ammonites have been hitherto reported from the Cretaceous of the Monobe area. In this paper I describe and illustrate the Upper Cretaceous ammonites collected mainly by Mr. Takeshi Kozai of Odochi Elementary School and partly by the late Mr. Motomu Hirata. They are classified into 22 species, of which 9 (listed in Table 1) are from the Cenomanian, 8 (Table 2) from the Turonian and 5 (Table 3) from the Coniacian through Campanian. They comprise several good age indicators which occur successively in the Monobe sequence. Several specimens, though incompletely preserved, seem to represent the species which are new to Japan, for example *Forbesiceras* aff. *F. beaumontianum* (d'Orbigny), *Mantelliceras* cf. *saxbii* (Sharpe), *Romaniceras* (*Romaniceras*) aff. *R.* (*R.*) *kallesi* (Zázvorka) and *Turrilites* (*Mesoturrilites*) aff. *T.* (*M.*) *aumalensis* Coquand.

Introduction

Hitherto little has been known as to the Upper Cretaceous ammonites of the Monobe area. Only *Mantelliceras* sp., on the basis of M. Hirata's Collection and two others on the basis of the Kyushu University Collection, were listed in a geological paper by Katto and Suyari (1956, p. 6). They were recorded under the Nagase Formation. No illustration has been given.

The late Mr. Motomu Hirata's Collection is available and included in the description of this paper. The Kyushu University Collection [GK.] of the ammonites from this area depends on the field work in 1956 of Mr. Makoto Ogawa, a student of the Department of Geology at that time, under the supervision of Dr. K. Kanmera. As a result of the recent geological mapping, Ogawa's ammonites have turned to be referred to the Hibihara Formation (Lower Cretaceous) and, therefore, excluded from the present description.

Recently Mr. Takeshi Kozai, with some school children, has collected numerous specimens of ammonites from various horizons of the Upper Cretaceous strata exposed along the River Kajisako, a tributary to the River Monobe [=Monobegawa]. This collection, which is at present kept at Odochi Elementary School [OES], is the majority of the material for the present study.

The stratigraphy, including the fossil localities and their stratigraphic positions, is described in the first paper of the present volume and not repeated here.

Before going further I thank Mr. Takeshi Kozai for his kind supply of the collection for this study, Dr. Masayuki Tashiro for his kind help in various ways, including the photographing, Professor Jiro Katto of Kochi University and Mr. Toshio Komatsu, Schoolmaster of Odochi Elementary School, for generosity of offering fascilities for my study. Miss Kazuko Hara has assisted me in preparing the typescript. Finally, this paper is one of the contributions to the "International Correlation of the Cretaceous System" which has been supported by the Science Rescarch Fund (No. 334043) of the Ministry of Education, Science and Culture [*Monbusho*].

Palaeontological Descriptions

For brevity the synonymy list is omitted in the following descriptions but the reference to previous works is clearly indicated in the text.

Class Cephalopoda
Subclass Ammonoidea
Order Ammonitida
Superfamily Desmocerataceae
Family Desmoceratidae Zittel, 1895
Genus *Desmoceras* Zittel, 1884

Type species:—*Ammonites latidorsatus* Michelin, 1836.

Remarks:—See Matsumoto (1954a, p. 248) and Cooper (1978, p. 79) for the diagnosis and subgeneric taxonomy of this genus. Contrary to Cooper's indication as *nom. nud.*, the subgenus *Pseudouhligella* has been valid since Matsumoto, 1938 (p. 22-23) who gave definition with designation of the type species (*Desmoceras japonicum* Yabe, 1904).

Desmoceras (*Pseudouhligella*) cf. *japonicum* Yabe

Pl. 7, Fig. 3

Material:—OES. 44005, somewhat deformed internal mould.

Description;—The specimen measures about 100 mm in diameter and 15 mm in width of umbilicus (15% of D). Whorl is higher than broad, with flattened parallel flanks and perpendicular umbilical walls. Three strongly sigmoidal constrictions with associated elevations are distinct on the last half whorl, which is probably the body-chamber. Weak riblets are discernible on the ventral part.

Remarks:—With respect to the above characters the specimen is well comparable with the holotype of *D.* (*P.*) *japonicum* Yabe (1904, p. 35, pl. 5, figs. 3-4) (reillustrated by Matsumoto 1954a, pl. 17, fig. 7 and 1938, text-fig. 27), from the Cenomanian of Hokkaido.

Occurrence:—In shale of loc. M-44, on the eastern side of the River Kajisako, collected by T. Kozai; Nagase Formation.

Genus *Mesopuzosia* Matsumoto, 1954

Type species:—*M. pacifica* Matsumoto, 1954.

Remarks:—See Matsumoto (1954b, p. 79) for the definition and the comparison with other genera. Cooper (1978, p. 73) ranked it down to a subgenus of *Puzosia*, in which

Austiniceras Spath, 1922 and *Anapuzosia* Matsumoto, 1954 are also included as subgenera. In this paper I would not discuss this problem but use *Mesopuzosia* for brevity.

Mesopuzosia cf. *indopacifica* (Kossmat)

Pl. 7, Figs. 4-6

Material:—OES. 03064, 03068, 03138 and 03151, all fragmentary whorls (internal moulds).

Description:—The fragmentary whorls are 25-30 mm in height and probably of middle growth-stage. One of them (OES. 03064) has inner whorls, showing rather evolute coiling. They are higher than broad. They have ribs of unequal length, which are very gently flexuous on the main part of the flank and projected fairly strongly forward as they approach the venter. Some ribs are more elevated than others and accompanied with a constriction.

Remarks:—The specimens are comparable with better preserved examples of *M. indopacifica* (Kossmat) (1898, p. 117, pl. 17, fig. 2) (also Collignon, 1932, p. 18, pl. 6, fig. 1; Matsumoto, 1954b, p. 84; Collignon, 1961, p. 50) from the Turonian of India, Madagascar and Hokkaido.

Occurrence:—In silty fine-grained sandstone at loc. M-03 on the River Kajisako, collected by T. Kozai; lower part of the Kajisako Formation.

Genus *Jimboiceras* Shimizu, 1935

Type species:—*Desmoceras planulatiforme* Jimbo, 1894.

Remarks:—See Matsumoto (1954b, p. 95) for the diagnosis and the comparison with other genera.

Jimboiceras sp. aff. *J. mihoense* Matsumoto

Pl. 6, Figs. 1, 2

Material:—OES. 05008-05003-05004-05006 (pieces of one individual); also (?) OES. 05005-05006.

Descriptive remarks:—A form shown by these poorly preserved specimens recalls us the inner whorl of *Jimboiceras mihoense* Matsumoto (1954b, p. 98, pl. 21, figs. 1-3), from the Upper Coniacian to Lower Santonian of Sakhalin and Hokkaido, and also *J. planulatiforme* (Jimbo) (1894, p. 27, pl. 1, fig. 4; Matsumoto, 1954b, p. 96, pl. 20, figs. 1-4), from the Turonian of Hokkaido and Sakhalin. Its ribs are more flexuous than in the former and coarser than in the latter.

Occurrence:—In dark grey shale at loc. M-05 on the River Kajisako, collected by T. Kozai, occurring along with *Inoceramus uwajimensis* Yehara.

Family Pachydiscidae Spath, 1922

Genus *Eupachydiscus* Spath, 1922

Type species:—*Ammonites isculensis* Redtenbacher, 1873.

Remarks:—See Matsumoto (1954a, p. 281; 1959, p. 30) for the generic diagnosis and the relation to other genera.

Eupachydiscus haradai (Jimbo)

Pl. 7, Fig. 7

Material:—OSE. 40001, body-chamber (internal mould) and much eroded septate part; OSE. 40002, another whorl.

Description:—Whorl is broadly rounded, somewhat broader than high, with considerably inflated flanks and rounded umbilical shoulders. Ribs are fairly coarse and moderately distant; stronger on the external mould. Long ribs are provided with strong tubercles at the umbilical shoulder, numbering 6 on the body-chamber of about 200°. Two or three shorter ribs are intercalated between the longer ones. Ribs show a gently concave curve on the flank, projecting moderately on the venter.

OSE. 40001 is measured as follows (in mm): Diameter=112, Umbilicus=32 (0.28), Height=41, Breadth=21×2 (?)

Remarks:—The specimens are identified with *E. haradai* (Jimbo) (1894, p. 29, pl. 18, fig. 2) (Matsumoto, 1954a, p. 281, pl. 24, fig. 2; pl. 25, figs. 1-3; pl. 26, figs. 1-3; Collignon, 1955, p. 44, pl. 9, fig. 1; Matsumoto, 1959, p. 33, text-fig. 13), from the Upper Santonian-Lower Campanian of Hokkaido, Sakhalin, British Columbia, California and Madagascar. The relationship of *E. haradai* with *E. isculensis* (Redtenbacher, 1873) is, I think, a problem which is to be worked out through investigations on populations at various places.

It is noted that OSE. 40001 has the body-chamber despite its smaller size than other well known examples. It may be still immature or there may be variation in size. An example of *E. isculensis* from the Gosau Group, illustrated by Wiedmann (*in* Herm *et al.*, 1979, p. 49, pl. 8, fig. A), is nearly as small as OSE. 40001, but has likewise the body-chamber. The holotype of that species (Redtenbacher, 1873, p. 122, pl. 29, fig. 1) is much larger, 185 mm in diameter. Collignon's (1932, p. 19, pl. 3, fig. 4) example from Madagascar is of intermediate size (diam.=145 mm).

Occurrence:—In dark grey shale at loc. M-40 on the River Kajisako, collected by T. Kozai, upper part of the Kajisako Formation. While *E. isculensis* is described to range from the Coniacian to the Lower Campanian (see Wiedmann *in* Herm *et al.*, 1979, p. 49), *E. haradai* is, so far, characteristic of the Upper Santonian and ranges up to the Lower Campanian in some areas.

Superfamily Acanthocerataceae
Family Forbesiceratidae Wright, 1952

I agree with Casey (1965, p. 461) to assign the family Forbesiceratidae to the Acanthocerataceae. Kennedy (1971) generally agreed with Casey, but ranked it at a subfamily of the Lyelliceratidae. The indication of the family under Hoplitaceae in his paper is probably a misprint.

Genus *Forbesiceras* Kossmat, 1898

Type species:—*Ammonites largilliertianus* d'Orbigny, 1841.

Remarks:—See Kennedy, 1971, p. 46 for diagnosis of the genus. Several species occurs from the Cenomanian of Hokkaido, although their descriptions are delayed.

Forbesiceras (?) sp. aff. *F. beaumontianum* (d'Orbigny)

Pl. 4, Fig. 3

Material:—OSE. 12002-12003, external and internal moulds.

Description:—Whorl is much compressed, with narrow umbilicus and probably narrow and flat venter. Sigmoidal ribs on the flank are numerous, dense, branching, narrowly flat and provided with clavate tubercles at the ventrolateral shoulder.

Remarks:—As the suture is not exposed, the generic assignment is not convincing. The shell-form and the ornament suggest a species allied to *Forbesiceras beaumontianum* (d'Orbigny) (1841, p. 328, pl. 98, figs. 1-2) (see also Kennedy, 1971, p. 47), from the Lower Cenomanian of France and southern England, but the ribs shown in the d'Orbigny's illustration are finer and more numerous than those in this specimen; those of *F. largilliertianum* (d'Orbigny, 1841, p. 320, pl. 95) (see also Kennedy, 1971, p. 47) are still finer.

Occurrence:—In shale at loc. M-12, on the right side of the River Kajisako, collected by T. Kozai; probably middle part of the Nagase Formation.

Family Acanthoceratidae Grossouvre, 1894

Genus *Mantelliceras* Hyatt, 1903

Type species:—*Ammonites mantelli* J. Sowerby, 1814 by the original designation of Hyatt (1903, p. 113) (*non* 1900).

Remarks:—See Matsumoto *et al*., 1957 (p. 5), Matsumoto *et al*., 1969 (p. 253) and Kennedy, 1971 (p. 49) for the diagnosis and relations with other genera.

Mantelliceras cf. *japonicum* Matsumoto, Muramoto et Takahashi

Pl. 1, Figs. 1, 2

Material:—Hirata Coll. No. 664 (Pl. 1, Fig. 1), an internal mould of an outer whorl; Ditto. No. 960 (Pl. 1, Fig. 2).

Description:—One of the figured specimens (No. 664) consists of the body-chamber of about a half whorl and the preceding 60° of the septate part. Its dimensions (in mm) under a secondarily compressed condition are as follows:

Diameter = 88.0 Umbilicus = 27.0 (.31) Height = 36.6 Breadth = 23.0 (+)

Long and short ribs are mostly alternating and separated by somewhat wider interspaces. They are rectiradiate on the main part, but some of them are prorsiradiate around the umbilicus. There are inner and outer ventrolateral tubercles on every rib, a row of tubercles at the umbilical margin and another row at an inner lateral part on the long ribs. The inner lateral tubercles are distinct and stronger than the umbilical ones on the septate part. On the body-chamber the inner lateral and the inner ventrolateral ones are much weakened and finally absorbed by the ribs.

Partly exposed sutures show the pattern and minor incisions similar to that of *M. japonicum* (see Matsumoto *et al.*, 1969, text-fig. 2). The other specimen (No. 960) is slightly smaller but very similar to the above described one.

Remarks:—If the effect of the secondary compression is excluded, the observable characters suggest that the specimens are probably identified with *Mantelliceras japonicum* Matsumoto, Muramoto et Takahashi (1969, p. 253, pl. 25, figs. 1-2; pl. 27, figs. 1-2; text-figs. 1-2), from the Lower Cenomanian of Hokkaido. The Monobe specimens are somewhat (but not much) smaller than the holotype. The last part is not completely preserved in the former.

Occurrence:—In sandy shale at Nagase, close to the dam site. No. 960 (of Hirata Collection) was obtained by Tokutaro Morita (1936-4-15) at Nagase about 1 km east of the railway station Inonoguchi (now abandoned). Both from the middle part of the Nagase Formation.

Mantelliceras cantianum Spath

Pl. 2, Figs. 1, 2

Material:—OSE. 28001, comparatively less deformed but partly damaged.

Description:—The measurements (in mm) at two points are as follows:

	Diam.	Umb.	Height	Breadth (costal)	B/H	B. (intercostal)
last	127.0	~41.0(.32)	55.0	49.0	0.89	46.5
−180°	87.5	29.0(.33)	33.0	35.0	1.06	33.0

The whorl at the last part is higher than broad and subelliptical in section; that in the main part is slightly broader than high or nearly as high as broad and subrounded in section. Umbilicus is of moderate size.

Ribs are strong, distant, alternately long and short, nearly rectiradiate for the most part, but sometimes curved forward around the umbilical margin. Double umbilical tubercles on the long ribs may be united and bullate on the last part. Inner ventrolateral tubercles distinct on the main part and weakened and then absorbed by the rib on the last part. Outer ventrolateral tubercles clavate, persisting for a longer period, but gradually weakened and finally disappear on the last part.

A long rib on one side may be extended to a short one on the other side although this may not be a specific character.

Remarks:—This specimen is evidently identified with *Mantelliceras cantianum* Spath, 1926 (see Kennedy, 1971, p. 55, pl. 18, fig. 1; pl. 20, fig. 1; pl. 26, figs. 1, 5), from the Lower Cenomanian of England, Madagascar, Texas and Hokkaido (Matsumoto *et al.*, 1969, p. 256, pl. 27, fig. 3; pl. 28, fig. 1).

Occurrence:—Loc. M-28, about 100 m southeast of the Nagase dam, collected by T. Kozai; lower portion of the middle part of the Nagase Formation.

Mantelliceros cf. *saxbii* (Sharpe)

Pl. 7, Figs. 1, 2

Material:—OSE. 53001, internal mould of a quarter whorl, and OSE. 61001a, b, external and internal moulds.

Description:—Whorl is much higher than broad, with height=49 mm and breadth=20 mm in OES. 53001 and h=28.4 mm and b=15.0 mm in OSE. 61001, although it may be somewhat compressed secondarily. The increase of whorl height is fairly rapid, as shown by much smaller height (about 30 mm in OSE. 53001) at about a quarter whorl earlier. There may be again some effect of deformation.

Numerous ribs, about 10-12 within a quarter whorl, are very gently flexiradiate in lateral view. One or two unequally shorter ribs are intercalated between the longer ones.

The umbilical tubercles at the end of the long ribs are bullate and not doubled. The inner and outer ventrolateral tubercles persist well; the former is nodate and may be weakened on some (not the presserved last) part; the latter characteristically clavate.

The specimens are almost wholly septate, but the suture whose head is at about the last third rib preserved may be the last. The details of the suture are not well seen, but the general pattern is similar to that of text-fig. 1d of *M.* aff. *saxbii* illustrated by Kennedy and Hancock (1971). L is not narrowed and the auxiliaries are descending.

Remarks:—With respect to the above characters, the two specimens are well comparable with *Mantelliceras saxbii* (Sharpe) redescribed by Kennedy and Hancock (1971). It resembles closely a secondarily compressed example (*op. cit.*, pl. 80, fig. 1a, b) from the Lower Cenomanian of England.

Occurrence:—Loc. M-53, and M-61 in dark grey fine-grained sandstone in the observable lower portion of the middle part of the Nagase Formation, collected by T. Kozai.

Genus *Calycoceras* Hyatt, 1900

Type species:—*Ammonites naviculare* Mantell, 1822.

Remarks:—As to the classification of this rather broad and variable genus, several authors (e. g. Matsumoto *et al.*, 1957, p. 9; Wiedmann, 1960, p. 731; Kennedy, 1971, p. 20; Thomel, 1972, p. 52; Matsumoto, 1975, p. 101; Cooper, 1978, p. 83) gave discussions, in which new genera or subgenera were proposed. I would not repeat the comments here.

Newboldiceras Thomel, 1972, with the type species: *Acanthoceras newboldi* Kossmat, 1897 could be used, since it is at least taxonomically convenient and may be stratigraphically useful. In this paper, however, I do not use it, because I have not yet arrived at a clear scheme of subgeneric classifiation.

Calycoceras cf. *orientale* Matsumoto, Saito et Fukada

Pl. 3, Fig. 1

Material:—OSE. 39001, an external mould of a large specimen on sandstone.

Description:—This is a large specimen, about 50 cm in diameter, whose outer half whorl is, however, deficiently impressed. The preceding part, which is under a deformed condition, is roughly measured (in mm) as follows:

Diameter = 340 Umbilicus = 110 (.32) Height = 130

The breadth cannot be measured, but the whorl is presumably higher than broad. The increase of whorl-height is moderately rapid.

Prominent, slightly prorsiradiate ribs are of moderate distance; one or two shorter ones intercalated between the longer ones. Umbilical tubercles at the end of the long ribs are bullate and prominently pointed at some distance from the umbilical margin. Inner ventrolateral tubercles are very prominent, although less so on some of the shorter ribs. Outer ventrolateral tubercles are moderately separated from the inner ones.

Remarks:—Although the external part is not impressed on this mould, the observable characters are very close to the diagnosis of *C. orientale* Matsumoto, Saito et Fukada (1957, p. 16, pl. 5, fig. 1; pl. 7, fig. 1), from the Cenomanian (rather upper part of "Middle Cenomanian") of Hokkaido. Large specimens are found also in Hokkaido.

Whether *C. orientale* is a mere variety of *C. asiaticum* (Jimbo, 1894) or a distinct species and whether *C. asiaticum* is a geographical subspecies of *C. newboldi* or not may be a problem to be worked out from the population concept. For the time being I follow Matsumoto *et al.*, 1957.

Occurrence:—A large sandstone block fallen at the cliff of loc. M-39, middle part of the Nagase Formation.

Calycoceras sp. nov. (?) aff. *C. naviculare* (Mantell)

Pl. 4, Figs. 1-2

Material:—OSE. 36001, 36003, 36004, 36007 (internal moulds) and 36005 (external mould) of fragmentary whorls of large individuals.

Descriptions:—No specimen shows a complete shape, but the available specimens have (or suggest) a depressed whorl, with a flattened venter between the outer ventrolateral tubercles (or angulations).

The whorl-breadth measures nearly 200 mm in OSE. 36004 (in which width of flat venter [V]=80 mm) and about 140 mm in OSE. 36007 (in which V=60 mm). Because of the persistence of tubercles or subangulations at the outer and also inner ventrolateral shoulders, the costal whorl section looks subpolygonal rather than broadly rounded or semicircular even at the late growth-stage of this large size.

In all the specimens ribs are strong and alternately long and short, sometimes two shorter ribs of unequal length are between the long ones. They are separated by the interspaces which are more or less broader than the ribs. The ribs are rather narrow on OSE. 36001 and 36007, but thicker and more distant than the above in OSE. 36003 and 36005. Another example, OSE. 36004, may be intermediate in this respect.

The umbilical tubercles at the end of the long ribs are bullate and distinct, being most prominent at the umbilical shoulder at some distance from the umbilical margin. The inner ventrolateral (i.e. lateral by some authors) tubercles are distinct but bullate on OES. 36001, 36004 and 36007 at the stage with whorl-height [H] of about 150 mm;

they are thickly nodose on the coarse ribs of OSE. 36003 and 36005, at the stage with H=about 100 mm, but become obsolete and absorbed by the major ribs of the outer whorl in OSE. 36005, of which ribs themselves are somewhat but not much weakened. Exceptional branching of shorter ribs at an inner ventrolateral tubercle is seen of OSE. 36005.

The outer ventrolateral tubercles also persist well; for instance, those on OSE. 36001 and 36004 are bullate but distinct even at the stage with H=50 mm or so (see Pl. 4, Fig. 2); they remain as subangulations on the ribs on OSE. 36007 (Pl. 4, Fig. 1). Siphonal tubercles are lost at the same stage.

The sutures, as exposed on OSE. 36001, show massive saddles, subrectangular L and generally shallow, minor incisions, although they do not show a complete pattern.

Remarks.—Calycoceras naviculare (Mantell) was redescribed independently by Kennedy (1971, p. 71), Cobban (1971, p. 13) and Thomel (1972, p. 53), of which the last author was rather a splitter. Generally I should like to follow Kennedy, but still keep *C. stoliczkai* Collignon (1937, p. 48) as being separable from *C. naviculare* at least subspecifically. The two syntypes of *C. stoliczkai* illustrated by Stoliczka (1864, pl. 39, figs. 2, 3) from India and an example from Madagascar (Collignon, 1964, pl. 364, fig. 1593) show such diagnostic features that the ribs often spring in two and only occasionally singly from the prominent umbilical tubercles or the secondary ribs arises at a point close to the umbilical shoulder, that both the inner and outer ventrolateral as well as siphonal tubercles disappear early in growth-stage and that the whorl is rounded or semicircular in section. In unmistakable examples of *C. naviculare* the ribs are independent and alternately long and short, inner ventrolateral tubercles are lost early in ontogeny but the outer ones persist longer. Moreover, *C. stoliczkai* occurs or begins to appear in older beds than *C. naviculare*.

A specimen from Hokkaido described by Matsumoto *et al.* (1957, p. 19, pl. 6, fig. 1) under *C.* cf. *stoliczkai* has also a rounded whorl with loss of both the inner and outer ventrolateral tubercles. The umbilical tubercles are prominent, but the ribs do not spring in two on this specimen, which is larger than the Stoliczka's. The intercalated ribs, however, appear close to the umbilical tubercles. This seems to suggest that the ribs may spring in two on the unexposed younger whorls. This Hokkaido specimen came from Unit II j of the Shiyubari area, which is assigned to the middle rather than the upper part of the Cenomanian sequences of this area. On the other hand an example from Hokkaido, which I (Matsumoto, 1975, p. 102, text-fig. 1) described under *C.* cf. *naviculare* was found from the Upper Cenomanian in the Ikushumbets sequence.

Turning back to the described specimens from the Monobe area, several fragmentary specimens from the same locality probably belong to a single species, which resembles *C. naviculare* in general aspects, but is characterized by the persistence of both the inner and the outer ventrolateral tubercles to the whorl of large size and consequently by a polygonal rather than rounded whorl-section. A new species may be required for the present specimens, but as the characters of the inner whorls are unknown, I hesitate to establish it.

The strong ribbing and the persistency of the tubercles in this form, which is allied to *C. navioulare*, suggest us the intimate relationship between the subgroup of *C. newboldi* and that of *C. naviculare*. The thick ornament of some specimens (OSE.

36003 and 36005) recalls us the similarity to an imperfectly known species which is provisionally called *C.* aff. *crassum* Thomel (Matsumoto, 1975, p. 104, pl. 13, fig. 2; text-fig. 2). That was, however, based on much smaller specimen than the present ones.

Occurrence:—In sandstone at loc. M-36, on the left bank of the River Kajisako, close to the artificial lake of the Nagase dam, upper part of the Nagase Formation; collected by T. Kozai.

Genus *Romaniceras* Spath, 1923

Type species:—Ammonites deverianus d'Orbigny, 1841.

Remarks:—Romaniceras and its allied genera have been revised recently by Kennedy *et al.*, 1980a, with comprehensive discussion on the taxonomy and phylogeny. I generally follow the results of their study, but for a few points which are not discussed in this paper.

One of the species from the Monobe area described below is rather an unusual form.

Romaniceras (*Romaniceras*) sp. nov. (?) aff. *R.* (*R.*) *kallesi* (Zàzvorka)

Pl. 5, Figs. 1, 2

Material:—OSE. 03082-03083, an external and an internal moulds of an individual, and OSE. 03153, an internal mould of about a quarter whorl.

Description:—Coiling is rather evolute, with moderate rate of whorl increase. Whorl is much higher than broad under the secondarily compressed condition; presumably somewhat higher than broad, with flattened flanks originally.

Ribs are rather narrow, fairly numerous (about 12 per 1/4 whorl) on earlier whorl (up to diameter=60 mm), becoming less so and separated by wider interspaces on later parts. They are nearly rectiradiate on the inner whorl of OSE. 03083 and sometimes gently flexuous on its outer whorl; in the latter and OSE. 03153, which represents an outer whorl, somewhat projected on the ventrolateral part. The ribs are alternately long and short; the shorter ones being of unequal length, some arising at about the middle of the flank or branched at the lateral tubercles, but others longer.

Lateral tubercles are normally prominent and situated below the middle of the flank, fairly close to the smaller umbilical tubercles; the clavate outer ventrolateral ones stronger than the inner ventrolateral; siphonal ones not well seen. On a limited part of OSE. 03083 (with whorl heights of 22 to 33 mm), the ornament is unusual in that the tubercles are temporarily weakened. This is probably a malform.

Remarks.—With respect to the narrow ribs and flattened flanks, this species is similar to *R.* (*R.*) *kallesi* (Zàzvorka, 1958), recently redefined by Kennedy *et al.* (1980a, p. 342), from the "early mid-Turonian" of Europe. On the outer whorl of that species the ribs are predominant over tubercles, whereas in ours the tubercles are kept fairly distinct, except for an unusual part mentioned above.

USGS. 15947, a specimen from New Mexico, which was indicated by Kennedy *et al.* (1980a, text-fig. 2) as *Shuparoceras* sp. nov., is flat sided and shows in its adolescent stage an ornament similar to the late whorl of the present species. As the character of its body-chamber is not known and as the ornament is moderately strong (especially prominent with respect to the lateral tubercles) in the main part of the septate whorls, it is better to assign it to *Romaniceras* (s. s.) at least for the time being. In fact, in the immature stages, it is fairly similar to another smaller specimen from New Mexico, which was illustrated under *R.* (*R.*) *kallesi* by Kennedy *et al.* (1980a, pl. 45, fig. 2).

The abnormal part with obsolete lateral tubercles looks similar to a whorl of *Tarrantoceras* Stephenson, 1955, in lateral view, but this is probably superficial.

Occurrence:—In silty sandstone at loc. M-03, on the River Kajisako, collected by T. Kozai; Zone of *Inoceramus hobetsensis*, lower part of the Kajisako Formation.

Romaniceras (*Romaniceras*) cf. *deverianum* (d'Orbigny)

Pl. 5, Fig. 3

Material:—OSE. 03056, 03070 and 03148, all fragmentary.

Descriptive remarks:—OSE. 03056 shows a venter, about 27 mm in breadth, having three rows of tubercles, distinctly clavate siphonal one and strong outer ventrolateral ones with a rounded base and a clavate top. The tubercles rest on rather broad and low ribs which cross nearly vertically the venter. OSE. 03070 shows a flat flank, about 49 mm in height, having distant ribs of moderate strength and breadth, on which tubercles are disposed at dissimilar distance, with the lateral one closer to the inner ventrolateral one than the umbilical one, the last of which is somewhat separated upward from the umbilical margin. OSE. 03056 shows both the ventral and lateral parts, and the umbilical tubercles are sharply bullate.

As the specimens are fragmentary, they are hardly identified with precision. They can be, however, compared with some of the variable forms of *R. deverianum* (d'Orbigny), which have been redescribed recently by Kennedy *et al.* (1980a, p. 332) on numerous specimens from Uchaux (France) and other regions.

Occurrence:—In fine-grained sandstone of the lower part of the Kajisako Formation, at loc. M-03 on the right bank of the River Kajisako, with *Inoceramus hobetsensis* Nagao et Matsumoto; Middle Turonian.

Romaniceras (?) sp. indet.

Material:—OSE. 51067, fragmentary whorl.

Descriptive remarks:—Although the specimen is incompletely preserved, it shows a rather rounded whorl on which gently arcuate (concave forward), strong ribs are disposed at wide but variable distance. On each rib there are a bullate tubercle at some distance from the umbilical margin, a strong lateral tubercle somewhat above the middle of the flank and a ventrolateral one. Although the three tubercles on the venter are not exposed, this specimen is probably referable to *Romaniceras*. It is similar to *R.* cf. *deverianum* described above in the number of tubercles and distant, long ribs, but it has a more rounded whorl and more arcuate and stronger ribs.

Occurrence:—In dark coloured, silty fine-grained sandstone at loc. M-51, with

Inoceramus teshioensis Nagao et Matsumoto, which suggests the Upper Turonian.

Kennedy *et al.* (1980a) stated that species of *Romaniceras* in their revised sense are confined to the Middle Turonian in Europe.

Wiedmann *in* Herm *et al.* (1979) reported a rare species of *Romaniceras* from the Coniacian of Austria. An example from the Upper Turonian of Japan is interesting to complete the range, although it is still an incomplete record.

Family Collignoniceratidae Wright et Wright, 1951

Genus *Collignoniceras* Breistroffer, 1947

Type species:—Ammonites woollgari Mantell, 1882.

Remarks:—See Kennedy *et al.*, 1980b (p. 558) for the up-to-date and reliable information of this genus.

Collignoniceras cf. *woollgari* (Mantell)

Pl. 5, Figs. 4–7

Material:—Numerous small, probably immature specimens, OSE. 03110 (Pl. 5, Fig. 4), 03120 (Pl. 5, Fig. 6), 03146 (Pl. 5, Fig. 5), 03051, 03052, 03053, 03054 [=03072], 03080, 03149 and 03152. A fragmentary whorl of probably middle growth stage, OSE. 03060 (Pl. 5, Fig. 7); fragmentary pieces of larger outer whorls, OSE. 03059 and 03150. All from one locality.

Description:—Immature specimens mostly show a rather evolute coiling, moderately wide umbilicus (about 40% of diameter), usually simple and prorsiradiate ribs, each of which has two (i. e. inner and outer) ventrolateral, small tubercles and a siphonal keel, with serration corresponding to the ribbing. Intercalated shorter ribs may be found occasionally, but in a few specimens (e. g. OSE. 03053 and 03054) intercalated or branched ribs occur more frequently. The umbilical tubercles are very small or bullate or indistinct on some ribs. The ribs are numerous and crowded in these small specimens, but as seen in OSE. 03146, they become gradually distant at diameters over 20 mm. The suture exposed on OSE. 03149 shows the same kind of pattern as what I have illustrated (Matsumoto, 1965, text-fig. 6).

OSE. 03060 of probably middle growth-stage shows moderately distant, equally long, prorsiradiate ribs which have ventrolateral tubercles of moderate intensity.

OSE. 03150 and 03059, fragmentary pieces of body-chamber, have distant, coarse ribs on which the umbilical tubercles are prominent and shifted outward and the two ventrolateral tubercles are united into a horn like strong elevation. The rib is projected forward towards the keel at the middle of the venter.

Remarks:—Although the material is incomplete, the specimens as a whole indicate the diagnostic characters of *Collignoniceras woollgari* (Mantell), redefined by Kennedy *et al.* (1980b, p. 560). The characters of the small specimens suggest *C. woollgari bakeri* (Anderson) (see Matsumoto, 1965, p. 16, pl. 3, figs. 3–4).

OSE. 03060 might be considered as *C. carolinum* (d'Orbigny) (see Kennedy *et al.*, 1980b, p. 514) on the ground of less distant ribs than those of the typical form of *C. woollgari* at the comparable stage. The ribs are, however, straightly prorsiradiate as in the latter and the rib density may be similar to that of some example of *C. woollgari* (e.g., Kennedy *et al.*, 1980b, pl. 66, figs. 1-3, at whorl-height=25-30 mm) at the corresponding size.

Occurrence:—In silty sandstone at loc. M-03, on the River Kajisako, collected by T. Kozai; Zone of *Inoceramus hobetsensis*, lower part of the Kajisako Formation.

Order Lytoceratida

The available specimens are all so fragmentary that brief descriptive remarks are given here.

Superfamily Lytocerataceae
Family Lytoceratidae Neumayr, 1875
Genus *Argonauticeras* Anderson, 1938

Type species:—*Lytoceras argonautarum* Anderson, 1902.

Remarks:—For the up-to-date redefinition of this taxon see Kennedy and Klinger (1978, p. 301), although they ranked it as a subgenus of *Ammonoceratites* Bowdich, 1822.

Argonauticeras (?) sp.

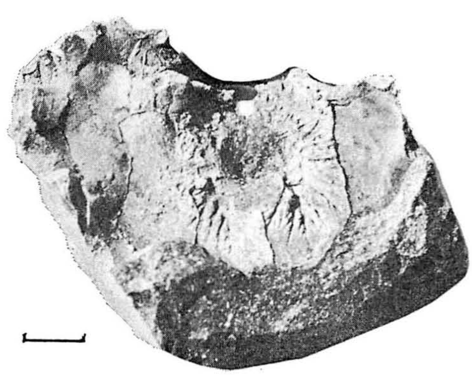
Text-fig. 1

Material:—OSE. 03125, a fragmentary whorl, showing a septum.

Descriptive remarks:—The whorl is broadly rounded, about 75 mm in breadth. A septal lobe of a lytoceratid type is well shown. Surface ornamentation is not clearly shown.

This specimen is not comparable with any species of the Lytocerataceae from the Upper Cretaceous. It is similar to some Lower Cretaceous species of *Argonauticeras* and is indicated here under that generic name with a query. I know rare occurrences of *Argonauticeras* like fragmentary ammonites from the Turonian of Hokkaido, which are awaiting description. The Hokkaido form has a more circular whorl-section.

Occurrence:—In silty sandstone at loc. M-03 on the River Kajisako, collected by T. Kozai.



Text-fig. 1. *Argonauticeras* (?) sp. OES. 03125, natural cross-section of a fragmentary whorl. Bar indicates 10 mm. (Photo by M. Tashiro)

Family Gaudryceratidae Spath, 1927
Genus *Gaudryceras* de Grossouvre, 1894

Type species:—*Ammonites mitis* von Hauer, 1866.

Remarks:—This genus has been recently reviewed by Kennedy and

Klinger (1979, p. 128), whom I would generally follow but not entirely be satisfied. Regretably, I have not yet completed the monograph of the gaudryceratids from Hokkaido. As the material from the Monobe area is deficient, I would not discuss the problem in this paper.

Gaudryceras cf. *denseplicatum* (Jimbo)

Pl. 6, Fig. 3

Material:—OSE. 03135, a fragmentary whorl, and OSE. 03300 internal and external moulds of another fragmentary whorl.

Descriptive remarks:—These specimens have gently flexuous, sharp lirae which show branching and intercalation on the flank. There are periodic, narrow and low major ribs, where minor lirae are approximated and elevated. The suture exposed on OSE. 03300 is of *Gaudryceras* type.

The above characters are identical with those of the inner whorl of *G. denseplicatum* (Jimbo) and the specimens are probably identified with it. Incidentally, *G. denseplicatum* (Jimbo, 1894) is regarded as a synonym of *G. glaneggense* (Redtenbacher, 1873) by Kennedy and Klinger (1979, p. 76). This may be correct, as I did think so in view of the resemblance of the body-whorl between the two holotypes, but it is necessary to make clear the characters at various growth-stages on the form from the Gosau Beds of Austria.

Occurrence:—In dark coloured silty sandstone at loc. M-03, on the River Kajisako, coll. by T. Kozai; Zone of *Inoceramus hobetsensis*, lower part of the Kajisako Formation.

Gaudryceras cf. *tenuiliratum* Yabe

Pl. 6, Fig. 4

Material:—OSE. 14006, fragmentary whorl, and OSE. 14052, external mould.

Descriptive remarks:—The shell, about 75 mm in restored diameter, bears flexuous lirae and fairly frequent, narrow and low major ribs on which a few approximated lirae run. The lirae are sometimes branching or intercalated and are narrow and normally separated by somewhat wider interspaces on the outer part of the flank.

The above ornamentation is the same as that of the body-chamber of *Gaudryceras tenuiliratum* Yabe (1903) (*non* Jones, 1963 from Alaska) whose lectotype was designated by Matsumoto (*in* Matsumoto (ed.) 1963, p. 29) and Jones (1963, p. 28) independently on the same specimen, i. e. original of *Lytoceras sacya*, Yokoyama, 1890, pl. 18, fig. 12, from the Urakawa area, Hokkaido. It is, however, necessary to know also the characters of the inner whorls to confirm the identity.

Incidentally, *G. tenuiliratum* was interpreted by Hirano (1978) as a transient polymorphic variety of *G. denseplicatum* (Jimbo). I would keep it as a distinct species, because they can be distinguished by the characters of both the immature and the adult stages and because in some cases *G. denseplicatum* occurs more abundantly than *G. tenuiliratum* even at high stratigraphic levels. They must have lived under somewhat different conditions.

Occurrence:—In blocks of dark grey shale at loc. M-14, on the valley slope of the River Kajisako, collected by T. Kozai; together with *Inoceramus* (*Platyceramus*) *amakusensis* Nagao et Matsumoto.

Gaudryceras cf. *striatum* (Jimbo)

Pl. 6, Fig. 5; Text-fig. 2

Material:—OSE. 14018, 14027, 14028, 14031, 14032, 14033 and 14034.

Descriptive remarks:—OSE. 14031 is about 200 mm in diameter, showing eroded sutures. Other specimens are fragmentary pieces of fairly large shell. They show very fine and dense lirae and fairly frequent, narrow major ribs. They are gently flexuous on the flank. On some part the major ribs occur less frequently.

The above characters on the fragmentary whorls suggest the body-chamber of *Gaudryceras striatum* (Jimbo) (1894, p. 35, pl. 22 fig. 6) (Yabe, 1903, p. 31, pl. 4, fig. 5), which attains sometimes to a fairly large size. OSE. 14031 (Text-fig. 2) is probably a phragmocone which can fit such a large body-chamber.

Occurrence:—In another block of dark grey shale at loc. M-14, on the left slope of the valley of the River Kajisako, collected by T. Kozai, upper part of the Kajisako Formation.

Text-fig. 2. *Gaudryceras* sp.
OES. 14031, probably an eroded phragmocone of *G.* cf. *striatum*, occurring with other examples of the same species. Bar indicates 30 mm. (Photo by M. Tashiro)

Order Ancyloceratida
Superfamily Turrilitaceae
Family Turrilitidae Gill, 1871
Genus *Turrilites* Lamarck, 1801
Subgenus *Mesoturrilites* Breistroffer, 1953

Type species:—Turrilites aumalensis Coquand, 1862.

Remarks:—See Wright *in* Moore (ed., 1975, p. L222) for the diagnosis, which is followed by Kennedy (1971, p. 30).

Turrilites (*Mesoturrilites*) sp. aff. *T.* (*M.*) *aumalensis* Coquand

Pl. 4, Fig. 4

Material:—OSE. 12004, fragmentary whorl.

Description:—For some reasons only a whorl (of the turrilitoid coiling) crops out from shale. It shows at least six, strongly clavate, distinct tubercles in the upper row, and smaller but probably clavate ones in the lower row. Ribs are very weak or almost suppressed. Basal part unexposed.

Remarks:—The specimen is so poorly preserved that the identification is provisional. It is, however, interesting to note its close similarity to an example of *T.* (*M.*) *aumalensis* Coquand, from the Lower Cenomanian of England (Kennedy, 1971, p. 31, pl. 7, fig. 9). A low spiral depression is discernible immediately below the upper row of tubercles in the British specimen, but it is somewhat distant from the upper row and close to the lower row in the present specimen.

Occurrence:—In shale at loc. M-12, on the right slope of the valley of the River Kajisako, collected by T. Kozai; probably middle part of the Nagase Formation.

Genus *Ostringoceras* Hyatt, 1900

Type species:—Turrilites puzosianus d'Orbigny, 1842.

Remarks:—See Kennedy (1971, p. 25) and Klinger and Kennedy (1978, p. 10) for the diagnosis and other up-to-date information about this genus.

Ostringoceras cf. *bechii* (Sharpe)

Pl. 4, Fig. 5

Material:—OSE. 12001, an external mould.

Description:—Two whorls of a probably high spire have a slightly inflated face which is ornamented with dense, slightly flexuous ribs, terminating in indistinct tubercles. A row of clavate tubercles are discernible in the lower part. (Two other rows which should exist are unexposed.)

Remarks:—This is probably comparable with *Ostringoceras bechii* (Sharpe) (1857, p. 66, pl. 26, fig. 13) (Kennedy, 1971, p. 25, pl. 8, figs. 9, 11, 13), from the Lower Cenomanian of England and Hokkaido, although the Hokkaido examples have not yet been illustrated.

Occurrence:—In shale at loc. M-12, on the right slope of the valley of the River Kajisako, collected by T. Kozai; probably middle part of the Nagase Formation.

Family Diplomoceratidae Spath, 1926

Genus *Scalarites* Wright et Matsumoto, 1954

Type species:—*Helicoceras scalare* Yabe, 1904.

Remarks:—See Wright and Matsumoto (1954, p. 115) and Matsumoto (1977a, p. 348) for the diagnosis and the relations to other genera.

Scalarites cf. *mihoensis* Wright et Matsumoto

Pl. 6, Figs. 6, 7

Material:—OSE. 03062, 03111 and 03117, fragmentary pieces.

Description:—These are gently arcuate or nearly straight and elliptical in section, although under secondarily compressed condition. Numerous, narrow, annular ribs are separated by somewhat broader interspaces.

