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Cover: A terminally resorbed maxillary tooth of iguanodontids (Ornithischia: Ornithopoda). The specimen is from the Kuwajima Formation, the Neocomian section of the Tetori Group, in Shiramine-mura, Ishikawa County, Ishikawa Prefecture, the west coast of Central Honshu, Japan (Shiramine-mura Board of Education, Coll. Cat. No. SBEI 001, 23 mm in dorsoventral length).

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1003 The first occurrence of Griesbachian conodonts in Japan

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Abstract. The Lower Triassic Griesbachian conodonts, *Hindeodus parvus* (Kozur and Pjatakova) and *Isarcicella isarcica* (Huckriede), occur in partly dolomitized dark gray carbonaceous pelagic limestones in Southwest Japan, i.e. the Taho Formation in Tahokamigumi, Shirokawa-cho, Higashiuwa-gun, Ehime Prefecture and the Kamura Formation in Kamura, Takachiho-cho, Nishiusuki-gun, Miyazaki Prefecture. The Griesbachian carbonate rock of the Taho Formation is underlain conformably by light gray dolomitic limestone including the Permian fusulinid *Staffella* sp. The carbonate rock of the Kamura Formation is also underlain conformably by dolostone of the Upper Permian Mitai Formation. This is the first confirmation of the Griesbachian in Japan.

Key words : Griesbachian, conodonts, *Hindeodus parvus* (Kozur and Pjatakova), *Isarcicella isarcica* (Huckriede), Kamura Formation, Taho Formation

Introduction

In Japan, two different lithofacies are distinguished in the Upper Permian to Lower Triassic sequence. One is a shelf facies composed of terrigenous sequences. The other is a pelagic facies and consists of chert and carbonate sequences. The shelf facies is exposed in the Southern Kitakami belt, Northeast Japan and the Maizuru belt, Southwest Japan. In these areas, however, the Permian-Triassic boundary is unconformable, and the upper Changxingian of the Permian and the Induan of the Triassic are lacking.

On the other hand, the Permian-Triassic boundary is confirmed in the chert sequence in the Chichibu belt, Southwest Japan (e.g., Yamakita, 1987). The chert sequence is of deep-sea pelagic origin and occurs in a Jurassic accretionary complex. The sequence consists mainly of bedded radiolarian cherts. The Permian-Triassic boundary unit consists of gray siliceous and black carbonaceous claystone, about 30 m in thickness, and yields Late Permian radiolarians in the lower part and Early Triassic conodonts in the upper part. No Induan fossils, however, have been found in the boundary unit.

The Upper Permian and Lower Triassic carbonate sequence of pelagic origin is distributed in Kamura, Takachiho-cho, Nishiusuki-gun, Miyazaki Prefecture, Kyushu. All previous workers concluded that the sequence lacks the upper Changxingian and Induan.

As a result of my current investigation on the carbonate sequence in Kamura, I discovered Lower Triassic Griesbachian conodonts for the first time in Japan. They came from the basal part of the Kamura Formation. Furthermore, the same Griesbachian conodonts were also collected from the drilling core of the Taho Formation distributed in Tahokamigumi, Shirokawa-cho, Higashiuwa-gun, Ehime Prefecture. I describe herewith three Griesbachian conodont species from these sections and the lithologic characteristics of the carbonate rocks of both formations.

Previous biostratigraphic studies

The Taho Formation.—The carbonate rock of the Triassic Taho Formation occurs as exotic blocks in Jurassic clastic rocks and attains 54 m in total thickness at the type locality. This formation generally dips 10 to 20°N and the uppermost part is bounded by a fault from Jurassic conglomeratic sandstone, but the lower limit is not exposed.

The carbonate rock yields abundant conodonts throughout and corresponds to the Smithian to middle Anisian and late Carnian to Norian. The Ladinian to lower Carnian part can not be observed due to a fault (Koike, 1981, 1994).

The Smithian carbonate rock is composed of massive biomicrite in the lower part (10 m thick) and of thinly bedded, massive, and partly dolomitized biomicrite in the upper part (6 m thick). The biomicrite includes small thin-shelled bivalves, probably *Halobia*, *Daonella*, *Bositra*, and other monotids, radiolarians, and subordinate echinoderm spines and crusts.

Anasibirites kingianus inaequicostatus (Waagen), *Meekoceras japonicus* (Shimizu and Jimbo), and other ammonoids and bivalves *Anodontophora* sp. and *Eumorphotis* sp. occur in the uppermost level of the Smithian (Bando, 1964). Conodonts *Neospathodus dieneri* Sweet and *Ellisonia triassica* Müller occur throughout the levels, and *N. waageni* Sweet and *N. conservativus* (Müller) occur in the upper part (Koike, 1981, 1990).

The Kamura Formation.—The Permian-Triassic limestone exposed in Kamura is also an exotic block in Jurassic clastic rocks and is about 100 m in maximum thickness. It extends about 5 km in a NE-SW direction with a nearly vertical dip. The upper and the lower limits of the limestone are in fault contact with mudstone of Jurassic or chert of Permian or Triassic age.

The Permian carbonate rock was divided into two formations, the Iwato and Mitai Formations in ascending order, by Kanmera and Nakazawa (1973) and Working Group on Permian-Triassic Systems [W.G.P.T.S.] (1975).

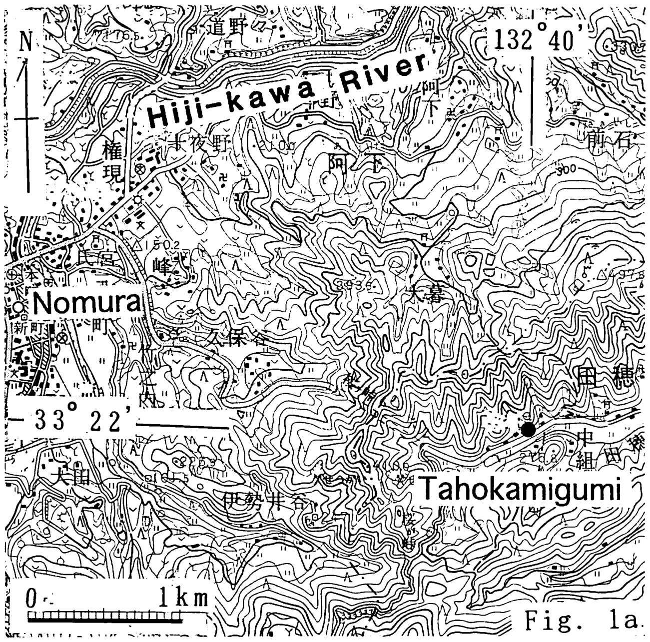
The Iwato Formation yields *Neoschwagerina megaspherica* Deprat, *Yabeina* cf. *katoi* (Ozawa) and other fusulinids which indicate the Middle Permian (Saito *et al*., 1958).