Remarks:—The specimens are comparable with *Scalarites mihoensis* Wright et Matsumoto (1954, p. 118, pl. 7, figs. 1-2; text-fig. 2), from the Turonian and the Coniacian of Hokkaido and South Sakhalin.

Occurrence:—In silty sandstone at loc. M-03, on the River Kajisako, collected by T. Kozai, Zone of *Inoceramus hobetsensis*, lower part of the Kajisako Formation. Very small fragmentary specimen of *Scalarites* sp. is found at loc. M-51 with *Inoceramus teshioensis* (OSE. 51057).

Genus *Polyptychoceras* Yabe, 1927

Type-species:—*Anisoceras pseudogaultinum* Yokoyama, 1890.

Remarks:—*Polyptychoceras* was introduced by Yabe (1927, p. 44) as a subgenus of *Hamites* in a list of species and subsequently defined by Shimizu (1935, p. 271), who designated the "genotype" and gave a generic diagnosis, but the illustrations (including Yabe, 1927, pl. 6, fig. 4) were incomplete. A diagrammatic figure of a reconstructed form of *P. obstrictum* (Jimbo) was shown by Wright and Matsumoto (1954, text-fig. 3; cited by Wright, 1957 in the *Treatise*", p. L227, fig. 254) and photographs of well preserved examples of *P. pseudogaultinum* and *P. haradanum* (Yokoyama) by Matsumoto and Nihongi (1979, figs. 1 and 3). Regretably, I have not yet completed the monograph of *Polyptychoceras* from Hokkaido.

Polyptychoceras cf. *subquadratum* (Yokoyama)

Pl. 6, Fig. 8

Material:—OSE. 14025.

Descriptive remarks:—This specimen shows a U-curved part and two nearly parallel arms which are separated by a narrow space. Its shell-form, size and coarse, radial, simple ribs suggest its close similarity to the holotype (Yokoyama, 1890, p. 182, pl. 20, fig. 4) and another illustrated example (Yabe, 1927, pl. 6, fig. 4) of *P. subquadratum*, both of which represent the last hooked part of the shell. A subquadrate section with a flattened dorsum in the late stage is another criterion of this species, but the character cannot be confirmed on the specimen which is embedded in shale.

Occurrence:—In a block of dark grey shale at loc. M-14, on the left slope of the valley of the River Kajisako, collected by T. Kozai; upper part of the Kajisako Formation.

Concluding Remarks

On the basis of the palaeontological descriptions, the investigated ammonites from the Upper Cretaceous of the Monobe area are sorted into the species listed in Tables 1-3. In the tables the abundance at each locality is also indicated.

Table 1. List of ammonites from the Nagase Formation (Cenomanian)

Species	Locality (*)
Desmoceras (*Pseudouhligella*) cf. *japonicum* Yabe	M-44 (○)
Forbesiceras (?) sp. aff. *F. beaumontianum* (d'Orbigny)	M-12 (○)
Mantelliceras cf. *japonicum* Matsumoto et Takahashi.	"Nagase" (●)
Mantelliceras cantianum Spath	M-28 (○)
Mantelliceras cf. *saxbii* (Sharpe)	M-53 (●)
Calycoceras cf. *orientale* Matsumoto, Saito et Fukada.	M-59 (○)
Calycoceras sp. nov. (?) aff. *C. naviculare* (Mantell)	M-36 (⬤)**
Turrilites (*Mesoturrilites*) sp. aff. *T.* (*M.*) *aumalensis* Coquand	M-12 (○)
Ostringoceras cf. *bechii* (Sharpe)	M-12 (○)

* The abundance is indicated with the following marks:
○: single specimen, ●: 2-4 specimens, ⬤: more than 5 specimens.
** This species is from the upper part and others from the middle part of the Nagase Formation.

Table 2. List of ammonites from the Kajisako Formation (part) (Turonian)

Species	Locality (*)
Mesopuzosia cf. *indopacifica* (Kossmat)	M-03 (●)
Romaniceras sp. nov. (?) aff. *R.* (*R.*) *kallesi* (Zázvorka)	M-03 (●)
Romaniceras (*Romaniceras*) cf. *deverianum* (d'Orbigny)	M-03 (●)
Romaniceras (?) sp.	M-51 (○)
Collignoniceras woollgari (Mantell)	M-03 (⬤)
Argonauticeras (?) sp.	M-03 (○)
Gaudryceras cf. *denseplicatum* (Jimbo)	M-03 (○)
Scalarites cf. *mihoensis* Wright et Matsumoto	M-03 (●, M-51 (○)

* The abundance is indicated with the same marks as in Table 1.

Table 3. List of ammonites from the Kajisako Formation (continued)
(Coniacian, Santonian and part of Campanian)

Species	Locality (*)
Jimboiceras sp. aff. *J. mihoensis* Matsumoto	M-05 (●)**
Eupachydiscus haradai (Jimbo)	M-40 (●)
Gaudryceras cf. *tenuiliratum* Yabe	M-14 (●)
Gaudryceras cf. *striatum* (Jimbo)	M-14 (⬤)
Polyptychoceras cf. *subquadratum* (Yokoyama)	M-14 (○)

* The abundance is indicated with the same marks as in Table 1.

** This species is from the middle portion of the lower part and others from the upper part of the Kajisako Formation.

Taxonomic results:—As is summarized in the tables, the ammonites from the Upper Cretaceous of the Monobe area are classified into 22 species, of which 9 are from the Nagase Formation, 9 from the lower part of the Kajisako Formation and 4 from the upper part of the same formation. Many of the specimens are identified with or comparable with previously known species, but some represent or suggest new ones. The species of the latter group are *Forbesiceras* (?) sp. aff. *F. beaumontianum*, *Calycoceras* sp. nov. (?) aff. *C. naviculare*, *Romaniceras* (*Romaniceras*) (?) sp. nov. (?) aff. *R.* (*R.*) *kallesi*, *Argonauticeras* (?) sp., *Turrilites* (*Mesoturrilites*) sp. aff. *T.* (*M.*) *aumalensis* and *Jimboiceras* sp. aff. *J. mihoensis*. No new specific name is proposed in this paper, because the material is insufficient.

Biostratigraphic results:—As is evident from the three lists, the ammonite species in Table 1 indicate clearly the Cenomanian age, those in Table 2 the Turonian age and those in Table 3 suggest the Coniacian through Campanian ages.

If I scrutinize more precisely the occurrences of the species in Tables 1 and 2, a finer age-correlation can be reasonably concluded as follows:

Lower Cenomanian, including localities M-53, M-28 and probably also M-12, as evidenced by *Mantelliceras* cf. *saxbii*, *M.* cf. *japonicum*, *M. cantianum*, *Ostringoceras* cf. *bechii* and *Turrilites* aff. (*T.*) (*Mesoturrilites*) *aumalensis*

Middle Cenomanian, represented by loc. M-39 with *Calycoceras* cf. *orientale*

Upper Cenomanian, suggested by loc. M-36 with *Calycoceras* aff. *C. naviculare*

Lower Turonian, without find of index ammonite, but with *Mytiloides* cf. *labiatus opalensis* at loc. M-55

Middle Turonian, well represented by loc. M-03 with *Collignoniceras* cf. *woollgari* and *Romaniceras* spp., along with *Inoceramus* (*Inoceramus*) *hobetsensis*

Upper Turonian, with *Romaniceras* (?) sp. and *Inoceramus* (*Inoceramus*) *teshioensis* at loc. M-51

The above correlation is based not only on the zonation in Hokkaido (see Matsumoto, 1975, 1977b) but also that in England and related areas in Europe (see Kennedy, 1971; Kennedy *et al.*, 1980a, b).

The ammonite species and localities are not sufficient for finer correlation of the Coniacian plus Santonian part, in which inoceramids play an important part. The bed at loc. M-05 with *Jimboiceras* aff. *mihoensis* is referred to the Coniacian, because it contains *Inoceramus uwajimensis*. This is not contradictory to the hitherto known range of *Jimboiceras*.

The occurrence of *Gaudryceras* cf. *striatum*, including a large form, indicates the existence of the Campanian strata at and near loc. M-14. According to Kozai and Tashiro (in the first paper of this volume; also personal communication), the shale blocks at loc. M-14 may have been derived from strata of considerable thickness and may comprise some extent of age. *Eupachydiscus haradai* ranges from the upper part of the Santonian to the lower part of the Campanian in the Japanese province. It occurs at loc. M-40 with *Inoceramus japonicus* Nagao et Matsumoto, an Upper Santonian index species. *Gaudryceras* cf. *tenuiliratum* and *Polyptychoceras* cf. *subquadratum* suggest rather the Santonian, but they are long-ranging.

Remarks on the palaeoenvironments:—The Cenomanian and Turonian part yielded a considerable number of ammonites belonging to the Acanthocerataceae i. e. the group which normally occur commonly in sediments of shallow seas. Turrilitids are often associated with the acanthoceratids in the shelf facies of Europe and other well studied areas.

The ammonites from the Coniacian onward are the gaudryceratids, desmoceratids and heteromorpha. No example of the Acanthocerataceae has been found.

Thus, the Cenomanian and Turonian sediments were formed under shallower environments than the Coniacian and Santonian ones, which in turn were formed in more off-shore, somewhat deeper environments. Lithologically, sandstone is predominant in the former, whereas shale is so in the latter. This is the general aspect, and in more details the palaeoenvironments must have been more complex and should be analysed from various kinds of information. This general aspect is, however, in harmony with the general features in the Cretaceous of Japan that the Cenomanian and the Turonian are often represented by coarse-grained sediments of shallow sea facies and that the Coniacian and the Santonian (plus lower part of the Campanian) are distributed more extensively and contain fine-grained sediments of off-shore facies. (This generality may not be applied to the Cretaceous of the Shimanto belt.)

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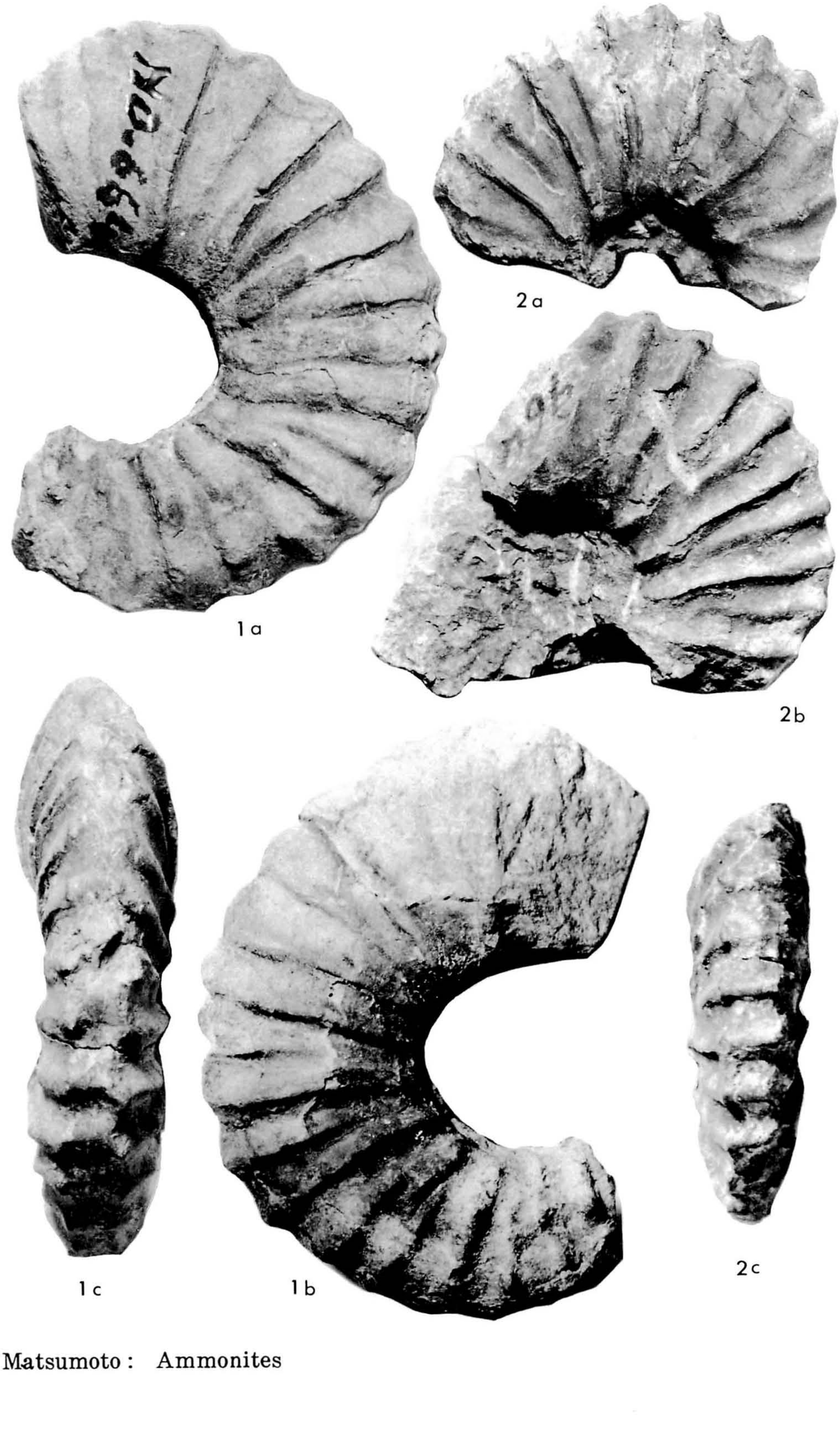
Plate 1

Explanation of Plate 1

Figs. 1, 2. *Mantelliceras* cf. *japonicum* Matsumoto, Muramoto et Takahashi............Page 35

1. M. Hirata Coll. No. 664, from Nagase. Two lateral (a, b) and ventral (c) views, ×1.
2. M. Hirata Coll. No. 960, from Nagase. Two lateral (a, b) and ventral (c) views, ×1.

Photos by M. Noda, without whitening



1a 2a 2b 1c 1b 2c

T. Matsumoto : Ammonites

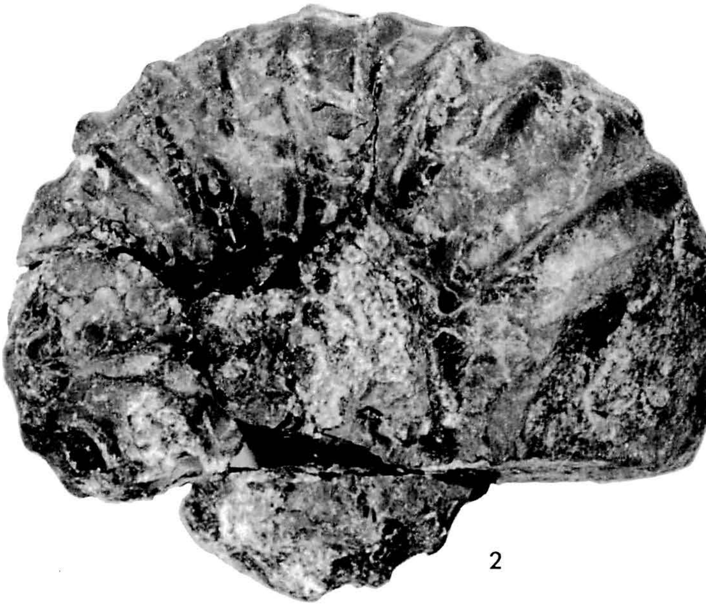
Plate 2

Explanation of Plate 2

Figs. 1, 2. *Mantelliceras cantianum* Spath ....Page 36

1. OES. 28001, from loc. M-28, Nagase, collected by T. Kozai Lateral (a) and frontal (b) views, ×0.85.
2. OES. 28001 (last half whorl excluded), showing the other side, ×1.

Photos by M. Tashiro, without whitening



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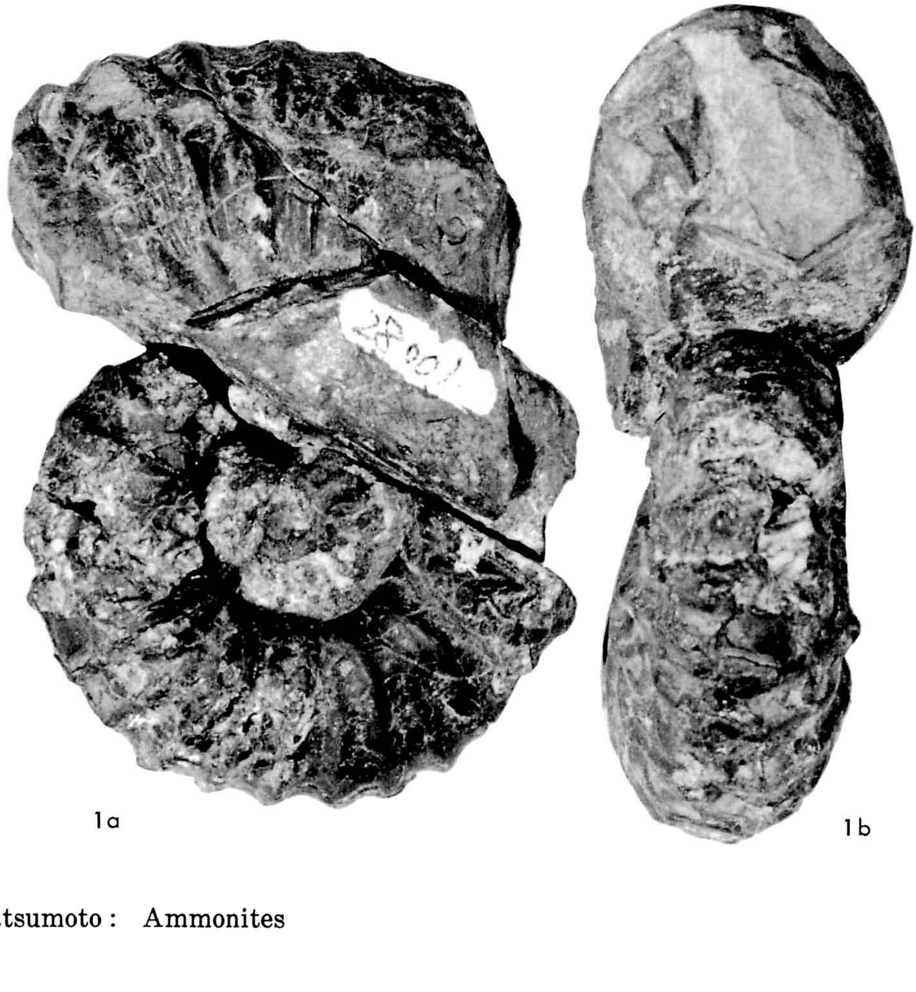

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T. Matsumoto : Ammonites

Plate 3

Explanation of Plate 3

Fig. 1. *Calycoceras* cf. *orientale* Matsumoto, Saito et Fukada .... Page 37
OES. 39001 from loc. M-39, on the left wall of a gorge of the River Kajisako, collected by T. Kozai. External mould showing the right side of a large shell, $\times 0.4$.

Photo by M. Tashiro, without whitening

1

T. Matsumoto : Ammonites

Plate 4

Explanation of Plate 4

Figs. 1, 2. *Calycoceras* sp. nov. (?) aff. *C. naviculare* (Mantell) ....Page 38

1. OES. 36007, from loc. M-36, left bank of the River Kajisako, collected by T. Kozai. Ventral view, ×0.8.
2. OES. 36001, from loc. M-36, collected by T. Kozai. Lateral view of a portion of the septate whorl, ×0.4.

Fig. 3. *Forbesiceras* (?) sp. aff. *F. beaumontianum* (d'Orbigny) ....Page 35

OES. 12003, from loc. M-12, right side of the River Kajisako, collected by T. Kozai. Lateral view, ×1.2.

Fig. 4. *Turrilites* (*Mesoturrilites*) sp. aff. *T.* (*M.*) *aumalensis* Coquand ....Page 46

OES. 12004, from loc. M-12, collected by T. Kozai. Lateral view of a whorl, nearly ×1.

Fig. 5. *Ostringoceras* cf. *bechii* (Sharpe) ....Page 46

OES. 12001, from loc. M-12, collected by T. Kozai. Lateral view of two whorls, ×1.5.

Photos by M. Tashiro, without whitening


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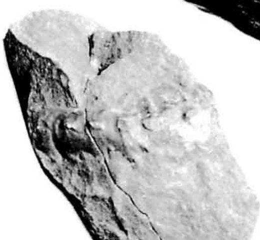
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T. Matsumoto: Ammonites

Plate 5

Explanation of Plate 5

Figs. 1, 2. *Romaniceras* (*Romaniceras*) sp. nov. (?) aff. *R.* (*R.*) *kallesi* (Zázvorka)....Page 40

1. OES. 03082, from loc. M-03, right bank of the River Kajisako, collected by T. Kozai. External mould, slightly enlarged (×10/9).
2. OES. 03083, from loc. M-03, collected by T. Kozai. Internal mould of the same individual as Fig. 1, slightly reduced (×0.9).

Fig. 3. *Romaniceras* (*Romaniceras*) cf. *deverianum* (d'Orbigny)........................Page 41

OES. 03056, from loc. M-03, collected by T. Kozai. Ventral view of a fragmentary whorl, ×1.

Figs. 4–7. *Collignoniceras* cf. *woollgari* (Mantell).....................................Page 42

4. OES. 03110; 5. OES. 03146; 6. OES. 03120; all immature specimens from loc. M-03, collected by T. Kozai. Lateral view, ×1.4(4), ×1.25(5), ×1(6).
7. OES. 03060, from loc. M-03, collected by T. Kozai. Lateral view of a fragmentary whorl of the middle growth-stage, ×1.

Photos by M. Tashiro, without whitening.


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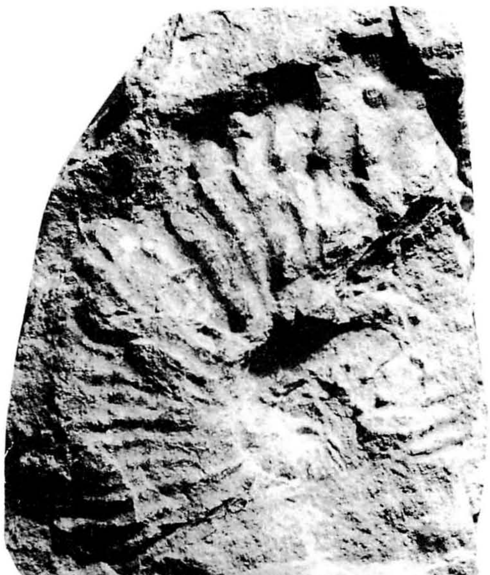
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T. Matsumoto : Ammonites

Plate 6

Explanation of Plate 6

Figs. 1-2. *Jimboiceras* sp. aff. *J. mihoense* Matsumoto................................Page 33

1. OES. 05008, from loc. M-05 on the right bank of the River Kajisako. Lateral view of two different parts (a, b) of an individual, ×1.
2. OES. 05005, from loc. M-05. Inner whorl of probably the same species, ×1.4.

Fig. 3. *Gaudryceras* cf. *denseplicatum* (Jimbo) ....Page 44

OES. 03135, from loc. M-03 on the right bank of the River Kajisako. Lateral view. ×1.

Fig. 4. *Gaudryceras* cf. *tenuiliratum* Yabe ....Page 44

OES. 14006, from a block at loc. M-14 on the left slope of the valley of the Kajisako. Lateral view of a deformed, fragmentary whorl (body-chamber), ×1.1.

Fig. 5. *Gaudryceras* cf. *striatum* (Jimbo) ....Page 45

OES. 14032, from another block at loc. M-14. Lateral view of a part of the body-chamber, ×3/4.

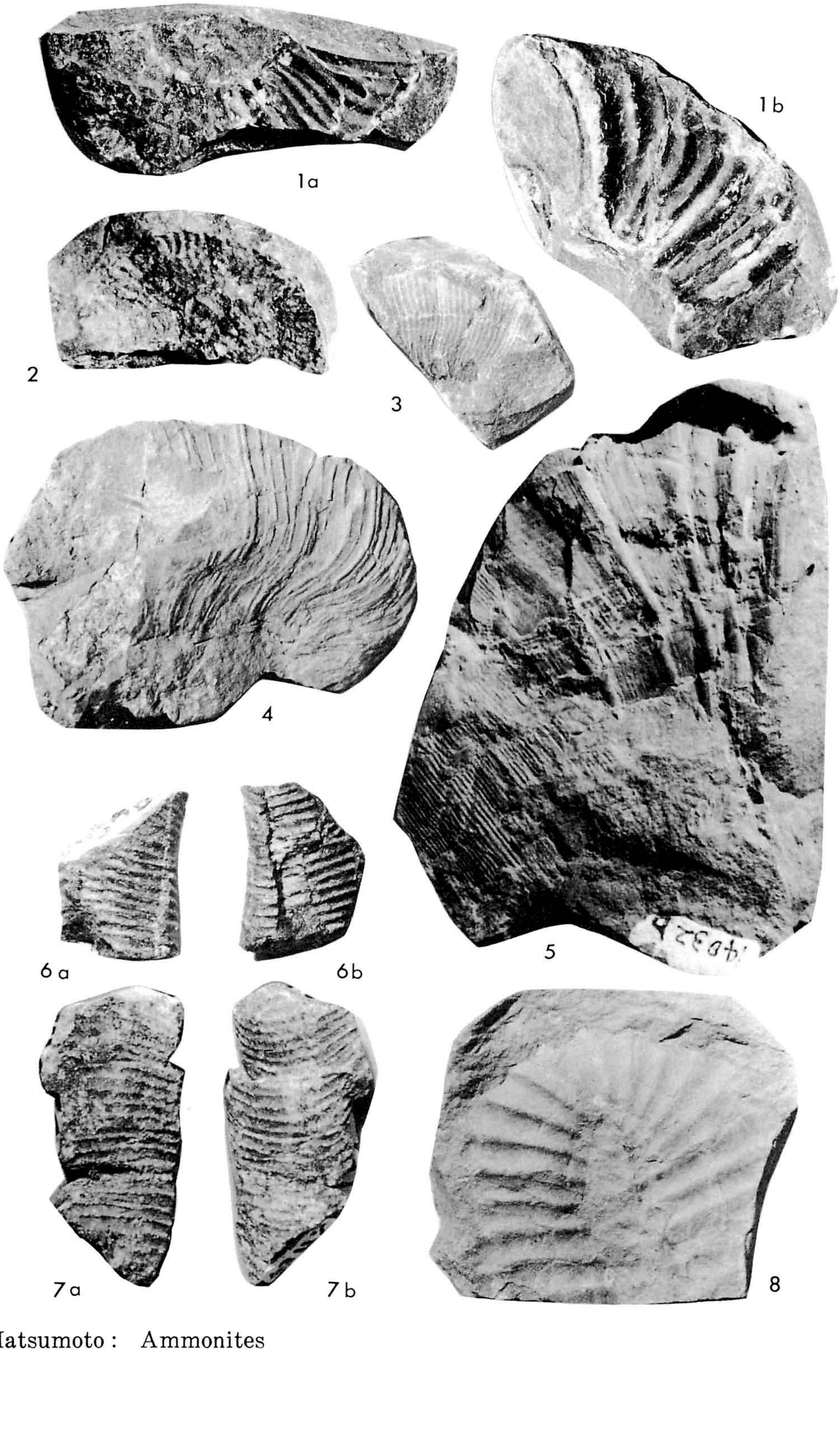
Figs. 6, 7. *Scalarites* cf. *mihoensis* Wright et Matsumoto ....Page 47

6. OES. 03062, from loc. M-03. The lateral (a, b) views, ×1.2.
7. OES. 03117, from loc. M-03. Two lateral (a, b) views, ×1.

Fig. 8. *Polyptychoceras* cf. *subquadratum* (Yokoyama) ....Page 47

OES. 14025, from loc. M-14 on the left slope of the valley of the Kajisako. Lateral view, ×1.

All specimens collected by T. Kozai.
Photos by M. Tashiro, without whitening



T. Matsumoto: Ammonites

Plate 7

Explanation of Plate 7

Figs. 1, 2. *Mantelliceras* cf. *saxbii* (Sharpe) ....Page 36

1. OES. 53001, from loc. M-53 on the left bank of the River Kajisako. Lateral view, ×5/6.
2. OES. 61001b, from loc. M-61 on a small western branch of the River Kajisako. External mould of the left side of OES. 61001a, ×5/6.

Fig. 3. *Desmoceras* (*Pseudouhligella*) cf. *japonicum* Yabe ....Page 32

OES. 44005, from loc. M-44 near Doiban, eastern side of the River Kajisako. Lateral view of a deformed specimen, ×0.8.

Fig. 4-6. *Mesopuzosia* cf. *indopacifica* (Kossmat) ....Page 33

4. OES. 03151, from loc. M-03 on the right bank of the River Kajisako. Lateral view, ×1.
5. OES. 03064a, from loc. M-03. Lateral view, ×1.
6. OES. 03064b, from loc. M-03. External mould of the same individual as above, ×1.

Fig. 7. *Eupachydiscus haradai* (Jimbo) ....Page 34

OES. 40001, from loc. M-40, on the left slope of the valley of the Kajisako. Lateral view, ×4/5.

All collected by T. Kozai.
Photos by M. Tashiro, without whitening.

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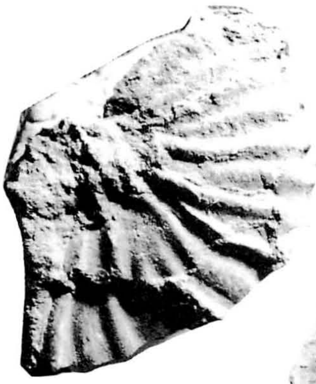

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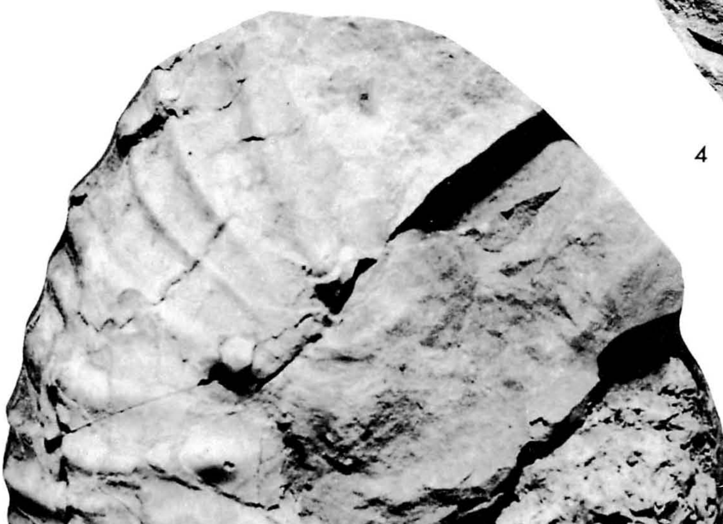

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5

T. Matsumoto : Ammonites

VI. UPPER CRETACEOUS INOCERAMIDS FROM THE MONOBE AREA, SHIKOKU

By

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Abstract

Previously only a species of the inoceramids was reported, though without description, from the Monobe area. Owing to the laborious field work by one of us (T. K.), a large number of inoceramid specimens has been obtained from various stratigraphic levels of the Upper Cretaceous deposits exposed along the River Kajisako of the Monobe area, central Shikoku. We describe and illustrate them in this paper. They are classified into 15 species, as summarized in Table 1. The biostratigraphic sequence of the species which occur fairly abundantly in the Monobe area conforms well to that in Hokkaido and other well studied areas in Japan. In addition to them, there are several species which are new to Japan, as exemplified by *Inoceramus* (*Inoceramus*) aff. *I.* (*I.*) *ginterensis* Pergament, *I.* (*I.*) aff. *I.* (*I.*) *hobetsensis* Nagao et Matsumoto, *Mytiloides* aff. *M. striatoconcentricus* (Gümbel) and *Inoceramus* (*Platyceramus*) aff. *I.* (*P.*) *rhomboides* Seitz, although each of them is represented by a single or a few specimen(s).

Introduction

One of us (T. K.) collected a considerable number of inoceramid specimens from various stratigraphic levels in the Upper Cretaceous of the Monobe area and sorted them preliminarily. They are transferred to the two others of us (T. M. and M. N.) for further palaeontological study. A specimen of previous collection kept by Professor Jiro Katto at the Department of Geology, Kochi University [KSG.] and a few specimens of subsequent collections, now kept at KSG., are also added to the material of the present study. The majority of the examined material is stored at Odochi Elementary School [OES.]. This paper is to report the result of our study.

The geographical and geological records of the localities of the examined specimens are written in the first paper (I) of this volume (see especially Text-figs. 2-4 of that paper).

Although the specimens before us are not excellent in the mode of preservation, they are interesting in that they show a succession of species in the sequence of the

Upper Cretaceous strata exposed almost continuously along the River Kajisako, a tributary to the River Monobe.

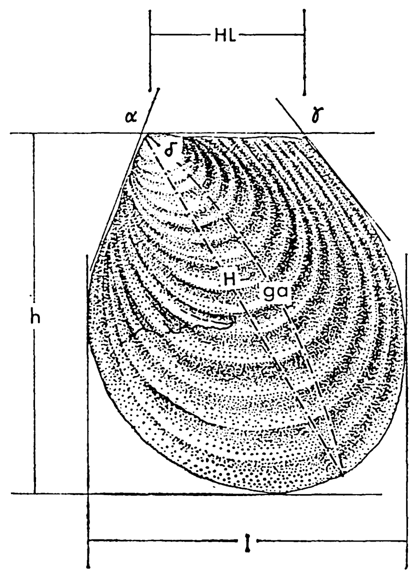
We intend to show in the palaeontological description below not only what kind of species occur at various localities in the sequence but also our assignement of inoceramid species in the light of up-to-date taxonomy.

In the description a synonymy list is omitted for brevity, but we indicated selected references in which the synonymy is fully listed. The measurements follow those which have already been explained by Noda (1975) and is here shown in Text-fig. 1. The linear dimension is in mm.

The repositories of the specimens described or mentioned in this paper are as follows, in addition to OES. and KSG. indicated above.

GK: Geological Collections, Kyushu University, Fukuoka
GMH: Geological Collections, Hokkaido University, Sapporo
JG: Jonan Geological Association, Oita
UK: University of Kyoto, Kyoto
UMUT: University Museum of the University of Tokyo

Before going further, we thank Dr. Masayuki Tashiro for his kind and instructive help in various ways in this study. Our thanks are also extended to Professor Jiro Katto and Mr. K. Nakano of Kochi University and Messrs. Toshio Komatsu and Hisafumi Akashi, previous and present masters of Odochi Elementary School, for their generous support of this study.



Text-fig. 1. Basic morphology for measurements

h: shell height, l: shell length, H: maximum dimension from the umbo to the ventral extremity, ga: growth axis, HL: hinge-line, α: anterior hinge angle, γ: posterior hinge angle, δ: obliquity. β (angle of umbonal inflation) is not indicated in this figure.

Palaeontological Description

Familia Inoceramidae Giebel, 1852

Genus *Inoceramus* Sowerby, 1814

Subgenus *Inoceramus* Sowerby, 1814

Inoceramus (*Inoceramus*) *hobetsensis* Nagao et Matsumoto

Pl. 8, Figs. 2-4; Pl. 9, Figs. 1, 2

Lectotype:—Nagao and Matsumoto, 1939, pl. 29, fig. 3 (Hokkaido University Collection), from the Turonian of the Hobetsu area, Hokkaido, designated by Noda (1975, p. 249).

Material:—OES. 03001, 03003, 03006, 03019, 03020, 03021, 03023, 03041, 03049, 03050, 03102, 03102, 03103, 03140, 03200 and many other comparable specimens (e. g. OES.

03002, 03004, 03011, 03013, 03018, 03024, 03030, 03035, 03039, 03044, 03046, 03116, 03167, 03170, 03171, 03204 etc.).

Measurements:—

specimen	h	l	H	HL	l/h	HL/l	α	β	γ	δ
OES. 03001	65.0	50.0	70.5	27.5	0.77	0.55	117°	70°	120°	63°
OES. 03021	47.8	38.2	53.9	17.0	0.80	0.45	90°	64°	143°	55°
OES. 03049	61.2	58.3	72.0	34.9	0.95	0.60	86°	65°	133°	53°
OES. 03103	48.9	45.4	58.4	28.4	0.93	0.63	82°	—	144°	50°

Descriptive remarks:—The specimens before us are mostly 40 to 65 mm in height, but the largest example is about 400 mm. They are identified with *I.* (*I.*) *hobetsensis* Nagao et Matsumoto, 1939 (see also Noda, 1975) on account of their somewhat obliquely elongated suboval outline, hinge-line of moderate length, gentle convexity, regular concentric ribs combined with minor concentric rings, more or less distinct radial sulcus running towards the middle of the ventral margin.

Noda (1975) has demonstrated on numerous specimens from the Onogawa Group (Kyushu) that *I. hobetsensis* shows a considerable extent of variation. Similar variation is shown also in the specimens from one and the same locality of the Monobe area. For example, a large specimen (e. g., Pl. 8, Fig. 4) is comparatively broader than normal ones. The radial sulcus is weak or appear late near the ventral margin in some specimens (e. g., Pl. 8, Figs. 2, 3) but is more distinct in some others. Even weakly nodulous elevations can be seen on either or both sides of the sulcus in a few specimens (e. g., Pl. 9, Fig. 1). In the case of the Onogawa Group (Noda, 1975), a certain serial change has been recognized as we ascend the sequence. In the present case, the specimens before us are all from loc. M-03, but as the sedimentation seems to have been very slow in the Upper Cretaceous of the Monobe area, there may be a question as to their detailed mode of occurrence.

Occurrence:—Abundant in the sandstone at loc. M-03, on the right bank of the River Kajisako, lower part of the Kajisako Formation.

Inoceramus (*Inoceramus*) sp. nov. (?) aff. *I.* (*I.*) *hobetsensis* Nagao et Matsumoto

Pl. 9, Fig. 3

Material:—OES. 51001, internal mould of left valve.

Measurements (approximate):—

specimen	h	l	H	HL (presumed)	l/h	HL/l	δ
OES. 51001	35.0	31.0	40.0	*ca* 15	0.88	0.48	58°

Descriptive remarks:—This specimen resembles some examples (e. g. OES. 03103, Pl. 8, Fig. 3) of *I.* (*I.*) *hobetsensis* described above, but has no radial sulcus and is characterized by regularly-spaced, sharp-headed concentric ribs which remind us those of *I.* (*I.*) *uwajimensis*. It shows, however, impressions of fine concentric rings on some part of the interspaces, although they are much weaker than those of *I.* (*I.*) *hobetsensis*.

There are several specimens from loc. Ik 2014 (Pombetsu) in the Zone of *I.* (*I.*) *teshioensis* of Hokkaido, which show the same features as above. They may represent a transitional form (possibly a distinct species) from *I.* (*I.*) *hobetsensis* of the Middle

Turonian to *I.* (*I.*) *uwajimensis* of the Lower to Middle Coniacian. It is interesting to see an example of this unnamed form in the Upper Turonian of the Monobe area.

Occurrence:—In silty fine-grained sandstone at loc. M-51, with numerous specimens of *I.* (*I.*) *teshioensis*, in lower part of the Kajisako Formation, probably Upper Turonian.

Inoceramus (*Inoceramus*) cf. *iburiensis* Nagao et Matsumoto

Pl. 9, Fig. 9

Lectotype of *I.* (*I.*) *iburiensis:*—GMH. 7208 (Nagao and Matsumoto, 1939, pl. 31, fig. 1a-c), from the Oyubari area, Hokkaido, designated by Matsumoto, 1981b.

Material:—OES. 03067 (left valve) and OES. 03126, 03098 (right v.). Also OES. 51025 and 51026, although fragmentary.

Descriptive remarks:—The three specimens from loc. M-03, are comparable with an immature shell of *I.* (*I.*) *iburiensis* Nagao et Matsumoto (1939) (see Matsumoto 1981b) in their highly inflated shell, with nearly vertical anterior part and steeply inclined ventral part, somewhat oblique orientation of the growth-axis towards the postero-ventral extremity, coarse concentric ribs separated by concave interspaces, minor rings (partly preserved), presence of a low radial sulcus near the ventral margin with some elevation of the rib on both sides of the sulcus. The broad posterior wing-like area is not well preserved.

Two fragmentary specimens from loc. M-51 are comparable with the ventral part of the present species.

The revised definition recently given by Matsumoto (1981b) has made clear the distinction of Turonian *I.* (*I.*) *iburiensis* from Coniacian *I.* (*I.*) *percostatus* Müller.

Occurrence:—In sandstone exposed at loc. M-03′, 30 cm above the horizon of *I.* (*I.*) *hobetsensis* at loc. M-03 and also loc. M-51 on the right bank of the River Kajisako, lower part of the Kajisako Formation.

Inoceramus (*Inoceramus*) *teshioensis* Nagao et Matsumoto

Pl. 8, Fig. 5; Pl. 9, Figs. 6-8

Lectotype of I. (*I.*) *teshioensis:*—UMUT. MM6487 [=I-711] (Nagao and Matsumoto, 1939, pl. 24, fig. 7; misspelled as I-721 in the explanation of plate), from the Turonian of the Abeshinai area, Hokkaido, designated by Noda (1975, p. 252).

Material:—OES. 51021 (right valve), 51023-51024 (left v.), 51054 (left v.); somewhat deformed left valves, OES. 51005, 51014, 51016, 51039, and right ones, OES. 51010, 51015, 51034-51044, 51046, 51067.

Measurements:—

specimen	h	l	H	HL	l/h	HL/l	α	γ	δ
OES. 51019	20.7	18.0	22.5	13.0	0.87	0.72	90°	114°	65°

Descriptive remarks:—The available specimens are more or less incompletely preserved, but they are probably identified or at least comparable with *I.* (*I.*) *teshioensis* Nagao et Matsumoto, 1939 (see also Noda, 1975, p. 251) on account of their rather small size (up to 50 mm or so in height), moderate convexity (if not secondarily compressed), moderately rounded ventral margin, subtrigonal dorsal outline, small difference between h and l, and regular concentric ribs combined with concentric rings, as well as their inequivalve state.

Occurrence:—In silty fine-sandstone at loc. M-51, immediately below a layer of tuff, 4 m above the bed with *I.* (*I.*) *hobetsensis* (loc. M-03), on the right bank of the River Kajisako, lower part of the Kajisako Formation.

Inoceramus (*Inoceramus*) *uwajimensis* Yehara

Pl. 9, Figs. 10, 11; Pl. 10, Fig. 2

Lectotype:—One of the syntypes of Yehara (1924, pl. 3, fig. 2), from the Furushiroyama Shale, Uwajima Group (western Shikoku), designated by Matsumoto in Takai and Matsumoto (1961, p. 273).

Material:—OES. 06001 =06002 (external and internal mould of right valve), 06005 (left v.), 06007, 06010 (left v.), 06011; OES. 05001, 05010, 05011, 05014 and other poorly preserved specimens.

Descriptive remarks:—The specimens are so incompletely preserved that they are hardly measured with precision. They are mostly 40 to 50 mm in height. The beak angle is small but seems to be variable.

The specimens are identified to or comparable with *I.* (*I.*) *uwajimensis* Yehara, 1924 (emended by Matsumoto, 1961 *in* Takai and Matsumoto, p. 273; Noda, 1975, p. 253; Noda and Matsumoto, 1976), from the Coniacian of Hokkaido and various other parts of Japan and adjacent areas, since they show the diagnostic characters, such as the high oval outline, with a pointed small beak, gentle convexity, sharp-headed concentric ridges separated by concave interspaces without perceptible minor ornament, etc. The ribs are normally regular but in some specimens (e. g., OES. 06006 and 05001) intercalation or bifurcation occurs occasionally. Such a feature is seen also in the populations of the Uwajima Group.

In the Monobe populations the ribs are somewhat more crowded than in the typical forms.

Inoceramus uwajimensis var. *yeharai* Nagao et Matsumoto (1939), which is characterized by the presence of the posterodorsal wing-like part, is also found in the population at loc. M-05, as represented by OES. 05001 (Pl. 9, Fig. 11). Noda (1975) suppressed the subspecific name *I. uwajimensis yeharai*, because it is found in the same population as the typical form of *I. uwajimensis* and because there is an intermediate form. As the presence or absence of the wing-like part must be significant for the inoceramids, we consider it desirable to keep the name *yeharai* as a form of *I. uwajimensis*. This form is apparently similar to *I. winkholdioides* Andert, 1934, to which Kauffman (1977, p. 71) synonymized it, but at every locality of abundant occurrence in Japan it constitutes a part of the population of *I. uwajimensis*, In other words, it cannot be separated as a distinct species. The biological implication of this form is, however, to be worked out.

I. (*I.*) *uwajimensis* is similar to, but can be distinguished from, *I.* (*I.*) *stantoni* Sokolow, 1914 [=*I. acutoplicatus* Stanton, 1899], from the Middle (? Upper) Coniacian of North America, by the more remarkably incurved umbo of the left valve and more persistency of minor rings in the latter species, as Matsumoto (*in* Takai and Matsumoto, 1961, p. 274) has already pointed out. Incidentally certain specimens of *I. uwajimensis* Yehara (1924, pl. 4, figs. 1, 3; *non* lectotype) are nothing but examples of *I.* (*I.*) *hobetsensis*.

Kauffman (in Herm *et al.*, 1979, p. 71) transferred *I. stantoni* to *Mytiloides* with a query on the ground of the internal structures. *I.* (*I.*) *uwajimensis* has a thick hinge plate with coarse resilifers, whereas *Mytiloides* has a thin hinge plate with fine and dense resilifers. Therefore, we keep to assign *I. uwajimensis* to *I.* (*Inoceramus*).

Occurrence:—In sandy shale of the lower part of the Kajisako Formation at loc. M-05 on the right bank and at loc. M-06 on the left bank of the River Kajisako. The bed at loc. M-06 may be stratigraphically a little lower than that at loc. M-05. The fossils occur abundantly in a particular part of about 30 cm thickness in the shale.

I. (*I.*) *uwajimensis* is a good index of the Coniacian (rather lower part) in the Japanese Cretaceous province, as has recently been discussed fully by Matsumoto (1981a).

Inoceramus sp. aff. *I.* (*Inoceramus*) *ginterensis* Pergament

Pl. 8, Fig. 1

Material:—OES. 38001, internal mould of right valve.

Measurements:—

specimen	h	l	H	HL	l/h
OES. 38001	71.0	41.0	71.5	34(?)	0.58

Description:—The shell is much higher than long, elongate-ovate to subrectangular in outline, with a long, nearly straight to gently concave anterior margin, asymmetrically rounded ventral margin which passes gradually to a gently arched posterior margin; the hinge-line is presumably of moderate length and there seems to be an ill-defined posterior wing. The convexity is moderate from anterior to posterior but rather gentle along the main part of the growth-axis. The anterior marginal part is nearly vertical or overhanging. An indistinct sinus seems to exist at the posteroventral extremity, although this is not convincing.

Major concentric ribs are weak in the early growth-stage and gradually become more distinct and widely spaced in the main part. Minor concentric rings are impressed on some parts.

Comparison:—This type of inoceramid species has not yet been reported from the Cretaceous of Japan. The specimen somewhat resembles the holotype and other examples of *I.* (*I.*) *ginterensis* Pergament (1966, p. 50, pl. 27, fig. 1 [holotype], pl. 25, fig. 5, pl. 26, figs. 1, 2; pl. 27, fig. 2; pl. 28, figs. 1, 2; pl. 29, fig. 1) (see also Kauffman and Powell *in* Kauffman *et al.*, 1977, p. 64), a world-wide Cenomanian species, but as it is the right valve alone, the precise identification is difficult. Normally *I.* (*I.*) *ginterensis* is larger than the present form and has no posteroventral sinus.

If the present form really has a weak posteroventral sinus, it may be allied to *I. arvanus* Stephenson (1954, p. 65, pl. 12, figs. 6-9), from the Cenomanian of Texas, but the former is much higher than the latter.

Kauffman (1978a, p. IV-5) recorded the rare occurrence of a " species transitional between *I.* (*I.*) *rutherfordi—I.* (*I.*) *arvanus* lineage of the older Cenomanian and the "*Inoceramus*" (*Cordiceramus*) *cordiformis* lineage of the Coniacian and Santonian" in the Upper Cenomanian of England. As there is no illustration nor detailed description of that species, we cannot compare our specimen with it.

Occurrence:—The specimen was found singly from a calcareous sandstone of the Nagase Formation at loc. M-38, on the left bank of the River Kajisako. This bed is somewhat higher than the bed with *Calycoceras* aff. *naviculare* (Mantell), both being within the upper part of the Nagase Formation.

Inoceramus mihoensis Matsumoto

Pl. 11, Fig. 3

Holotype:—GK. H358, from loc. N134f, Zone Mh5 (Upper Coniacian) of the Miho Group in the Naibuchi valley, South Sakhalin (Matsumoto, 1957, p. 65, pl. 21, fig. 1).

Material:—KSG. 3061, external mould of a left valve, obtained by M. Tashiro.

Measurements:—

h	l	H	HL	l/h	α	β	γ	δ
20.7	21.9	22.9	—	1.06	$\geqq$95°	95°	*ca* 140°	56°

Descriptive remarks:—The specimen is identified with a young shell of *I. mihoensis* Matsumoto (1957, p. 65, pl. 21, figs. 1-4) (also Noda and Matsumoto, 1976, pl. Cr-33, fig. 6), from the Coniacian of South Sakhalin, Hokkaido, eastern Kyushu and other areas, on account of its subtrigonal outline with a fairly large beak angle (β), nearly straight anterior (i.e. anterodorsal) and posterior margins and rounded ventral margin, moderate convexity and rather irregular concentric ribs. The abrupt geniculation of the valve normally seen in a late growth-stage of *I. mihoensis* is not observable in this young specimen.

I. mihoensis was regarded by Matsumoto (1957) as allied to *I. inconstans* Woods (1912, p. 285), but the latter is composite and the typical form designated by Woods (1912, p. 291, text-figs. 44, 42; pl. 51, fig. 1) is distinct from *I. mihoensis* in its obliquely extended growth-axis, regular ribs combined with minor rings, fairly long hinge-line and distinct posterior wing. We agree with Kauffman (1977, p. 186) in regarding *I. mihoensis* as closely allied to *I. deformis* Meek [to which *I. schloenbachi* Böhm may be a synonym] and *I. erectus* Meek, as one of us (Matsumoto, 1981a) has already mentioned. Therefore, we hesitate to refer *I. mihoensis* to *Cremnoceramus* Cox, 1969 (with the type species *I. inconstans* Woods), as Kauffman (*in* Herm *et al.*, 1979, p. 68) is pending the final generic assignment of *I. etectus* and *I. deformis*.

Occurrence:—In sandy shale of the lower part of the Kajisako Formation at loc. M-60, on the right bank of the River Kajisako, stratigraphically about 7 m above the bed with *I.* (*I.*) *uwajimensis*.

In Hokkaido and eastern Kyushu *I. mihoensis* appears later than *I. uwajimensis*, but the two species coexist in a certain part. In other words, *I. mihoensis* occurs in the middle and upper parts of the Coniacian, whereas *I. uwajimensis* indicates the lower to middle part of the Coniacian in the Japanese sequence. This is not in harmony with the succession of allied species in North America and Germany, as has been pointed out by one of us (Matsumoto, 1981a).

Subgenus *Platyceramus* Seitz, 1961

Platyceramus Heinz (1932, p. 10), without diagnosis nor distinction from other well defined genera, had been *nomen nudum* until Seitz (1961, p. 54) gave a diagnosis. Following Heinz' intention, Seitz (1961) designated *Inoceramus mantelli* (de Mercey) Barrois, 1879 as the type species, which was clearly redefined by Seitz (1962).

It is questionable whether *Platyceramus* should be treated as a subgenus of *Inoceramus* or that of *Mytiloides* or an independent genus. In this paper we follow Seitz (1962) provisionally.

Inoceramus (*Platyceramus*) *amakusensis* Nagao et Matsumoto

Pl. 10, Figs. 7, 8

Lectotype:—UMUT. MM6514 [=I-960] (Nagao and Matsumoto, 1940, p. 13, pl. 5, fig. 1), from Member I-c (Lower Santonian) of the Himenoura Group in the Amakusa area, western central Kyushu, designated by Matsumoto and Ueda (*in* Ueda, 1962, p. 162, text-fig. 12).

Material:—KSG. 3062 [=OES. 56002], from loc. M-56; OES. 34001, 34002, 34003, 14001, 14005, 14023, 14029, 14044, 14104. There are many other fragmentary specimens from locs. M-34 and M-14, which can be called *I.* (*P.*) cf. *amakusensis.*

Measurements:—

specimen	h	l	H	HL	l/h	H/l	α	γ	δ
KSG. 3062	24.0	20.8	26.0	12.8	0.83	0.61	100°	116°	67°
OES. 34002	40.5	34.0	—		0.84		112°	110°	60°
OES. 14044 (restored)	156	130	165	75	0.83	0.58			

Descriptive remarks:—The specimens before us are mostly identified with *I.* (*P.*) *amakusensis* Nagao et Matsumoto (1940, p. 13, pl. 3, fig. 6; pl. 4, figs. 1, 3, 4; pl. 5, fig. 1) (also Matsumoto and Ueda *in* Ueda, 1962, p. 161, pl. 22, figs. 1, 2, 3; text-fig. 12; Noda and Matsumoto, 1976, pl. Cr-33, fig. 7), a good index of Lower Santonian in the Japanese province, on account of their less inflated and rather flat, upright (less oblique), high and moderately broad (i.e. l/h=0.8 or so) form, with a long hinge line and a long and gently arcuate posterior margin, and low and irregular concentric ribs combined with minor concentric rings, the latter of which are distinct in late growth-stages.

Some of the specimens are deformed, incompletely preserved or small and probably immature, but are comparable with the present species.

Occurrence:—In dark grey shale, alternated with sandstone, at loc. M-34 and in sandy shale at loc. M-56, middle part of the Kajisako Formation on banks of the River Kajisako, also in blocks of dark grey shale at loc. M-14 on left slope of the valley of the Kajisako. One of them, containing a typical form (OES. 14044) was obtained at a point close to the outcrop of loc. M-40.

Inoceramus (*Platyceramus*) sp. aff. *I.* (*P.*) *rhomboides* Seitz

Pl. 10, Fig. 1

Material:—OES. 14022, external mould of a right valve.

Measurements:—

specimen	h	l	H	HL	l/h	HL/l	α	γ	δ
OES. 14022	102.8	106.0	129.2	53.2	1.03	0.50	100°	140°	55°

Description:—The shell is rather flat, gently convex and roughly rhomboidal in outline, with a fairly long hinge-line, a small beak which is scarcely projected over the hinge-line, a nearly straight and low anterior margin which makes an obtuse angle (about 100°) with the hinge-line, an asymmetrically curved ventral margin which is rather narrowly rounded at the middle part, passing gradually to the gently arched, long posterior margin, which makes an angle of about 140° with the hinge-line. The axis of growth is at first nearly straight and then very gently curved forward, with $\delta=45°$ to 55°.

The concentric ribs are distinct but somewhat irregular in distance. For instance, they are fairly dense in some parts of the middle growth-stage. Minor concentric rings are weak. As the shell is secondarily compressed, some radial wrinkles near the ventral margin may be a secondary feature by deformation but could be interpreted as incipient divergent ribs appearing in the late growth-stage.

Comparison:—The specimen is closely allied to *I.* (*P.*) *rhomboides* Seitz (1961), but not precisely identified with *I.* (*P.*) *rhomboides rhomboides* Seitz (1961, p. 82, pl. 3, fig. 2; pl. 4, fig. 2 [holotype], fig. 7), from the Lower and Middle Santonian of Germany, which has regular and fairly distant, strong concentric ribs. There are, however, some examples of *I.* (*P.*) *rhomboides*, which have irregular or denser ribs, such as those figured by Seitz (1961, pl. 3, fig. 7; pl. 4, fig. 5 under *I.* (*P.*) *rhomboides* subsp. indet), from the Middle and Lower Santonian of Germany, with which our specimen may be more closely comparable, if not quite identical. The rhomboidal to subrhomboidal outline is also variable in the German species, as Seitz mentioned. Weak divergent ribs exist in *I.* (*P.*) *rhomboides heinei* Seitz (1961, p. 87, pl. 3, figs. 1, 8; pl. 4, figs. 3, 9), from the Lower Santonian of Germany. We do not know at present whether the subspacies established by Seitz are adequate or not on population concept.

For the time being, we call our form *I.* (*P.*) sp. aff. *I.* (*P.*) *rhomboides* Seitz, although we do not conclude at present that our form is specifically distinct from *I.* (*P.*) *rhomboides*. It could be a subspecies of *I.* (*P.*) *rhomboides*.

In some places of Hokkaido, western Kyushu and elsewhere, there are specimens which can be likewise called *I.* (*P.*) aff. *rhomboides*, although they have not yet been fully illustrated (except for Matsumoto and Yoshimatsu, 1982 in press). They occur with *I.* (*P.*) *ezoensis*, indicating a Santonian age.

Occurrence:—In a block of dark grey shale at loc. M-14, derived from the Kajisako Formation, Santonian.

Inoceramus (*Platyceramus*) cf. *ezoensis* Yokoyama

Pl. 10, Fig. 4

Lectotype:—One of the two specimens illustrated by Yokoyama (1890, pl. 18, fig. 7a, b) from Urakawa, Hokkaido, is here designated as the lectotype of *Inoceramus ezoensis.* It should be kept at the "Bayerische Staatssammlung für Paläontologie und historische Geologie", München (Munich).

Material:—OES. 14105 a (internal) and b (external) moulds of a left valve.

Descriptive remarks:—Although a single specimen, with deficiency of the postero-ventral part, is available, this is comparable with *I.* (*P.*) *ezoensis* Yokoyama (1890, p. 175, pl. 18, fig. 7 [non fig. 6]) (also Nagao and Matsumoto, 1940, p. 16, pl. 7, fig. 1; pl. 10, fig. 3; Matsumoto *et al.*, 1963, p. 29; Noda and Matsumoto, 1976, sheet 268 [Cr-34], fig. 3 [*non* fig. 4]) in its obliquely subrounded outline with subequal length and height, at first posteroventrally oblique and then upright axis of growth, showing an anteriorly concave curvature, moderately strong and broad concentric ribs, which show regularly increasing distance with growth, and fine concentric rings combined with the major concentric ornament.

We agree with Seitz (1961, p. 92, pl. 3, fig. 3; pl. 4, fig. 8) in his revised concept of *I.* (*P.*) *ezoensis*, from which "var. *vanuxemiformis* Nagao et Matsumoto (1940, p. 17) is excluded and affiliated to *I.* (*P.*) *cycloides vanuxemiformis* (Nagao and Matsumoto, 1940, pl. 11, fig. 2). Another syntype of var. *vanuxemiformis* (Nagao and Matsumoto, 1940, pl. 10, fig. 4), from the Campanian Hakobuchi Group, is, in Matsumoto's opinion (*in* Matsumoto and Yoshimatsu, 1982, in press), better regarded as an example of *I.* (*P.*) *cycloides chicoensis* Anderson (see Seitz, 1961) rather than that of *I.* (*P.*) *cycloides cycloides* (ascribed by Seitz, 1961, p. 63).

Clearer redescriptions of these species or subspecies on the material from Hokkaido are to be given on another occasion.

Occurrence:—In a block of dark grey shale at loc. M-14, derived from the upper part of the Kajisako Formation, on left slope of the valley of the Kajisako.

Inoceramus (*Platyceramus*) *japonicus* Nagao et Matsumoto

Pl. 10, Figs. 5, 6; Pl. 11, Figs. 1, 2

Holotype:—UMUT. MM6524 [=GT. I-1013], from the Kunitan Formation of the Kuji Group, Northeast Japan (Nagao and Matsumoto, p. 24, pl. 9, fig. 1), designated by Matsumoto and Ueda, 1962 (*in* Ueda, p. 165, pl. 24, fig. 1).

Material:—KSG. 3059 (collected by K. Suyari and J. Katto), OES. 31001, 31002, 31003, 31004, 40002, 41001, 14002, 14008, 14102, 14038, 14047, 14103 and many other fragmentary, comparable specimens.

Measurements:—

specimen	h	l	H	HL	l/h	HL/l	α	γ	δ
KSG. 3059	44.0	41.5	50.5	21.6	0.94	0.52	120°	140°	60°
OES. 40002	62.6	59.0	68.6	28.0	0.94	0.47	132°	144°	44°
OES. 14102	115.6	85.6	117.4	46.3	0.74	0.54	104°	137°	62°

Descriptive remarks:—*I.* (*P.*) *japonicus* is variable in shell outline, as has been pointed out by Nagao and Matsumoto (1940), who sorted the various forms into three subgroups, forma α, β and γ. The lectotype, from Northeast Japan, belongs to forma γ, which is much oblique toward the posteroventral extremity and has a gently convex anterior margin. Many, if not all, of the specimen from Hokkaido (e.g., Nagao and Matsumoto, 1940, pl. 7, fig. 2; pl. 8, figs. 2-4; Noda and Matsumoto, 1976, sheet 268 [Cr-34], fig. 2) represents forma β, which is less oblique than forma γ and resembles in outline typical *I.* (*P.*) *ezoensis*. Forma α is represented by the specimens from the Amakusa area, western Kyushu and elsewhere (e.g. Nagao and Matsumoto, 1940, pl. 6, fig. 2; Noda and Matsumoto, 1976, sheet 268 [Cr-34], fig. 1), and characterized by a high form with a shorter hinge-line and the axis of growth tending to be upright in the late growth-stage.

One of us (M. Noda) is now studying biometrically on the ground of population concept whether these three forms can be distinguished subspecifically or otherwise. Pending the issue of that result, we follow provisionally Nagao and Matsumoto, 1940. Aside from the shell outline, this species is characterized by the regular, moderately broad concentric ribs of moderate intensity and fine concentric rings in more or less early growth-stage before the divergent ribs predominate. In other words *I.* (*P.*) *japonicus* is closely allied to *I.* (*P.*) *ezoensis* in early growth-stages.

Likewise, *I.* (*P.*) *undulatoplicatus* Römer (see Seitz, 1961) is closely allied to *I.* (*P.*) *rhomboides* (Seitz) and, accordingly, *I.* (*P.*) *japonicus* is definitely distinguished from it. The divergent ribs gradually appear in various lineages (phylogenetic lines) of *I.* (*Platyceramus*) and this character does not deserve a generic criterion. For this reason *Cladoceramus*, with type-species *I. undulatoplicatus* Römer, is unnecessary.

Now in the specimens of the Monobe area, there is a considerable variation, although they are not always well preserved for precise measurements. OES. 14102, for example, is referable to forma α and incipient divergent ribs appear in the late growth-stage of this specimen. KSG. 3059 (Pl. 10, Fig. 6) is referable to forma β while OES. 40002 (Pl. 3, Fig. 5) may be rather forma γ. In many specimens of larger sizes (e.g. OES. 41001, 14047 and 14103, Pl. 11, Figs. 1, 2), the divergent ribs predominate but the outline is not clearly shown. Some of them may be forma α.

The Monobe area belongs to Southwest Japan and geographically closer to the Amakusa area. It is interesting to find examples of the all three forms in this area, although their respective numbers cannot be counted precisely in the available material.

Occurrence:—In dark grey shale of the upper part of the Kajisako Formation at loc. M-31 on the right bank and locs. M-40 and M-41 on the left side of the valley of the Kajisako; also in blocks of shale at M-14, some of which (e.g. OES. 14038) is close to and probably derived from the outcrop of M-41.

Genus *Mytiloides* Brongniart, 1822

Remarks:—We follow Kauffman and Powell (in Kauffman *et al.*, 1977, p. 71) in elevating *Mytiloides* to genus rank. This genus, with type species *Ostracites labiatus* Schlotheim, 1813 and a typical representative *M. mytiloides* (Mantell, 1822) [*M. labiatus mytiloides* by Seitz (1935)], have been fully redescribed in that paper.

Mytiloides cf. *labiatus opalensis* Böse

Pl. 9, Fig. 12

Material:—KSG. 3060 [=OES. 55001], obtained by K. Nakano from loc. M-55, left internal mould, without umbonal part.

Descriptive remarks:—The shell is of moderate size and gently convex, so far as the preserved part is concerned. It is suboval in outline and somewhat obliquely elongated to the ventral extremity. It is ornamented with regularly spaced concentric ribs of moderate intensity. Minor concentric striae or rings are very faint and only partly impressed.

As the umbonal part is lacking, the precise identification is difficult. With respect to the described characters, this specimen closely resembles some examples of *Mytiloides labiatus opalensis* Böse, which were described and illustrated as forma *elongata* by Seitz (1935, p. 457, pl. 38, figs. 4-6; pl. 39, figs. 2-4; text-fig. 13). Its outline is somewhat similar to that of *M. labiatus subhercynicus* Seitz (1935, p. 465, pl. 40, figs. 1-5; text-fig. 18), but the latter has the growth-axis curved toward the posteroventral extremity and more distinct concentric striae combined with low and rather dense concentric ribs.

We have not yet arrived at a conclusion whether the taxa *opalensis*, *mytiloides*, *subhercynicus* etc. should be regarded as distinct species or subspecies of *M. labiatus* or otherwise. We follow for the time being the concept of Seitz (1935) and Tröger (1967), although Kauffman (1977 and elsewhere) holds the view of specific distinction.

Occurrence:—In sandstone of the lower part of the Kajisako Formation at loc. M-55, about 2.5 m below the bed at loc. M-03 with *I.* (*I.*) *hobetsensis* and *M. teraokai.*

Mytiloides teraokai (Matsumoto et Noda)

Pl. 9, Figs. 4-5

Holotype:—GK. H6833 (Matsumoto and Noda, 1968, p. 319, pl. 32, fig. 1), from the Middle Turonian of the Tano area, eastern Kyushu.

Material:—OES. 03007, 03008, 03016, 03017, 03026, 03104, 03168 and 03175, internal moulds (composite in OES. 03168).

Measurements:—

specimen	h	l	H	HL	l/h	HL/l	α	β	γ	δ
OES. 03008	45.0	47.4	54.8	24.4	1.05	0.51	110°	99°	133°	64°
OES. 03026	30.8	34.2	34.4	14.9	1.11	0.44	123°	—	140°	60°
OES. 03168	33.9	31.8	35.0	15.5	0.94	0.49	120°	100°	134°	56°

Descriptive remarks:—The specimens are clearly identified with *M. teraokai* (Matsumoto et Noda) (1968, p. 319, pl. 32, figs. 1-5; text-fig. 2; Noda, 1975, p. 248, pl. 32, figs. 1-5, 9; Noda and Matsumoto, 1976, Cr. 36, fig. 6) in having a gently convex shell with gradually flattened posterior wing-like part, small anterior ear, somewhat obliquely elongated growth-axis, with $\delta=55-65°$, asymmetrically curved concentric ribs and fine concentric rings or lines.

Matsumoto and Noda (1968, p. 323) once suggested that this species may be assigned to *I.* (*Platyceramus*). Now we assign it to *Mytiloides*, because it is closely allied to *M. hercynicus* (Petrascheck). Kauffman (1977, p. 182) also referred it to *Mytiloides*.

Occurrence:—In sandstone of the lower part of the Kajisako Formation, at loc. M-03 on the right bank of the River Kajisako. The species is associated with *I.* (*I.*) *hobetsensis*.

Mytiloides sp. aff. *M. striatoconcentricus* (Gümbel)

Pl. 10, Fig. 3

Material:—OES. 51002, composite internal mould of right valve.

Measurements (approximate):—

specimen	h	l	H	HL	l/h	HL/l	δ
OES. 51002	26.5	16.0	28.0	8.0	0.6	0.5	60°

Description:—The shell is small, much higher than long, extending obliquely to the posteroventral part. The hinge-line seems to be short, about a half of the shell length. The posterior wing seems to be small but is actually not well exposed. The ventral margin is narrowly rounded at the middle, passing to a gently arcuate anteroventral margin.

The surface is ornamented with numerous, dense, fine concentric rings or lirae. In addition to them there are low concentric major undulations which increase their distance regularly with growth.

The apex of the beak is unpreserved but seems to exceed the hing-line and the umbonal angle seems to be acute.

Comparison:—This kind of inoceramid species has not yet been reported from the Cretaceous of Japan. The described specimen resembles closely examples of *M. striatoconcentricus striatoconcentricus* (Gümbel) described by Tröger (1967, p. 84, pl. 9, figs. 11-15 and 17), from the Upper Turonian and the lowest Coniacian [=Unteres Oberturon by German authors before Seibertz, 1979] of Germany. It has, however, a smaller l/h and is particularly characterized by the presence of low, major concentric undulations. It may be a new subspecies of *M. striatoconcentricus*, but the material is too insufficient to establish the new subspecies.

Occurrence:—Rarely found in silty fine-sandstone at loc. M-51, with *I. teshioensis*, Upper Turonian.

Genus *Sphenoceramus* Böhm, 1915

Remarks:—The group of *Inoceramus naumanni* in the sense of Nagao and Matsumoto (1940, p. 31), which occurs characteristically in the Upper Cretaceous (from Coniacian onward) of the North Pacific region, can be ascribed to *Sphenoceramus* Böhm, since it is similar to the group of *I. lingua-I. lobatus*, from northwestern Europe and related region, although the subgeneric separation between the two groups is worthwhile to be considered. Another problem is whether *Sphenoceramus* is related to *Mytiloides* or *Inoceramus* (s. s.) or otherwise. These problems are not discussed in this paper. For the time being, *Sphenoceramus* Böhm, with the type species *Inoceramus* *cardissoides* Goldfuss, is treated here as an independent genus.

Sphenoceramus cf. *naumanni* (Yokoyama)

Material:—OES. 14021 and 14024.

Descriptive remarks:—External moulds of several specimens on the above numbered rock specimens are before us. They are too poorly preserved for precise identification. The shell is small, obliquely elongated along the growth-axis and ornamented with fine concentric rings. On a larger specimen of OES. 14021, weak posterior groove is impressed. Provisionally this form is compared with *Sphenoceramus naumanni* (Yokoyama) (see Nagao and Matsumoto, 1940, p. 31).

Concluding Remarks

On the basis of the preceding descriptions, the inoceramids from the Monobe area are sorted into the species listed in Table 1, in which the localities and the abundance of the species are also indicated.

Table 1. List of the inoceramid species from the Monobe area.

species	Locality (abundance*)
Inoceramus (*Inoceramus*) *hobetsensis*	M-03(●)
I. (*I.*) sp. nov. (?) aff. *I.* (*I.*) *hobetsensis*	M-51(○)
I. (*I.*) cf. *iburiensis*	M-03(●), M-51(●)
I. (*I.*) *teshioensis*	M-51(⬤)
I. (*I.*) *uwajimensis*	M-05(⬤), M-06(⬤)
I. sp. aff. *I.* (*I.*) *ginterensis*	M-38(○)
Inoceramus mihoensis	M-60(○)
I. (*Platyceramus*) *amakusensis*	M-34(⬤), M-14(⬤), M-56(○)
I. (*P.*) cf. *ezoensis*	M-14(○)
I. (*P.*) aff. *I.* (*P.*) *rhomboides*	M-14(○)
I. (*P.*) *japonicus*	M-31(⬤), M-14(⬤), M-40(●), M-41(●)
Mytiloides cf. *labiatus opalensis*	M-55(○)
M. teraokai	M-03(⬤)
M. sp. aff. *M. striatoconcentricus*	M-51(○)
Sphenoceramus naumanni	M-14(⬤)

* ○: single specimen, ●: 2 or 3, ⬤: more than 3 specimens.

Taxonomic results:—The examined specimens are classified into 15 species, of which 11 are hitherto known from the Cretaceous of the Japanese province. The rest four species are new to Japan and called provisionally in this paper *I.* (*I.*) sp. nov. (?) aff. *I.* (*I.*) *hobetsenis*, *I.* sp. aff. *I.* (*I.*) *ginterensis* Pergament, *I.* (*Platyceramus*) aff. *I.* (*P.*) *rhomboides* Seitz and *Mytiloides* aff. *M. striatoconcentricus* (Gümbel), since the material is insufficient for the establishment of new species or subspecies. For some of the hitherto known species a taxonomic discussion has been given, if necessary.

Biostratigraphic results:—No inoceramid specimen has been found from the main part of the Nagase Formation, that is Lower and Middle Cenomanian on the evidence of ammonite species. From loc. M-38, which is in the upper part of the Nagase Formation and somewhat above loc. M-36 with *Calycoceras* aff. *naviculare* (Mantell), came a single inoceramid specimen. It suggests an Upper Cenomanian age, because it is allied to, if not quite identical with. *I.* (*I.*) *ginterensis*, a world-wide Upper Cenomanian species.

Upward from this locality, inoceramid specimens occur at various levels in the lower and the upper parts of the Kajisako Formation. The succession of the species in the Monobe sequence well conforms with that in the reference sequences in the Yezo Group of Hokkaido, the Onogawa Group of eastern Kyushu, the Himenoura Group of western Kyushu etc. (see Matsumoto, 1977, in which more references are indicated), and thus enables us to conclude the age correlation as follows:

Lower Turonian, suggested by *Mytiloides* cf. *labiatus opalensis* from loc. M-55.

Middle Turonian, represented by loc. M-03 and M-03′, with abundant *Inoceramus* (*I.*) *hobetsensis* and *M. teraokai* and a few specimens of *I.* (*I.*) cf. *iburiensis*, respectively.

Upper Turonian, represented by loc. M-51, with *I.* (*I.*) *teshioeesis*, *I.* (*I.*) cf. *iburiensis*, *I.* (*I.*) sp. nov. (?) aff. *I.* (*I.*) *hobetsensis* and *M.* aff. *striatoconcentricus*.

Coniacian, represented by locs. M-05 and M-06, with *I.* (*I.*) *uwajimensis* and then by loc. M-60, with *I. mihoensis*.

Lower Santonian, represented by locs. M-34, M-56 and part of M-14, with *I.* (*Platyceramus*) *amakusensis*.

Upper Santonian, represented by locs. M-31, M-40, M-41 and part of M-14, with *I.* (*P.*) *japonicus*.

Santonian is also suggested by blocks at M-14 in which *I.* (*Platyceramus*) cf. *ezoensis*, *I.* (*P.*) aff. *rhomboides* and *Sphenoceramus* cf. *naumanni* are found, in addition to *I.* (*P.*) *amakusensis* and *I.* (*P.*) *japonicus*.

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Plate 8

Explanation of Plate 8

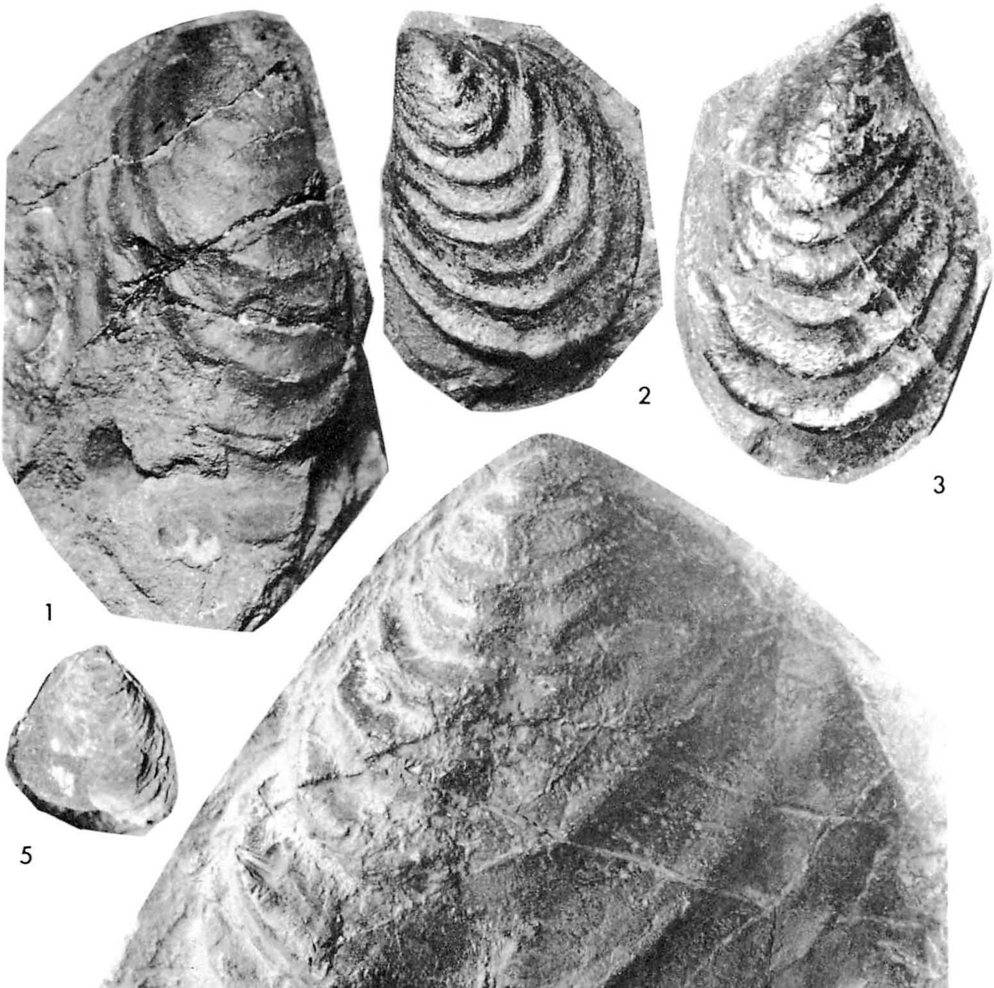
Fig. 1. *Inoceramus* sp. aff. *I.* (*Inoceramus*) *ginterensis* Pergament ....Page 58
OES. 38001, from loc. M-38 on the left bank of the River Kajisako, near the top of the Nagase Formation. Right valve, ×1.

Figs. 2-4. *Inoceramus* (*Inoceramus*) *hobetsensis* Nagao et Matsumoto ....Page 54
2. OES. 03021, from loc. M-03 on the right bank of the River Kajisako, lower part of the Kajisako Formation. Left valve. ×1.
3. OES. 03130, from loc. M-03. Right valve, ×1.
4. OES. 03183, from loc. M-03. Large left valve (plaster cast taken from the external mould), ×0.5.

Fig. 5. *Inoceramus* (*Inoceramus*) cf. *teshioensis* Nagao et Matsumoto ....Page 56
OES. 51004a, from loc. M-51 on the right bank of the River Kajisako, lower part of the Kajisako Formation. Left internal mould of a young shell, ×1.

All collected by T. Kozai.

Photos by M. Noda, without whitening.



T. Matsumoto *et al.*: Inoceramids

Plate 9

Explanation of Plate 9

Figs. 1, 2. *Inoceramus* (*Inoceramus*) *hobetsensis* Nagao et Matsumoto ....Page 54

1. OES. 03184, from loc. M-03, right bank of the River Kajisako, lower part of the Kajisako Formation. Nodulous form (right valve), ×0.5.
2. OES. 03001, from loc. M-03. Left valve with a weak sulcus, ×1.

Fig. 3. *Inoceramus* (*Inoceramus*) sp. nov. (?) aff. *I.* (*I.*) *hobetsensis* Nagao et Matsumoto ....Page 55

OES. 51001, from loc. M-51, right bank of the River Kajisako, lower part of the Kajisako Formation. Left valve, ×1.

Figs. 4, 5. *Mytiloides teraokai* Matsumoto et Noda ....Page 64

4. OES. 03008, from loc. M-03. Right valve, ×1.
5. OES. 03168, from loc. M-03. Right valve, ×0.8.

Figs. 6-8. *Inoceramus* (*Inoceramus*) *teshioensis* Nagao et Matsumoto ....Page 56

6. OES. 51021, from loc. M-51. Right valve (young shell), ×1.
7. OES. 51054, from loc. M-51. Left valve (young part), ×1.2.
8. OES. 51067, from loc. M-51. Right valve, ×1.

Fig. 9. *Inoceramus* (*Inoceramus*) cf. *iburiensis* Nagao et Matsumoto ....Page 56

OES. 03067, from loc. M-03′, slightly above loc. M-03. Inflated umbilical part, ×1.5.

Figs. 10, 11. *Inoceramus* (*Inoceramus*) *uwajimensis* Yehara ....Page 57

10. OES. 06005, from loc. M-06, left bank of the River Kajisako, upper portion of the lower part of the Kajisako Formation. Left valve in several accumulated shells, ×1.
11. OES. 05001, from loc. M-05, right bank of the River Kajisako, the same horizon as above. Left valve ("*yeharai*" type), ×1.

Fig. 12. *Mytiloides* cf. *labiatus opalensis* Böse ....Page 64

KSG. 3060 [=OES. 55001], from loc. M-55, right bank of the River Kajisako, lower part of the Kajisako Formation. Left valve, ×1.

All collected by T. Kozai, except KSG. 3060 (K. Nakano Coll.)

Photos by M. Tashiro (3, 6-8) and M. Noda (others), without whitening.

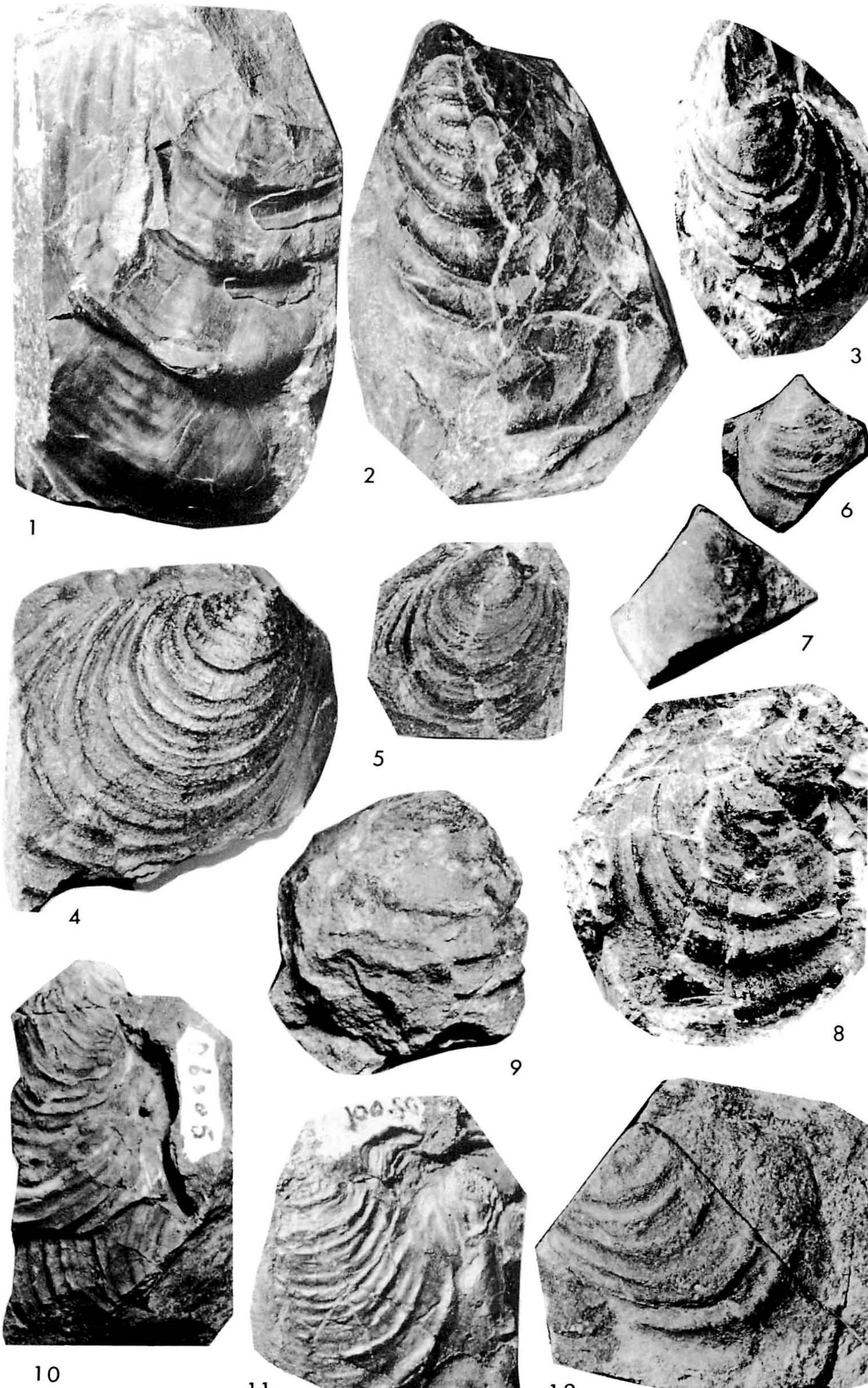

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Plate 10

Explanation of Plate 10

Fig. 1. *Inoceramus* (*Platyceramus*) sp. aff. *I.* (*P.*) *rhomboides* Seitz....................Page 61
OES. 14022, a block at loc. M-14 on left slope of the valley of the Kajisako, middle part of the Kajisako Formation. External mould of a right valve, ×1.

Fig. 2. *Inoceramus* (*Inoceramus*) *uwajimensis* Yehara.................................Page 57
OES. 06010, from loc. M-06, left banks of the River Kajisako, lower portion of the middle part of the Kajisako Formation. Left valve, ×1.5.

Fig. 3. *Mytiloides* sp. aff. *M. striatoconcentricus* (Gümbel) ....Page 65
OES. 51002, from loc. M-51, right bank of the River Kajisako, upper part of the Nagase Formation. Right valve, ×1.