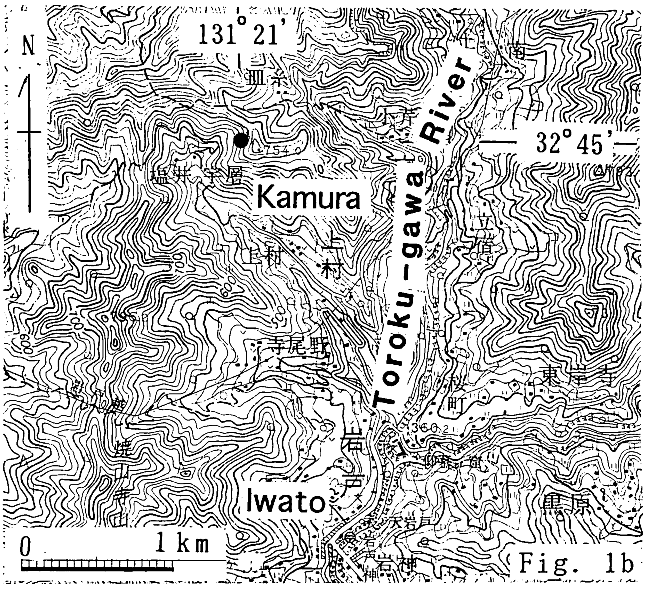
The Mitai Formation (43 m thick) includes the *Palaeofusulina* sp.-*Reichelina changhsingensis* Assemblage in the lower 15 m and the *Nankinella* sp. B-*Staffella* sp. B Assemblage in the upper 28 m. The *Palaeofusulina* sp.-*Reichelina changhsingensis* Assemblage contains *Palaeofusulina* sp., *Reichelina changhsingensis* (Sheng and Chang), and *Codonofusiella kueichoensis* Sheng. The assemblage was correlated with the lower Changxingian in South China. The *Nankinella* sp. B-*Staffella* sp. B Assemblage includes *Nankinella* sp. B, *Stafella* sp. A, *S*. sp. B, *Codonofusiella* sp., and *Dunbarula* ? sp. The assemblage was correlated with the middle to upper Changxingian in South China (Kanmera and Nakazawa, 1973; W.G.P.T.S., 1975).

The Triassic Kamura Formation yields conodonts throughout the levels and bivalves and ammonoids in part. A detailed study on conodonts by Watanabe *et al*. (1979) revealed that the limestone is of Smithian to Norian age.

The Lower Triassic limestone is composed of massive or thinly bedded biomicritic limestone and dolomitized biomicrite including thin-shelled bivalves and ammonoids.

Kambe (1963) described the following mollusks from about 6 to 20 m above the base of the Kamura Formation: *Eumorphotis multiformis* (Bittner), *Pteria ussurica yabei* Nakazawa, *Leptochondria* cf. *minima* (Kiparisova), *Unionites canalensis* Catullo, and *U. fassaensis* (Wissmann). The following ammonites were reported by Kambe (1963) and W.G.P.T.S. (1975) in the same horizon: *Clypites japonicus* Kambe, *Aspenites kamurensis* Kambe, *Parahedenstroemia* sp., *Meekoceras* cf. *gracilitatus* White, and *Koninckites* sp. Kambe (1963), W.G.P.T.S. (1975), and Nakazawa *et al*. (1994) referred this fauna of bivalves and ammonoids to the lower Owenitan (Smithian).





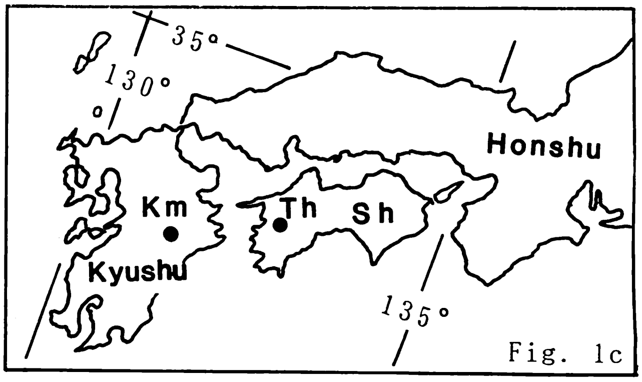


Figure 1. Maps showing locations of the study sections. **1a.** Solid circle shows location of core section at Tahokamigumi, Shirokawa-cho, Higashiuwa-gun, Ehime Prefecture. **1b.** Solid circle shows Kamura outcrop section at Kamura, Takachiho-cho, Nishiusuki-gun, Miyazaki Prefecture. **1c.** Index map. Th: Tahokamigumi, Km: Kamura, Sh: Shikoku. (1a and 1b are a part of 1 : 50,000 topographic maps of "Unomachi" and "Mitai" published by Geographical Survey Institute of Japan).

Neospathodus dieneri Sweet, *N*. sp. A and other conodonts were reported from the same horizon by Watanabe *et al*. (1979).

The boundary between the Upper Permian Mitai Formation and the Lower Triassic Kamura Formation was regarded as disconformable and the Griesbachian and Dienerian strata are absent (Kanmera and Nakazawa, 1973 ; Watanabe *et al*., 1979).

Biostratigraphy and lithofacies of the Upper Permian and Lower Triassic

Tahokamigumi section.—In order to get information about the Permian-Triassic boundary, drilling was conducted at Tahokamigumi in 1994. The drilling point is shown in Figure 1. The diameter of the drilling core is 70 mm and the well was bored for 50 m downward from the ground surface. As the general dip of the carbonate rock is 20° to 30°, the core penetrated the carbonate rock nearly perpendicular to the bedding. The upper 23 m belongs to the Triassic, the lower 27 m to the Permian. The Griesbachian conodont *Hindeodus parvus* (Kozur and Pjatakova) and ?*Isarcicella isarcica* (Huckriede) occur in the level of 22.80 to 22.90 m beneath the ground surface, together with *Hindeodus minutus* (Ellison) which ranges from the underlying Permian Shirokawa Formation newly proposed herein. The carbonate rock including Griesbachian conodonts is massive, dark gray, carbonaceous micrite with small shells of gastropods and carapaces of ostracodes.

The dark gray micrite is conformably underlain by massive, light gray micrite at the level of 23.45 m beneath the ground surface. The light gray micrite yields a fusulinid *Staffella* sp. with other foraminifers and calcareous algae at the uppermost part. Thus, the boundary between the dark gray micrite and light gray micrite represents the Permian-Triassic boundary.

The Permian-Triassic boundary can be easily distinguished by a remarkable contrast in color of carbonate rocks. The Permian carbonate rock is light gray to white, while the Triassic carbonate rock is dark gray. The basal part of the Taho Formation as well as the uppermost part of the Shirokawa Formation is highly dolomitized. Very thin calcite veins and stylolites are observed along most of the boundary. As far as observed in the field, however, there is no sign of a remarkable unconformity.

?*Neospathodus kummeli* Sweet and *N. dieneri* Sweet appear in the light gray dolomitic micrite, 6 m above the base of the Taho Formation. Coexistence of the two mentioned conodont species represents a Dienerian age.

The columnar section illustrated in Figure 2 shows lithofacies and the occurrence of fusulinids, conodonts, and mollusks near the Permian-Triassic boundary in the study section.

Kamura section.—The upper Permian Mitai Formation and the Triassic Kamura Formation were studied in detail in this study along Section I of Watanabe *et al*. (1979). In Section I, the Mitai Formation is highly dolomitized in the uppermost part and fossils are barren. *Dunbarula* sp., ?*Leella* sp., and *Staffella* sp. occur in the level about 8 m beneath the top of the Mitai Formation. These fusulinids are characteristics of the *Nankinella* sp. B-*Staffella* sp. A Assemblage proposed by W.G.R.T.S. (1975).