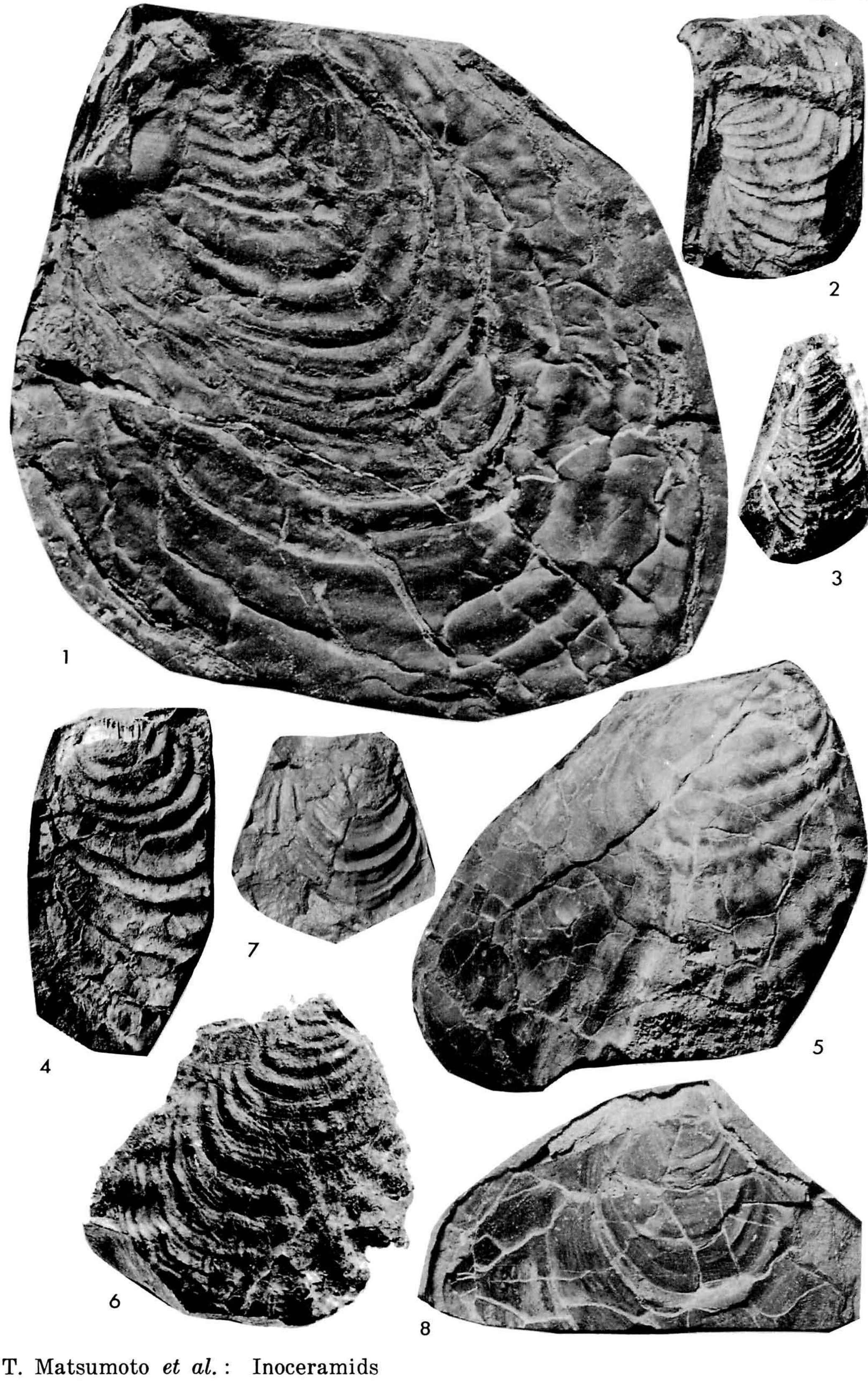
Fig. 4. *Inoceramus* (*Platyceramus*) cf. *ezoensis* Yokoyama..............................Page 62
OES. 14105a, another block at loc. M-14. Internal mould of the left valve, ×1.

Figs. 5, 6. *Inoceramus* (*Platyceramus*) *japonicus* Nagao et Matsumoto..................Page 62
5. OES. 40002, from loc. M-40, left slope of the valley of the Kajisako, middle part of the Kajisako Formation. Right valve (internal mould), ×0.5.
6. KSG. 3059, from a road-side exposure close to M-31, right side of the River Kajisako, middle part of the Kajisako Formation. Right valve (composite internal mould), ×1.

Figs. 7, 8. *Inoceramus* (*Platyceramus*) *amakusensis* Nagao et Matsumoto ....Page 60
7. KSG. 3062 [=OES. 56002], from loc. M-56, left bank of the River Kajisako. Young shell (right valve), ×1.
8. OES. 34002, from loc. M-34, a road-side exposure on the right side of the River Kajisako, middle part of the Kajisako Formation. Left valve, ×1.

All collected by T. Kozai, except KSG. 3059 (K. Suyari and J. Katto Coll.) and KSG. 3062 (M. Tashiro Coll.)

Photos by M. Tashiro (3, 4, 6) and M. Noda (others), without whitening.



T. Matsumoto *et al.* : Inoceramids

Plate 11

Explanation of Plate 11

Figs. 1, 2. *Inoceramus (Platyceramus)* cf. *japonicus* Nagao et Matsumoto..............Page 62

1. OES. 14047, in a block at loc. M-14, on the left slope of the valley of the Kajisako, derived from the Kajisako Formation. A large specimen in which divergent ribs are predominant; umbonal part unpreserved, ×0.5.

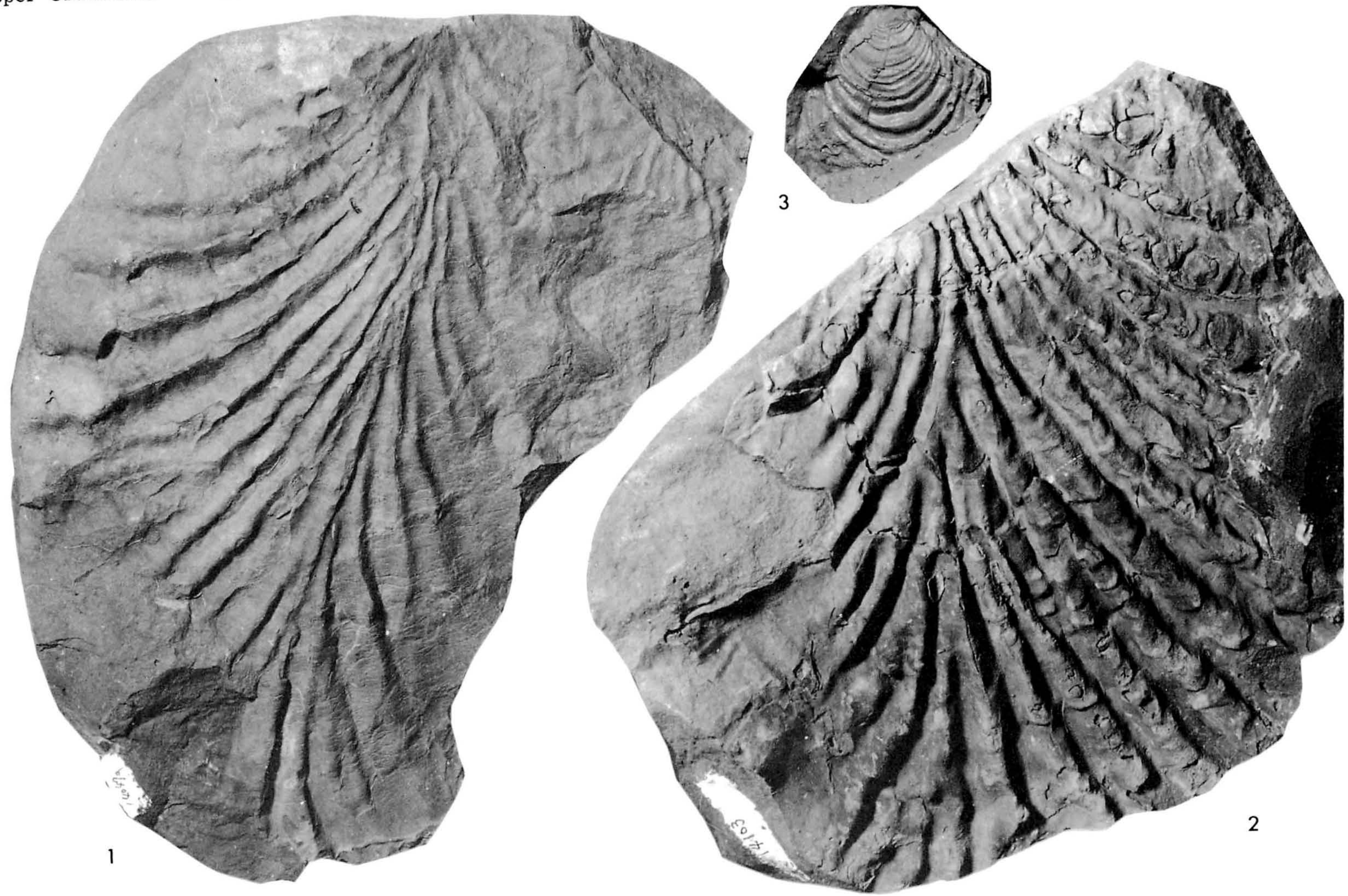
2. OES. 14103, another large example in another block at loc. M-14, ×0.75.

Fig. 3. *Inoceramus mihoensis* Matsumoto ....Page 59

KSG. 3061, from loc. M-60 on the right bank of the River Kajisako, lower part of the Kajisako Formation. Rubber replica of a left valve, taken from an external mould, ×1.

Figured specimens (1, 2) collected by T. Kozai and (3) by M. Tashiro.

Photos by M. Noda, without whitening.



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VII. BIVALVE FOSSILS FROM THE UPPER CRETACEOUS OF THE MONOBE AREA, SHIKOKU

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Abstract

Cenomanian to Santonian bivalve fossils from the Nagase and Kajisako Formations of the Monobe area are examined excluding inocerami in this paper. 27 species, inclusive 3 new species, of 22 genera are described from the formations. The fauna of the Kajisako Formation is probably the first record for the abundant occurrence of Turonian bivalves in Southwest Japan. It is also an interesting fact that the Middle Cenomanian bivalve fauna of the Nagase Formation is undoubtedly comparable with the shallow marine bivalve fauna of the Mifune Group in Central Kyushu.

Introduction

Recently many bivalve fossils have been collected from the Upper Cretaceous of the Monobe area, Shikoku. In this paper we report the result of our study on them but for inoceramids (see another paper in this volume by Matsumoto *et al.*). We give the systematic description in the main part and some biostratigraphic considerations at the end. The specimens described in this paper are kept in the Department of Geology, Faculty of Science, Kochi University.

Before going further, we would like to express our hearty thanks to Professor Emeritus Tatsuro Matsumoto of Kyushu University for his continuous guidance and reading the first draft. We wish also to express our sincere thanks to Professor Minoru Tamura of Kumamoto University for his valuable suggestion, and to Mr. Toshio Komatsu, Master, and other staffs of Odochi Elemently School of Monobe for every facility kindly rendered to this study.

Systematic Description

Class Bivalvia

Subclass Palaeotaxodonta

Order Nuculoida

Family Nuculidae Gray, 1824

Genus *Acila* Adams et Adams, 1858
Subgenus *Truncacila* Grant et Gale, 1931
Acila (Truncacila) hokkaidoensis (Nagao)

Plate 12, Figs. 1, 2

Synonymy:—See Tashiro, 1976, p. 35.

Material:—KSG 3001, a right external mould from loc. M-55; KSG 3002 is an imperfect left valve from loc. M-31.

Measurements:—(in mm)

Specimem	Length	Height	Thickness
KSG 3001	23.0	16.0	—
KSG 3002	21.3	16.1	7.2

Remarks:—The two specimens, like the specimens from the Futaba, Uwajima and Himenoura Groups (Saito, 1962; Tashiro, 1976), are smaller and have more numerous ribs on the disk than the specimen from Hokkaido (Nagao, 1932). They are, however, comparable to *Acila (Truncacila) hokkaidoensis* (Nagao) in view of the diagnostic outline of shell and the position of the bisecting line (see Tashiro, 1976) on the disk.

Occurrence:—Fine grained sandstone of the upper part of the Nagase Formation at loc. M-55, Lower Turonian (with *Mytiloides* cf. *labiatus opalansis*): Dark gray siltstone of the middle part of the Kajisako Formation at loc. M-31, Upper Santonian (with *Inoceramus japonicus*).

Nuculoida, gen. et sp. indet.

Material:—KSG 2071 and KSG 2072 are internal moulds of right valve, KSG 2073 is an internal mould of left valve, from loc. M-50.

Description:—Shell small, roundly subtrigonal, longer than high; umbo located at about 2/3 from front of the valve; umbonal angle about 100°; taxodont teeth of nuculoid type strongly impressed; inner margin finely crenulated.

Measurements:—(in mm)

Specimen	Length	Height
KSG 2701	8.0	7.1
KSG 2072	7.8	6.9
KSG 2073	7.5	6.6

Remarks:—Since the specimens are internal mould, their generic position is not determined.

Occurrence:—Coarse grained sandstone of the lower part (?) of the Nagase Formation at loc. M-50, Lower (?) Cenomanian.

Family Nuculanidae Adams et Adams, 1858
Genus *Ezonuculana* Nagao, 1938
Ezonuculana mactraeformis mactraeformis (Nagao)

Plate 12, Fig. 3

Synonymy:—See Tashiro, 1976, p. 41, 42.

Material:—KSG 3003a, a right valve, KSG 3003b, a left valve, from loc. M-31.

Remarks:—The specimen (KSG 3003a) is measured 10.2 mm in length and 7.0 mm in height. It is undoubtedly assigned to *Ezonuculana mactraeformis mactraeformis* (Nagao) (redefined by Tashiro, 1976), from the Upper-Yezo, the Futaba and the Lower Himenoura Groups. The subspecies is distinguished from *Ezonuculana mactraeformis obsoleta* Tashiro, from the Upper Himenoura Subgroup of Kyushu (Tashiro, 1976), in its distinct concentric ribs on the disk.

Occurrence:—Dark gray siltstone of the middle part of the Kajisako Formation at loc. M-31, Upper Santonian (with *Inoceramus japonicus*).

Subclass Pteriomorphia

Order Arcoida

Family Glycymerididae Newton, 1922

Genus *Glycymeris* Da Costa, 1778

Subgenus *Hanaia* Hayami, 1965

Glycymeris (*Hanaia*) cf. *hokkaidoensis* (Yabe et Nagao)

Plate 12, Figs. 4-6

Compare:—

1928. *Pectunculus hokkaidoensis* Yabe et Nagao, *Sci. Rept. Tohoku Imp. Univ.*, ser. 2, vol. 9, no. 3, p. 82, pl. 17, fig. 22.
1971. *Glycymeris* (*Hanaia*) *hokkaidoensis* (Yabe et Nagao); Tashiro, *Trans. Proc. Palaeont. Soc. Japan*, n.s., no. 84, p. 235, pl. 28, fig. 16.
1975. *Glycymeris* (*Glycymerita*) *hokkaidoensis* (Yabe et Nagao); Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 33.
1979. *Glycymeris hokkaidoensis* (Yabe et Nagao); Matsukuma, *Venus*, vol. 38, p. 107.

Material:—KSG 3004 and KSG 3005, internal moulds of right valve; KSG 3006, internal mould of left valve; KSG 3007 and KSG 3008, external moulds of left and right valves; all from loc. M-38.

Measurements:—(in mm)

Specimen	Length	Height
KSG 3004	14.0	13.5
KSG 3005	14.5	12.8
KSG 3006	17.5	15.7
KSG 3007	—	17.0
KSG 3008	17.3	17.3

Remarks:—This species is characterized by the subquadrate outline and asymmetrically bent hinge plate which is subhorizontal on the anterior half and oblique on the posterior half in the young stage. The asymmetrically bent hinge plate is one of the characteristic features of subgenus *Hanaia* (Tashiro, 1971). In our opinion the subgenus *Hanaia* is a distinct taxon belonging to genus *Glycymeris*, ranging from the Neocomian? to the Turonian. On the other hand, subgenus *Glycymerita* (Finlay and Marwick, 1937) is a characteristic glycymeridid which ranges from the latest Cretaceous to the Paleogene Tertiary. *Glycymeris* (*Hanaia*) *hokkaidoensis* (Yabe et Nagao) probably ranges from the Middle to Upper Cenomanian in age.

Occurrence:—Sandstone of the upper part of the Nagase Formation at loc. M-38, occurring together with *Inoceramus* aff. *ginterensis*.

Subgenus *Pseudoveletuceta* Tashiro, 1971

Glycymeris (*Pseudoveletuceta*) *mifunensis* Tashiro

Plate 12, Figs. 7-9

1971. *Glycymeris* (*Pseudoveletuceta*) *mifunensis* Tashiro, *Trans. Proc. Palaeont. Soc. Japan.* n.s., no. 84, p. 236, pl. 28, figs. 24-30, text-fig. 6.
1976. *Glycymeris* (*Pseudoveletuceta*) *mifunensis* Tashiro; Tamura, *Mem. Fac. Educ. Kumamoto Uuiv., Nat. Sci.*, no. 25, p. 53, pl. 1, figs. 23-24.
1975. *Glycymeris* (*Pseudoveletuceta*) *mifunensis* Tashiro; Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 35, pl. 1, fig. 8.
1978. *Glycymeris mifunensis* Tashiro; Matsukuma, *Venus*, vol. 38, p. 107.

Material:—KSG 3009 and KSG 3010, internal moulds of left valve, from loc. M-39.

Measurements:—(in mm.)

Specimen	Length	Height
KSG 3009	14.0	12.3
KSG 3010	9.0	7.1

Remarks:—In this Monobe Area, the occurrence of this species is very rare. It is characterized by the narrow hinge plate with numerous taxodont teeth, nearly smooth external surface only fine radial striae except for round-topped radial ribs on the umbonal part, and rounded outline. Valve is rather thin for a Cretaceous glycymeridid. This species was originally described as a member of the brackish or near shore faunas of the Middle Cenomanian Mifune Group in Central Kyushu by Tashiro (1971).

Occurrence:—Sandstone of the middle part of the Nagase Formation from loc. M-39, Middle Cenomanian (immediately above the bed with *Calycoceras* cf. *orientale*).

Glycymeris (s. l.) sp.

Material:—KSG 3011, an internal mould of left valve, from loc. M-44.

Remarks:—This specimen is measured 6.0 mm, in length and 5.8 mm in height. The shell is roundly subquadrate, moderately inflated. The hinge plate is stronger than that of *Glycymeris* (*Pseudoveletuceta*) *mifunensis* Tashiro, 1971. This specimen is similar to *Glycymeris* (*Hanaia*) *hokkaidoensis* (Yabe et Nagao, 1928) in its outline. But it is doubtful that this specimen is referable to *G.* (*H.*) *hokkaidoensis*, because the features of surface ornamentation and hinge plate are unknown in detail.

Occurrence:—Coarse grained sandstone of the basal part (?) of the Nagase Formation at loc. M-44, Lower Cenomanian.

Family Cucullaeidae Stewart, 1930

Genus *Cucullaea* Lamarck, 1801

Subgenus *Idonearca* Conrad, 1862

Cucullaea (Idonearca) ezoensis ezoensis Yabe et Nagao

Plate 14, Fig. 3

1928. *Cucullaea ezoensis* Yabe et Nagao, *Sci. Rept. Tohoku Imp. Univ.*, sér. 2, vol. 9, no. 3, p. 81, pl. 16, figs. 1-3.
1975. *Cucullaea (Idonearca) ezoensis ezoensis* Yabe et Nagao; Hayami, *Univ. Mus., Univ. Tokyo, Bull.*, no. 10, p. 31.

Material:—KSG 3012, a left valve from loc. M-28.

Description:—Shell subquadrate in outline, longer than high, moderately inflated; umbo prominent, prosogyrous, located at a little anterior from the mid-point of the valve; dorsal margin as long as a half length of the valve; anterior margin straight, vertically truncated; ventral margin weakly arched; posterior margin nearly straight, obliquely truncated; posteroventral margin well rounded; posterior carina extending from umbo to postero-ventral margin, well elevated, but not angulated; posterior area distinctly depressed; a weak radial ridge on the posterior area extending from the umbo to nearly the mid-point of the posterior margin; surface ornamented with fine narrow, round-topped radial ribs which are narrower than their interspaces, distinct near the umbo, but almost effaced on the ventral part.

Observation:—The internal features of this specimen are unknown. The specimen is measured 20.0 mm in length, 18.0 mm in height and 8.0 mm in thickness

Comparison:—This specimen from the Nagase Formation is smaller than the lectotype of Yabe and Nagao (1928), but is undoubtedly identified with *Cucullaea ezoensis ezoensis* Yabe et Nagao, from the Mikasa Formation of Hokkaido, on account of its diagnostic features. *Cucullaea (Idonearca) ezoensis amaxensis* Matsumoto (1938), from the Goshonoura Group of Kyushu, is clearly distinguishable from this subspecies in its different outline with generally obliquely expanded posterior part and nearly smooth surface. *Cucullaea (Idonearca) acuticarinata* Nagao (1934), from the Miyako Group of NE Japan, also differs from this species in its distinctly angulated posterior carina and smooth surface.

Occurrence:—Sandstone of the lower part of the Nagase Formation at loc. M-28, together with *Mantelliceras cantianum*, which indicates Lower Cenomanian.

Family Noetidae Stewart, 1930

Subfamily Noetinae Stewart, 1930

Genus *Matsumotoa* Okada, 1958

Matsumotoa sp.

Plate 14, Fig. 4

Material:—KSG 2080, an internal mould of left valve, and KSG 2081, an internal mould of right valve, from loc. M-50.

Description:—Shell very small, inequilateral, elongatedly subquadrate in outline, moderately inflated; umbo prominent, located at about two fifths from the front of valve; dorsal margin long, nearly straight; anterior margin short, nearly vertically truncated from dorsal margin; ventral margin weakly arched but slightly concave on central part of the margin; posterior margin straight, obliquely expanded to posterior; inner surface smooth; a low and broad radial inner ridge extended from umbo to the central part of the dorsal margin; hinge plate narrow for the genus, elongated along the dorsal margin with numerous taxodont teeth; teeth on both sides of umbo elongated, horizontally parallel like as in *Cucullaea;* central teeth small, converging toward ventral; anterior adductor scar larger than posterior; both adductor scars distinctly impressed; inner margin smooth; surface ornamented by numerous radial ribs each of which is narrower than its interspace.

Measurements:—(in mm)

Specimen	Length	Height
KSG 2080	10.0	8.0
KSG 2081	11.5	9.0

Observation:—A narrow ligament area is observable under the beak but indistinct in detail of its ligament features. As the available material is only a fragmentary external mould, the surface ornamentation is not clear. This species is probably referable to *Matsumotoa* Okada, 1958, in its features of hinge structure.

Occurrence:—Sandstone of the lower part (?) of the Nagase Formation at loc. M-50, Lower (?) Cenomanian.

Order Mytiloida

Family Mytilidae Rafinesque, 1815

Genus *Septifer* Recluz, 1848

Septifer mifunensis Tamura

Plate 12, Figs. 10-17

1976. *Septifer mifunensis* Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, Nat. Sci., no. 25, p. 54, pl. 2, figs. 1-18.

Material:—KSG 3013, an internal mould of right valve, KSG 3014 and KSG 3015, external moulds, and KSG 3016, an internal mould of left valve, all from loc, M-39.

Measurements:—

Specimen	Length	Height
KSG 3013	20.5	15.2
KSG 3014	ca 21.5	13.5
KSG 3016	21.8	17.5

Remarks:—The specimens from the Nagase Formation, are probably conspecific with the holotype and other examples of *Septifer mifunensis* Tamura (1976) from the Middle Cenomanian Mifune Group in Kyushu. They are somewhat more strongly inflated and have less numerous radial ribs than the holotype. These minor differences are regarded as variation within the same species. *Crenella gyliakiana* Matsumoto (1938), from the Goshonoura Group and Mifune Group (Tamura, 1976) of Central Kyushu, is apparently similar to this species in its subtrigonal outline, but differs clearly in its more numerous and weaker radial ribs on the surface, and distinct crenulations on the inner posterior dorsal margin, *Septifer ushibukensis* Tashiro et Otsuka (1980), from the Uppermost Formation of the Himenoura Group (U-IVc Member of the Group) of Kyushu, is characterized by more numerous and weaker radial ribs and less inflated valve than this species,

Occurrence:—Sandstone of the middle part of the Nagase Formation at loc. M-39, together with *Calycoceras* cf. *orientale*, Middle Cenomanian.

Family Pectinidae Rafinesque, 1815

Genus *Nippononectes* Tashiro, 1982

Nippononectes monobensis Tashiro

Plate 12, Figs. 19, 20

1982. *Nippononectes monobensis* Tashiro, *Mem. Fac. Sci. Kochi Univ.*, ser. E, Geol., vol. 3, p. 3, pl. 2, figs. 6-9.

Material and *Measurements*:—See Tashiro, 1982.

Remarks:—Genus *Nippononectes* is characterized by the *Camptonectes*-like fine diverging striae and the *Camptochlamys*-like weak radial ribs on the surface. The radial ribs are stronger on the left valve than on the right valve, and generally spinose on both lateral marginal parts. *Nippononectes elegans* Tashiro, from the Lower Cretaceous Hibihara Formation of the Monobegawa Group of Kochi Prefecture (Tashiro, 1982), is very small and characterized by more numerous radial ribs than this species, The type species of *Nippononectes, N, tamurai* (Tashiro), from the Upper Campanian and Lower Maastrichtian of the Himenoura and Izumi Group (Tashiro, 1976, 1978), is larger and has finer and less numerous radial ribs than this species.

Occurrence:—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis*, Middle Turonian; fine-grained sandstone of the lower part of the same formation at loc. M-51, stratigraphically somewhat higher than loc. M-03, together with *Inoceramus* cf. *teshioensis*, probably Upper Turonian.

Family Propeamussiidae Abbott, 1954

Genus *Parvamussium* Sacco, 1897

Parvamussium cowperi yubarense (Yabe et Nagao)

Plste 12, Fig. 18

Synonymy:—See Tashiro, 1976, p. 52.

Material:—KSG 3019, left internal mould from loc. M-31. Several other imperfect external and internal moulds, from loc. M-03.

Remarks:—A sole perfect specimen (KSG 3019), an internal mould, is measured 10.1 mm in length and 10.2 mm in height. It has 8 distinct radial inner ribs which extend from the umbo to the venter but not reaching the margin. The specimens from this area are probably conspecific with *Parvamussium cowperi yubarense* (Yabe et Nagao) which is widely distributed in the Upper Cretaceous (Cenomanian to Santonian) of Japan. This species differs from *Parvamussium kimurai* (Hayami) from the Lower Cretaceous of Japan (Hayami, 1965) and *Parvamussium hinagense* Tamura from the Lower

Cretaceous of Japan and Borneo (Tamura, 1973), in its weaker radial ribs on the external surface and less developed secondary internal radial ribs than those Lower Cretaceous species.

Occurrence:—Dark gray siltstone of the upper part of the Kajisako Formation at loc. M-31, with *Inoceramus japonicus*; Fine-grained sandstone of the basal part of the same formation at loc. M-03, with *Inoceramus hobetsensis*.

Family Plicatulidae Larmarck, 1801

Genus *Plicatula* Lamarck, 1801

Plicatula sp.

Plate 12, Figs. 21, 22

Material:—KSG 3020, an external mould of left valve from loc. M-03; KSG 3017, an internal mould of right valve from the same locality.

Description:—Shell pyriform or longitudinally ovate in outline, consisting of nearly flat left valve and strongly inflated right valve; anterior and posterior margins nearly straight or weakly concave; ventral margin semicircular; umbo less prominent on left valve, a little elevated on right valve, orthogyrous, located near the central point of the dorsal margin; hinge short, straight and horizontal; anterior and posterior ears very small, indistinctly separated from the disk; surface of left valve ornamented by numerous flexuous radial ribs, each of which is low, round-topped, broad but narrower than the interspace, bi- or trifurcate near the ventral margin and granulated or spinose on the ventral area; growth lines of left valve distinctly developed on the almost whole part of the surface; inner surface of left valve ornamented with numerous flexuous and round-topped radial ribs; inner margin crenulated.

Measurements:—(in mm)

Specimen	Length	Height
KSG 3017	18.0	21.0
KSG 3020	13.5	19.0

Observation:—The radial ribs on the surface number about 20 on the shell margin. 10 or so ribs on the anterior marginal part are broadened and strongly granulated. 10 or fewer ribs on the ventral part are narrow but distinct and finely granulated. Other several ribs on the posterior marginal part are generally weak, low and broad.

Comparison:—*Plicatula kiiensis* Hayami, from the Lower Cretaceous Arida Formation of Kii Peninsula (Hayami, 1965), is discriminated from this species in its more regular and more numerous radial ribs, and smaller but strongly spinose granulations on the radial ribs.

Occurrence:—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis*, Middle Turonian.

Genus *Atreta* Etallon, 1862

Atreta intsulaevis Tashiro

Plate 12, Figs. 23 and 24

1978. *Atreta intsulaevis* Tashiro, *Trans. Proc. Palaeont. Soc. Japan*, n. s., no. 106, p. 322, pl. 44, figs. 1-4.

Material:—KSG 3021—KSG 3022, internal moulds of right valve from loc. M-03.

Measurements:—(in mm)

Specimen	Length	Height
KSG 3021	20.0	21.3
KSG 3022	15.0	11.4

Remarks:—The specimens from the Nagase Formation are attached generally to the external surface of *Inoceramus hobetsensis* Nagao et Matsumoto with its right valve. They are undoubtedly conspecific with *Atreta intsulaevis* Tashiro, from the Himenoura Group of Kyushu (Tashiro, 1978). The typical specimens of this species in Kyushu generally occur together with *Inoceramus amakusensis* Nagao et Matsumoto. This species resembles *Pycnodonte amakusensis* Tashiro (1978), from the Himenoura Group of Kyushu, in its flat valve with which it attached to other material such as inoceramid shell, but differs clearly in its orthogyrate umbo.

Occurrence:—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis* (Middle Turonian).

Family Ostreidae Rafinesque, 1815

Genus *Pycnodonte* Fischer de Waldheim, 1835

Pycnodonte amakusensis Tashiro

Plate 12, Figs. 25 and 26

1978. *Pycnodonte amakusensis* Tashiro, *Trans. Proc. Palaeont. Soc. Japan*, n. s., no. 106, p. 323, pl. 43, fig. 9, pl. 44, figs. 5-11.

Material:—KSG 3025—KSG 3026, internal moulds of left valve from loc. M-03; KSG 3055, an internal mould of left valve from loc. M-34; and KSG 3018, an internal mould from loc. M-40.

Measurements:—(in mm)

Specimen	Length	Height
KSG 3025	13.0	14.0
KSG 3026	13.0	15.6
KSG 3055	11.0	11.1
KSG 3018	7.0	9.7

Remarks:—The right valve of this species is not yet known in this area. The outline of this species is somewhat variable from subcircular to roundly subquadrate. The specimens from loc. M-03 attach themselves to the surface of *Inoceramus hobetsensis* Nagao et Matsumoto, with left valve. On the other hand, the specimen from loc. M-43 attaches to *Inoceramus amakusensis* Nagao et Matsumoto, and from loc. M-40 to *Inoceramus japonicus* Nagao et Matsumoto, both in the same way.

Occurrence:—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, (Middle Turonian); dark gray siltstone of the middle part of the same formation at loc. M-34, (Santonian); and dark gray mudstone of the upper part of the same formation at loc. M-40, (Upper Santonian).

Genus *Crassostrea* Sacco, 1897

Crassostrea aff. *C. kawauchidensis* Tamura

Compare:—

1977. *Crassostrea kawauchidensis* Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, Nat. Sci., p. 114, pl. 2, figs. 1-5, pl. 12, figs. 21-24.

Material:—KSG 3027, a block of siltstone in which numerous crowded valves of this species are contained, collected from loc. M-22.

Remarks:—The largest specimen of this species is measured about 10 cm in height and 3 cm or more in the thickness of test. The specimens from this area are similar to *Crassostrea kawauchidensis* Tamura, from the Middle Cenomanian of the Mifune Group in Kyushu (Tamura, 1977), in its elongated outline. The specimens from this area are, however, not clear in the features of the hinge structure. *C. kawauchidensis* is also known from the Upper Formation (IIIc Member in Matsumoto, 1938; Tamura, Tashiro and Motojima, 1968) of the Goshonoura Group.

Occurrence:—Siltstone of the Nagase (?) Formation at loc. M-22, Cenomanian (?).

Genus *Gryphaeostrea* Conrad, 1865

Gryphaeostrea kochiensis sp. nov.

Plate 14, Figs. 1-2, 22-23

Material:—KSG 3056 (holotype), KSG 3057, KSG 2085—KSG 2087 (paratypes), external moulds of left valve; KSG 2088—KSG 2089 (paratypes), internal moulds of right valve; KSG 2090 (paratype), a right valve; all the specimens from loc. M-03.

Diagnosis:—Shell small, roundly ovate, higher than long, nearly flat in left valve, strongly inflated in right valve; umbo located nearly at mid-length of the valve; umbonal angle of left valve is about 110°; hinge line short and nearly straight; anterior and posterior margins of left valve straight or somewhat convex; ventral margin of left valve well rounded; surface of left valve ornamented with regularly spaced concentric wrinkles; internal surface of left valve nearly smooth except for a small rounded adductor scar which is located at a little posterior and higher than the center of valve; inner margin smooth; surface of right valve nearly smooth except for very fine growth lines.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3056	10.8	11.8	—
KSG 3057	9.8	12.5	—
KSG 2085	12.5	16.7	—
KSG 2086	8.6	12.1	—
KSG 2090	8.3	13.0	4.0
KSG 2088	10.2	14.8	6.0

Observation:—The concentric wrinkles on the surface of left valve count 7-10. The wrinkles are angular on the top and somewhat weakly laminated on the ventral part, generally closely space near the umbo, numbering about 5 or more. The hinge structure is indistinct. The umbo of left valve is weakly opisthogyrate. On the other hand, the umbo of right valve is strongly opithogyrate, and attached to some other material on the top.

Comparison:—*Gryphaeostrea vomer* Stephenson, from the Maastrichtian of North America (Stephenson, 1941), is similar to this species in its outline and number of the concentric wrinkles, but differs in its more laminated and strongly prominent wrinkles, *Gryphaeostrea eversa* (Mellville) from the basin of Paris and *Gryphaeostrea eversa meridionalis* Freneix, from the Paleocene of Angola (Freneix, 1979), resemble this species in the features of concentric wrinkles, but differ in the large size and prominent umbo of the right valve. This species is discriminated from *Gryphaeostrea inscripta* (d'Archiac) from the Tertiary of Gosse (Cossmann, 1922) and *Gryphaeostrea plicatella* (Morton) from the Tertiary of North America (Stenzel, 1971), in its less prosogyrate umbo of the left valve and smaller valve in size.

Occurrence:—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis*, Middle Turonian.

Order Trigonioida Dall, 1889

Family Trigoniidae Lamarck, 1819

Subfamily Apiotrigoniinae Tashiro, 1979

Genus *Apiotrigonia* Cox, 1952

Subgenus *Apiotrigonia* Cox, 1952

Apiotrigonia (*Apiotrigonia*) *undulosa* Nakano

Plate 13, Fig. 1-6

Synonymy:—See Tashiro, 1979, p. 188.

Material:—KSG 3031-KSG 3033, external moulds of right valve; KSG 3034 and KSG 3036, external moulds of left valve; and KSG 3035, internal mould of left valve; all the specimens from loc. M-03. The other materials are listed in Tashiro, 1979.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3031	20.0	13.8	—
KSG 3032	16.5	10.5	—
KSG 3034	18.0	14.1	2.8
KSG 3035	17.1	11.0	—
KSG 3036	11.9	10.0	3.0

Remarks:—The specimens from the Kajisako Formation are smaller than the holotype (Nakano, 1957, pl. 8, fig. 8), from the Futaba Group of Fukushima Prefecture (NE Japan). Other specimens from the Furushiroyama Formation of the Uwajima Group of the Shimanto Belt, of Ehime Prefecture in Shikoku, are likewise smaller than the holotype. This species ranges probably from the Middle Turonian to the Coniacian, judging from the associated species of inocerami and ammonites.

Occurrence:—Fine-grained sandstone from the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis* (Middle Turonian). Fine-grained sandstone of the lower part of the Kajisako Formation at loc. M-51, with *Inoceramus* cf. *teshioensis* (Upper Turonian).

Subfamily Pterotrigoniinae van Hoepen, 1929

Genus *Pterotrigonia* van Hoepen, 1929

Subgenus *Acanthotrigonia* van Hoepen, 1929

Pterotrigonia (*Acanthotrigonia*) *pustulosa* (Nagao)

Plate 13, Fig. 14

1930. *Trigonia pustulosa* Nagao, *Jour. Fac. Sci. Hokkaido Imp. Univ.*, ser. 4, vol. 1, no. 1, p. 17, pl. 3, figs. 9-12.
1978. *Pterotrigonia* (*Acanthotrigonia*) *pustulosa* (Nagao) ; Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 27, Nat. Sci., p. 92, with a full list of synonymy, pl. 4, figs. 8-12.

Material:—KSG 3037, an imperfect left external mould collected from loc. M-53.

Remarks:—The specimen from the Nagase Formation is undoubtedly identified with the syntypes from Members IIb and IIe of the Goshonoura Group in Kyushu, being characterized by finely pustulated sculptures on the area. The specimen is an imperfect mould of the anterior ventral part, measurred 24 mm in length and about 21 mm in height. Another specimen from this area which was collected by the late Mr. H. Hirata, is preserved in the Fossil Museum of Kochi-Godaisan. Hirata's specimen is also an imperfect external mould, which shows clearly the features of the escutcheon and the area. This species was also reported from the Miyanohara Formation of Sakawa area in Kochi Prefecture by Amano (1956) and Hirata (1974). Its age is probably restricted to the uppermost Albian (Member IIb of the Goshonoura Group) and Lower Cenomanian (this area).

Occurrence:—Sandstone of the lower part of the Nagase Formation at loc. M-53, with *Mantelliceras* cf. *saxbii* (see, Matsumoto in this volume), Lower Cenomanian.

Pterotrigonia (*Acanthotrigonia*) *mashikensis* (Tamura et Tashiro)

Plate 13, Figs. 15-20

1967. *Acanthotrigonia mashikensis* Tamura et Tashiro, *Mem. Fac. Educ. Kumamoto Univ.*, no. 18, Nat. Sci., p. 19, text-fig. 2, pl. 1, figs. 1-7.
1975. *Pterotrigonia* (*Acanthotrigonia*) *mashikensis* Tamura et Tashiro; Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 120.
1977. *Pterotrigonia* (*Acanthotrigonia*) *mashikensis* (Tamura et Tashiro) ; Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, Nat. Sci., p. 116, pl. 4, figs. 1-8.

Material:—KSG 3038-KSG 3040, external moulds, from loc. M-39.
Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3038, r. ext. mould	37.6	28.5	18.5
KSG 3039, 1. ext. mould	ca 27.0	26.0	9.5
KSG 3040, 1. ext. mould	—	30.5	11.5

Remarks:—The specimens from the Nagase Formation are undoubtedly conspecific with the specimens of *Pterotrigonia* (*Acanthotrigonia*) *mashikensis* (Tamura et Tashiro) from the Mifune Group of Central Kyushu (Tamura and Tashiro, 1970; Tamura, 1977). It is clossely similar to *Pterotrigonia* (?*Pterotrigonia*) *brevicula* (Yehara), from the Middle Yezo Group of Hokkaido (Yehara, 1923; Nakano and Numano, 1961) and *Pterotrigonia* (*Pterotrigonia*) *sakakurai* (Yehara), from the Goshonoura Group of Kyushu (Yehara, 1923; Nakano and Numano, 1961; Tamura, 1975), in its rounded outline, inflated valve and broader costae on the disk. It is, however, distinguishable from *P.* (?*P.*) *brevicula* in its less rostrated posterior area and from *P.* (*P.*) *sakakurai* in its narrow apical angle and smaller valve.

Occurrence:—Sandstone of the middle part of the Nagase Formation at loc. M-39, Middle Cenomanian. Coarse grained sandstone of the basal part of the Nagase Formation at loc. M-28, Lower Cenomanian.

Pterotrigonia (*Acanthotrigonia*) cf. *higoensis* (Tamura et Tashiro)

Plate 13, Fig. 21

Compare:—

1967. *Acanthotrigonia higoensis* Tamura et Tashiro, *Mem. Fac. Educ. Kumamoto Univ.*, no. 15, Nat. Sci., p. 17, text-fig. 2, pl. 1, figs. 14-17.
1975. *Pterotrigonia* (*Acanthotrigonia*) *higoensis* (Tamura et Tashiro); Hayami, *Univ. Mus., Univ. Tokyo, Bull.* no. 10, p. 120.
1977. *Pterotrigonia* (*Acanthotrigonia*) *higoensis* (Tamura et Tashiro); Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, Nat. Sci., p. 116, pl. 4, figs. 9-12.

Material:—KSG 3059, external mould of right valve, from loc. M-39.

Remarks:—The specimen is measured 40 mm in length, about 31 mm in height and 13.0 mm in thickness. It is characterized by tuberculated, strong costae on the anterior half of the disk and well inflated and rounded valve. It is probably identified with *Pterotrigonia* (*Acanthotrigonia*) *higoensis* (Tamura et Tashiro), from the Middle Cenomanian Mifune Group of Central Kyushu (Tamura and Tashiro, 1967; Tamura and Matsumura, 1974; Tamura, 1977). This species is similar to *Pterotrigonia* (*Acanthotrigonia*) *mashikensis* (Tamura et Tashiro, 1967) in its rounded outline and less numerous costae on the disk for the species of pterotrigoniins, but discriminated in its distinct tuberculations on the costae and more inflated valve. It also resembles *Pterotrigonia* (?*Pterotrigonia*) *brevicula* (Yehara, 1915), but the latter has a strongly rostrated but not plicated posterior area.

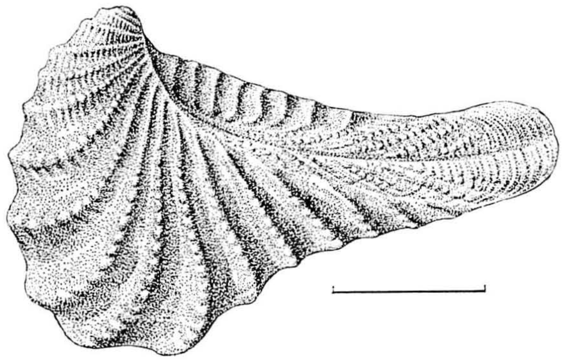
Occurrence:—Sandstone of the middle part of the Nagase Formation at loc. M-39, Middle Cenomanian.

Subgenus *Scabrotrigonia* Dietrich, 1933

Pterotrigonia (*Scabrotrigonia*) *monobeana* sp. nov.

Plate 13, Figs. 7-13, Text-fig. 1

Material:—KSG 3041 (holotype), an external mould of left valve; KSG 3042-KSG 3043 (paratypes), external moulds of right and left valves; all from loc. M-39.



Text-fig. 1. *Pterotrigonia* (*Scabrotrigonia*) *monobeana* sp. nov.; lateral view of left valve; scale 5 mm.

Diagnosis:—Shell small, lanceolated or elongated subtrigonal in outline, with strongly rostrated posterior part, well inflated; umbo opisthogyrous, moderately prominent, located at a point about a fifth from the front of the valve; umbonal angle about 80°; anterior margin semicircular; ventral margin long, weakly concave; siphonal margin narrow, well rounded; posterior dorsal margin long, weakly concave; posterior carina distinct near the umbo but gradually disappearing on the posterior part; escutcheon carina indistinct except for the umbonal region; disk semicircular in outline, ornamented with strong costae, about 25 in number; 4 or so costae on the umbonal region subconcentric, finely crenulated as in *Haidaia*; about 9 costae on the middle part elongated and oblique, finely tuberculated; 5 or so costae on the posterior part short, subradial, indistinctly tuberculated, widely spaced, narrower than their interspaces; area narrow and much elongated; 3 or more oblique costellae each of which connnected with a costella on the escutcheon, appear close to the umbo; the other part of the area with weak pustulations as in *Pterotrigonia* (*Acanthotrigonia*) *pustulosa* (Nagao); several ill-defined chevron-shaped costellae which disappear near the distinct median groove also appear on the main part of the area; the chevron-shaped costellae connected with the costae of the disk on the posterior carina and with the costellae of the escutcheon on the escutcheonal carina; escutcheon rather broad, lanceolate, ornamented with 10 or more transverse costellae.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3041	18.9	10.9	3.2
KSG 3042	20.0	—	—
KSG 3043	ca 40.0	ca 22.0	—

Observation:—This species is characterized by much elongated outline and strongly rostrated posterior area, The pustulations on the area are distinct but very weak and appear only on the median part of the area of KSG 3041, but are indistinct on the area of KSG 3042. The pustulations are nearly effaced on the posterior part of the area. The growth lines are indistinct on the disk but distinctly sculptured on the posterior part of the area. The subgeneric assignment of this species to *Scabrotrigonia* is provisional, since it has some characters which recall us *Acanthotrigonia*.

Comparison:—This species is closely allied to *Pterotrigonia* (*Acanthotrigonia*) *longilova* (Jimbo), from the Middle Yezo Group of Hokkaido (Jimbo, 1894; Matsumoto, 1963; Hayami and Kase, 1981), in its elongated outline and strongly rostrated posterior area, but discriminated by its chevron shaped costellae on the area and oblique costellae on the umbonal part of the area. The specimen from the Miyanohara Formation of Kochi Prefecture, which was described by Yehara (1923) as *Trigonia longiloba*, also resembles this species in its elongated outline and oblique costellae on the area. Many specimens in our collection which were collected from the Miyanohara Formation are undoubtedly conspecific with '*Trigonia longilova*' of Yehara, but clearly discriminated from this species in its less numerous costae on the disk and less elongated outline. The specimens of '*Trigonia longiloba*' of Yehara from Kochi Prefecture is more similar to *Pterotrigonia* (*Acanthotrigonia*) *mifunensis* (Tamura et Tashiro) from the Mifune Group of Kyushu (Tamura and Tashiro, 1967) than this species in its crescent outline and less developed *Haidaia*-like crenulations on the umbonal part of the disk.

This species is similar to *Pterotrigonia* (*Acanthotrigonia*) *pustulosa* (Nagao, 1930), in its oblique costellae and pustulations on the area, but differs in its much elongated outline and chevron shaped costellae on the area. This species is clearly discriminated from the type species of *Scabrotrigonia*, *Pterotrigonia* (*Scabrotrigonia*) *scabra* (Lamarck), from the Upper Cretaceous of Europe, in its ill-defined chevron shaped costellae on the area and much rostrated posterior area. It also resembles *Pterotrigonia* (*Acanthotrigonia*) *yeharai* Nakano et Numano, from the Goshonoura Group of Central Kyushu (Nakano and Numano, 1961; Tamura, Tashiro and Motojima, 1968; Tamura, 1975), in its *Haidaia*-like crenulation of costae on the disk and the elongated outline, but differs from *P.* (*A.*) *yeharai* in its more rostrated posterior area and sculptured pustulations and chevrons on the area.

Pterotrigonia (*Scabrotrigonia*) *obsoleta* (Nakano, 1958), from the Goshonoura Group, and *Pterotrigonia* (*Scabrotrigonia*) *kobayashii* (Nakano, 1958), from the Mikasa Formation of Hokkaido, are similar to this species in their imperfect chevron shaped costellae on the area, but differ clearly in their numerous costae on the disk and higher valve.

Occurrence:—Sandstone of the middle part of the Nagase Formation at loc. M-39, with *Calycoceras* cf. *orientale* (see Matsumoto's paper in this volume), Middle Cenomanian.

Subclass Heterodonta

Order Veneroida

Family Lucinidae Fleming, 1828

Genus *Myrtea* Turton, 1822

Myrtea sp. cf. *Myrtea ezoensis* (Nagao)

Plate 14, Fig. 14

Material:—KSG 3044, an external mould of left valve; KSG 3045, an external mould of right valve; and several fragmental specimens; all from loc. M-03.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3044	ca 9.0	8.2	2.0
KSG 3045	10.0	9.0	2.1

Remarks:—These specimens are probably conspecific with the typical specimen of *Myrtea ezoensis* (Nagao), from the Upper Yezo Group of Hokkaido (Nagao, 1932; also see Tashiro, 1976).

Occurrence:—Fine-grained sandstone in the basal part of the Kajisako Formation at loc. M-03, occurring together with *Inoceramus hobetsensis*, Middle Turonian.

Family Carditidae Fleming, 1828

Genus *Fenestricardita* Casey, 1961

Fenestricardita densigranulata Tashiro

Plste 14, Figs. 11-12

1976. *Fenestricardita densigranulata* Tashiro, *Palaeont. Soc. Japan, Spec. Pap.* no. 19, p. 61, pl. 8, figs. 19-24.

Material:—KSG 3046, an external mould of left valve and KSG 3047, an internal mould of left valve, from loc. M-03.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3046	8.1	7.5	1.6
KSG 3047	13.0	10.5	—

Remarks:—The two specimens are undoubtedly referable to *Fenestricardita densigranulata* Tashiro, from the Himenoura Group of Kyushu (Tashiro, 1976). Recently one of us (Tashiro) has recognized this species in the Furushiroyama Formation of the Uwajima Group of the Shimanto Belt in Ehime Prefecture. It is similar to *Fenestricardita ovata* Tashiro, from the Himenoura Group of Kyushu (Tashiro, 1976), but is distinguished by its subquadrate outline.

Occurrence:—Rare in the fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03 with *Inoceramus hobetsensis*, Middle Turonian. This species ranges probably from the Middle Turonian to the Lower Campanian.

Family Astartidae d'Orbigny, 1844

Genus *Eriphyla* Gabb, 1864

Eriphyla (*Eriphyla*) *higoensis* Tashiro

Plate 14, Figs. 15-17, Text-fig. 2

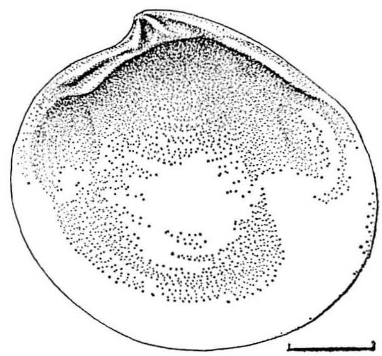
1976. *Eriphyla higoensis* Tashiro, *Palaeont. Soc. Japan, Spec. Pap.*, no. 19, p. 64, pl. 8, figs. 6-12

Material:—KSG 3042 and KSG 3043, left valves, KSG 3044, a right valve, and KSG 3045, an internal mould of right valve, all from loc. M-03.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3042	17.2	14.0	—
KSG 3043	21.3	18.0	3.0
KSG 3044	21.3	18.3	4.0
KSG 3045	20.6	19.9	—

Remarks:—This species is characterized by its less inflated valve and more anterior location of the umbo than *Eriphyla japonica* Ichikawa et Maeda, from the Izumi Group (Ichikawa and Maeda, 1958) and the Upper Himenoura Subgroup (Tashiro, 1976), and *Eriphyla izumensis* Ichikawa et Maeda, from the Izumi Group (Ichikawa and Maeda, 1958) from Southwest Japan.



Text-fig. 2. *Eriphyla (Eriphyla) higoensis* Tashiro; internal view of right valve; scale 5 mm.

Occurrence:—Common in the fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis*, Middle Turonian. This species was originally described on the specimens from the Himenoura Group of Kyushu. It is also found from the Furushiroyama Formation of the Uwajima Group in Ehime Prefecture, and the Futaba Group in Fukushima Prefecture. Therefore, it ranges from the Middle Turonian to the Lower Campanian.

Family Mactromyidae Cox, 1929

Genus *Clisocolus* Gabb, 1869

Clisocolus (Clisocolus) odochiensis sp. nov.

Plate 14, Figs. 5-10

Material:—KSG 3048 (holotype), left valve; KSG 3049 and KSG 3050 (paratypes), right valves; all from loc. M-03.

Diagnosis:—Shell subovate, strongly inflated; umbo pointed but not so prominent for the genus, situated at about the mid-length of the valve, slightly prosogyrate; anterior dorsal margin weakly convex, but narrowly concave near the umbo; posterior dorsal margin nearly straight; both lateral margins convex, passing gradually to well rounded ventral margin; weak posterior carina perceptible near the umbo, but not discernible on the major part; inner margin smooth; surface of the valve nearly smooth except for very weakly marked growth lines; lunular area narrowly depressed but not separated from the disk; escutcheon indistinct; a small and weak vertical cardinal tooth under the beak.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
KSG 3048	34.2	27.6	13.6
KSG 3049	24.9	24.2	9.0
KSG 3050	30.8	28.0	11.0
KSG 3051	28.0	26.2	10.5

Observation:—The test of the valve is rather thin for the genus. The outline is somewhat variable from roundly subquadrate to subovate. The umbo is rather pointed and less prominent for the Upper Cretaceous *Clisocolus*. The lateral teeth are unknown. The cardinal tooth is nodulated. The long and strong nymphs are observable along the anterior and the posterior dorsal margins.

Comparison:—This species is allied to *Clisocolus japonicus* Tashiro et Otsuka (1982) (=*Clisocolus* n. sp., m. s., by Tashiro, Taira and Matsumoto, 1980) from the Uppermost Formation of the Upper Himenoura Subgroup in Kyushu, in its rounded outline and inflated valve, but differs clearly in its more prosogyrate and less prominent umbo. It is distinguished from *Clisocolus moreauensis* (Meek et Hayden) (see Speden, 1970), from the Fox Hills Formation of South Dakota, which is characterized by larger and prominent umbo and more orbicular outline. It resembles *Clisocolus corrugatus* Popenoe, from the Turonian of California (Popenoe, 1937; Speden, 1979), in its strongly prosogyrate and rather pointed umbo, but that species has stronger concentric striae on the surface and more anterior location of the umbo. It is similar to *Clisocolus dubius* (Gabb) in having prosogyrate umbo and somewhat shouldered dorsal margin, but is discriminated that by its less produced anterior margin and thicker nymphs. It is distinguished from *Clisocolus* (*Crenocolus*) *crenulatus* Ichikawa et Maeda (1966), from the Izumi Group of the Izumi Mountains, in that the latter has distinct inner marginal crenulations.

Occurrence:—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis*, Middle Turonian.

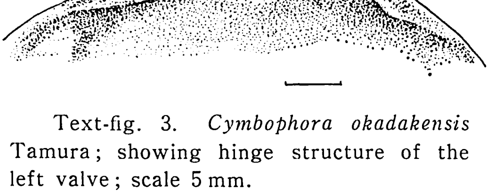
Family Mactridae Lamarck, 1809

Genus *Cymbophora* Gabb, 1869

Cymbophora okadakensis Tamura

Plate 14, Figs. 18–19, Text-fig. 3

1977. *Cymbophora okadakensis* Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, Nat. Sci., p. 119, pl. 5, figs. 8–15.



Text-fig. 3. *Cymbophora okadakensis* Tamura; showing hinge structure of the left valve; scale 5 mm.

Material: — KSG 3053, an internal mould of right valve, from loc. M-39.

Remarks:—This specimen is measured 48 mm in length and about 35 mm in height. The hinge structure of this species is well preserved. Two narrow cardinal teeth and a small triangular resilifer are situated under the beak; both lateral teeth are also distinct. The surface of the valve is nearly smooth except for fine growth lines.

This specimen is undoubtedly identified with *Cymbophora okadakensis* Tamura, from the Mifune Group of Kyushu (Tamura, 1977). *Cymbophora* cf. *hetonaiensis* (Nagao et Otatume), from the Himenoura Group of Kyushu (Tashiro, 1976), resembles this species in its roundly subtrigonal outlines, but differs in its small valve and distinct concentric striae on the surface.

Occurrence:—Sandstone of the middle part of the Nagase Formation at loc. M-39, with *Calycoceras orientale*, Middle Cenomanian.

Family Corbiculidae Gray, 1847

Genus *Veloritina* Meek, 1972

Veloritina cf. *matsumotoi* Tamura

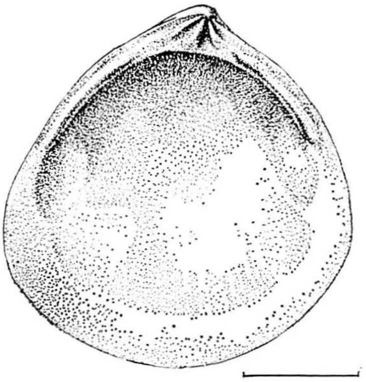
Plate 14, Fig. 13, Text-fig. 4

Compare:—

1977. *Veloritina matsumotoi* Tamura, *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, Nat. Sci., p. 133, pl. 6, figs. 20–26.

Material:—KSG 3054, an internal mould of left valve, from loc. M-39.

Description:—Shell small, trigonal ovate in outline, inequilateral, weakly inflated; anterior dorsal margin weakly concave; posterior dorsal margin slightly convex; anterior margin moderately arched and gradually passing into broadly arched ventral margin; posterior margin nearly straight or slightly convex; postero-ventral part narrowly rounded; ligament external, narrow along periphery of the posterior dorsal margin; umbo prosogyrous, moderately prominent, located at about two thirds from front of the valve; hinge formula is as follows:—AIII AI 3a 1 3b PI PIII/AII 2a 2b 4b PII; both lateral teeth very long; anterior lateral teeth weakly arched; cardinal 2b and 2a are nearly equall in size; cardinal 1 is larger than 3a and 3b; inner ventral margin smooth; anterior and posterior adductor scars weakly impressed; siphonal sinus deep, sharply angulated on the top of the sinus.



Text-fig. 4. *Veloritina* cf. *V. matsumotoi* Tamura; internal view of left valve; scale 5 mm.

Remarks:—This specimen is measured 17.7 mm in length and 15.9 mm in height. The external features are unknown in detail. It is probably smooth judging from several fragmental external moulds. Judging from the hinge structure and inner features, this species is possibly identified with *Veloritina matsumotoi* Tamura, from the Mifune Group in Kyushu (Tamura, 1977).

Occurrence:—Sandstone of the middle part of the Nagase Formation at loc. M-39; Middle Cenomanian.

Subclass Anomalodesmata Dall, 1889

Order Pholadomyida Newell, 1965

Family Periplomatidae Dall, 1895

Genus *Periploma* Schumacher, 1817

Periploma (*Periploma*) aff. *P.* (*P.*) *mifunensis* Tamura

Plate 14, Fig. 20

Compare :—

1977. *Periploma mifunensis* Tamura; *Mem. Fac. Educ. Kumamoto Univ.*, no. 26, Nat. Sci., p. 142, pl. 11, figs. 23-26.

Material :—KSG 3058, a left valve, from loc. M-03.

Description :—Shell subovate, longer than high; umbo improminent, located at two fifths from posterior end of the valve; apical angle about 120°; anterior margin well rounded; ventral margin broadly arched; posterior margin short, weakly convex; posterior dorsal margin short, slightly concave; surface ornamented with fine crowded concentric striae; a narrow slit extended from umbo towards ventral margin but soon disappears, being as short as one fourth of valve height.

Observation :—This specimen is measured 31 mm in length, 22 mm in height and 2.5 mm in thickness. The antero-ventral margin is not precisely shown, because of the weathering. The outline of this species is, however, determinable from the distinct growth lines.

Comparison :—This species closely resembles *Periploma* (*Periploma*) *mifunensis* Tamura, from the Mifune Group of Kyushu (Tamura, 1977), in some features. It is, however, somewhat longer than *P.* (*P.*) *mifunensis* in the shell outline. *Periploma ambigua* Tashiro, from the Himenoura Group of Kyushu (Tashiro, 1976), is easily discriminated from this species in its more posterior location of the umbo and more rounded outline of the valve.

Occurrence :—Fine-grained sandstone of the basal part of the Kajisako Formation at loc. M-03, with *Inoceramus hobetsensis*, Middle Turonian.

Concluding remarks

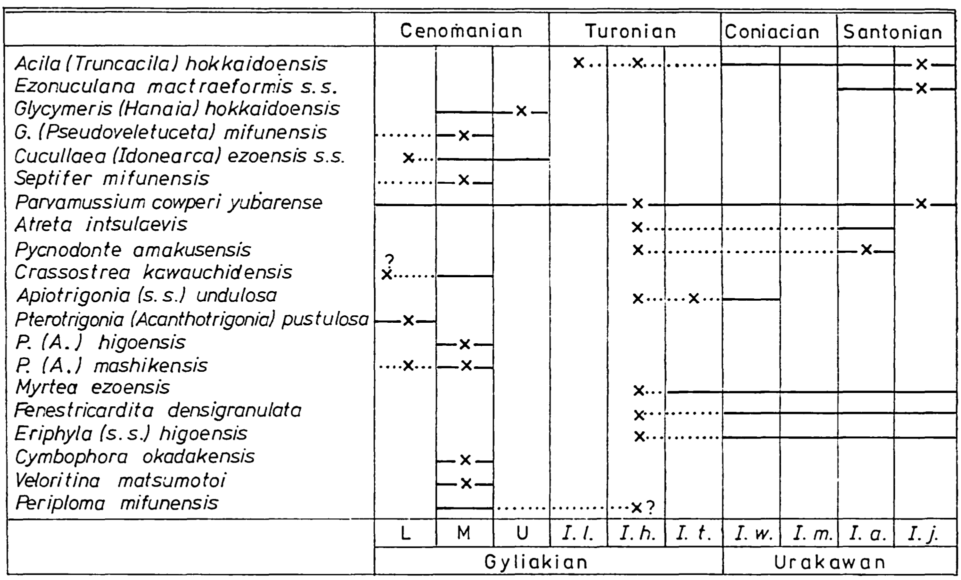
In the Upper Cretaceous Nagase and Kajisako Formations of the Monobe Area, there are fossiliferous beds at three levels, each of which is characterized by a particular assemblage of bivalve species, aside from several inoceramid beds and other ones with bivalves of scattered occurrence (see Text-fig. 5).

One of them is represented by the fossil locality M-39. The bivalve species from this locality are mostly identified with the species from the Lower Formation of the Mifune Group in Central Kyushu, except for one species, *Pterotrigonia* (*Scabrotrigonia*) *monobeana* sp. nov. This assemblage has been hitherto known only from the Lower Formation of the Mifune Group (Tamura and Tashiro, 1976, 1977; also see Matsumoto, 1939; Tamura and Tashiro, 1966). The species are characterized by shallow marine and brackish water faunas.

Since *Calycoceras* cf. *orientale* (see Matsumoto, in this volume), was collected from a bed about 1 m in thickness lower than this bed (M-39), the geological age of this

Acila (Truncacila) hokkaidoensis			○	○							○
Ezonuculana mactraeformis s.s.											○
Glycymeris (Hanaia) cf. hokkaidoensis			◎								
G. (Pseudoveletuceta) mifunensis		○									
G. (s.l.) sp.						○					
Cucullaea (Idonearcà) ezoensis s. s.					○						
Matsumotoa sp.						○					
Septifer mifunensis		◎									
Nippononectes monobensis								○	○		
Parvamussium cowperi yubarense								○			○
Plicatula sp.								○			
Atreta intsulaevis								○			
Pycnodonte amakusensis								◎		◎	
Crassostrea aff. kawauchidensis							○				
Gryphaeostrea kochiensis								○			
Apiotrigonia (s.s.) undulosa								◎	○		
Pterotrigonia (Acanthotrigonia) pustulosa	△										
P. (A.) cf. P. (A.) higoensis		△									
P. (A.) mashikensis		○			△						
P. (Scabrotrigonia) monobeana		△									
Myrtea cf. M. ezoensis								○			
Fenesticardita densigranulata								○			
Eriphyla (s.s.) higoensis								○			
Clisocolus (s.s.) odochiensis								○			
Cymbophora okadakensis		△									
Veloritina cf. V. matsumotoi		△									
Periploma aff. mifunensis								△			
Locality (M)	53	39	38	55	28	50	22	03	51	34	31
Formation	Nagase F.						N?	Kajisako F.			

Text-fig. 5. List of fossils from the Nagase and Kajisako Formations,
◎: abundant ○: common △: rare



Text-fig. 6. The presumable ranges of the selected bivalves in the Cretaceous of Japan; L: Lower Cenomanian, M: Middle Cenomanian, U: Upper Cenomanian, *I.l.*: *Mytiloides labiatus* Zone, *I.h.*: *Inoceramus hobetsensis* Zone, *I.t.*: *I. teshioensis* Zone, *I.w.*: *I. uwajimensis* Zone, *I.m.*: *I. mihoensis* Zone, *I.a.*: *I. amakusensis* Zone, *I.j.*: *I. japonicus* Zone, **X**: occurrence in the Monobe area.

fossil bed is probably Middle Cenomanian. On the other hand, the Lower Formation of the Mifune Group was determined as Middle Cenomanian on the ground of '*Inoceramus costatus*' and *Eucalycoceras* cf. *spathi* (Tamura and Matsumura, 1974; Matsumoto *in* Tamura and Matsumura, 1974). So far as we can see, the Lower Formation of the Mifune Group is undoubtedly correlated with the part including this bivalve assemblage bed and the bed of *Calycoceras* cf. *orientale* (both M-39). The two fossiliferous units (i. e., Lower Formation of the Mifune Group and the beds represented by loc. M-39 of the Nagase Formation), typify the Middle Cenomanian bivalve faunas in Japan.

Locality M-03 of the Kajisako Formation is characterized by the occurrence of abundant ammonites, inocerami and other bivalve fossils. The species of inocerami, *Inoceramus hobetsensis* and *Mytiloides teraokai* (see Matsumoto *et al.* in this volume), and certain ammonites (see Matsumoto in this volume), indicate clearly this fossil bed is of Middle Turonian age. The bivalve fauna of this locality resembles that of the Lower Member of the Lower Himenoura Subgroup (Himenoura L-I) (Tashiro and Noda, 1973; Tashiro, 1976), in Kyushu, lower part of the Uwajima Group (Furushiroyama Formation) (Tanabe, 1972), in Shikoku, and basal part of the Futaba Group (Saito, 1962), in NE Japan, in its constituting bivalve genera and subgenera, e. g., *Apiotrigonia* (*Apiotrigonia*), *Eriphyla* (*Eriphyla*), *Myrtea*, *Nippononectes*, *Fenestricardita*, *Parvamussium*, *Atreta*, *Acila* (*Truncacila*), *Pycnodonte* and *Inoceramus*.

The Middle Turonian bivalve fauna has been very poorly known in Japan until the discovery of this fauna in Kajisako Formation, except for the upper part of the Mikasa Formation in Hokkaido. The Middle Turonian bivalve fauna of the Mikasa Formation somewhat differs from this fauna of the Kajisako Formation, because it containes the genera *Meekia*, *Leptosolen*, *Yaadia*, *Heterotrigonia*, '*Aphrodina*' and *Cymbophora*. The species of inocerami, e. g., *Inoceramus hobetsensis* and *I. iburiensis*, are however, common between the Mikasa Formation and Kajisako Formation.

Locality M-31 of the Kajisako Formation, is characterized by the occurrence of *Inoceramus japonicus*, *Acila* (*Truncacila*) *hokkaidoensis*, *Ezonuculana mactraeformis mactraeformis* and *Parvamussium cowperi yubarense*. The species occurring at locality M-31 are mostly identified with those of the Middle Member of the Lower Himenoura Subgroup (Himenoura L-II) (Tashiro and Noda, 1973; Tashiro, 1976) in Kyushu, and the middle part of the Upper Yezo Group of Hokkaido (Nagao, 1930, 1938).

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Plate 12

Explanation of plate 12

Acila (*Truncacila*) *hokkaidoensis* (Nagao) ....Page 70

Fig. 1. Lateral view of left valve, gum cast of external mould (KSG 3002a), ×1.2, loc. M-55, Nagase Formation.

Fig. 2. Lateral view of right valve, gum cast of external mould (KSG 3002b), ×1.2, loc. ditto.

Ezonuculana mactraeformis mactraeformis (Nagao) ....Page 70

Fig. 3. Lateral view of right valve (KSG 3003), ×1.2, loc. M-31, Kajisako Formation.

Glycymeris (*Hanaia*) cf. *hokkaidoensis* (Yabe et Nagao) ....Page 71

Fig. 4. Inner view of right valve, gum cast of internal mould (KSG 3004), ×1.2, loc. M-55, Nagase Formation.

Fig. 5. Inner view of left valve, gum cast of internal mould (KSG 3006), ×2, loc. ditto.

Fig. 6. Inner view of left(?) valve, gum cast of internal mould (KSG 3005), ×1.2, loc. ditto.

Glycymeris (*Pseudoveletuceta*) *mifunensis* Tashiro ....Page 72

Fig. 7. Inner view of left valve, gum cast of internal mould (KSG 3009), ×2.5, loc. M-39, Nagase Formation.

Fig. 8. Inner view of right valve, gum cast of internal mould (KSG 3010a), ×1.5, loc. ditto.

Fig. 9. Inner view of right valve, gum cast of internal mould (KSG 3010b), ×1.5, loc. ditto.

Septifer mifunensis Tamura ....Page 74

Fig. 10. Lateral view of left valve, gum cast of external mould, ×1.2, loc. M-39, Nagase Formation.

Fig. 11. Inner view of right valve, gum cast of internal mould (KSG 3013), ×1.2, loc. ditto.

Fig. 12. Anterior ventral view of right valve, gum cast of external mould (KSG 3013), ×1.2, loc. ditto.

Fig. 13. Anterior ventral view of left valve, gum cast of external mould, ×1.2, loc. ditto.

Fig. 14. Lateral view of right valve, gum cast of external mould, ×1.2, loc. ditto.

Fig. 15. Lateral view of left valve, gum cast of external mould (KSG 3013), ×1.5, loc. ditto.

Fig. 16. Lateral view of left valve, gum cast of external mould (KSG 3014), ×1.5, loc. ditto.

Fig. 17. Inner view of left valve, showing hinge structure, gum cast of umbonal mould (KSG 3014a), ×1.5, loc. ditto.

Parvamussium cowperi yubarense (Yabe et Nagao) ....Page 75

Fig. 18. Inner view of right valve, gum cast of internal mould (KSG 3019), ×1.2, loc. M-31, Kajisako Formation.

Nippononectes monobensis Tashiro ....Page 75

Fig. 19. Lateral view of left valve, gum cast of external mould (KSG 3017), ×5, loc. M-03, Kajisako Formation.

Fig. 20. Lateral view of left valve, gum cast of external mould (KSG 3018), ×5, loc. M-51, Kajisako Formation.

Plicatula sp. ....Page 76

Fig. 21. Lateral view of right valve, gum cast of external mould (KSG 3020), ×2, loc. M-03, Kajisako Formation.

Fig. 22. Same specimen, ×2.

Atreta intsulaevis Tashiro...Page 77

Fig. 23. Internal mould of right valve (KSG 3021), ×1.2, loc. M-03, Kajisako Formation.

Fig. 24. Inner view of right valve, gum cast of KSG 3021.

Pycnodonte amakusensis Tashiro ....Page 77

Fig. 25. Internal mould of left valve (KSG 3025), ×1.2, loc. M-03, Kajisako Formation.

Fig. 26. Inner view of left valve, gum cast of internal mould (KSG 3026), ×1.2, loc. ditto.

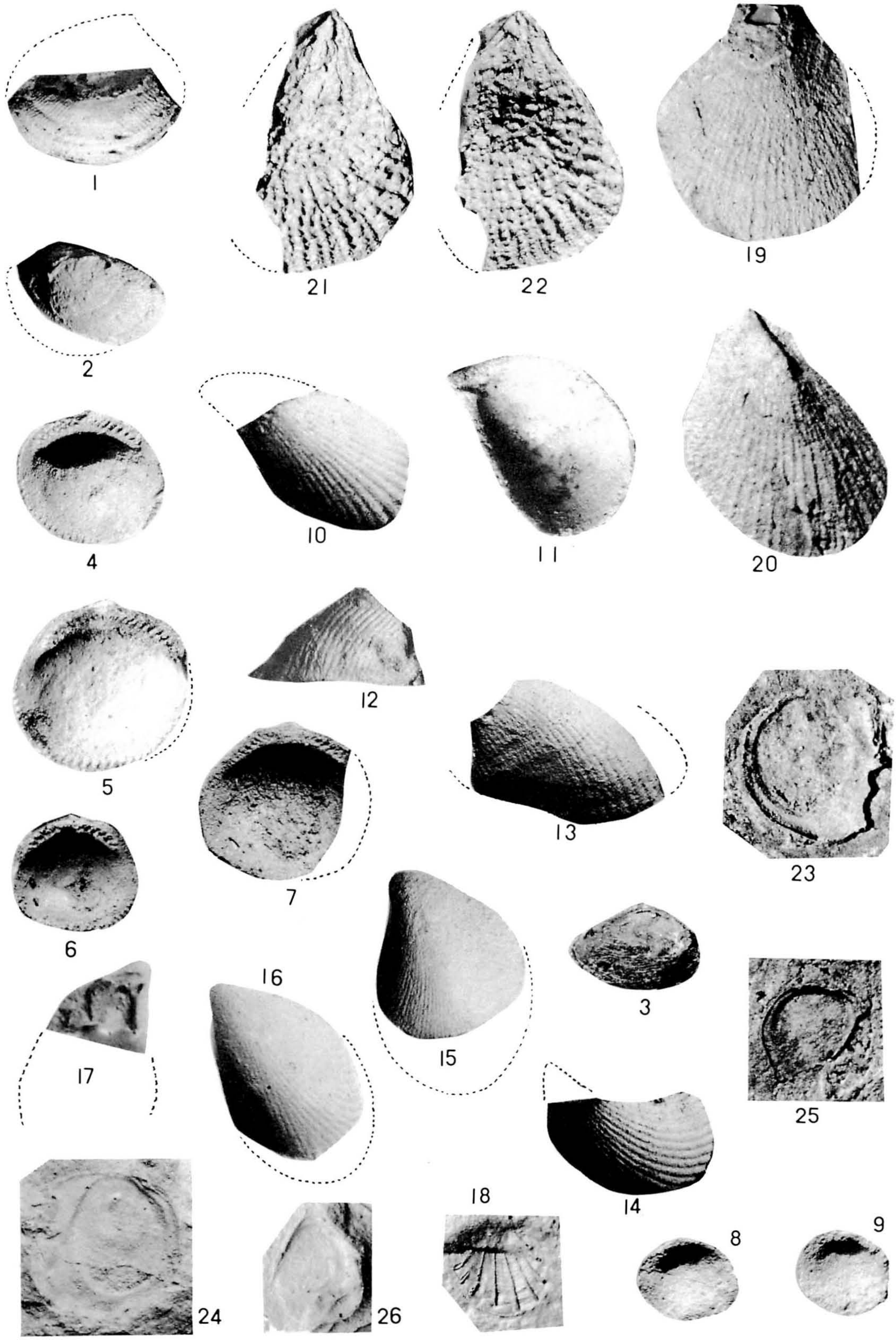
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Plate 13

Explanation of plate 13

Apiotrigonia (*Apiotrigonia*) *undulosa* Nakano ....Page 79

Fig. 1. Lateral view of left valve, gum cast of external mould (KSG 2064), ×1.5, loc. M-03, Kajisako Formation.

Fig. 2. Posterior dorsal view of KSG 2064, ×1.5.

Fig. 3. Lateral view of right valve, gum cast of external mould (KSG 3032), ×2, loc. ditto.

Fig. 4. Lateral view of right valve, gum cast of external mould (KSG 3033), ×1.5, loc. ditto.

Fig. 5. Lateral view of left valve, gum cast of external mould (KSG 3036), ×1.5, loc. ditto.

Fig. 6. Lateral view of left valve, gum cast of external mould (KSG 3031), ×2.5, loc. ditto.

Pterotrigonia (*Scabrotrigonia*) *monobeana* sp. nov. ....Page 82

Fig. 7. Lateral view of left valve, gum cast of external mould (KSG 3041), holotype, ×3, loc. M-39, Nagase Formation.

Fig. 8. Posterior dorsal view of same specimen, gum cast, ×3.

Fig. 9. Lateral view of same specimen, gum cast, ×3.

Fig. 10. Leteral view of imperfect right valve, gum cast of external mould (KSG 3000), ×1.5, loc. ditto.

Fig. 11. Lateral view of left valve, gum cast of external mould (KSG 3043), ×1.2, loc. ditto.

Fig. 12. Posterior dorsal view of imperfect left valve, gum cast of external mould (KSG 3014b), ×2, loc. ditto.

Fig. 13. Same specimen, gum cast, ×2.

Pterotrigonia (*Acanthotrigonia*) *pustulosa* (Nagao) ....Page 80

Fig. 14. Lateral view of imperfect left valve, gum cast of external mould (KSG 3037), ×1.5, loc. M-53, Nagase Formation.

Pterotrigonia (*Acanthotrigonia*) *mashikensis* (Tamura et Tashiro) ....Page 80

Fig. 15. Lateral view of right valve, gum cast of external mould (KSG 3038), ×1, loc. M-39, Nagase Formation.

Fig. 16. Lateral view of left valve, gum cast of external mould (KSG 3039), ×1, loc. ditto.

Fig. 17. Dorsal view of KSG 3039, gum cast, ×1.2.

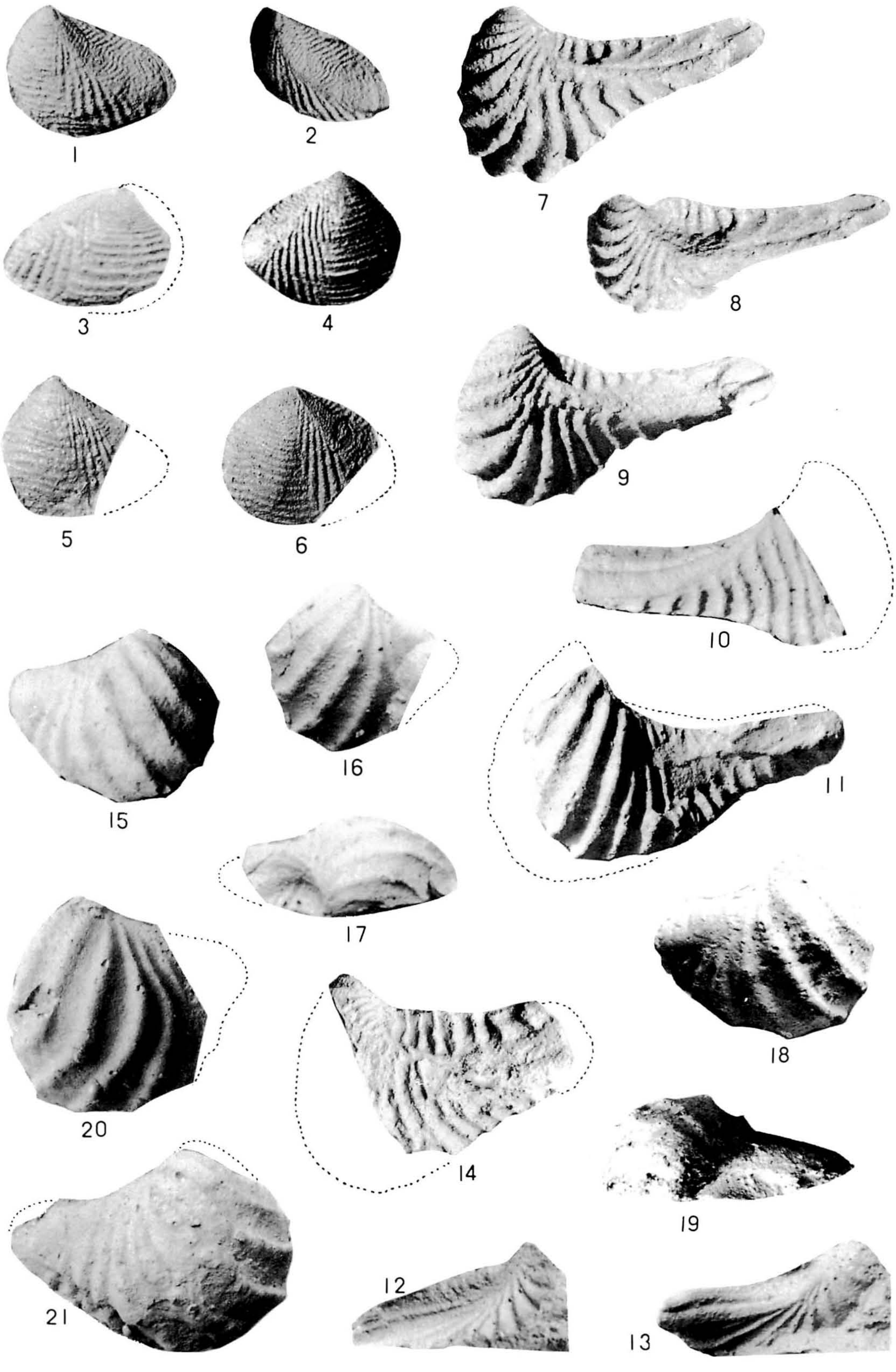
Fig. 18. Lateral view of right valve, gum cast of external mould (KSG 3038), ×1, loc. ditto.

Fig. 19. Dorsal view of KSG 3038, gum cast, ×1.2.

Fig. 20. Lateral view of left valve, gum cast of external mould (KSG 3040), ×1, loc. ditto.

Pterotrigonia (*Acanthotrigonia*) cf. *higoensis* (Tamura et Tashiro) ....Page 81

Fig. 21. Lateral view of right valve, gum cast of external mould (KSG 3059), ×1, loc. M-39, Nagase Formation.



M. Tashiro and T. Kozai : Bivalves

Plate 14

Explanation of plate 14

Gryphaeostrea kochiensis sp. nov. ....Page 78

Fig. 1. Lateral view of left valve, gum cast of external mould (KSG 3057), ×1.2, loc. M-03, Kajisako Formation.

Fig. 2. Lateral view of left valve, gum cast of external mould (KSG 3056), ×1.2, loc. ditto.

Fig. 22. Lateral view of left valve, gum cast of external mould (KSG 2085), ×1.5, loc. ditto.

Fig. 23. Lateral view of left valve, gum cast of external mould (KSG 2086), ×1.5, loc. ditto.

Cucullaea (*Idonearca*) *ezoensis ezoensis* Yabe et Nagao ....Page 73

Fig. 3. Lateral view of left valve (KSG 2080), ×1.5, loc. M-28, Nagase Formation.

Matsumotoa sp.

Fig. 4. Lateral view of internal mould of right valve (KSG 2080), ×3, loc. M-50, Nagase Formation.

Clisocolus (*Clisocolus*) *odochiensis* sp. nov..Page 85

Fig. 5. Lateral view of right valve, gum cast of external mould (KSG 3051), ×2, loc. M-03, Kajisako Formation.

Fig. 6. Lateral view of right valve (KSG 3049), ×1.2, loc. ditto.

Fig. 7. Dorsal view of KSG 3049, ×1.2.

Fig. 8. Lateral view of right valve, holotype (KSG 3050), ×1.2, loc. ditto.

Fig. 9. Dorsal view of KSG 3051, ×2.

Fig. 10. Lateral view of right valve (KSG 3048), ×1.2, loc. ditto.

Fenestricardita densigranulata Tashiro ....Page 84

Fig. 11. Lateral view of left valve, gum cast of external mould (KSG 3046), ×3, loc. M-03, Kajisako Formation.

Fig. 12. Lateral view of left internal mould (KSG 3047), ×1.5, loc. ditto.

Veloritina cf. *matsumotoi* Tamura

Fig. 13. Inner view of left valve, gum cast of internal mould (KSG 3054), ×1.5, loc. M-39, Nagase Formation.

Myrtea sp. cf. *Myrtea ezoensis* (Nagao)..Page 83

Fig. 14. Lateral view of left valve, gum cast of external mould (KSG 3044), ×3.5, loc. M-03, Kajisako Formation.

Eriphyla (*Eriphyla*) *higoensis* Tashiro..Page 84

Fig. 15. Inner view of right valve, gum cast of internal mould (KSG 3045), ×1.2, loc. M-03, Kajisako Formation.

Fig. 16. Same specimen, showing hinge structure, ×2.

Fig. 17. Lateral view of right and left valves (KSG 3043), ×1.5, loc. ditto.