The basal 3 m of the Kamura Formation is represented by dark gray micritic limestone. The limestone yields Griesbachian conodonts, *Hindeodus parvus* (Kozur and Pjatakova) and *Isarcicella isarcica* (Huckriede), with *Hindeodus minutus* (Ellison) and *Neogondolella carinata* (Clark) that range down to the Upper Permian. The limestone considerably resembles Griesbachian conodont-bearing carbonate rock of the Taho Formation in lithofacies and in containing small shells of gastropods and carapaces of ostracodes. The carbonate rock at the level 3 to 6 m above the base is light gray dolomitic micrite and is partly intercalated with dark gray micrite. The dark gray micrite appears similar lithologically to the micrite in the basal part. The light gray micrite includes small and thin-shelled bivalves and calcareous algae. Conodonts have not yet been found in this part.

The carbonate rock 6 to 12 m above the base is light gray, partly dolomitized micrite with large and fairly thick-shelled bivalves. The bivalves include *Eumorphotis multiformis* (Bittner), *Pteria ussurica yabei* (Nakazawa), *Unionites canalensis* Catullo and others. Besides the bivalves, ammonoids *Clypites japonicus* Kambe, *Aspenites kamurensis* Kambe, and *Meekoceras* cf. *gracilitatus* White occur in this portion (Kambe, 1963 ; W.G.P.T.S. 1975). The bivalve and ammonoid faunas were considered to indicate a probable Owenitan age (Kambe, 1963 ; Nakazawa *et al*., 1994). Conodonts have not yet been obtained from this section, but *Neospathodus dieneri* (Sweet) occurs in the same level in Section III of Watanabe *et al*. (1979). There is a possibility that this portion is of Dienerian age because the Smithian conodonts such as *Neospathodus waageni* (Sweet), *N. bicuspidatus* (Müller), and *N. conservativus* (Müller) appear above the level.

The boundary between the Upper Permian Mitai and Lower Triassic Kamura Formations can be easily distinguished in the field by the contrasting color of the limestones, namely, light gray to white dolomitic micrite of the Mitai Formation vs dark gray micrite of the Kamura Formation. Under the microscope, stylolite occurs along the boundary. There is no evidence, however, indicating disconformity such as erosional surfaces or basal conglomerate immediately above the Mitai Formation.

Conodont biostratigraphy of the Lower Triassic in the Tethyan region

The Griesbachian is characterized by the occurrence of *Hindeodus parvus* and *Isarcicella isarcica* in association with *Hindeodus minutus* and/or *Neogondolella carinata* which range down to the Permian or Carboniferous (Sweet, 1970b ; Kozur and Mostler, 1973). The *Hindeodus parvus* Zone and the *Isarcicella isarcica* Zone, in ascending order, were proposed for the lowermost two biozones of the Triassic in several areas (e.g., Matsuda, 1981). The *Hindeodus parvus* and *Isarcicella isarcica* Zones are characterized by the first appearance of *Hindeodus parvus* and *Isarcicella isarcica*, respectively. The *Neogondolella carinata* Zone is proposed

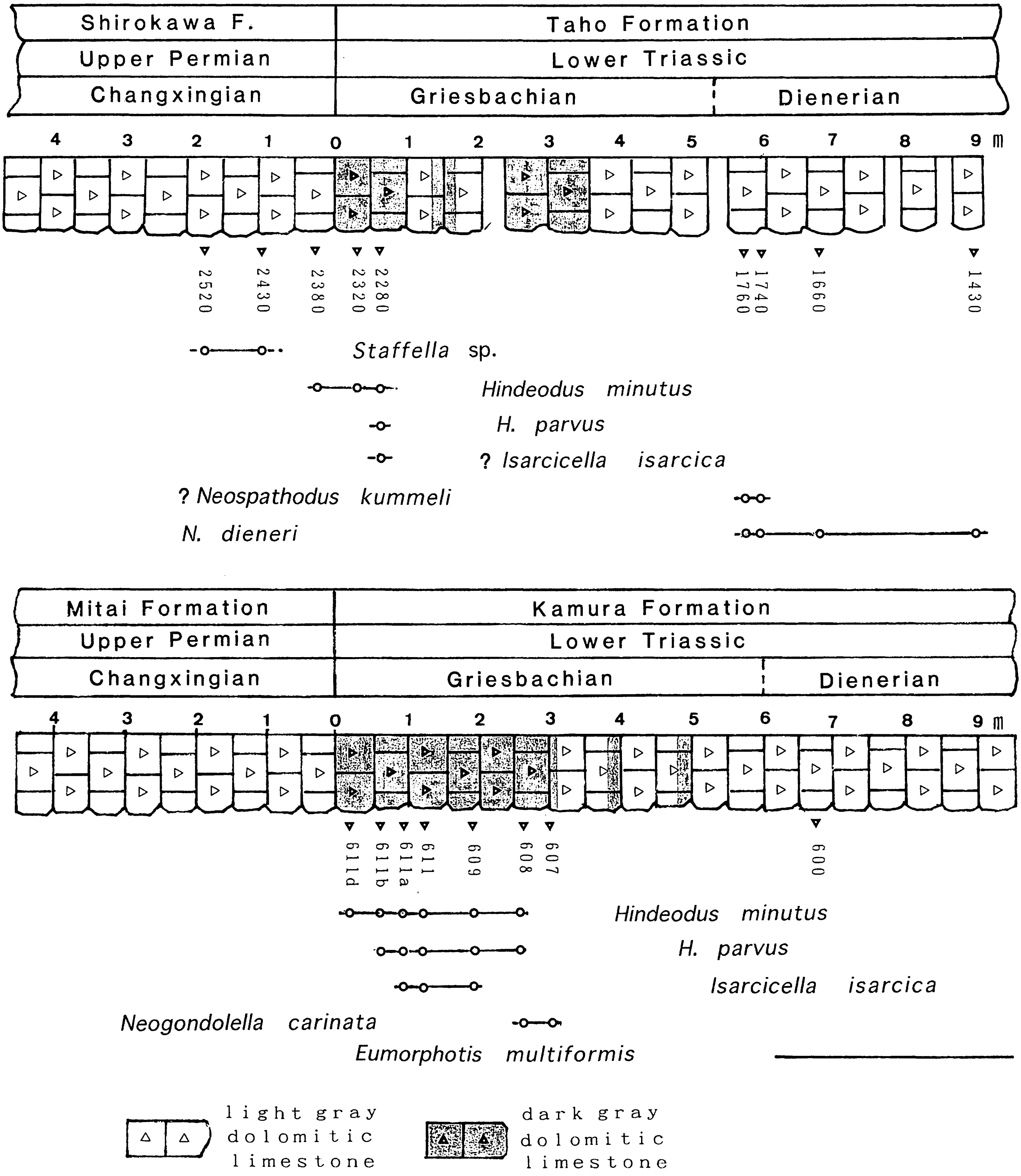


Figure 2. Columnar sections and vertical distribution of conodonts, foraminifers, and molluscs near the Permian-Triassic boundary in the Tahokamigumi and Kamura sections.

in some areas above the *Isarcicella isarcica* Zone, which is marked by the occurrence of *Neogondolella carinata* without any Dienerian conodonts such as *Neospathodus dieneri* or *N. kummeli* (Sweet, 1970b).