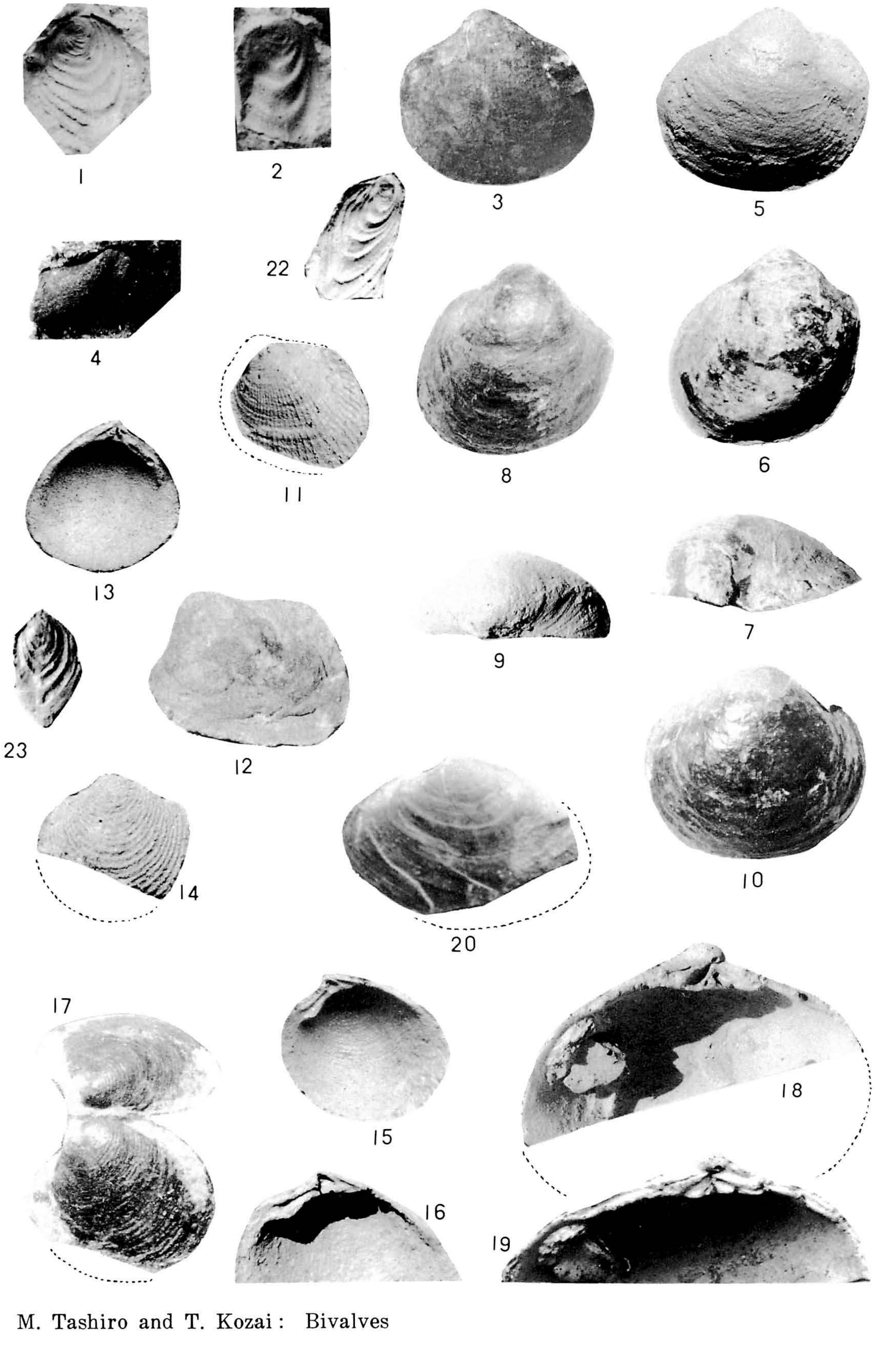
Cymbophora okadakensis Tamura ....Page 86

Fig. 18. Inner view of left valve, gum cast of internal mould (KSG 3053), ×1, loc. M-39, Nagase Formation.

Fig. 19. Same specimen, showing hinge structure, ×1.2.

Periploma sp. aff. *Periploma mifunensis* Tamura ....Page 88

Fig. 20. Lateral view of right valve (KSG 3058), ×1.5, loc. M-03, Kajisako Formation.



M. Tashiro and T. Kozai: Bivalves

VIII. RADIOLARIANS FROM THE KAJISAKO FORMATION, MONOBE AREA, SHIKOKU

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Abstract

To investigate the succession of the radiolarians in the Upper Cretaceous sequence of the Monobe area which consists of type localities in the southwestern part of Japan, we have selected a section along the course of the River Kajisako, which flows across the Kajisako Formation.

Generally speaking, radiolarians are poorly preserved and not evenly distributed, except for certain limited portions. Based on the radiolarians, the upper portion of the upper part of the Kajisako Formation is correlated to the Campanian, and the rest main part of the upper member to the Santonian. The Santonian/Campanian boundary may be placed within the upper part of the Kajisako Formation which is mainly composed of black shale.

1. Introduction

During the last decade, Cretaceous radiolarian biostratigraphy has made considerable progress on a global scale, being especially applied to the sediments of ocean bottom and orogenic belts. The results indicate that radiolarians have proved quite satisfactory for stratigraphic studies. In Japan, the first report on the Cretaceous radiolarians was incidentally made from the Shimanto Belt of Southwest Japan (Nakagawa and Nakaseko, 1977). However, subsequent studies on radiolarians are almost concentrated on the tectonically deformed strata to interpret the stratigraphic framework and tectonic process. The first author has been engaged in a study of the Cretaceous radiolarians from the Shimanto Belt of the Kochi Prefecture, with soml result (Okamura, 1981), whereas the second author has continued to study comprehensively the Mesozoic radiolorians (Nakaseko *et al.*, 1979; Nakaseko and Nishimura, 1979, 1981 etc.)

The purpose of the present paper is to present a stratigraphic succession of the radiolarians in the Upper Cretaceous Kajisako Formation of the Monobe area, Kochi Prefecture. The formation represents an outer-arc shelf facies lying on the inner side of the Shimanto Belt, the accretionary complex (Taira, 1982; this volume). The studied section lies along the course of the River Kajisako, which flows from north to south in the midst of the Monobe area. The Upper Cretaceous sequence exposed along this section mainly comprises shale and fine-grained sandstone, and attains about 250 meters in thickness. The present paper deals with the interval from the main to upper parts of the Kajisako Formation. Since this area has been under intensive studies in geology as well as paleontology by various workers, the section is considered as one of the reference sequence both micro- and megafossil biostratigraphy in Southwest Japan.

2. Material

The geologic setting of the Kajisako Formation and the sampling localities for mega- and microfossil groups in relation to lithostratigraphy are described by Tashiro *et al.* (1982; this volume). Radiolarians were collected from the shale or mudstone except one sample from sandy siltstone. About 30 samples were from the lower to upper part of the Kajisako Formation at each stratigraphic interval of about three meters along the main course of the River Kajisako. Among them, about 10 samples showed relatively better preservation and have provided sufficiently good material to investigate radiolarian assemblages. According to Tashiro *et al.* (1982), a fault run along the main stream of the River Kajisako, and the exact correlation is difficult between the sequences on both sides of the fault. Each sequence, however, shows a continuous stratigraphic succession. All samples were taken from a few tens of centimeters below the fresh rock surface of river bed. The locations of the selected samples are shown in Text-fig. 1 of this paper and their stratigraphic positions are indicated in Text-figs. 3, 4 of

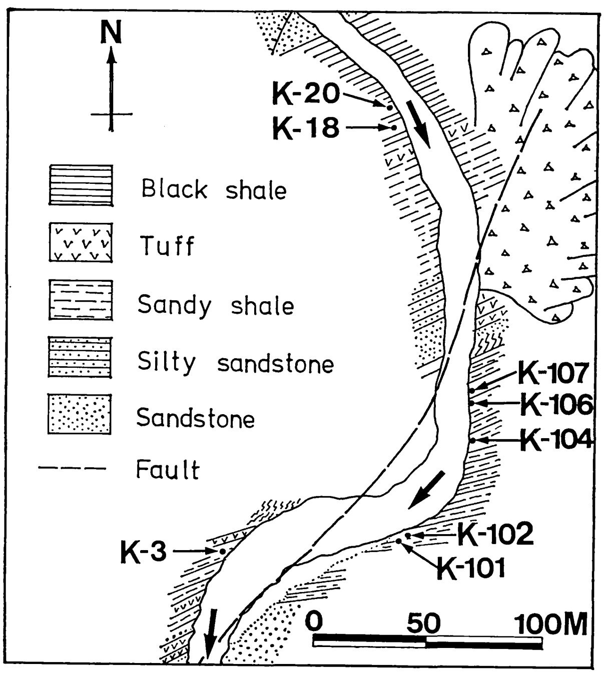

Fig. 1. Map showing the sampling points of the River Kajisako.

Article I by Tashiro *et al.* (1982) of this volume.

3. Radiolarians

Radiolarians analysed in the present study are generally not so well preserved as compared with these from other areas in Shikoku, for example, the Shimanto Belt. A total of 22 genera and 36 species have been identified under a scanning electron microscope (SEM). Their species list is shown in Text-fig. 2. The abundance of radiolarians remarkably differs by horizon, since it appears to depend on lithofacies. They are abundant in the upper part of the Kajisako Formation which is composed of black shale, but rare in the sandy lower part of the Formation. It is distinct that the faunal diversity tend to increase from the lower to the upper horizon. For instance, the radiolorians encountered in the lower part (K-3) of the Kajisako Formation comprise five genera and five species, while those in the upper part (K-18, K-19, M-40 and M-41) are 15 genera and 27 species. Among the species identified, *Amphipyndax stocki* is consistently found throughout the sequence studied. Especially it is remarkable that *Amphipyndax stocki* dominates over all other taxa throughout its sequence, marking up 50 per cent of the total population in each assemblage. Among the species appeared

TAXA \ SAMPLE	KAJISAKO FORMATION										PLATE – FIG. no.
	K-3	K-101	K-102	K-104	K-106	K-107	K-18	K-20	M-40	M-41	
Alievium gallowayi		●	●		●		●		●	●	15-4
Amphipyndax alamedaensis							●				18-8
A. elliptica						●					18-7
A. enesseffi								●	●	●	18-4
A. stocki	●	●	●	●	●	●	●	●	●	●	18-5,6
Archaeodictyomitra regina					●	●					17-2
A. squinaboli	●	●	●		●		●			●	17-1,8
Archaeospongoprunum bipartitum									●		15-2,3
A. cortinaensis			●						●	●	16-1
A. nishiyamai										●	16-4
A. salumi				●	●	●				●	15-1
Artostrobium urna			●		●			●		●	17-11
Cryptamphorella sphaerica						●					17-13
Crucella cf. *espartoensis*						●	●	●	●	●	15-10
Diacanthocapsa cf. *ancus*			●								17-12
D. aff. *galeata*						●				●	18-2,3
Diacanthocapsa sp.						●			●		18-1
Dictyomitra formosa	●		●		●	●			●	●	17-5
D. koslovae										●	17-4
D. multicostata						●	●	●		●	17-3
Theosyringium pulchrum				●		●					18-9
Orbiculiforma monticelloensis			●		●					●	16-7
Patellula planoconvexa										●	16-3
Phaseliforma concentrica			●							●	16-5,6
Praeconocaryomma universa	●	●			●				●	●	15-13
Pseudoaulophacus delvallensis							●	●			15-5
P. floresensis		●	●		●		●		●	●	15-8
P. lenticulatus		●	●	●	●	●	●	●		●	15-6,7
P. pargueraensis			●	●	●					●	16-2
P. praefloresensis		●	●		●	●					15-9
Pseudodictyomitra cf. *pseudomacrocephala*			●							●	17-10
Pyramispongia sp. A	●		●	●		●	●		●	●	16-8,9
Spongosaturninus ellipticus						●					15-11
Spongurus cf. *marcaensis*						●					15-12
Stichomitra communis						●					17-9
Thanarla aff. *praeveneta*					●					●	17-6,7

Fig. 2. Stratigraphic distribution of radiolarians in the Upper Cretaceous along the River Kajisako.

at the horizon K-3, the lower part of Kajisako Formation, *Amphipyndax stocki* is a form which made its initial appearance in the Cenomanian or Turonian (Foreman, 1973). Furthermore *Dictyomitra formosa* and *Praeconocaryomma universa* are hitherto unknown below the Coniacian (Pessagno, 1976). *Alievium gallowayi* which occurs in the sample K-18 is important zone marker species in the Great Valley Sequence by Pessagno (1976). According to him, the base of the *Alievium gallowayi* Zone (Santonian) is defined by the first evolutionary appearence of the species. *Alievium praegallowayi* becomes extinct in the lower part of this zone shortly after giving rise to *A. gallowayi*. In the present sequence, *Alievium gallowayi* occurs abundantly at this horizon but *A. praegallowayi* is not detected. On the other hand, characteristic species from the uppermost horizon examined K-20, *Amphipyndax enesseffi* made its first appearence in the Campanian Stage (Foreman, 1976). This species is progressive morphotype among the lineage of the Genus *Amphipyndax* group. Based on these data, the upper part can be correlated to the *Alievium gallowayi* Zone (Santonian) to *Crucella espartoensis* Subzone (E. Campanian) of Pessagno (1976). However, based on the inoceramids Matsumoto *et al.* (1982; this volume), correlate the upper part of the Kajisako Formation to the upper Santonian. The radiolarian evidence is inconsistent with that conclusion.

For the comparative study, the continuous reference section exposed on the eastern side of the fault along the River Kajisako has been also examined. The section is good for correlating mega- and microfaunas examined. Radiolarians occured in five samples, K-101, 102, 104, 106 and K-107. Among these samples, two horizons show co-occurence of mega- and micro-fauna. The radiolarian sample K-101 and megafossil sample M-56 which contained *Inoceramus amakusensis* are from the same horizon (Matsumoto *et al.*). From the sample of the dark gray shale in the upper subdivision of the sequence, megafossil *I. amakusensis* and *I. ezoensis* (sample no. M-57) and radiolorian assemblage (sample no. K-107) were recovered. *Pseudoaulophacus lenticulatus*, *P. praefloresensis* are consistently found throughout the sequence studied. The two species of the genus *Pseudoaulophacus* appear in the lower Coniacian (Pessagno, 1976) and are commonly found in ammonites bearing Santonian and Campanian sediments of the Shimanto Belt in Kochi Prefecture (Okamura, 1980). *Alievium gallowayi* and *Pseudoaulophacus floresensis* are found from the horizons K-101, K-102 and K-107. According to Pessagno (1976), the two species made their initial appearance in the Santonian and define the base of *Alievium gallowayi* Zone. Furthermore, *Artostrobium urna*, which was used to defined the *A. urna* Zone by Foreman (1973), occurred rarely at few horizons in the Kajisako section and also quite scarce throughout the time-equivalent sequence with the Shimanto Belt. Such radiolarian species of Campanian aspect as seen at K-20 on the western section are not recognized in eastern section under consideration. Therefore, the eastern section can be correlated to the Santonian. This conclusion is consistent with that from the megafossils. The existence of a fault along the River Kajisako between the eastern and western banks is, thus, confirmed.

Localities M-40 and M-41 are isolated from the above mentioned continuous exposures. They are on the north side of a fault of NE-SW trend and outside the area of the map (Text-fig. 1). They yield radiolaria and also some megafossils abundantly. Species composition of M-40 and M-41 corresponds to the sample K-20, and *Amphipyndax enesseffi* which occurs in both samples M-40 and M-41 is important species of Campanian

Stage. However, most species occurred in these samples are ranging up from the Coniacian or Santonian Stage.

4. Summary and conclusion

Based on the radiolarians, the Cretaceous sequence from the upper part of the Kajisako Formation in the Monobe area was correlated to the Coniacian to Campanian. The Coniacian/Santonian boundary may be placed somewhere within the interval between K-3 and K-101, and the Santonian/Campanian boundary between K-18 and K-20. The stages occur as discrete, and the exact identification of their boundaries is difficult, because of the separated distribution of good samples and the presence of a fault.

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Appendix

Lists of species and synonyms

Alievium gallowayi (White)
(Plate 15, fig. 4)
Baculogypsina (?) *gallowayi* White, 1928, p. 305, pl. 41, figs. 9-10.
Aulophacus gallowayi (White) in Pessagno, 1963, p. 202, pl. 3, figs. 5-6.
Pseudoaulophacus gallowayi (White) in Pessago, 1963, p. 202, pl. 2, figs. 1, 3, 6, pl. 4, figs. 2, 5, 7, pl. 7, figs. 2, 4.
Alievium gallowayi (White) in Pessago, 1972, pp. 299-300, pl. 25, figs. 4-6, pl. 26, fig. 5, pl. 31, figs. 2, 3; Pessagno, 1976, p. 27, pl. 8, figs. 13, 14, pl. 9, fig. 1; Nakaseko et Nishimura, 1981, pl. 2, fig. 3.

Amphipyedax alamedaensis (Campbell et Clark)
(Plate 18, fig. 8)
Phormocampe (*Cyrtocorys*) *alamedaensis* Campbell et Clark, 1944, p. 37, pl. 7, fig. 41.
? *Stichomitra alamedaensis* (Campbell et Clark) in Foreman, 1968, pp. 77-78, pl. 8, fig. 4.
Amphipyndax sp., Pessagno, 1975, p. 1016, pl. 4, fig. 9.
Amphipyndax alamedaensis (Campbell et Clark) in Nakaseko et Nishimura, 1981, pl. 12, figs. 3-4, pl. 17, fig. 11.

Amphipyndax elliptica Nakaseko et Nishimura
(Plate 18, figs. 7, 7′)
Amphipyndax elliptica Nakaseko et Nishimura, 1981, pl. 12, figs. 7, 8a, b.

Amphipyndax enesseffi Foreman
(Plate 18, fig. 4)
Amphipyndax enesseffi Foreman, 1966, p. 356, figs. 10, 11; Riedel et Sanfilippo, 1974, p. 775, pl. 10, figs. 12, 13; Foreman, 1977, pl. 1, fig. 2; Foreman, 1978, p. 745, pl. 4, fig. 3; Nakaseko et Nishimura, 1979, pl. 6, figs. 5, 6; Nakaseko et Nishimura, 1981, pl. 12, figs. 9, 10, pl. 17, fig. 14.

Amphipyndax stocki (Campbell et Clark)
(Plate 18, figs. 5, 5′, 6)
Stichocapsa megalocephala Campbell & Clark, 1944, pl. 8, figs. 26, 34.

Stichocapsa stocki Campbell et Clark, 1944, p. 44, pl. 8, figs. 31-33.
Dictyomitra uralica Gorbovetz, Kozlova et Gorbovez, 1966, p. 116, pl. 6, figs. 6, 7.
Amphipyndax stocki (Campbell et Clark) in Foreman, 1968, p. 78-79, pl. 8, figs. 12a, b; Riedel et Sanfilippo, 1974, p. 775, pl. 15, fig. 11; Petrushevskaya et Kozlova, 1972, p. 545, pl. 8, figs. 16, 17; Pessagno, 1975, p. 1016, pl. 4, figs. 4-8; Foreman, 1978, p. 745, pl. 4, fig. 4; Nakaseko et Nishimura, 1981, pl. 12, fig. 5.

Archaeodictyomitra regina (Campbell et Clark)
(Plate 17, fig. 2)
Lithomitra (Lithomitrissa) regina Campbell et Clark, 1944, p. 41, pl. 8, figs. 30, 38, 40..
Dictyomitra regina (Campbell et Clark) in Foreman, 1968, pp. 68-69, pl. 8, figs. 5a-c.
Archaeodictyomitra (?) *regina* (Campbell et Clark) in Pessagno, 1976, pp. 49-50, pl. 14, figs. 1-3.

Archaeodictyomitra squinaboli Pessagno
(Plate 17, figs. 1, 8)
Archaeodictyomitra squinaboli Pessagno, 1976, p. 50, pl. 5, figs. 2-8; Nakaseko et Nishimura, 1981, pl. 6, fig. 7, pl. 15, fig. 1.

Archaeospongoprunum bipartitum Pessagno
(Plate 15, fig. 2, 3)
Archaeospongoprunum bipartitum Pessagno, 1973, pp. 59-60, pl. 11, figs. 4-6; Pessagno, 1976, p. 33, pl. 6, fig. 3.

Archaeospongoprunum cortinaensis Pessagno
(Plate 16, fig. 1)
Archaeospongoprunum cortinaensis Pessagno, 1973, pp. 60-61, pl. 9, figs. 4-6; Riedel et Sanfilippo, 1974, p. 775, pl. 1, figs. 9-11; Pessagno, 1976, p. 33, pl. 1, fig. 3; Pessagno, 1977, p. 29, pl. 1, fig. 8; Nakaseko et Nishimura, 1981, pl. 1, fig. 9.

Archaeospongoprunum nishiyamai Nakaseko et Nishimura
(Plate 16, fig. 4)
Spongoprunum sp. Foreman, 1971, p. 1674, pl. 1' fig. 2.
Archaeospongoprunum nishiyamai Nakaseko et Nishimura, 1981, pl. 1, figs. 3-5, pl. 14, fig. 4.

Archaeospongoprunum salumi Pessagno
(Plate 15, fig. 1)
Archaeospongoprunum salumi Pessagno, 1973, pp. 63-64, pl. 13, figs. 2-5; Pessagno, 1976, p. 33, pl. 11, figs. 2-3.

Artostrobium urna Foreman
(Plate 17, fig. 11)
Artostrobium urna Foreman, 1971, p. 1677, pl. 4, fig. 6; Riedel et Sanfilippo, 1974, p. 775, pl. 11, figs. 4-6; Foreman, 1975, p. 613, pl. 1F, figs. 6, 7, pl. 6, fig. 6; Nakaseko et Nishimura, 1981, pl. 13, fig. 2, pl. 17, fig. 10.

Cryptamphorella sphaerica (White)
(Plate 17, fig. 13)
Baculogypsina (?) *sphaerica* White, 1928, p. 306, pl. 41, figs. 12, 13.
Aulonia sphaerica (White) in Pessagno, 1962, p. 366, pl. 6, fig. 3.
Holocryptocapsa (?) *sphaerica* (White) in Pessagno, 1963, p. 226, pl. 1, fig. 3.
Cryptamphorella sphaerica (White) in Dumitrica, 1970, p. 82, pl. 12, figs. 73-77, pl. 20, figs. 133a-b; Petrushevskaya et Kozlova, 1972, p. 541, pl. 2, figs. 15, 16; Nakaseko et Nishimura, 1981, pl. 5, figs. 1, 2.

Curucella cf. *espartoensis* Pessagno
(Plate 15, fig. 10)
Crucella espartoensis Pessagno, 1971, pp. 54-55, pl. 18, figs. 1-4; Pessagno, 1976, p. 32, pl. 8, fig. 16.

Diacanthocapsa cf. *ancus* (Foreman)
(Plate 17, fig. 12)

Theocapsomma ancus Foreman, 1968, p. 32, pl. 4, fig. 3.
Diacanthocapsa cf. *ancus* (Foreman) in Dumitrica, 1970, p. 64-65, pl. 6, figs. 35a-b, pl. 7, fig. 40, pl. 20, fig. 125; Nakaseko et Nishimura, 1981, pl. 5, fig. 5.

Diacanthocapsa aff. *D. galeata* Dumitrica
(Plate 18, figs. 2, 3)
Diacanthocapsa galeata Dumitrica, 1970, pp. 65-66, pl. 8, figs. 45-47, 49, pl. 20, figs. 126, 128a-b.

Diacanthocapsa sp. Dumitrica
(Plate 18, fig. 1)
Diacanthocapsa sp. Dumitrica, 1970, pl. 8, fig. 44.

Dictyomitra formosa Squinabol
(Plate 17, fig. 5)
Dictyomitra formosa Squinabol, 1904, p. 232, pl. 10, fig. 4; Moore, 1973, p. 829, pl. 1, figs. 1-2; Pessagno, 1976, p. 51, pl. 8, figs. 10-12; Nakaseko et Nishimura, 1981, pl. 8, figs. 7, 8, pl. 16, figs. 4, 11.
Dictyomitra torquata Foreman, 1973, pl. 15, figs. 9-11.
Dictyomitra duodecimocostata (Squinabol) in Foreman, 1975, p. 614, pl. 7, fig. 8.
Dictyomitra deuodecimocostata (Squinabol) *duodecimocostata* Foreman, 1978, pl. 4, figs. 8, 9.

Dictyomitra koslova Foreman
(Plate 17, fig. 4)
Dictyomitra sp. Kling, 1971, pl. 8, fig. 2; Foreman, 1971, p. 1677, pl. 3, fig. 5; Foreman, 1973, pl. 15, figs. 13-15.
Dictyomitra torquata Foreman in Moore, 1973, p. 829, pl. 9, figs. 1-3; Riedel et Sanfilippo, 1974, p. 778, pl. 5, figs. 2-3, pl. 14, fig. 2.
Dictyomitra koslova Foreman, 1975, p. 614, pl. 7, fig. 4; Foreman, 1978, p. 746, pl. 4, fig. 10; Nakaseko et Nishimura, 1981, pl. 8, figs. 2-5, pl. 16, figs. 2, 3.

Dictyomitra multicostata Zittel
(Plate 17, fig. 3)
Dictyomitra multicostata Zittel, 1876, p. 81, pl. 2, fig. 2; Campbell et Clark, 1944, p. 39, pl. 8, figs. 22-24, 35, 42; Foreman, 1968, pl. 7, figs. 4a-b; Pessagno, 1976, p. 52, pl. 14, figs. 4-9; Nakaseko et Nishimura, 1981, pl. 8, fig. 1, pl. 16, fig. 1.
?*Dictymitra striata* Lipman, 1952, p. 41, pl. 3, figs. 12-14.
Dictyomitra lamellicostata Foreman, 1968, p. 63, pl. 7, figs. 9a-b.

Orbiculiforma monticelloensis Pessagno
(Plate 16, fig. 8)
Orbiculiforma monticelloensis Pessagno, 1973, p. 72-73, pl. 16, fig. 5-6, pl. 18, figs. 1-2; Pessagno, 1976, p. 35, pl. 6, figs. 4-5.

Patellula planoconvexa (Pessaguo)
(Plate 16, fig. 3)
Stylospongia planocovexa Pessagno, 1963, p. 199, pl. 3, figs. 4-6, pl. 6, fig. 1.
Patellula planoconvexa (Pessagno) in Petrushevkaya et Kozlova, 1972, p. 527, pl. 3, fig. 13; Nakaseko et Nishimura, 1981, pl. 2, fig. 8.

Phaseliforma concentrica (Lipman)
(Plate 16, figs. 5, 6)
Cromyodruppa concentrica Lipman, 1952, p. 29, pl. 1, figs. 8-9.
Phaseliforma concentrica (Lipman) in Pessagno, 1976, p. 26, pl. 9, fig. 13.

Praeconocaryomma universa Pessagno
(Plate 15, fig. 13)
Praeconocaryomma universa Pessagno, 1976, p. 42, pl. 6, figs. 14-16.
Praeconocaryomma (?) sp. aff. *P. universa* Pessagno in Nakaseko et Nishimura, 1981, pl. 1, figs. 13-14, pl. 14, fig. 1.

Pseudoaulophacus delvallensis Pessagno
(Plate 15, fig. 5)

Pseudoau]ophacus delvallensis Pessagno, 1976, p. 27-28, pl. 9, figs. 9-10.

Pseudoaulophacus floresensis Pessagno
(Plate 15, fig. 8)
Pseudoaulophacus florensis Pessagno, 1963, p. 200, pl. 2, figs. 2, 5, pl. 4, fig. 6, pl. 7, figs. 1, 5; Pessagno, 1972, p. 304, 306, pl. 26, fig. 6, pl. 28, figs. 4-6, pl. 29, figs. 1-2, pl. 31, fig. 1; Pessagno, 1976, p. 28, pl. 9, fig. 6; Nakaseko et Nishimura, 1981, pl. 2, fig. 4.

Pseudoaulophacus lenticulatus (White)
(Plate 15, figs. 6, 7)
Baculogypsina (?) *lenticulata* White, 1928, p. 306, pl. 41, figs. 9, 11.
Aulophacus lenticulata (White) in Pessagno, 1962, pp. 364-366, pl. 6, figs. 1-2.
Pseudoaulophacus lenticulata (White) in Pessagno, 1963, p, 202, p. 202, pl. 2, figs. 8-9; Pessagno, 1972, p. 306, 308-309, pl. 29, figs. 5-6, pl. 30, figs. 1-3; Pessagno, 1976, p. 28, pl. 9, figs. 11-12; Nakaseko et Nishimura, 1981, pl. 2, figs. 7a, b.

Pseudoaulophacus pargueraensis Pessagno
(Plate .16, fig. 2)
Pseudoaulophacus pargueraensis Pessagno, 1963, p. 204, pl. 2, figs. 4, 7, pl. 6, figs. 4, 5; Pessagno, 1922, p. 309, pl. 30, fig. 4; Riedel et Sanfilippo, 1974, p. 780, pl. 2, figs. 12-14; Nakaseko et Nishimura, 1981, pl. 2, fig. 5.

Pseudoaulophacus praefloresensis Pessagno
(Plate 15, fig. 9)
Pseudoaulophacus praeflorensis Pessagno, 1972, p. 309-310, pl. 27, figs. 2-6; Pessagno, 1976, p. 28, pl. 5, fig. 11

Pseudodictyomitra pseudomacrocephala (Squinabol)
(Plate 17, fig. 10)
Dictyomitra pseudomacrocephala Squinabol, 1903, pp. 139-140, pl. 10, fig. 2; Cita, 1964, pp. 143-144, pl. 12, fig. 8; Moore, 1973, p. 829, pl. 9, figs. 8-9; Petrushevskaya et Kozlova, 1972, p. 550, pl. 2, fig. 5; Foreman, 1975, p. 614, pl. 7, fig. 10; Dumitrica, 1975, fig. 2, 3.
Dictyomitra (?) *Pseudomacrocephala* Squinabol in Pessagno, 1976, p. 53-54, pl. 3, figs. 2-3.
Dictyomitra malleolla Aliev, 1961, p. 62-63, pl. 2, figs. 5-7; Aliev, 1965, p. 48-49, pl. 8, figs. 4-6; Pessagno, 1969, p. 610-613, pl. 5, fig. A.
Dictyomitra sp. in Foreman, 1973, p. 264, pl. 4, fig. 16.
Dictyomitra macrocephala Squinabol in Riedel et Sanfilippo, 1974, p. 778, pl. 4, figs. 10-11, pl. 14, fig. 11.
Pseudodictyomitra pseudomacrocepahla (Squinabol) in Pessagno, 1977, p. 51, pl. 8, figs. 10-11; Nakaseko & Nishimura, 1981, pl. 9, figs. 1-4, pl. 16, figs. 5-8.

Pyramispongia sp. A
(Plate 16, figs. 8, 9)

Spongosaturninus ellipticus Campbell et Clark
(Plate 15, fig. 11)
Spongosaturninus ellipticus Campbell et Clark, 1944, p. 8, pl. 1, figs. 8-9, 12, 14, 16; Pessagno, 1976, p. 39, pl. 11, figs. 15-16.

Spongurus cf. *marcaensis* Pessagno
(Plate 15, fig. 12)
Spongurus marcaensis Pessagno, 1976, p. 32-33, pl. 11, fig. 7.

Stichomitra communis Squinabol
(Plate 17, fig. 9)
Stichomitra communis Squinabol, 1903, p. 141, pl. 8, fig, 40; Nakaseko *et al.*, 1979, pl. 7, fig. 10; Nakaseko et Nishimura, 1981, pl. 11, fig. 11, pl. 16, fig. 14.
Dictyomitra tekschaensis Aliev, 1967, p. 29, fig. k.
Dictyomitra spp. cf. *D. tekschaensis* Aliev in Foreman, 1975, p. 615, pl. 2H, fig. 1.

Thanarla sp. aff. *T. praeveneta* Pessagno
(Plate 17, figs. 6, 7)
Thanarla praveneta Pessagno, 1977, p. 46, pl. 7, figs. 11, 16, 18, 23, 27.

Thanarla sp. aff. *T. praeveneta* Pessagno in Nakaseko et Nishimura, 1981, pl. 6, fig. 16, pl. 15, fig. 9.

Theosyringium pulchrum Squinabol

(Plate 18, fig. 9)

Theosyringium pulchrum Squinabol, 1904, pl. 8, fig. 7.

Eusyringium sp. aff. *Theosyringium pulchrum* Squinabol in Nakaseko et Nishimura, 1981, pl. 11, fig. 9, pl. 17, fig. 4.

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Plate 15

Explanation of Plate 15

Fig. 1. *Archaeospongoprunum salumi* Pessagno..Page 98
Sample no. K-104, ×200.
Figs. 2, 3. *Archaeospongoprunum bipartitum* Pessagno..............................Page 98
Sample no. M-40, ×400.
Fig. 4. *Alievium gallowayi* (White) ....Page 97
Sample no. M-41, ×400.
Fig. 5. *Pseudoaulophacus delvallensis* Pessagno....................................Page 100
Sample no. K-104, ×400.
Figs. 6, 7. *Pseudoaulophacus lenticulatus* (White) ....Page 100
Fig. 6: Sample no. K-102; Fig. 7: Sample no. M-41, ×200.
Fig. 8. *Pseudoaulophacus floresensis* Pessagno ....Page 100
Sample on. K-102, ×200.
Fig. 9. *Pseudoaulophacus praefloresensis* Pessagno ....Page 100
Sample no. K-107, ×400.
Fig. 10. *Curucella* cf. *espartoensis* Pessagno ....Page 98
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Fig. 11. *Spongosaturninus ellipticus* Campbell et Clark...........................Page 100
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Fig. 13. *Praeconocaryomma universa* Pessagno ....Page 99
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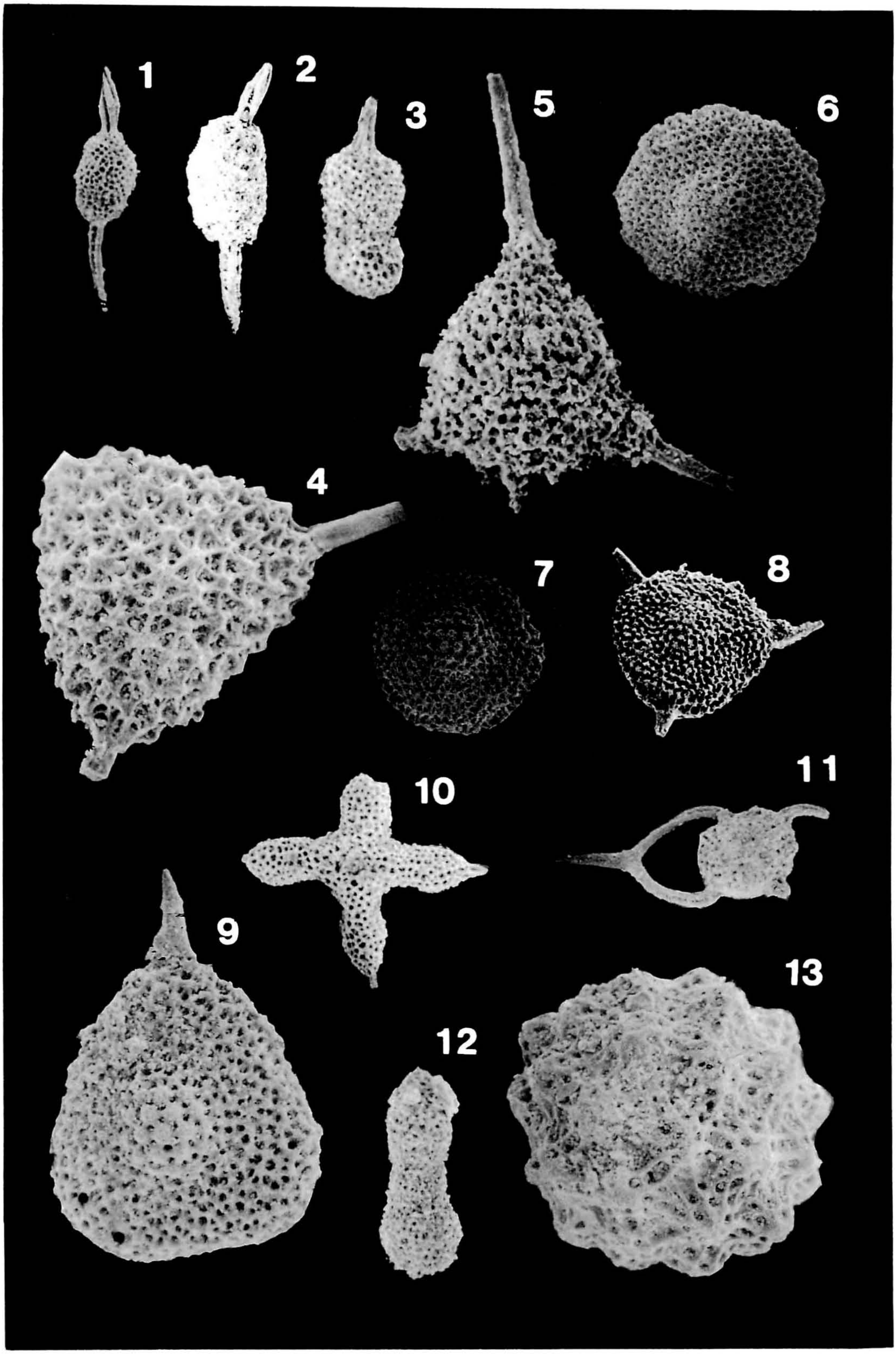

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Plate 16

Explanation of Plate 16

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Fig. 2. *Pseudoaulophacus pargueraensis* Pessagno ....Page 100
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Fig. 3. *Patellula planoconvexa* (Pessagno) ....Page 99
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Fig. 4. *Archaeospongoprunum nishiyamai* Nakaseko et Nishimura.......................Page 98
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Figs. 5, 6. *Phaseliforma concentrica* (Lipman) ....Page 99
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Fig. 7. *Orbiculiforma monticeloensis* Pessagno ....Page 99
Sample no. K-102, ×400.

Figs. 8, 9. *Pyramispongia* sp. A ....Page 100
Fig. 8: Sample no. K-107, ×200; Fig. 9: Sample no. M-41, ×400.

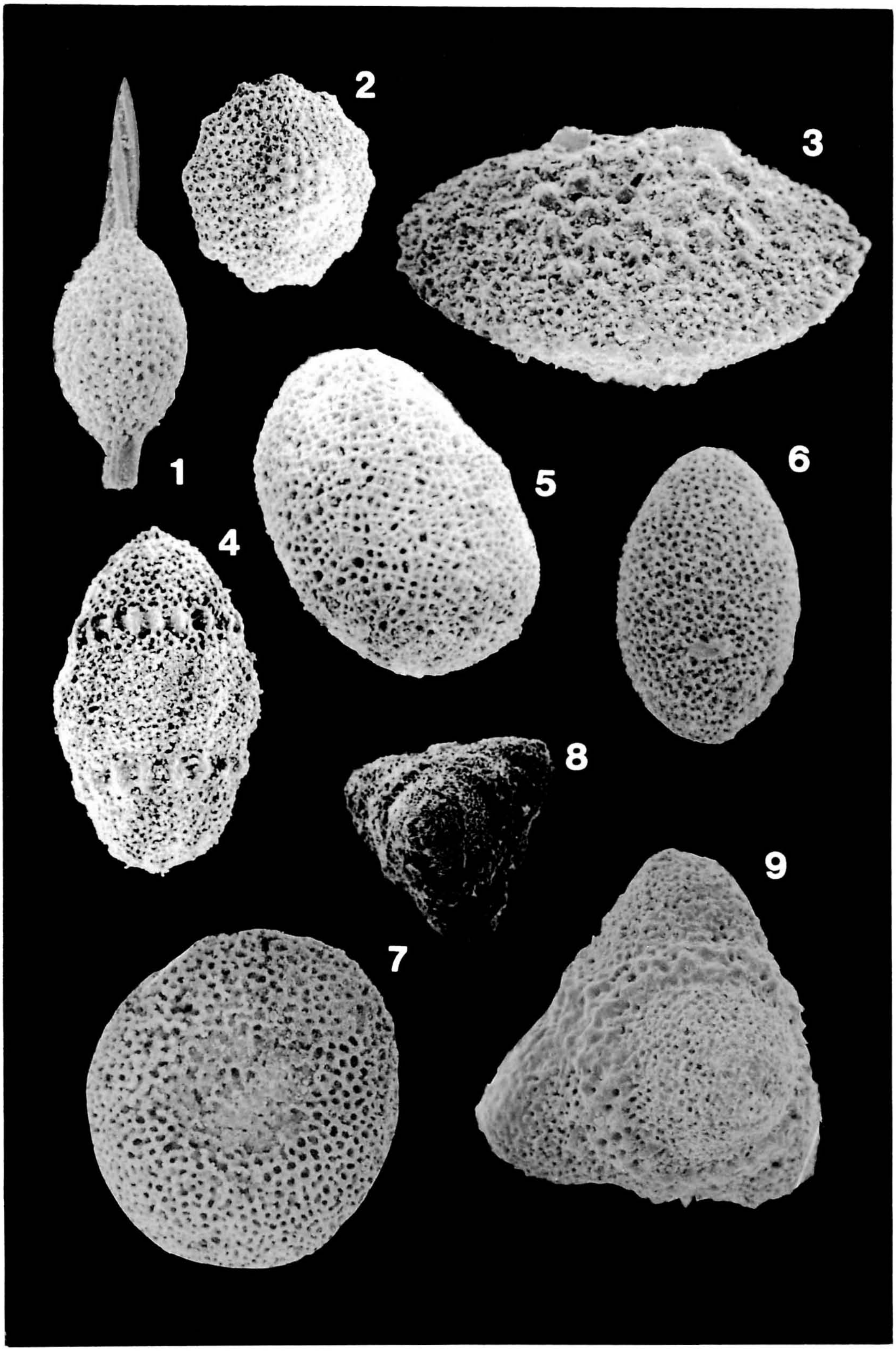
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Plate 17

Explanation of Plate 17

Figs. 1, 8. *Archaeodictyomitra squinaboli* Pessagno ....Page 98
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Fig. 11. *Artostrobium urna* Foreman................................Page 98
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Fig. 12. *Diacanthocapsa* cf. *ancus* (Foreman)................................Page 98
Sample no. K-102, ×400.