In the Southern Alps, the occurrence of *Hindeodus parvus* with *H. minutus* characterizes the lower part of the Tesero Horizon (oolitic units) of the basal Werfen Formation and *H. parvus* ranges upward to the limestone of the Mazzin or Seis Member of the Werfen Formation (Schönlaub, 1991). The occurrence of *Isarcicella isarcica* is restricted within the upper part of the range of *Hindeodus parvus* (Schönlaub, 1991). The Tesero Horizon includes foraminifers and brachiopods of a Permian aspect with Triassic pelecypods and gastropods in the lower part. The Tesero Horizon and the lower part of the Mazzin Member are referred to the *Otoceras* Zone. The upper part of the Mazzin Member including *Isarcicella isarcica* with the *Claraia wangi*-*C. griesbachi* Assemblage was correlated to the *Ophiceras* Zone (e.g., Schönlaub, 1991).

In the Abadeh region, Central Iran, *Hindeodus parvus* occurs with *Xenodiscus* sp. in the Stromatolite Limestone just above the boundary clay yielding *Claraia* sp. The boundary clay and the Stromatolite Limestone are regarded as the *Hindeodus parvus* Zone and correlated to the upper part of the *Otoceras woodwardi* Zone. *Isarcicella isarcica* occurs with ammonoids referable to *Ophiceras* in alternating beds of limestone and shale overlying the Stromatolite Limestone (Iranian-Japanese Research Group, 1981).

In the Salt Range, Pakistan, the *Hindeodus parvus* Zone and the *Isarcicella isarcica* Zone correspond to the dolostone of the middle unit of the Kathwai Member yielding *Ophiceras connectens* Schindewolf (Pakistan-Japanese Research Group (PJRG), 1985). PJRG (1985) correlated the *Hindeodus parvus* Zone and the *Isarcicella isarcica* Zone with the upper part of the *Otoceras woodwardi* Zone and the *Ophiceras tibeticum* Zone, respectively, and concluded that the middle unit paraconformably overlies the dolostone of the lower unit containing Permian-type brachiopods and foraminifers and that the lower part of the *Otoceras woodwardi* Zone is probably missing in this region.

In Guryul Ravine, Vihi District of Kashmir, India, the *Hindeodus parvus* Zone occupies the upper half of unit E_2 of the Khunamuh Formation which is composed of shale intercalating limestone layers and yields *Otoceras woodwardi* Griesbach. The *Isarcicella isarcica* Zone and the *Neogondolella carinata* Zone occupy almost all of unit E_3 which is constituted by shale intercalating limestone layers and yields *Ophiceras tibeticum* Griesbach. The *Hindeodus parvus* Zone and the *Isarcicella isarcica* Zone were correlated to the upper part of the *Otoceras woodwardi* Zone and the *Ophiceras tibeticum* Zone, respectively (Nakazawa *et al*., 1975). Unit E_1, the basal unit of the Khunamuh Formation, is composed of shale intercalating limestone layers as well as unit E_2 and contains Permian type brachiopods and bivalves with *Claraia bioni* Nakazawa and *Hypophyceras* ? sp. Nakazawa *et al*. (1975) regarded unit E_1 as the Upper Permian. Teichert *et al*. (1970) and Nakazawa (1993), however, referred unit E_1 to the basal part of the Triassic.

In the Selong section, South Tibet, *Hindeodus parvus* coexists with *Otoceras latilobatum* in the lower part of the lower half of unit 5 and with *O. woodwardi* in the upper part of the lower half of unit 5, the basal part of the Kangshare Formation. The upper half of unit 5 was referred to the *Neogondolella carinata* Zone and includes *Ophiceras tibeticum* with *Neogondolella carinata* (Wang *et al*., 1989). According to Orchard (1994), *Isarcicella isarcica* occurs slightly higher in the same bed (Orchard, 1994).

In the Meishan section in Changxing, South China, *Hindeodus parvus* first appears at the base of bed 27 and ranges into bed 28 of the Yinkeng Formation. Bed 26 (mixed bed 1 or lower transitional bed) just below bed 27 includes Permian type brachiopods, foraminifers, and conodonts, plus *Otoceras* ? sp., *Hypophiceras* sp., and claraiids (Zhang, 1987 ; Yin *et al*., 1994). The *Hindeodus parvus* Zone occupying bed 27 and bed 28 was referred to the upper *Otoceras* Zone and bed 26 was correlated to the lower *Otoceras* Zone (Yin *et al*., 1994).

Considering the biostratigraphic studies mentioned above, the correlation of conodont zones with standard ammonoid zones has not yet been sufficiently clearly established. The base of the *Hindeodus parvus* Zone has been located at the base of the *Otoceras latilobatum* Zone in South Tibet, at the base of the "*Otoceras*" Zone in the Southern Alps, within the "*Otoceras*" Zone or at the base of the "*Otoceras woodwardi*" Zone in South China, within the "*Otoceras woodwardi*" Zone above the *O. latilobatum* Zone in Central Iran, in the Salt Range, Pakistan, and in Kashmir, India. Recently, there is a tendency to apply *Hindeodus parvus* as an index fossil of the Permian-Triassic boundary (Permian-Triassic Boundary Working Group, 1994).

The base of the *Isarcicella isarcica* Zone has been proposed in the *Otoceras latilobatum* Zone in South Tibet, near the base of the *Ophiceras* Zone in the South Alps, in Central Iran, in the Salt Range, and in Kashmir, India.

In the Kamura section, *Hindeodus parvus* and *Isarcicella isarcica* occur 60-260 cm and 90-190 cm above the base of the Kamura Formation, respectively. *Hindeodus minutus* occurs just above the base and ranges upward to 260 cm above the base. *Neogondolella carinata* ranges higher up to 300 cm above the base of the formation. The biostratigraphic succession in the occurrence of conodont species in the Kamura Formation accords with that in the several sections in the Tethys Realm mentioned above. Consequently, the base of the Kamura Formation is regarded as representing the base of the Triassic, and the basal 300 cm of the formation is undoubtedly the Griesbachian. In the Tahokamigumi section, the occurrence of *Hindeodus parvus* is restricted to just around 45 cm above the base of the Taho Formation. However, the basal 340 cm of the formation probably represents the Griesbachian, judging from the lithofacies similar to that characterizing the Griesbachian in the Kamura Formation.

Systematic paleontology

Order Conodontophorida Eichenberg, 1930

Genus ***Hindeodus*** Rexroad and Furnish, 1964

Hindeodus minutus (Ellison, 1941)

Figures 3-1, 2

Spathognathodus minutus Ellison, 1941, p. 120, pl. 20, figs. 50-52.
Anchignathodus minutus (Ellison). von Bitter, 1972, p. 65-66, pl. 6, figs. 2a-i; Wang and Dai, 1981, pl. 1, figs. 3-4; Zhao *et al*., 1981, pl. 7, figs. 1, 3; Duan, 1987, pl. 3, fig. 10; Jiang, 1988, pl. 2, figs. 5a-b.
Ozarkodina minuta (Ellison). Baesemann, 1973, p. 704-706, pl. 2, figs. 1-15, 19, 20.
Hindeodus minutus (Ellison). Matsuda, 1981, p. 78-91, pl. 1, figs. 1-13, pl. 2, figs. 1-12, pl. 3, figs. 1-13, pl. 4, figs. 1-12; Matsuda, 1985, pl. 1, fig. 1; Wang and Higgins, 1989, p. 279, pl. 13, figs. 6-7; Schönlaub, 1991, pl. 1, fig. 10; Wang and Cao, 1993, p. 253, pl. 55, figs. 4-7.
Anchignathodus typicalis Sweet, 1970a, p. 7-8, pl. 1, figs. 13, 22.
Hindeodus typicalis (Sweet). Sweet in Ziegler, 1977, p. 223-224, pl. 2, figs. 1-6; Paul, 1982, figs. 5-5, 7, 10, 12-13, 15; Perri and Andraghetti, 1987, p. 308-309, pl. 32, figs. 1-5; Beyers and Orchard, 1991, pl. 4, figs. 1, 4; Kozur, 1992, p. 102-103, fig. 19.
Ellisonia teicherti Sweet, 1970a, p. 8, pl. 1, figs. 3-4, 7-8, 12; Zhao *et al*., 1981, pl. 7, figs. 4, 14, 22-24.

Remarks.—Detailed synonymy was given by Matsuda (1981) and Wang and Higgins (1989). The multielement species *Hindeodus minutus* consists of six elements, Pa, Pb, M, Sa, Sb, and Sc elements. The Pa element has been treated as a form species *Spathognathodus minutus* since Ellison (1941) described it. On the other hand, the Pb, M, Sa, Sb, and Sc elements were referred to the quinquimembrate skeletal apparatuses of *Ellisonia teicherti* by Sweet (1970a). Baesemann (1973) regarded *S. minutus* as one element of the multielement species *Ozarkodina minuta*. Since then, most workers have followed Baesemann's opinion. However, there remains complicated confusion in naming of the genus and species.

Sweet (1970a) proposed the unimembrate species *Anchignathodus typicalis* composed of the Pa element. However, Sweet (1977) ascribed *A. typicalis* as the Pa element of the seximembrate genus *Hindeodus* as well as *S. minutus*. Sweet (1977) distinguished *Hindeodus minutus* and *H. typicalis* based on the ratio of length to width, denticulation, and lateral profile of the upper margin of blade. On the other hand, Matsuda (1981) regarded *H. typicalis* as a synonym of *H. minutus* because several morphologic characters of the former fall within the variation of the latter.

Each of the six elements of *H. minutus* illustrated by Baesemann (1973) and Matsuda (1981) and *H. typicalis* by Sweet (1977) is considerably similar in morphology, and these two species are difficult to distinguish. I refer *H. typicalis* as a junior synonym to *H. minutus*.

Material studied.—Two specimens of Pa element from Taho Formation; 13, 8, 12, 31, 23, and 12 specimens of M, Sa, Sb, Sc, Pa, and Pb elements, respectively from Kamura Formation.

Repository.—YNUC15759-15760

Hindeodus parvus (Kozur and Pjatakova, 1975)

Figures 3-3—15

Spathognathodus isarcicus Huckriede. Staesche, 1964, p. 288-289, figs. 60-61.
Anchignathodus isarcicus (Huckriede). Sweet in Teichert *et al*., 1973, p. 424, 426, pl. 11, fig. 5; Clark *et al*., 1979, pl. 1, fig. 19.
Isarcicella isarcica (Huckriede). Sweet in Ziegler, 1977, p. 229-230, morphotype 1 in text-fig. "Terminology of *Isarcicella* Kozur 1975" in p. 225; Perri and Andraghetti, 1987, p. 309-311, pl. 32, figs. 6-7.
Anchignathodus parvus Kozur and Pjatakova. Kozur, 1975, p. 7-9, pl. 1, figs. 17, 19, 20, 22; Kozur *et al*., 1975, p. 4, pl. 1, figs. 6, 12-15, pl. 7, figs. 7, 9; Kozur and Pjatakova, 1976, p. 123-125, figs. 1a-e, non lg-h; Kozur, 1977, p. 1120-1121, figs. 17, 19, 20; Wang and Dai, 1981, p. 141, pl. 1, figs. 13, 14; Duan, 1987, pl. 3, figs. 2, 3; Jiang, 1988, pl. 2, fig. 8; Beyers and Orchard, 1991, pl. 4, figs. 2-3.
Hindeodus parvus (Kozur and Pjatakova). Matsuda, 1981, p. 91-93, pl. 5, figs. 1-3; Matsuda, 1985, pl. 1, fig. 2; Schönlaub, 1991, pl. 1, figs. 12-14, 18-25; Wang, Z. and Cao, 1993, p. 253-254, pl. 55, figs. 1-3; Wang, C.Y., 1994, pl. 1, figs. 1-2 (Morphotype 1), figs. 3-5 (Morphotype 2).

Remarks.—The Pa element of *Hindeodus parvus* is closely similar to that of *H. minutus* which has a large and high cusp. However, the cusp of *H. parvus* is higher and sometimes bowed posteriorly.

Kozur and Pjatakova (1976) illustrated a neoprioniodiniform (M) element and hindeodelliform (Sc) element with a spathognathodiform (Pa) element. The M and Sc elements coincide with those of *H. minutus*. Permian-Triassic Boundary Working Group (1994) emphasized that *H. parvus* is a seximembrate species. However, the five elements other than the Pa element of *H. parvus* have never been figured or described.

More than 140 specimens of the Pa element of *H. parvus* have been collected in association with 23 Pa elements of *H. minutus* from the basal part of the Kamura Formation. The ramiform elements occur in very small numbers and these elements seem to belong to *H. minutus*. According to Matsuda (1981), ramiform elements of *H. parvus* have not been confirmed in the sample from the Guryul Ravine section in Kashmir. Accordingly, it is probable that *H. parvus* is a unimembrate species.

Sweet (1977) suggested that the genus *Hindeodus* was seximembrate. Therefore, *H. parvus* does not belong to typical *Hindeodus*.

Some workers (e.g., Sweet, 1977; Sweet *et al*., 1992) included *H. parvus* in *Isarcicella* proposed by Kozur (1975) because *H. parvus* is a unimembrate species composed of a Pa element, like *Isarcicella*, and it resembles *Isarcicella isarcica* in morphologic characters. However, *H. parvus* is not a typical *Isarcicella*, whose Pa element is characterized by one or two long denticles on either or both sides of the upper surface of the basal expansion.

I therefore treat '*parvus*' as a *Hindeodus* because it is morphologically very like the Pa element of *H. minutus*.

Material studied.—Two specimens from Taho Formation, 146 specimens from Kamura Formation.