Fig. 13. *Cryptamphorella sphaerica* (White) ....Page 98
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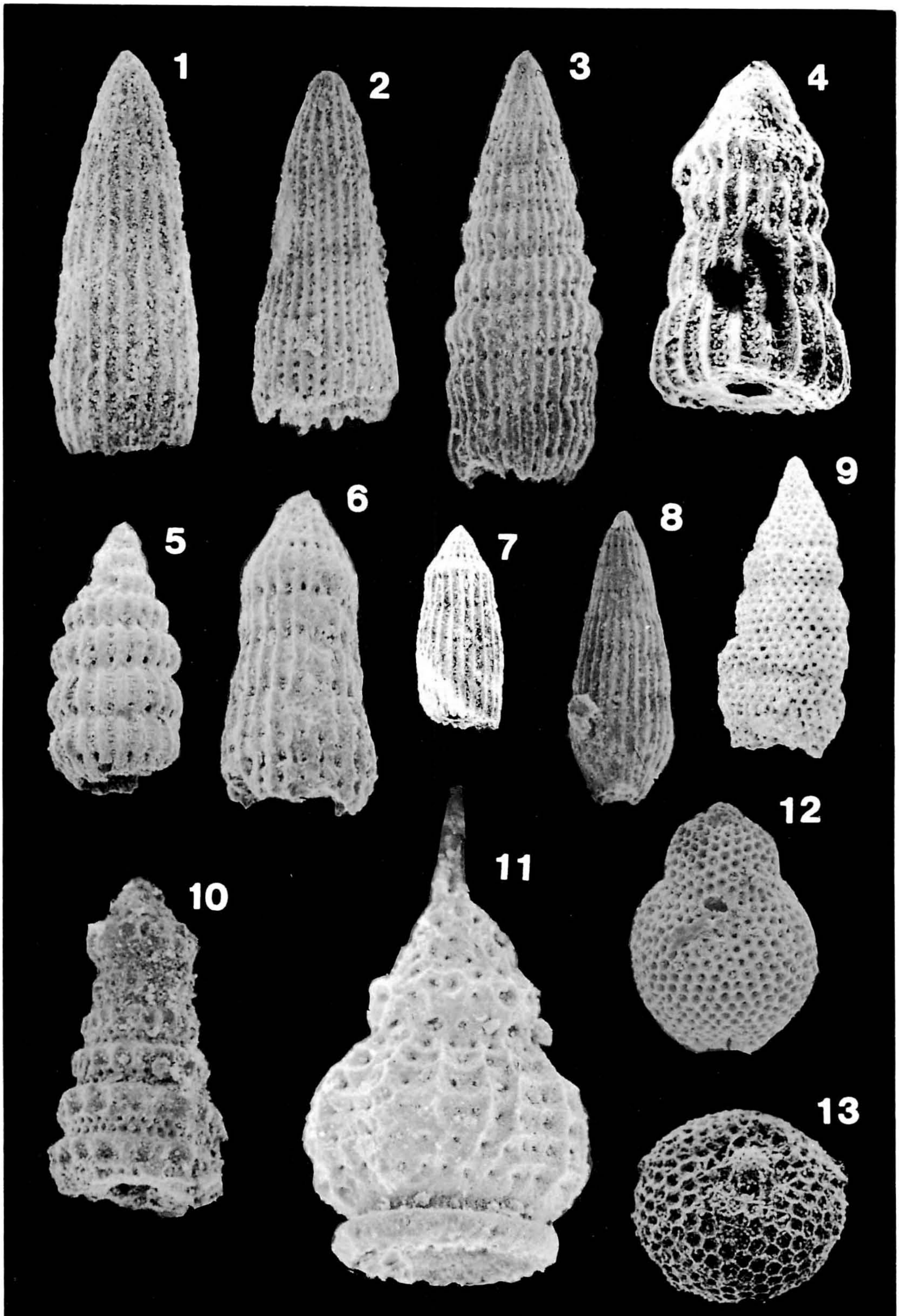

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Plate 18

Explanation of Plate 18

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Figs. 2, 3. *Diacanthocapsa* aff. *D. galeata* Dumitrica .... Page 99
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Fig. 5, 5′, 6. *Amphipyndax stocki* (Campbell et Clark) .... Page 97
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Fig. 7, 7′. *Amphipyndax elliptica* Nakaseko et Nishimura .... Page 97
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Fig. 8. *Amphipyndax alamedaensis* (Campbell et Clark) .... Page 97
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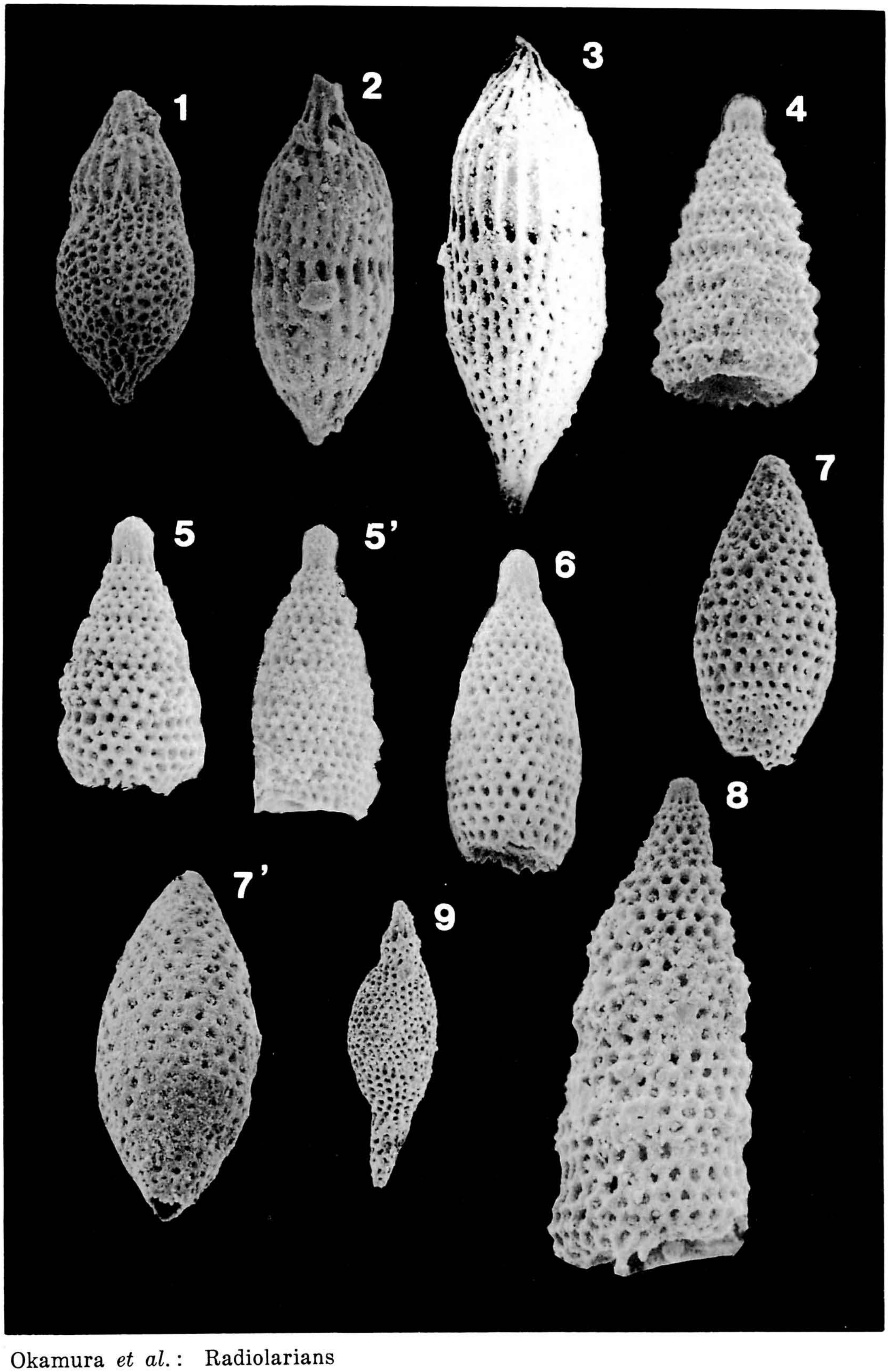
Fig. 9. *Theosyringium pulchrum* Squinabol .... Page 101
Sample no. K-107, ×400.



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IX. NOTES ON UPPER CRETACEOUS PLANKTONIC FORAMINIFERA FROM THE KAJISAKO FORMATION, KOCHI PREFECTURE, JAPAN

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Abstract

The first record of Upper Cretaceous planktonic foraminifera is presented from the Kajisako Formation exposed along the Kajisako River, Kochi Prefecture, Shikoku. The foraminiferal fauna is stratigraphically grouped into three assemblages, which are assignable to Turonian, Santonian and Campanian in age, respectively. A total of 26 species belonging to the genera *Heterohelix*, *Pseudotextularia*, *Globigerinelloides*, *Hedbergella*, *Whiteinella*, *Dicarinella*, *Falsotruncana*, *Marginotruncana*, *Archaeoglobigerina*, and *Globotruncana* are listed with some remarks on their taxonomy.

Introduction

Stratigraphic investigations in recent years by the members of Kochi University revealed that a fossiliferous Cretaceous sequence is developed in the Odochi area, Monobe-mura, Kami-gun, Kochi Prefecture (Katto *et al.*, 1980; Tashiro *et al.*, 1981). In and around this area, Cretaceous strata belonging to the Chichibu Belt in the Outer Side of Southwest Japan are divided into the lower Monobegawa and the upper Sotoizumi Groups (Katto and Suyari, 1956). A reconnaissance study of planktonic foraminifera of the Kajisako Formation, an upper unit of the Sotoizumi Group, has been carried out based on samples collected from exposures along the Kajisako River. The present paper is a contribution resulted from a cooperative work on Cretaceous biostratigraphy of the Monobe area.

Foraminiferal Fauna

Geologic setting of the Odochi area and descriptions on lithology of strata exposed there can be found in a paper by Tashiro *et al.* included in this volume. Most of the samples studied were collected by Tashiro and his collaborators of Kochi University. Additional samples were collected by one of us (K. S.). Those samples with the prefix K were collected by Tashiro and his collaborators, and those with the prefix IGPS were sampled by us. All the rock samples were prepared by using a hydrofluoric acid solution to separate foraminiferal specimens from a hard black shale. Among the samples from the Odochi area, more than half of them are barren of foraminifera. Especially, planktonic forms were recovered only from 11 samples of the Kajisako Formation. The stratigraphic position of these samples and their geographic location are shown in Figs. 1 and 2. The planktonic species identified from the Kajisako Formation are listed in table 1. Of the 26 species 17 are very rare and occur sporadically. Due to the poverty in Foraminifera no attempt was made on population statistics in the present study. Foraminiferal specimens are generally poor to moderate in their state of preservation.

The planktonic foraminiferal fauna from the western bank of the Odochi River can be grouped stratigraphically into three assemblages on the basis of specific composition. The lower assemblage, represented by the sample IGPS-38 from the lower part of the Kajisako Formation, is characterized by the occurrence of species of *Marginotruncana* and *Falsotruncana loeblichae* (Douglas) and the absence of *Globotruncana*. The middle assemblage occupies the lower part of the upper Kajisako Formation, and occurs in samples IGPS-17, K-12, -16, and -18. A diagnostic feature of this assemblage is the occurrence of species of *Dicarinella, Marginotruncana* and *Globotruncana*. The upper assemblage being represented by samples IGPS-30 and -29 from the upper part of the formation is marked by the presence of *Globotruncana* and the absence of *Dicarinella* and *Marginotruncana*. Another fauna found in those strata exposed along the eastern bank of the river is, as a whole, correlative with the middle assemblage.

The lower assemblage can be assigned to a late Turonian or early Coniacian age based on the occurrence of *Marginotruncana paraconcavata* Porthault, *M. pseudolinneiana* Pessagno, and *Falsotruncana loeblichae*. However, the absence of the archaeoglobigerine forms may be in favor of the Turonian aspect of this assemblage. The middle assem-

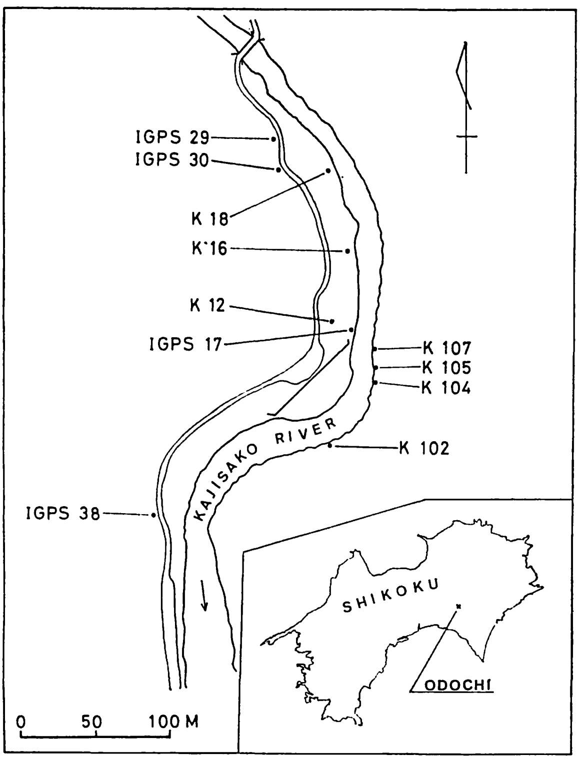

Fig. 1. Location map showing the area of study and sample localities.

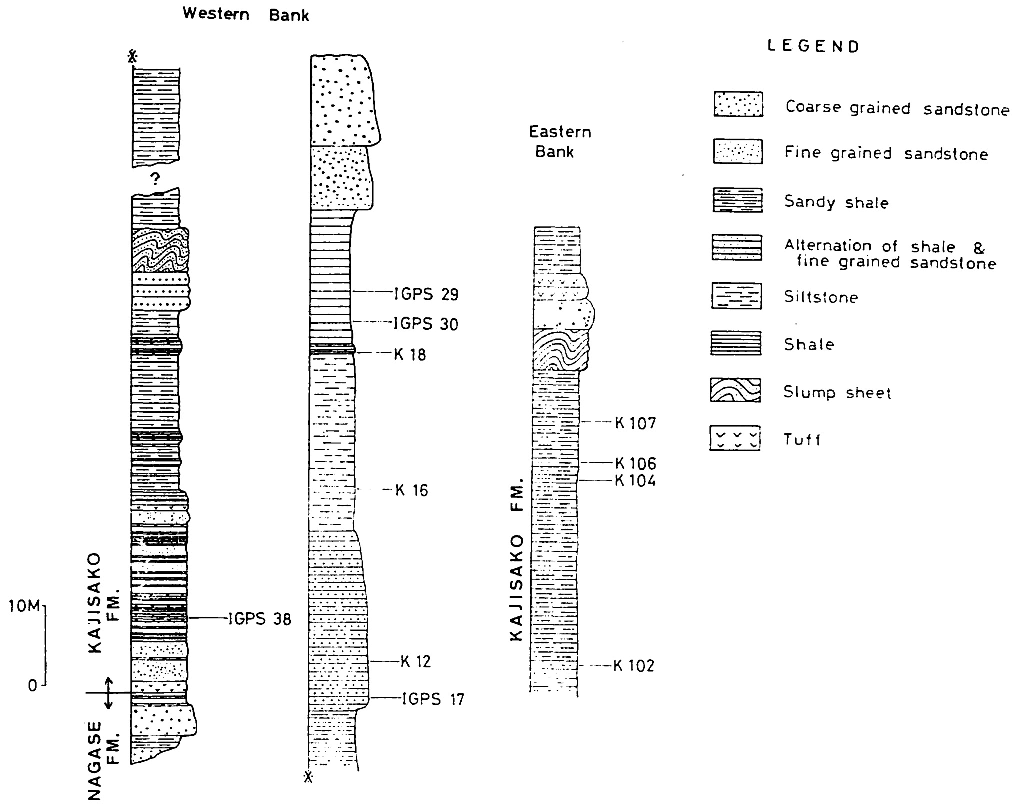

Fig. 2. Lithological successions and sample positions.

blage is considered to be of Santonian age because of the concurrence of the following species: *Dicarinella canaliculata* (Reuss), *D. concavata* (Brotzen), *D. imbricata* (Mornod), *D. japonica* (Takayanagi), *Marginotruncana angusticarenata* (Gandolfi), *M. paraconcavata*, *M. pseudolinneiana*, *Globotruncana fornicata* Plummer, and *G.* cf. *lapparenti* Brotzen. The upper assemblage is assigned to the Campanian on account of the presence of *Globotruncana hilli* Pessagno and *G. linneiana* (d'Orbigny) and the absence of species belonging to such genera as *Whiteinella, Dicarinella* and *Marginotruncana.* The stratigraphic distribution of the majority of taxa appeared in the Kajisako Formation agrees well with their previous records in the Cretaceous sections of Europe and North America (e. g., Groupe de Travail Européen des Foraminifères Planctoniques [=G. T. E. F. P. in the later portion of the present paper], 1979; Pessagno, 1967; Douglas, 1969). No typical Coniacian foraminiferal assemblage has yet to be found in the Kajisako fauna.

Taxonomic Notes

The following notes on taxonomy and stratigraphic distribution are given for the identified taxa from the Kajisako Formation. All the figured specimens are catalogued and deposited in the Institute of Geology and Paleontology, Tohoku University, Sendai, Japan.

Table 1. Stratigraphic distribution of planktonic foraminifera in the Kajisako Formation.

Species \ Localities	Western Bank							Eastern Bank			
	IGPS-38	IGPS-17	K-12	K-16	K-18	IGPS-30	IGPS-29	K-102	K-104	K-1.5	K-106
Heterohelix reussi (Cushman)	×	×	—	—	—	×	—	×	—	—	×
H. striata aegyptica Ansary et Tewfik	—	—	—	—	—	—	—	×	—	—	—
Pseudotextularia carseyae (Plummer)	—	—	×	—	—	—	—	—	—	—	—
Globigerinelloides asper (Ehrenberg)	—	—	—	—	—	×	—	—	—	—	—
G. escheri escheri (Kaufmann)	—	×	—	—	—	—	×	×	—	—	—
G. ultramicra (Subbotina)	—	×	—	—	—	×	—	×	×	×	—
Hedbergella delrioensis (Carsey)	×	×	×	×	×	×	—	×	×	×	×
H. flandrini Porthault	—	—	—	—	—	—	—	×	—	—	—
H. planispira (Tappan)	—	—	—	—	—	—	×	×	—	—	—
Whiteinella archaeocretacea Pessagno	×	—	×	×	×	—	—	×	×	×	×
W. baltica Douglas et Rankin	×	×	×	×	—	—	—	×	×	×	—
W. brittonensis (Loeblich et Tappan)	×	—	—	—	—	—	—	×	—	—	—
Dicarinella canaliculata (Reuss)	—	×	×	—	—	—	—	—	—	×	—
D. concavata (Brotzen)	—	—	×	—	—	—	—	—	—	—	—
D. imbricata (Mornod)	—	×	—	—	—	—	—	×	×	×	×
D. japonica (Takayanagi)	—	—	—	—	—	—	—	×	—	—	—
Falsotruncana loeblichae (Douglas)	×	—	—	—	—	—	—	—	—	—	—
Marginotruncana angusticarenata (Gandolfi)	—	—	—	—	—	—	—	—	—	×	—
M. paraconcavata Porthault	×	×	—	—	—	—	—	—	—	×	—
M. pseudolinneiana Pessagno	×	×	×	×	×	—	—	×	×	×	×
Archaeoglobigerina bosquensis Pessagno	—	×	—	—	—	×	×	—	×	—	—
A. cretacea (d'Orbigny)	—	—	—	×	—	—	—	×	—	—	×
Globotruncana fornicata Plummer	—	×	—	—	—	—	×	×	×	×	×
G. hilli Pessagno	—	—	—	—	—	×	—	—	—	—	—
G. cf. lapparenti Brotzen	—	×	—	—	—	—	—	—	—	×	—
G. linneiana (d'Orbigny)	—	—	—	—	—	×	×	—	—	—	—

Genus *Heterohelix* Ehrenberg, 1843

Heterohelix reussi (Cushman)

Pl. 19, Figs. 1a-c

Guembelina reussi Cushman, 1938, p. 11, pl. 2, figs. 6a-9b.
Heterohelix reussi (Cushman). Montanaro Gallitelli, 1957, p. 137-138, pl. 31, fig. 18; Pessagno, 1967, p 263, pl. 85, figs. 1-9, pl. 86, figs. 1, 2.

Specimens with a slightly compressed test and a moderate increase in the size of chambers which are covered with fine costae are identified with the present species. Although opinions are divided as to the taxonomic relationship between *Heterohelix reussi* and *H. globulosa* (Ehrenberg) among authors (Pessagno, 1967; Masters, 1977), Pessagno's concept is adopted in this study. The species is rare but recorded from the Turonian to Campanian part of the Kajisako Formation.

Heterohelix striata aegyptica Ansary et Tewfik

Pl. 19, Figs. 2a, b

Heterohelix striata (Ehrenberg) var. *aegyptica* Ansary et Tewfik, 1966, p. 41, pl. 3, figs. 2a, b.
Heterohelix striata aegyptica Ansary et Tewfik. Darmoian, 1975, p. 196, pl. 2, figs. 8, 9.

A broken specimen having a rapidly tapering chambers is tentatively identified with this subspecies. It is characterized by the last pair of chambers occupying the large proportion of the test and a rapid increase in the size of chambers. A single specimen was found from the Santonian part of the Kajisako Formation.

Genus *Pseudotextularia* Rzehak, 1891

Pseudotextularia carseyae (Plummer)

Pl. 19, Figs. 7a, b

Ventilabrella carseyae Plummer, 1931, p. 178, pl. 9, figs. 7-10.
Pseudotextularia carseyae (Plummer). Brown, 1969, p. 54-55, pl. 4, figs. 8, 9, text-figs. 11, 12.
Planoglobulina carseyae (Plummer). Montanaro Gallitelli, 1957, p. 141-142, pl. 32, fig. 13.

One specimen referred to this species is characterized by a thick test consisting of chambers of which thickness is largest compared with both width and height. Its test surface is moderately coarse and is covered by continuous costae. The early portion of the test is missing due to a poor state of preservation, but the arrangement and mode of growth of its chambers fit well with those of the typical form. This species occurs in the Santonian part of the Kajisako Formation.

Genus *Globigerinelloides* Cushman et ten Dam, 1948

Globigerinelloides asper (Ehrenberg)

Pl. 19, Figs. 3a, b

Phanerostomum asperum Ehrenberg, 1854, p. 23, pl. 30, figs. 26b (?26a, pl. 32, group 1, fig. 24, pl. 32, group 2, fig. 42).
Globigerina voluta White, 1928, p. 197-198, pl. 28, figs. 5a, b.
Globigerinella messinae messinae Brönnimann, 1952, p. 42-44, pl. 1, figs. 6, 7, text-figs. 20a-q.
Globigerinelloides asperus (Ehrenberg). Pessagno, 1967, p. 274-275, pl. 60, figs. 4, 5.
Globigerinelloides asper (Ehrenberg). Masters, 1980, p. 96-97, fig. 1, pl. 60, figs. 1-5.

This species is distinguished from its related forms by having a small and semi-involute planispiral test consisting of 5 ½ to 6 chambers in the last whorl and roughly hispid surface. These Kajisako specimens are almost identical with the topotypes figured by Masters (1980). The species is rare and has been found only in the Campanian part of the Kajisako Formation.

Globigerinelloides escheri escheri (Kaufmann)

Pl. 19, Figs. 4a, b, 6a, b

Nonionina escheri Kaufmann, 1865, p. 198, text-figs. 110a-e.
Globigerinelloides escheri escheri (Kaufmann). Brönnimann, 1952, p. 46-49, text-figs. 22, 23.

A few specimens tentatively referred to *G. escheri escheri* have a slightly compressed and almost evolutely planispiral test bearing always 6 chambers in the last whorl. The present taxon may be distinguished from *G. asper* in possessing a larger and more evolute test in adult and in having a smoother surface. The species occurs in the Santonian and Campanian parts of the Kajisako Formation.

Globigerinelloides ultramicra (Subbotina)

Pl. 19, Figs. 5a, b

Globigerinella ultramicra Subbotina, 1949, p. 33, pl. 2, figs. 17, 18. (*fide* Ellis and Messina, Cat. Foram.).
"*Globigerinelloides*" *japonica* Takayanagi, 1960, p. 131, pl. 9, figs. 12a, b, text-figs. 22a-e.
Globigerinelloides bollii Pessagno, 1967, p. 275, pl. 62, fig. 5, pl. 81, figs. 1, 8, pl. 97, figs. 1, 2, pl. 100, fig. 3.
Globigerinelloides ultramicra (Subbotina). Masters, 1977, p. 413, pl. 12, figs. 3-5.

As discussed by Masters (1977), *Globigerinelloides ultramicra* is easily discriminated from its allied forms by having a small sized test with 7 to 8 gradually enlarging chambers in the final whorl. Also, the species has a smoother surface compared with that of other *Globigerinelloides* found in other studied samples. This species is fairly common in the Santonian and Campanian parts of the Kajisako Formation.

Genus *Hedbergella* Brönnimann et Brown, 1958

Hedbergella delrioensis (Carsey)

Pl. 20, Figs. 2a-c

Globigerina cretacea d'Orbigny var. *del rioensis* Carsey, 1926, p. 43-44.
Globigerina portsdownensis Williams-Mitchell, 1948, p. 96-97, pl. 8, figs. 4a-c.
Globigerina gautierensis Brönnimann, 1952, p. 11-14, pl. 1, figs. 1-3, text-figs. 2a-c, g-m (non d-f).
Praeglobotruncana crassa Bolli, 1959, p. 265 pl. 21, figs. 1a-c.
Hedbergella delrioensis (Carsey). Loeblich and Tappan, 1961, p. 275, pl. 2, figs. 11a-13c.

Specimens assigned to this species have a low trochospiral test with mostly 5 chambers in the last whorl. Its aperture forms an arch being interiomarginal and extraumbilical-umbilical in position, and is covered by a spatulate lip. The spiral side is rather flat. Compared with such typical form as that figured by Loeblich and Tappan (1961), the present specimens are rather small in size and have slightly compressed chambers. Due to a poor state of preservation, the last and the preceding chambers do not exhibit such a distinct surface feature as that noted by the previous workers. This rare species is one of the consistent components of the Kajisako Formation.

Hedbergella flandrini Porthault

Pl. 20, Figs. 6a-c

Hedbergella flandrini Porthault, 1970, p. 64, pl. 10, figs. 1-3; G.T.E.F.P., 1979a, p. 129-134, pl. 24, figs. 1a-2c, pl. 25, figs. 1a-3c.

This species is recognized by its compressed and very low trochospiral test with

5 to 6 spatulate chambers in the final whorl, fairly smooth surface, and distinctly lobulate periphery. Rare specimens were found in the Santonian sample.

Hedbergella planispira (Tappan)

Pl. 20, Figs. 5a-c

Globigerina planispira Tappan, 1940, p. 122, pl. 19, figs. 12a-c.
Hedbergella planispira (Tappan). Loeblich and Tappan, 1961, p. 276-277, pl. 5, figs. 4-11; G.T. E.F.P., 1979a, p. 134-144, pl. 27, figs. 1a-3c, pl. 28, figs. 1a-4c.

Small, very low trochospiral specimens with commonly 6 to 7 chambers in the last whorl are assigned to *Hedbergella planispira.* In the figured, well-preserved specimens, an arched aperture is visible with its narrow but distinct lip which expands near the umbilicus. This species is recorded from the Santonian and Campanian parts of the Kajisako Formation, but has quite a limited occurrence.

Genus *Whiteinella* Pessagno, 1967

Whiteinella archaeocretacea Pessagno

Pl. 20, Figs. 1a-c

Whiteinella archaeocretacea Pessagno, 1967, p. 298-299, pl. 51, figs. 2-4, pl. 54, figs. 19-21, 22-24, 25, pl. 100, fig. 8; G.T.E.F.P., 1979a, p. 161-168, pl. 33, figs. 1a-3c, pl. 34, figs. 1a-2c.

This species is characterized by a low trochospiral test with commonly 5 chambers in the last whorl, somewhat laterally compressed chambers, nearly umbilically positioned aperture and portici extending to the center of a small umbilicus in well-preserved specimens. It is fairly common in the Turonian and Santonian samples of the Kajisako Formation.

Whiteinella baltica Douglas et Rankin

Pl. 20, Figs. 3a-c

Whiteinella baltica Douglas et Rankin, 1969, p. 197-198, fig. 9; G.T.E.F.P., 1979a, p. 169-174, pl. 35, figs. 1a-5, pl. 36, figs. 1a-2b.
Hedbergella bornholmensis Douglas et Rankin, 1969, p. 193, fig. 6

A low trochospiral and almost laterally symmetrical form bearing 3 ½ to 5 subglobular chambers in the final whorl and the primary aperture which is extraumbilical-umbilical in position and which is accompanied by porticus covering the narrow umbilicus are all diagnostic features of this species. According to the discussion given by the G.T.E.F.P. (1979a, p. 169, 174), which was based on the re-examination of the topotypic material, "*Hedbergella bornholmensis*" is considered to be a synonym of this species. It is common in the Turonian and Santonian parts of the Kajisako Formation.

Whiteinella brittonensis (Loeblich et Tappan)

Pl. 20, Figs. 4a-c

Hedbergella brittonensis Loeblich et Tappan, 1961, p. 274, pl. 4, figs. 1, 2, 5-8 (non 3, 4).

Whiteinella brittonensis (Loeblich et Tappan). G.T.E.F.P., 1979a, p. 175-180, pl. 37, figs. 1a-2c, pl. 38, figs. 1a-2c.

High trochospiral specimens with 5 to 6 globular chambers in the final whorl are assigned to *Whiteinella brittonensis*. Although these specimens are poorly preserved, its distinctly spinose surface, which is a diagnostic feature of the species, is recognizable in most of them. This species occurs in the Turonian and Santonian parts of the Kajisako Formation.

Genus *Dicarinella* Porthault, 1970

Dicarinella canaliculata (Reuss)

Pl. 21, Figs. 1a-c

Rosalina canaliculata Reuss, 1854, p. 70, pl. 26, figs. 4a-b.
Marginotruncana canaliculata (Reuss). Pessagno, 1967, p. 302-304, pl. 74, figs. 5-8.
Dicarinella canaliculata (Reuss). G.T.E.F.P., 1979b, p. 67-70, pl. 53, figs. 1a-3c.

A flattened trochospiral form showing sub-rectangular lateral view, truncated periphery with two widely spaced keels which are parallel over the whole margin, 5 to 7 chambers in the last whorl, and almost straight, radial and depressed sutures on the umbilical side, are all diagnostic features of this species. These rare and poorly preserved specimens are recorded from the Santonian portion of the Kajisako Formation.

Dicarinella concavata (Brotzen)

Pl. 21, Figs. 4a-c

Rotalia concavata Brotzen, 1934, p. 66, pl. 3, fig. b.
Globotruncana concavata (Brotzen). G.T.E.F.P., 1979a, p. 71-78, pl. 54, figs. 1a-2c, pl. 55, figs. 1a-2c.

Two specimens are referred to this species. They are very poorly preserved, but the identification was made because of their distinctly plano-convex test with two closely spaced keels, radial and depressed umbilical sutures, and 5 to 6 inflated chambers visible on the umbilical side. The distribution of this species is limited to the Santonian portion of the Kajisako Formation.

Dicarinella imbricata (Mornod)

Pl. 21, Figs. 2a-3c

Globotruncana imbricata Mornod, 1950, p. 589-590, pl. 15, figs. 21-34, text-fig. 5.
Marginotruncana imbricata (Mornod). Pessagno, 1967, p. 306-307, pl. 57, figs. 3-5.
Dicarinella imbricata (Mornod). Caron, 1976, p. 332-333, pl. 3, figs. 1-6, pl. 4, figs. 1-6, pl. 5, figs. 1-6; G.T.E.F.P., 1979b, p. 87-92, pl. 58, figs. 1a-2d, pl. 59, figs. 1a-2c.

This species is characterized by its low trochospiral test showing a convexo-concave profile in lateral view, two separated keel at the peripheral margin of each chamber except for the last-formed one or two, 5 to 6 chambers in the final whorl that increase very gradually in size, imbricated aspect of chamber arrangement, and radial and depressed sutures on the umbilical side. It is fairly common but limited to the Santonian portion of the Kajisako Formation.

Dicarinella japonica (Takayanagi)

Pl. 21, Figs. 5a-c

Globotruncana japonica Takayanagi, 1960, p. 135-136, pl. 10, figs. 4a-c.

This species is recognized by its low trochospiral test showing a biconvex lateral view, usually 4 ½ chambers in the last whorl, two distinctly separated keels which are parallel over the entire test and which tend to become an imperforate band on the last one or two chambers, and radially depressed sutures on the umbilical side. It differs from *Dicarinella imbricata* in having a fewer number of chambers per whorl, biconvex outline in lateral view, and non-imbricate aspect in the sequence of chambers. It is only found in the Santonian part of the Kajisako Formation.

Genus *Falsotruncana* Caron, 1981

Falsotruncana loeblichae (Douglas)

Pl. 23, Figs. 5a-c

Praeglobotruncana loeblichae Douglas, 1969, p. 170-171, pl. 5, figs. 7a-c (non 6a-c).
Falsotruncana loeblichae (Douglas). Caron, 1981, p. 67, pl. 1, figs. 3a-c, pl. 2, figs. 3a, b.

A single, poorly preserved specimen is referable to this species. It has a flattened trochospiral test bordered by a wide peripheral band over the entire test, 5 ½ chambers in the final whorl that are broadly truncated except for the last-formed one, radially depressed sutures on the umbilical side, nearly radial to slightly curved and depressed sutures on the spiral side, principal aperture being extraumbilical-umbilical in position which is bordered by a narrow lip, and a fairly wide and shallow umbilicus without portici or tegilla. The present specimen is dextrally coiled, in marked contrast to Caron's definition (1981) that the genus is always sinistrally coiled. It was recorded from the Turonian part of the Kajisako Formation.

Genus *Marginotruncana* Hofker, 1956

Marginotruncana angusticarenata (Gandolfi)

Pl. 22, Figs. 1a-c

Globotruncana linnei (d'Orbigny) var. *angusticarenata* Gandolfi, 1942, p. 126, 150, 153, pl. 4, figs. 17, 30, text-fig. 46.
Globotruncana angusticarinata Gandolfi. Sigal, 1952, p. 34, text-flg. 37.
Globotruncana lapparenti Brotzen *angusticarinata* Gandolfi. Hagn and Zeil, 1954, p. 44-45, pl. 7, figs. 9-10.
Globotruncana (*Globotruncana*) *renzi angusticarinata* Gandolfi. van Hinte, 1963, p. 67-68, pl. 2, figs. 3a-c.
Marginotruncana angusticarenata (Gandolfi). Pessagno, 1967, p. 300-301, pl. 65, figs. 14-19, pl. 98, figs. 5, 9-11.

A few specimens identifiable with this species were found in the Santonian part of the formation. Although they are poorly preserved, a somewhat spiroconvex test with two peripheral keels, and 6 chambers in the last whorl that are strongly elongate spirally as well as umbilically in the direction of coiling are all characteristic to *Marginotruncana angusticarenata*. Some hypotype specimens shown under the name of *Marginotruncana sinuosa* Porthault, 1970 in the atlas by G. T. E. F. P. (1979b, pl. 75) are almost identical to the Kajisako specimens.

Marginotruncana paraconcavata Porthault

Pl. 22, Figs. 2a-c

Marginotruncana paraconcavata Porthault, 1970, p. 77-78, pl. 10, figs. 21-23b; G. T. E. F. P., 1979b. p. 119-122, pl. 66, figs. 1a-2b.

The specimens assigned to this species are large, low trochospiral, plano-convex, and are truncated peripherally by two keels separated by a narrow imperforate band. Usually 4 to 5 chambers are present in the final whorl, and petaloidal and elongated in the direction of coiling. Sutures are raised, umbilically sigmoidal and spirally curved. Umbilicus is large and flanked by a beaded umbilical shoulder. *Marginotruncana paraconcavata* is recorded from the Turonian and Santonian parts of the Kajisako Formation.

Marginotruncana pseudolinneiana Pessagno

Pl. 22, Figs. 3a-c

Marginotruncana pseudolinneiana Pessagno, 1967, p. 310, pl. 65, figs. 24-27, pl. 76, figs. 1-3; G. T. E. F. P., 1979b, p. 123-128, pl. 67, figs. 1a-2d, pl. 68, figs. 1a-2c.
Globotruncana pseudolinneiana (Pessagno). Douglas and Rankin, 1969, p. 207-208, figs. 16A-C, figs. 17A-C.

This species is recognized by its low trochospiral test with a rectangular profile in lateral view, two widely separated peripheral keels, normally 5 to 7 chambers in the final whorl that are crescent-shaped on the umbilical side, that are separated by raised, thickened and beaded sutures, and that are subrectangular in outline on the spiral side with horse-shoe shaped rims, and a large umbilicus with portici. The portici can be observed in some well-preserved specimens from the Kajisako Formation as shown in the figure. They are not complete but exhibit a very similar structure to that observed by G. T. E. F. P. in their hypotype (1979b, pl. 67, fig. 2c). It is common throughout the Turonian and Santonian parts of the formation.

Genus *Archaeoglobigerina* Pessagno, 1967

Archaeoglobigerina bosquensis Pessagno

Pl. 22, Figs. 5a-c

Archaeoglobigerina bosquensis Pessagno, 1967, p. 316-317, pl. 60, figs. 7-12.

Relatively high trochospiral forms are found to be *Archaeoglobigerina bosquensis.* Although specimens identifiable with this species are rare and poorly preserved, they have 6 to 7 inflated subspherical chambers in the last whorl and a fairly deep, open umbilicus. Neither keels nor imperforate bands are observed on the outer margin of the chambers. These specimens occur in the Santonian and Campanian parts of the Kajisako Formation.

Archaeoglobigerina cretacea (d'Orbigny)

Pl. 22, Figs. 4a-c

Globigerina cretacea d'Orbigny, 1840, p. 34, pl. 3, figs. 12-14.
Globotruncana globigerinoides Brotzen, 1936, p. 177, pl. 12, figs. 3a-c.
Globotruncana cretacea (d'Orbigny). Banner and Blow, 1960, p. 8, pl. 7, figs. 1a-c.
Archaeoglobigerina cretacea (d'Orbigny). Pessagno, 1967, p. 317, pl. 70, figs. 3-8, pl. 94, figs. 4-5; G. T. E. F. P., 1979b, p. 173-176, pl. 78, figs. 1-3, pl. 80, figs. 1a-e.
Rugoglobigerina cretacea (d'Orbigny). Bandy, 1967, p. 21, text-figs. 10(1).

Low trochospiral forms with 5 to 6 globular chambers in the last whorl are referred to this species. Two weakly developed keels are usually seen on each chamber margin except for the last one or two chambers. The umbilicus is deep and wide, and is covered by a tegilla, though only a fragment of the tegilla is preserved.

Genus *Globotruncana* Cushman, 1927

Globotruncana fornicata Plummer

Pl. 23, Figs. 1a-c

Globotruncana fornicata Plummer, 1931, p. 198-199, pl. 13, figs. 4a-6; Masters, 1977, p. 564-566, pl. 44, figs. 4-6.

This species is distinguished from its allied double-keeled species by its low trochospiral test with 4 to 5 chambers in the final whorl which are on the spiral side narrow, crescent-shaped, elongate in the direction of coiling, and typically undulating. Also, these chambers are undulating and imbricate on the umbilical side. This species was found in the Santonian and Campanian portions of the Kajisako Formation.

Globotruncana hilli Pessagno

Pl. 23, Figs. 2a-c

Globotruncana hilli Pessagno, 1967, p. 343-344, pl. 64, figs. 9-14, 21-23; pl. 94, fig. 1, pl. 97, fig. 7.

Two poorly preserved specimens from the Campanian portion of the Kajisako Formation is tentatively referred to this species. They possess a small, rather thick, low trochospiral test with 5 chambers in the final whorl, which are nearly flat on the spiral side and somewhat convex on the umbilical side. The chambers are petaloidal in shape on the spiral side and are subrectangular in form on the umbilical side. The peripheral margin of the chambers are truncated by two widely spaced keels. Compared with the later chambers, the earlier chambers in the final whorl have much weaker keels on the periphery.

Globotruncana cf. *lapparenti* Brotzen

Pl. 23, Figs. 4a-c

Cf. *Rosalina linnei* d'Orbigny. de Lapparent, 1918, p. 1-17, pl. 1, figs. 1, 7 (non figs. 2-4, pl. 2, fig. 2), pl. 6, figs. 2, 3, pl. 8, pl. 9, figs. 2, 3 (non fig. 6), text-figs. la-h (p. 4), text-fig. 2a, d, m, n (p. 5), text-fig. 3 (p. 10), (non text-fig. 5d (p. 13)).
Cf. *Globotruncana lapparenti* Brotzen, 1936, p. 175-176.
Cf. *Globotruncana* (*Globotruncana*) *lapparenti* Brotzen. Reichel, 1950, p. 613, pl. 16, fig. 9, pl. 17, fig. 9.

Among the globotruncanids found in the Kajisako Formation, there are a few specimens comparable with this species. Although the present specimens are poorly preserved, they are characterized by the flattened sides especially on the spiral side, 5 chambers in the last whorl, equatorially lobulate and truncate periphery with two distinct and fairly widely spaced keels which are nearly parallel with each other over the test, chambers crescent-shaped on the spiral side and imbricate on the umbilical side, and raised and strongly beaded sutures on both sides. This form is recorded from the Santonian part of the formation.

Globotruncana linneiana (d'Orbigny)

Pl. 23, Figs. 3a-c

Rosalina linneiana d'Orbigny, 1839, p. 101, pl. 5, figs. 10-12.
Globotruncana linneiana (d'Orbigny). Subbotina, 1953, p. 176, pl. 5, figs. 7-9, pl. 6, figs. 1-4; Pessagno, 1967, p. 346-349, pl. 72, figs. 1-4, pl. 97, figs. 11-13; Masters, 1977, p. 583-585, pl. 46, figs. 3, 5, 6.

This species is distinguishable from *Globotruncana lapparenti* in having radial sutures on the umbilical side, as has been remarked by Masters (1977). Further more, differences in the position of the primary aperture together with the shape of chambers on both sides make it easy to distinguish this species from *Marginotruncana pseudolinneiana*. In the Kajisako Formation, it was found only from the Campanian section.

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Plate 19

Explanation of Plate 19

Figs. 1a-c. *Heterohelix reussi* (Cushman) ....Page 106
IGPS coll. cat. no. 97687 from sample K-102.
1a. Side view; 1b. top view; 1c. edge view.

Figs. 2a, b. *Heterohelix striata aegyptica* Ansary et Tewfik ....Page 107
IGPS coll. cat. no. 97688 from sample K-102.
2a. Side view; 2b. top view.

Figs. 3a, b. *Globigerinelloides asper* (Ehrenberg) ....Page 107
IGPS coll. cat. no. 97690 from sample IGPS-30.
3a. Side view; 3b. edge view.

Figs. 4a, b, 6a, b. *Globigerinelloides escheri escheri* (Kaufmann)......................Page 107
4a, b. IGPS coll. cat. no. 97692 from sample K-102.
6a, b. IGPS coll. cat. no. 97691 from sample IGPS-17.
4a, 6a. Side view; 4b, 6b. edge view.

Figs. 5a, b. *Globigerinelloides ultramicra* (Subbotina) ....Page 108
IGPS coll. cat. no. 97693 from sample K-102.
5a. Side view; 5b. edge view.

Figs. 7a, b. *Pseudotextularia carseyae* (Plummer) ....Page 107
IGPS coll. cat. no. 97689 from sample K-12.
7a. Side view; 7b. edge view.