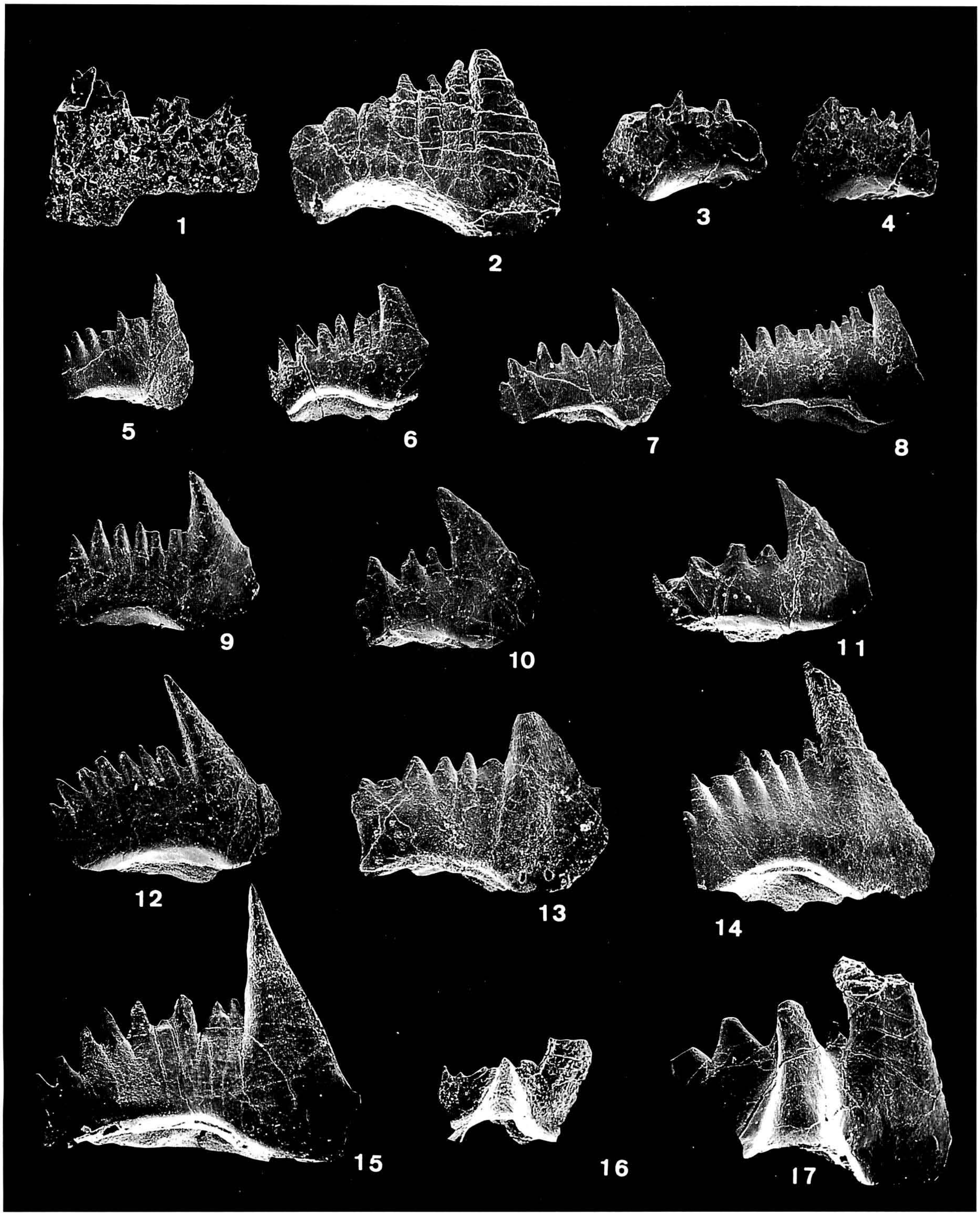


Figure 3. Griesbachian conodonts from the Tahokamigumi and Kamura sections. All×100. **1, 2.** *Hindeodus minutus* (Ellison), 1 : YNUC15759 from Taho Formation, 2 : YNUC15760 from Loc. 611d, Kamura Formation. **3-15.** *Hindeodus parvus* (Kozur and Pjatakova) from Kamura Formation except for 3-4 from Taho Formation, 3-4 : YNUC15761-15762, 5 : YNUC15763 from Loc. 611a, 6 : YNUC15764 from Loc. 611, 7 : YNUC15765 from Loc 611a′, 8 : YNUC15766 from Loc. 611, 9-10 : YNUC15767-15768 from Loc. 611a, 11 : YNUC15769 from Loc. 611a′, 12-15 : YNUC15770-15773 from Loc. 611a. **16-17.** *Isarcicella isarcica* (Huckriede), 16 : YNUC15774 from Loc. 609, 17 : YNUC15775 from Loc. 611a′ of Kamura Formation.

Repository.—YNUC15761-15773

Genus ***Isarcicella*** Kozur, 1975

Isarcicella isarcica (Huckriede)

Figures 3-16, 17

Spathognathodus isarsicus Huckriede, 1958, p. 162, pl. 10, figs. 6, 7a-7c; Staesche, 1964, p. 288-289, figs. 62-64; Hirsch and Süssli, 1973, p. 528, pl. 1, figs. 1-2.

Anchignathodus isarcicus (Huckriede). Sweet, 1970b, p. 233-224, pl. 1, figs. 18-19; Sweet in Ziegler, 1973, p. 13-14, *Anchignathodus* pl. 1, fig. 1; Sweet in Teichert *et al*., 1973, p. 424, 426, pl. 11, figs. 6, 7; Clark *et al*., 1979, pl. 1, fig. 19.

Isarcicella isarcicus (Huckriede). Kozur, 1975, p. 11-12, pl. 1, fig. 18; Kozur *et al*., 1975, p. 6-7, pl. 7, figs. 3-6, 8; Kozur, 1977, fig. 18.

Isarcicella isarcica (Huckriede). Sweet in Ziegler, 1977, p. 229-230, morphotypes 2 and 3 in text-fig. "Terminology of *Isarcicella* Kozur 1975" in p. 225; Kozur, 1978, pl. 8, figs. 23, 28; Matsuda, 1981, p. 93-94, pl. 5, figs. 4-7; Wang and Dai, 1981, p. 142-143, pl. 2, figs. 9-11; Paull, 1982, figs. 5-14, 16-19; Matsuda, 1985, pl. 1, fig. 3; Jiang, 1988, pl. 2, figs. 9a-b; Schönlaub, 1991, pl. 2, figs. 5-10, 12; Wang, Z. and Cao, 1993, p. 254, pl. 55, figs. 8-9.

Remarks.—The material referred to this species from the Kamura Formation carries a large lateral denticle on one side of the upper surface of the widely expanded cavity. This morphological feature is well assigned to this species.

Studied material.—Three specimens from Kamura Formation. A questionable specimen from Taho Formation.

Repository.—YNUC15774-15775

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References cited

Baesemann, J.F., 1973: Missourian (Upper Pennsylvanian) conodonts of northeastern Kansas. *Journal of Paleontology*, vol. 47, no. 4, p. 689-710.

Bando, Y., 1964: The Triassic stratigraphy and ammonite fauna of Japan. *Science Report of the Tohoku University, Second Series* (*Geology*), vol. 36, no. 5, p. 1-137.

Beyers, J.M. and Orchard, M.J., 1991: Upper Permian and Triassic conodont faunas from the type area of the Cache Creek Complex, south-central British Columbia, Canada. *In*, Orchard, M.J. and McCracken, A.D. *eds*., *Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera*. *Geological Survey of Canada, Bulletin* 417, p. 269-297.