Scale bar 100 μm

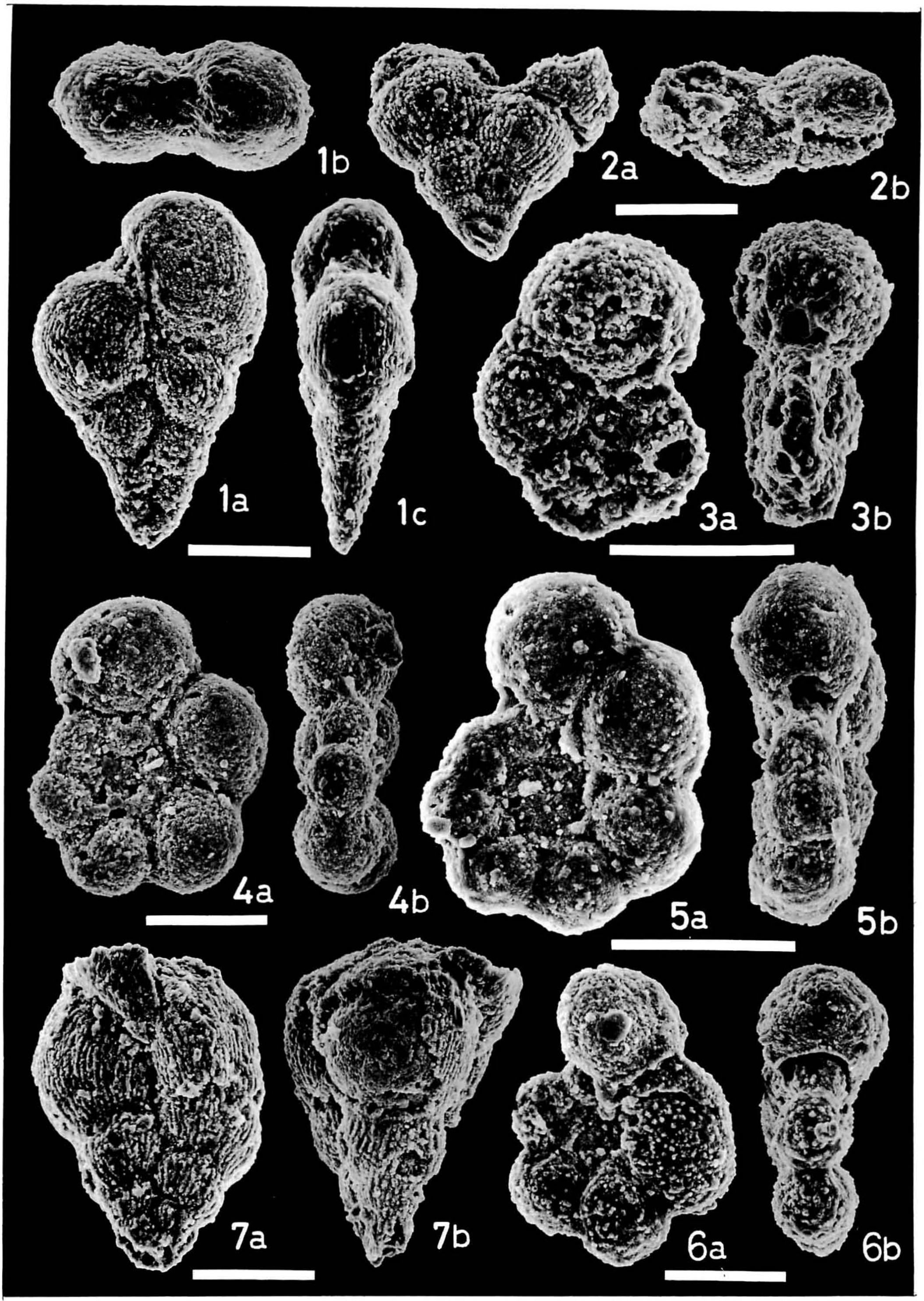
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Plate 20

Explanation of Plate 20

Figs. 1a-c. *Whiteinella archaeocretacea* Pessagno ....Page 109
IGPS. cat. no. 97697 from sample IGPS-38.
1a. Spiral view; 1b. edge view; 1c. umbilical view.

Figs. 2a-c. *Hedbergella delrioensis* (Carsey) ....Page 108
IGPS coll. cat. no. 97694 from sample K-107.
2a. Spiral view; 2b. edge view; 2c. umbilical view.

Figs. 3a-c. *Whiteinella baltica* Douglas et Rankin ....Page 109
IGPS coll. cat. no. 97698 from sample IGPS-17.
3a. Spiral view; 3b. edge view; 3c. umbilical view.

Figs. 4a-c. *Whiteinella brittonensis* (Loeblich et Tappan) ....Page 109
IGPS coll. cat. no. 97699 from sample K-102.
4a. Spiral view; 4b. edge view; 4c. umbilical view.

Figs. 5a-c. *Hedbergella planispira* (Tappan) ....Page 109
IGPS coll. cat. no. 97696 from sample K-102.
5a. Spiral view; 5b. edge view; 5c. umbilical view.

Figs. 6a-c. *Hedbergella flandrini* Porthaut ....Page 108
IGPS coll. cat. no. 97695 from sample K-102.
6a. Spiral view; 6b. edge view; 6c. umbilical view.

Scale bar 100 μm

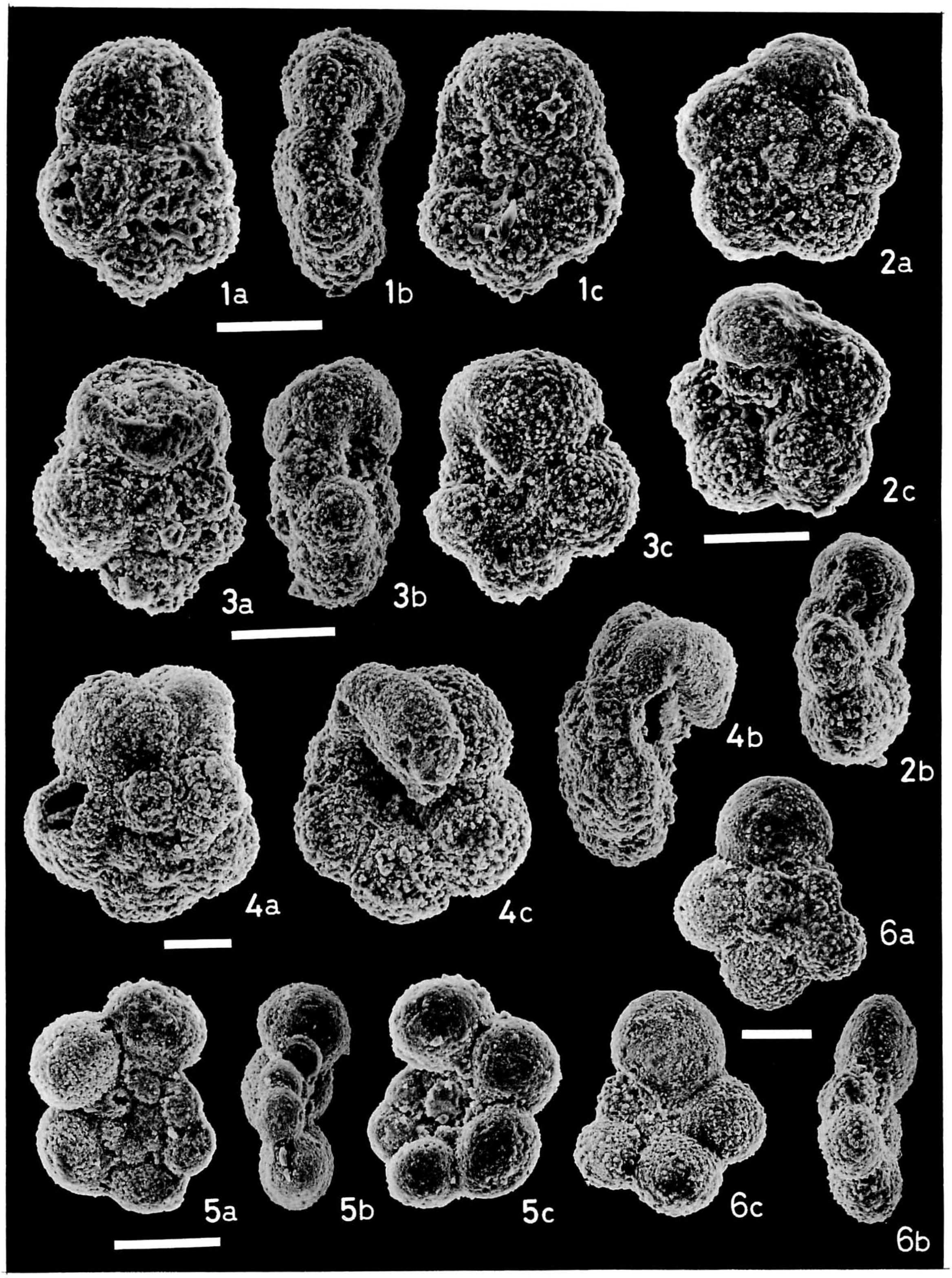
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Plate 21

Explanation of Plate 21

Figs. 1a-c. *Dicarinella canaliculata* (Reuss) ....Page 110
IGPS coll. cat. no. 97700 from sample K-12.
1a. Spiral view; 1b. edge view; 1c. umbilical view.

Figs. 2a-c, 3a-c. *Dicarinella imbricata* (Mornod) ....Page 110
2a-c. IGPS coll. cat. no. 97702 from sample K-102.
3a-c. IGPS coll. cat. no. 97703 from sample K-107.
2a, 3a. Spiral view; 2b, 3b. edge view; 2c, 3c. umbilical view.

Figs. 4a-c. *Dicarinella concavata* (Brotzen) ....Page 110
IGPS coll. cat. no. 97701 from sample K-12.
4a. Spiral view; 4b. edge view; 4c. umbilical view.

Figs. 5a-c. *Dicarinella japonica* (Takayanagi) ....Page 111
IGPS coll. cat. no. 97704 from sample K-102.
5a. spiral view; 5b. edge view; 5c. umbilical view.

Scale bar 100 μm

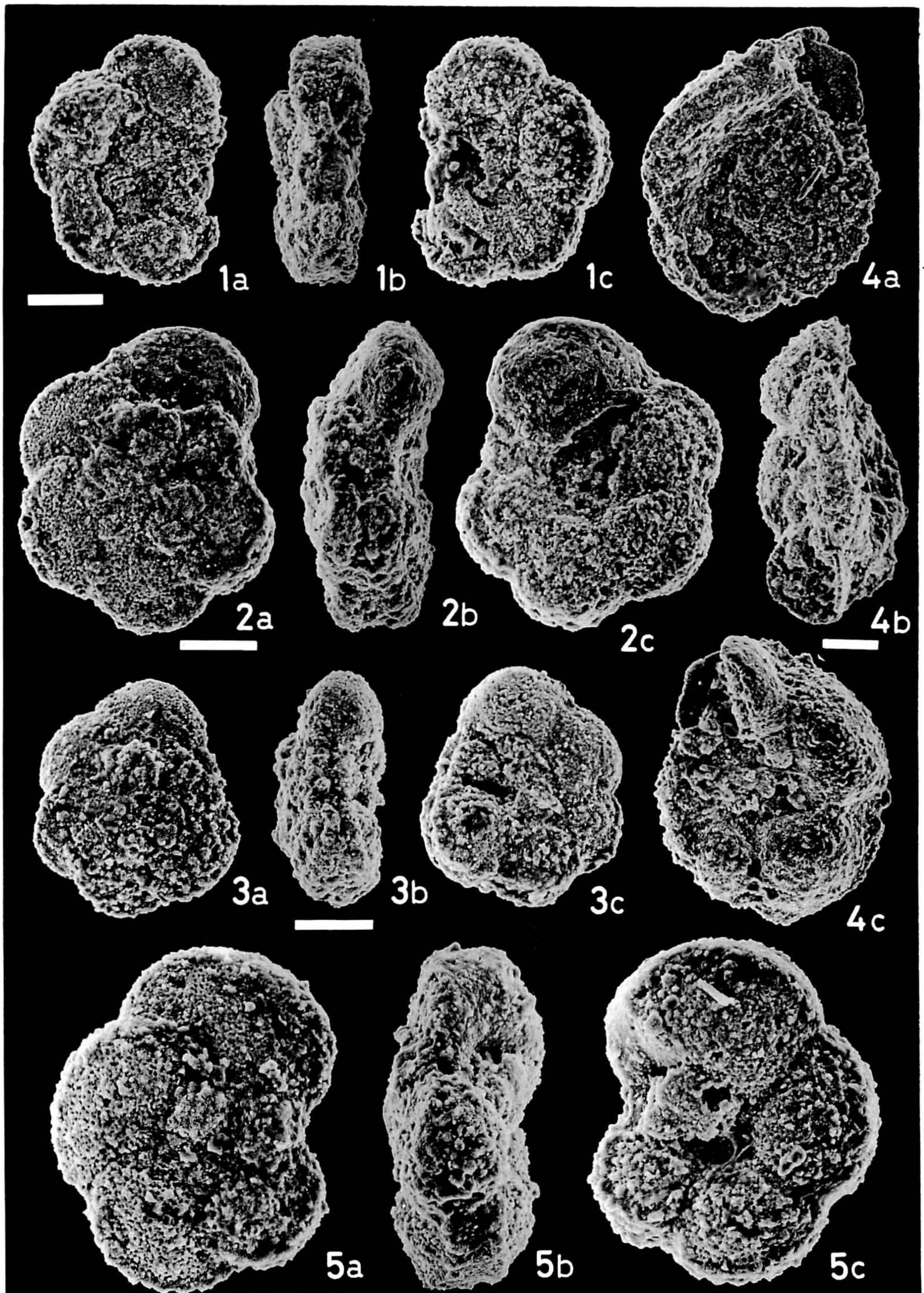

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Plate 22

Explanation of Plate 22

Figs. 1a-c. *Marginotruncana angusticarenata* (Gandolfi) ....Page 111
IGPS coll. cat. no. 97706 from sample K-105.
1a. Spiral view; 1b. edge view; 1c. umbilical view.

Figs. 2a-c. *Marginotruncana paraconcavata* Porthault ....Page 112
IGPS coll. cat. no. 97707 from sample IGPS-38.
2a. Spiral view; 2b. edge view; 2c. umbilical view.

Figs. 3a-c. *Marginotruncana pseudolinneiana* Pessagno................................Page 112
IGPS coll. cat. no. 97708 from sample K-102.
3a. Spiral view; 3b. edge view; 3c. umbilical view.

Figs. 4a-c. *Archaeoglobigerina cretacea* (d'Orbigny) ....Page 113
IGPS coll. cat. no. 97710 from sample K-102.
4a. Spiral view; 4b. edge view; 4c. umbilical view.

Figs. 5a-c. *Archaeoglobigerina bosquensis* Pessagno ....Page 112
IGPS coll. cat. no. 97709 from sample IGPS-30.
5a. Spiral view; 5b. edge view; 5c. umbilical view.

Scale bar 100 μm

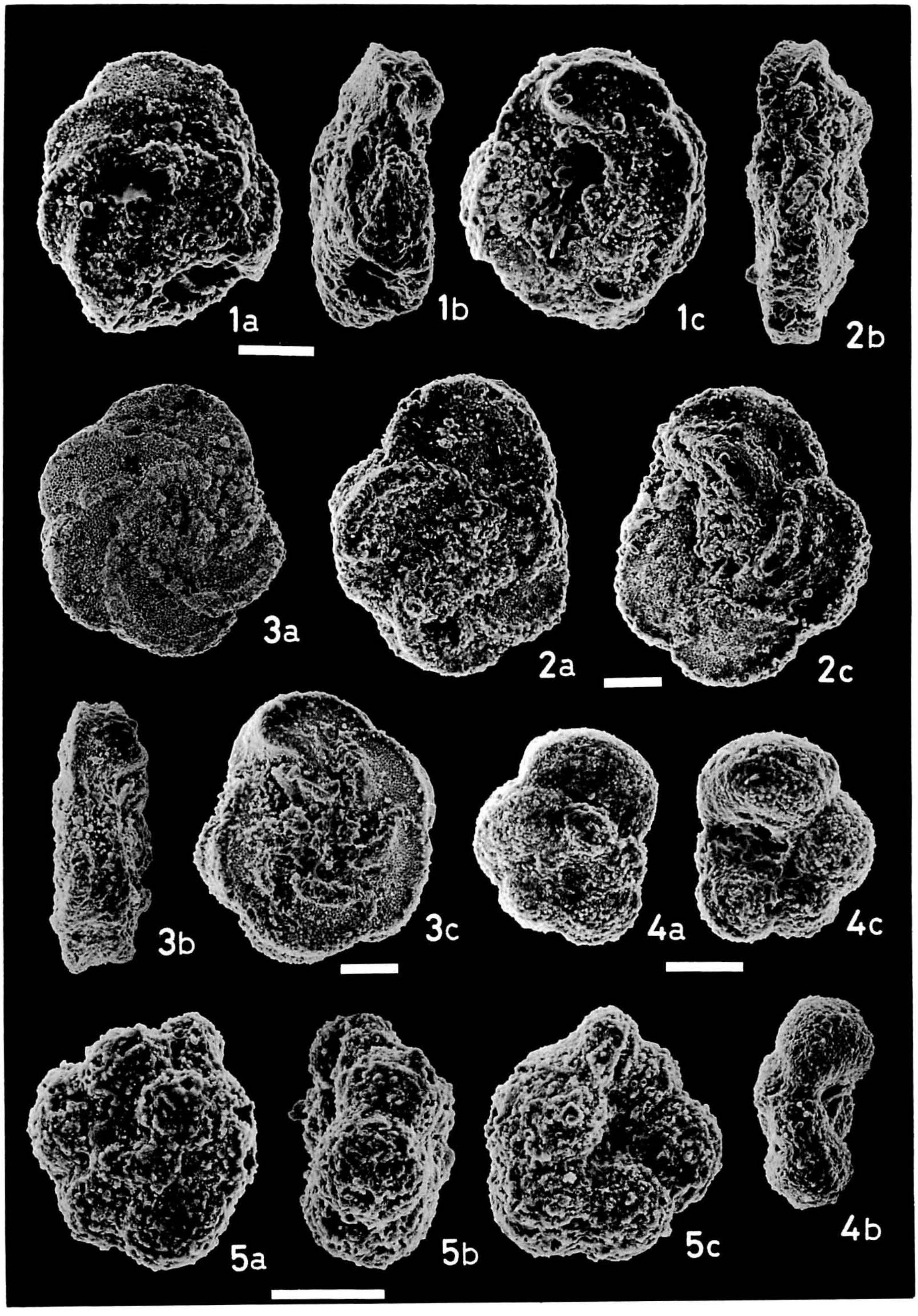

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Plate 23

Explanation of Plate 23

Figs. 1a-c. *Globotruncana fornicata* Plummer ....Page 113
IGPS coll. cat. no. 97711 from sample K-107.
1a. Spiral view; 1b. edge view; 1c. umbilical view.

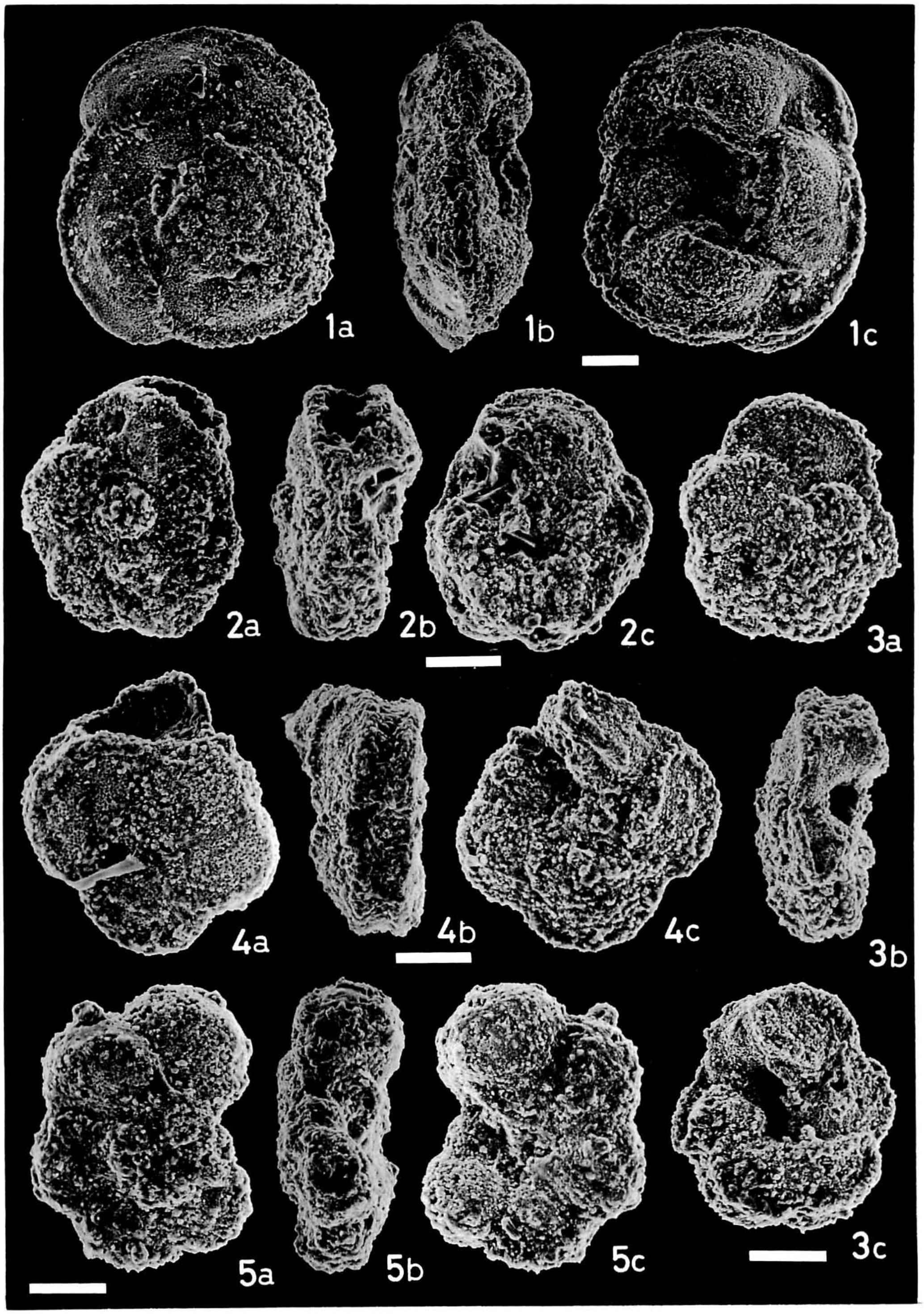
Figs. 2a-c. *Globotruncana hilli* Pessagno ....Page 113
IGPS coll. cat. no. 97712 from sample IGPS-30.
2a. Spiral view; 2b. edge view; 2c. umbilical view.

Fig. 3a-c. *Globotruncana linneiana* (d'Orbigny) ....Page 114
IGPS coll. cat. no. 97714 from sample IGPS-30.
3a. Spiral view; 3b. edge view; 3c. umbilical view.

Fgs. 4a-c. *Globotruncana* cf. *lapparenti* Brotzen ....Page 114
IGPS coll. cat. no. 97713 from sample K-105.
4a. Spiral view; 4b. edge view; 4c. umbilical view.

Figs. 5a-c. *Falsotruncana loeblichae* (Douglas) ....Page 111
IGPS coll. cat. no. 97705 from sample IGPS-38.
5a. Spiral view; 5b. edge view; 5c. umbilical view.

Scale bar 100 μm



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X. CONCLUDING REMARKS ON THE MULTIDISCIPLINARY RESEARCH IN THE UPPER CRETACEOUS OF THE MONOBE AREA, SHIKOKU

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Abstract

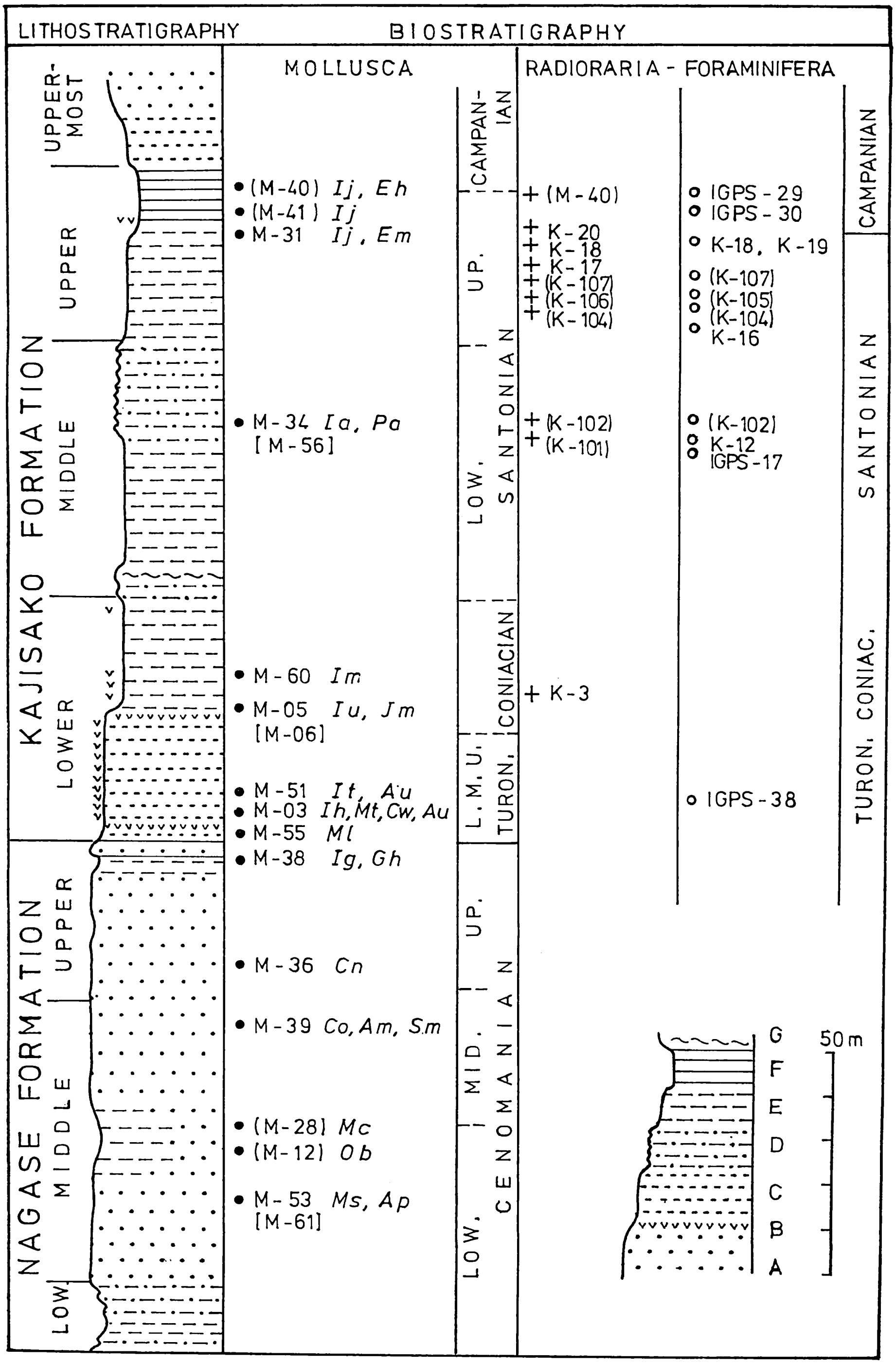
Results of the present multidisciplinary study are summarized, considering their implications. A conclusion of higher reliability is led for the age correlation on the basis of integrated mega- and microbiostratigraphy, but a discrepancy is pointed out as to a certain part.

In the Outer Zone of Southwest Japan, the Cretaceous System is distributed in two belts, i. e. the Chichibu Belt in the north and the Shimanto Belt in the south. There are considerable differences between the two belts in the pattern of distribution, structural features, litho- and bio-facies and stratigraphic sequences of the Cretaceous System. Recently the studies of the Cretaceous System have been very active in both belt. For instance, a book entitled "*Geology and Palaeontology of the Shimanto Belt*" (Taira and Tashiro [eds.], 1981) contains the results of the up-to-date studies of the Cretaceous System in the Shimanto Belt, although the papers are mostly written in Japanese with English abstracts. Keeping pace with the study in the Shimanto Belt, the Cretaceous System in the Chichibu Belt is also being studied intensively. The present publication is one of the results of such studies.

In the Chichibu Belt, the Cretaceous strata are exposed in a number of narrow basins (see Text-fig. 1 of Article III). The Monobegawa valley in the eastern part of Kochi Prefecture is one of those basins. The geological structure of the Monobe area, i. e. the central part of the valley, is described by Hada *et al.* in Article II, with emphasis on high-angled faults of strike-slip movement (see Text-figs. 1, 2 of Article II).

For some reasons, the sequences of the Lower Cretaceous have been better exposed in most Cretaceous basins of the Chichibu Belt and the Monobegawa Group has been used as a comprehensive term to represent the mainly marine part of the Lower Cretaceous, whereas the Upper Cretaceous sequences have been incompletely recorded.

As a result of the present study a nearly complete stratigraphic sequence from the Cenomanian to the Campanian has been recognized along a single route of the River Kajisako, a tributary to the River Monobe, on the evidence of fossils. There are also some other exposures which supplement this route. The locations of the routes, the lithostratigraphic sequences along the routes and the localities of both mega- and



micro-fossils are shown in Text-figs. 1-4 of Article I and Text-fig. 1 of Article IX. The species identified by the specialists of respective biological groups are listed in the following tables with reference to the localities.

Ammonoidea by Matsumoto in Tables 1-3 of Article V

Inoceramidea by Matsumoto *et al.* in Table 1 of Article VI

Bivalvia other than the inoceramids by Tashiro and Kozai in Text-figs. 5, 6 of Article VII

Radiolaria by Okamura *et al.* in Table 1 of Article VIII

Planktonic foraminifera by Takayanagi *et al.* in Table 1 of Article IX

Text-fig. 1 in this article shows a simplified summary of the litho- and biostratigraphy of the Upper Cretaceous in the Monobe area.

The Nagase Formation, which occupies the lower part of the sequence, consists primarily of sandstone and yields ammonites and bivalves which indicate the Cenomanian. The successive occurrences of ammonite species, *Mantelliceras* cf. *saxbii* at loc. M-53, *Calycoceras* cf. *orientale* at loc. M-39 and *Calycoceras* aff. *naviculare* at loc. M-36, indicate the Lower, the Middle and the Upper Cenomanian, respectively. At loc. M-39 in the same bed with *Calycoceras* cf. *orientale*, there occur seven species of bivalves of which six are common to those from the Lower Formation of the Mifune Group in central Kyushu (Tamura, 1976-79). This is a fine contribution to the correlation, since the Lower Mifune is also referred to the Middle Cenomanian on the basis of an ammonite and inoceramids (Tamura and Matsumura, 1974). In other words the bivalve fossils of the Lower Mifune and the Middle Nagase represent the Middle Cenomanian bivalve fauna in Southwest Japan. At loc. M-38, near the top of the Nagase Formation, there occurs *Inoceramus* sp. allied to *I.* (*I.*) *ginterensis*, a world-wide Upper Cenomanian species and is associated with *Glycymeris* (*Hanaia*) *hokkaidoensis*. This part is probably the upper part of the Upper Cenomanian.

Besides the successive exposures along the River Kajisako, the Nagase Formation is exposed at and near the Nagase Dam on the main stream of the Monobe [=Monobegawa] and is extended northeastward to the south of Doiban (see Text-fig. 1 of Article

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←—Text-fig. 1. A summarized diagram showing the litho- and biostratigraphy of the Upper Cretaceous in the Monobe area, Shikoku.

Legend for lithology—A: coarse or medium-grained sandstone, B: tuff or tuffite, C: fine-grained sandstone, D: sandstone and shale in alternation, E: sandy siltstone, F: mudstone, G: slump beds. Selected molluscan species in ascending order, with abbreviations—*Ms*: *Mantelliceras* cf. *saxbii*, *Ap*: *Pterotrigonia* (*Acanthotrigonia*) *pustulosa*; *Ob*: *Ostringoceras* cf. *bechii*; *Mc*: *Mantelliceras cantianum*; *Co*: *Calycoceras* cf. *orientale*, *Am*: *P.* (*Acanthotrigonia*) *mashikensis*, *P.* (*A.*) *monobeana* and *P.* (*A.*) *higoensis*, *Sm*: *Septifer mifunensis*, etc.; *Cn*: *Calycoceras* aff. *naviculare*; *Ig*: *Inoceramus* (*Inoceramus*) aff. *ginterensis*, *Gh*: *Glycymeris* (*Hanaia*) *hokkaidoensis*, etc.; *Ml*: *Mytiloides* cf. *labiatus opalensis*; *Ih*: *Inoceramus* (*Inoceramus*) *hobetsensis*, *Mt*: *Mytiloides teraokai*, *Cw*: *Collignoniceras woollgari*, *Au*: *Apiotrigonia undulosa*; *It*: *Inoceramus* (*Inoceramus*) *teshioensis*, *Au*: *Apiotrigonia undulosa*; *Iu*: *Inoceramus* (*Inoceramus*) *uwajimensis*, *Jm*: *Jimboiceras* aff. *mihoensis*; *Im*: *Inoceramus mihoensis*; *Ia*: *Inoceramus* (*Platyceramus*) *amakusensis*, *Pa*: *Pycnodonte amakusensis*; *Ij*: *Inoceramus* (*Platyceramus*) *japonicus*, *Em*: *Ezonuculana mactraeformis*, etc., *Eh*: *Eupachydiscus haradai*. [ ]: locality on the other side of the river at the same horizon as the above indicated locality, ( ): approximate allocation of a separated locality. Conclusions of age by means of mollusca (●) and radiolaria (+)—foraminifera (○) are indicated side by side.

I and geological map of Article II). This belt includes fossil localities (M-28, M-12 and M-44) of some more ammonites, which indicate or suggest the Cenomanian (mostly Lower Cenomanian) (see Table 1 of Article V).

The lowest part, about 12 m, of the Kajisako Formation consists of dark coloured fine-grained sandstone with frequent intercalation of tuffaceous layers. The mega-fossils occur at three levels in this part. The inoceramid and ammonite species from locs. M-55, M-03 [=M-03′] and M-51 indicate the Lower Turonian, the Middle Turonian and the Upper Turonian, respectively. The selected species, among others, are *Mytiloides* cf. *labiatus opalensis* from M-55, *M. teraokai, Inoceramus* (*Inoceramus*) *hobetsensis, Collignoniceras woollgari, Romaniceras* cf. *deverianum* and *R.* aff. *kallesi* from loc. M-03, and *Inoceramus* (*Inoceramus*) *teshioensis* and *Mytiloides* aff. *striatoconcentricus* from loc. M-51. This tripartite subdivisions of the Turonian in the Japanese scale, originally established in Hokkaido, approximately correspond to those in the Wessex- Paris basin of northwestern Europe (see Hancock *et al.*, 1977, for example). Well preserved micro-fossils have been scarcely detected from this part, but the foraminifera from the sample of loc. IGPS-38 (between N-14 and N-15) show a Turonian age.

In the bed at loc. M-03, bivalves including inoceramids and other families occur abundantly, as listed in Text-fig. 5 of Article VII. They are associated with the ammonites of ornate type (Acanthocerataceae) and include some new species. They represent the Middle Turonian bivalve fauna of Southwest Japan and the present study has much improved the knowledge of that fauna which was poor previously. Some of the constituting species, however, range upward to the Upper Turonian or to the Coniacian or still higher to the Santonian, as is shown in Text-fig. 6 of Article VII. *Nippononectes monobensis* and *Apiotrigonia undulosa* are found from loc. M-03 and loc. M-51 both, as is *Scalarites* cf. *mihoensis*, a heteromorph ammonite.

The above mentioned lowest part is followed by still more thickness (about 14.5 m) of strata with similar lithology and altogether constitute the lower half of the lower part of the Kajisako Formation. No identifiable fossils have been found from this 15 m unit. The upper half, about 22.5 m, of the Lower Kajisako consists of dark gray sandy siltstone, with some intercalates of tuffaceous layers. In this part there are beds with mega-fossils at two horizons. The lower bed is exposed at loc. M-05 on the right bank and also at loc. M-06 on the left bank. It is characterized by *Inoceramus* (*Inoceramus*) *uwajimensis*, which is associated with *Jimboiceras* aff. *mihoensis*. The upper bed is exposed at loc. M-60, where *Inoceramus mihoensis* is found. The part which includes these two beds is undoubtedly referred to the Coniacian (see Matsumoto *in* Matsumoto *et al.*, 1981 for the zonation and the international correlation of the Coniacian). The assemblage of radiolarian species from loc. K-3 below M-60 show the age not younger than the Coniacian. Below this locality down to loc. N-15, samples have been collected at several horizons to inspect micro-fossils. They are, however, so poorly preserved that the very point of the Turonian-Coniacian boundary cannot be determined in the Kajisako section, although it should be somewhere within the interval between N-15 and K-2 [=M-05]. Likewise, no reliable evidence has been obtained to determine the very boundary of Coniacian-Santonian in the Kajisako section, despite the efforts to identify micro-fossils from many samples.

The middle part of the Kajisako Formation begins with alternating beds of dark-gray siltstone and fine-grained sandstone, with some strata of a slump structure, consists of dark gray siltstone in the middle portion, and ends with another unit of alternating siltstone and fine-grained sandstone. It is altogether about 70 m in thickness. Mega-fossils are found from several localities which belong to its upper half. *Inoceramus* (*Platyceramus*) *amakusensis*, among others, occurs from loc. M-34 on the right bank and loc. M-56 on the left bank. This indicates the Lower Santonian in the Japanese scale (see Matsumoto *in* Matsumoto and Haraguchi, 1978 for the Santonian mega-fossil biostratigraphy). The planktonic Foraminifera from samples of locs. K-12 and IGPS-17 [=K-11], which are close to loc. M-34, also indicate a Santonian age. Those from samples at locs. K-102, K-104, K-105 and K-107 and the radiolarian species from samples from locs. K-101 [=M-56], K-102, K-104, K-106 and K-107, all indicate the Santonian age of the sequence of about 35 m exposed on the left bank, as has been discussed in Articles VIII and IX.

The upper part of the Kajisako Formation, about 40 m in thickness, consists of dark gray shale (silty in the lower half and clayey in the upper half), with intercalated tuffaceous layers at the midst. In a layer at loc. M-31 slightly above the tuffite, *Inoceramus* (*Platyceramus*) *japonicus* occurs commonly. This is an index of the Upper Santonian in the Japanese scale of mega-fossil biostratigraphy. It is associated with *Acila* (*Truncacila*) *hokkaidoensis*, *Ezonuculana mactraeformis* and *Parvamussium* cf. *yubarense*, bivalve species which occur commonly in the Coniacian and the Santonian muddy sediments of Hokkaido (called the Upper Yezo Group). Micro-fossil data, however, have given us a different conclusion. Namely, as has been described in Articles VIII and IX, five species among the radiolarias from loc. K-20 [=M-31] and K-18 are the characteristic ones which begin to appear in the Campanian of the Great Valley sequence in California and also the oceanic sequence, and the planktonic foraminifera from loc. IGPS-30 [=K-21] and IGPS-29 [=K-23] likewise indicate a Campanian age. There is, thus, a slight but unnegligicle discrepancy between the conclusions from the micro- and mega-fossil biostratigraphy.

The mudstone which is referred to the Upper Kajisako is also exposed at several localities near Doiban, which are separated by a fault from the main exposure of the Kajisako. Again the Santonian is indicated by the inoceramid species: *I.* (*Platyceramus*) *amakusensis* (loc. M-14), *I.* (*P.*) cf. *ezoensis* (M-14), *I.* (*P.*) aff. *rhomboides* (M-14), *I.* (*P.*) *japonicus* (M-14, M-40, M-41) and *Sphenoceramus* cf. *naumanni* (M-14). Loc. M-14 includes several large blocks of mudstone which may have come from beds of some thickness, that means beds of several stratigraphic levels. Of the ammonites from this part (see Table 3 of Article V), *Eupachydiscus haradai* (from loc. M-40) ranges from the Upper Santonian to the Lower Campanian in the Japanese scale and *Gaudryceras striatum* is common in the Campanian. Incidentally, Tanaka and Kozai (1982) have recently reported *Epiaster nobilis* Stoliczka from loc. M-14. As is described in Article VIII, the assemblage of radiolarian species from M-41 indicates a Santonian age, whereas that from M-40 a Campanian age. This is a very interesting fact, which suggests that the Santonian-Campanian boundary in the sense of micro-fossil biostratigraphy may be located within the Zone of *Inoceramus japonicus*, i.e. within the Upper Santonian in the sense of mega-fossil biostratigraphy. This idea, which has been obtained from the study of the Monobe area, Shikoku, should be examined carefully in the sequences of

Hokkaido and other areas.

The uppermost part of the Kajisako Formation is occupied by a unit of sandstone, about 20 m in thickness. No fossil of good age indicator has been found there. Judging from the conformable stratigraphic relationship with the fossiliferous mudstone mentioned above, this part can be referred to the Campanian. If we consider the effect of the post-Cretaceous erosion, there may have been some more sediments lying on this observable uppermost part.

Summarizing the above, the Upper Cretaceous sequences of the Monobe area represent a good succession from the Lower Cenomanian to a certain part of the Campanian. Hitherto the Upper Cretaceous has been known in the Arida Valley of Wakayama Prefecture, but there are many uncertainties as to its stratigraphy and contained fossils. Now, the Monobe area has become the best place in showing the sequences of the Upper Cretaceous in the Chichibu Belt of Southwest Japan. The problem of the Albian-Cenomanian boundary can be examined in this area, although this is left for further study.

Broadly speaking, the stratigraphic sequence of the Upper Cretaceous in the Monobe area shows a major cycle of sedimentation, with the transgression peak in the Santonian. This is in harmony with the general tendency in the Upper Cretaceous of Hokkaido and other areas in Japan. It should be also noted that tuffaceous layers are intercalated frequently in the Turonian and the Lower Coniacian. This suggests the volcanic activity in an adjacent region, probably in the Inner Zone of Southwest Japan (see Article III).

Another, remarkable fact is that the Upper Cretaceous of this area is not so thick as in the contemporary sedimentary series of other areas in Japan. Especially, the whole sequence of the Turonian is represented by a unit of less than 20 m in thickness. This is a high contrast to the extremely thick Lower Onogawa Group of the nearly the same time interval in eastern central Kyushu, which is made up of 6250 m piles of conglomerate and turbidites.

In connexion with this fact, the clay minerals in the Upper Cretaceous rocks of the present area have been inspected by Mitsushio and Higashi (see Article IV). From a more comprehensive viewpoint, considering the sedimentology and the tectonics as well as the stratigraphy, the palaeotectonic implications of the Upper Cretaceous sediments of the Chichibu Belt are discussed by Taira, who has shown his idea in a diagrammatic model of Text-fig. 2, giving an explanation in Article III.

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