Clark, D.L., Paull, R.K., Solien, M.A. and Morgan, W.A., 1979: Triassic conodont biostratigraphy in the Great Basin. *In*, Sandberg, C.A. and Clark, D.L. *eds*., *Conodont Biostratigraphy of the Great Basin and Rocky Mountains*. *Brigham Young University Geology Studies*, vol. 26, pt. 3, p. 179-183.

Duan, J., 1987: Permian-Triassic conodonts from southern Jiangsu and adjacent areas, with indexes of their colour alteration. *Acta Micropalaeontologica Sinica*, vol. 4, no, 4, p. 351-368. (*in Chinese*)

Ellison, S.P. Jr., 1941: Revision of Pennsylvanian conodonts. *Journal of Paleontology*, vol. 15, p. 107-143.

Hirsch, F. and Süssli, P., 1973: Lower Triassic conodonts from the Lower Elikah Limestone, Central Alborz Mountains (North Iran). *Eclogae Geologicae Helvetiae*, vol. 66, no. 3, p. 525-531.

Huckriede, R., 1958: Die Conodonten der mediterranen Trias und ihr stratigraphischer Wert. *Paläontologische Zeitschrift*, vol. 32, no. 3/4, p. 141-175.

Iranian-Japanese Research Group, 1981: The Permian and the Lower Triassic Systems in Abadeh region, Central Iran. *Memoirs of the Faculty of Science, Kyoto University, Series of Geology and Mineralogy*, vol. 47, p. 61-133.

Jiang, W., 1988: Research on Upper Permian conodonts in Sichuan Basin and its significance to oil and gas. *Journal of Southwestern Petroleum Institute*, no. 2, p. 1-9.

Kambe, N., 1963: On the boundary between the Permian and Triassic Systems in Japan. *Geological Survey of Japan, Report* no. 198, p. 1-66.

Kanmera, K. and Nakazawa, K., 1973: Permian-Triassic relationships and faunal changes in the eastern Tethys. *In*, Logan, A. and Hills, L.V. *eds*., *The Permian and Triassic Systems and Their Mutual Boundary*. *Canadian Society of Petroleum Geologists, Memoir* 2, p. 100-109.

Koike, T., 1981: Biostratigraphy of the Triassic conodonts in Japan. *Science Reports of the Yokohama National University, Section II* (*Biology and Geology*), no. 28, p. 25-42.

Koike, T., 1990: The conodont apparatus of *Ellisonia triassica* Müller. *Science Reports of the Yokohama National University, Section II* (*Biology and Geology*), no. 37, p. 35-46.

Koike, T., 1994: Skeletal apparatus and its evolutionary trends in a Triassic conodont *Ellisonia dinodoides* (Tatge) from the Taho Limestone, Southwest Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 173, p. 366-383.

Kozur, H., 1975: Beiträge zur Conodontenfauna des Perm. *Geologische und Paläontologische Mitteilungen, Innsbruck*, vol. 5, no. 4, p. 1-44.

Kozur, H., 1977: Revision der Conodontengattung *An-*

chignathodus und ihrer Typusart. *Zeitschrift für geologische Wissenschaften*, *Berlin*, vol. 5, p. 1113-1127.

Kozur, H., 1978 : Beiträge zur Stratigraphie des Perms. Teil II : Die Conodontenchronologie des Perms. *Freiberger Forschungheft C* 334, p. 85-161.

Kozur, H., 1992 : Dzhulfian and Early Changxingian (Late Permian) Tethyan conodonts from the Glass Mountains, West Taxas. *Neues Jahrbuch für Geologie und Paläontology*, *Abhandlungen*, vol. 187, no. 1, p. 99-114.

Kozur, H. and Mostler, H., 1973 : Beiträge zur Mikrofauna permotriadischer Schichtfolgen. Teil I : Conodonten aus der Tibetzone des Niederen Himalaya (Dolpogebiet, Westnepal). *Geologische und Paläontologische Mitteilungen*, *Innsbruck*, vol. 3, no. 9, p. 1-23.

Kozur, H., Mostler, H. and Rahimi-Yazd, A., 1975 : Beiträge zur Mikrofauna permotriadischer Schichtfolgen. Teil II : Neue Conodonten aus dem Oberperm und der basalen Trias von Nord- und Zentraliran. *Geologische und Paläontologische Mitteilungen*, *Innsbruck*, vol. 5, no. 3, p. 1-23.

Kozur, H. and Pjatakova, M., 1976 : Die Conodontenart *Anchignathodus parvus* n. sp., Eine wichtige Leitform der basalen Trias. *Koninklijk Nederlands Akademie van Wetenschappen—Amsterdam*, *Series B*, vol. 79, no. 2, p. 123-128.

Matsuda, T., 1981 : Early Triassic conodonts from Kashmir, India. *Journal of Geosciences, Osaka City University*, vol. 24, no. 3, p. 75-108.

Matsuda, T., 1985 : Late Permian to Early Triassic conodont paleobiology in the "Tethys Realm". *In*, Nakazawa, K. and Dickins, J.M. *eds.*, *The Tethys* : *Her Paleogeography and Paleobiogeography from Paleozoic to Mesozoic*. p. 157-170, Tokai University Press, Tokyo.

Nakazawa, K., 1993 : Stratigraphy of the Permian-Triassic transition and the Paleozoic/Mesozoic boundary. *Bulletin of Geological Survey of Japan*, vol. 44, no. 7, p. 425-445. (*in Japanese*)

Nakazawa, K., Ishibashi, T., Kimura, T., Koike, T., Shimizu, D. and Yao, A., 1994 : Triassic biostratigraphy of Japan based on various Taxa. *In*, Guex, J. and Baud, A. *eds.*, *Recent developments of Triassic stratigraphy*. *Mémoires de Géologie* (*Lausanne*), no. 22, p. 83-103.

Nakazawa, K., Kapoor, H.M., Ishii, K., Bando, Y., Okimura, Y. and Tokuoka, K., 1975 : The Upper Permian and the Lower Triassic in Kashmir, India. *Memoirs of the Faculty of Science*, *Kyoto University*, *Series of Geology and Mineralogy*, vol. 42, p. 1-106.

Orchard, M.J., 1994 : Conodonts from *Otoceras* beds. Are they Permian. *Albertiana*, vol. 13, p. 8-11.

Pakistan-Japanese Research Group, 1985 : Permian and Triassic Systems in the Salt Range and Surghar Range, Pakistan. *In*, Nakazawa, K. and Dickins, J.M. *eds.*, *The Tethys* : *Her Paleogeography and Paleobiogeography from Paleozoc to Mesozoic*, p. 221-312, Tokai University Press, Tokyo.

Paull, R.K., 1982 : Condont biostratigraphy of Lower Triassic rocks, Terrace Mountains, northwestern Utah. *Utah Geological Association*, *Publication* no. 10, p. 235-250.

Permian-Triassic Boundary Working Group, 1994 : Newsletter no. 3. *Albertiana*, vol. 14, p. 6-14.

Perri, M.C. and Andraghetti, M., 1987 : Permian-Triassic boundary and Early Triassic conodonts from the Southern Alps, Italy. *Rivista Italiana di Paleontologica e Stratigrafia*, vol. 93, no. 3, p. 291-328.

Saito, M., Kambe, N. and Katada, M., 1958 : 1/50,000 Geological sheet-map and explanatory text, Mitai. *Geological Survey of Japan*. (*in Japanese with English abstract*)

Schönlaub, H.P., 1991 : The Permian-Triassic of the Gartnerkofel-1 core (Carnic Alps, Austria) : conodont biostratigraphy. *In*, Holser, W.T. and Shönlaub, H.P. *eds.*, *The Permian-Triassic Boundary in the Carnic Alps of Austria* (*Gartnerkofel Region*). *Abhandlungen der Geologischen Bundesanstalt*, vol. 45, p. 79-98.

Staesche, U., 1964 : Conodonten aus dem Skyth von Sudtirol. *Neus Jahrbuch für Geology und Paläontologie*, *Abhandlungen*, vol. 119, no. 3, p. 247-306.

Sweet, W.C., 1970a : Permian and Triassic conodonts from a section at Guryul Ravine, Vihi district, Kashmir. *University of Kansas Paleontological Contributions*, *Paper* 49, 10 p.

Sweet, W.C., 1970b : Uppermost Permian and Lower Triassic conodonts of the Salt range and Trans-Indus ranges, West Pakistan. *In*, Kummel, B. and Teichert, C. *eds.*, *Stratigraphic Boundary Problems* : *Permian and Triassic of West Pakistan*. *Department of Geology*, *University of Kansas*, *Special Publication*, no. 4, p. 207-275.

Sweet, W.C., 1977 : Genus *Hindeodus* Rexroad and Furnish, 1964 and genus *Isarcicella* Kozur, 1975. *In*, Ziegler, W. *ed.*, *Catalogue of Conodonts*, vol. 3, p. 203-230, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Sweet, W.C., Zunyi, Y., Dickins, J.M. and Hongfu, Y., 1992 : Permo-Triassic events in eastern Tethys—an overview. *In*, Sweet, W.C., Zunyi, Y., Dickins, J.M. and Honghu, Y. *eds*. *Permo-Triassic Events in the Eastern Tethys*. p. 1-8, Cambridge University Press.

Teichert, C., Kummel, B. and Kapoor, H.M., 1970 : Mixed Permian-Triassic fauna, Guryul Ravine, Kashmir. *Science*, vol. 167, p. 174-175.

Teichert, C., Kummel, B. and Sweet, W.C., 1973 : Permian-Triassic strata, Kuh-e-Ali Bashi, northwestern Iran. *Bulletin of Museum of Comparative Zoology*, *Harvard University*, vol. 145, no. 8, p. 359-472.

von Bitter, P.H., 1972: Environmental control of conodont distribution in the Shawnee Group (Upper Pennsylvanian) of eastern Kansas. *University of Kansas Paleontological Contributions*, *Article* 59, p. 1-105.

Wang, C.Y., 1994 : A conodont-based high-resolution eventostratigraphy and biostratigraphy for the Permian-Triassic boundaries in South China. *Palaeoworld*, no. 4, p. 234-248.

Wang, Y., Chen, C., Rui, L., Wang, Z., Liao, Z. and He, J., 1989 : A potential global stratotype of Permian-Triassic boundary. *In*, *Developments in Geoscience*, p. 221-229. *Chinese Academy of Science*, *Contribution to 28th International Geological Congress, 1989, Washington D.C.*, Science Press, Beijing.

Wang, Z. and Cao, Y., 1993 : Triassic conodonts. *In*, Wang C.Y. *ed.*, *Conodonts of Lower Yangtze Valley. An Index to Biostratigraphy and Organic Metamorphic Maturity*, p. 249-267. Science Press, Peiping. (*in Chinese with English summary*)

Wang, Z. and Dai, J., 1981 : Triassic conodonts from the Jiangyou-Beichuan area, Shichuan Province. *Acta Palaeontologica Sinica*, vol. 20, no. 2, p. 138-150. (*in Chinese*)

Wang, Z. and Higgins, A.C., 1989 : Conodont zonation of the Namurian-Lower Permian strata in South Guizhou, China. *Palaeontologia Cathayana*, no. 4, p. 261-325.

Watanabe, K., Kanmera, K. and Nakajima, K., 1979 : Conodont biostratigraphy in the Kamura Limestone (Triassic), Takachiho-cho, Nishiusuki-gun, Miyazaki Prefecture. *Prof. Kanuma, M. Memorial Volume*, p. 127-137. (*in Japanese*)

Working Group on the Permian-Triassic Systems, 1975 : Stratigraphy near the Permian-Triassic boundary in Japan and its correlation. *Journal of Geological Society of Japan*, vol. 81, no. 3, p. 165-184. (*in Japanese*).

Yamakita, S., 1987 : Stratigraphic relationship between Permian and Triassic strata of chert facies in the Chichibu Terraine in eastern Shikoku. *Journal of Geological Society of Japan*. vol. 93, no. 2, p. 145-148. (*in Japanese*)

Yin, H., Wu, S., Din, M. and Zhang, K., 1994 : The Meishan section. Candidate of the global stratotype section and points of the Permian-Triassc boundary. *Albertiana*, vol. 14, p. 15-31.

Zhang, K.X., 1987 : The Permo-Triassic conodont fauna in Changxing area, Zhejiang province and its stratigraphic significance. *Earth Science-Journal of China University of Geosciences*, vol. 12, no. 2, p. 193-200. (*in Chinese with English abstract*)

Zhao, J., Sheng, J., Yao, Z., Liang, X., Chen, C., Rui, L. and Liao, Z., 1981 : The Changxingian and Permian-Triassic boundary of South China. *Bulletin of Nanjing Institute of Geology and Palaeontology, Academia Sinica*, no. 2, p. 1-85. (*in Chinese with English summary*)

Tahokamigumi 田穂上組, Shirokawa-cho 城川町, Higashiuwa-gun 東宇和郡, Kamura 上村, Takachiho-cho 高千穂町, Nishiusuki-gun 西臼杵郡

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1004 Pseudorthoceratid cephalopods from the Early Devonian Fukuji Formation of Gifu Prefecture, Central Japan

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Abstract. Seven species of Lochkovian (Early Devonian) pseudorthoceratid cephalopods are described and figured from the D1 member of the Fukuji Formation in Gifu Prefecture, central Japan. The fauna includes two pseudorthoceratines: *Fukujiceras kamiyai* gen. et sp. nov. and an indeterminate genus and species of the subfamily; four spyroceratines: *Spyroceras fukujiense* sp. nov., *Spyroceras melolineatum* sp. nov., *Hamadaites labyrinthus* gen. et sp. nov. and *Mitorthoceras ? kamitakarense* sp. nov.; and a cayutoceratine: *Buchanoceras* sp. The occurrence of Early Devonian pseudorthoceratids is first reported in Japan. The description of the new genera is made placing emphasis on ontogenetic variations, especially early juvenile shell morphology. The fauna may represent warm-temperate water conditions.

Key words: Pseudorthoceratid cephalopods, Fukuji Formation, Lochkovian, Devonian

Introduction

The Fukuji Formation is a mixed carbonate and fine clastic unit containing an exceptionally well-preserved and abundant Early Devonian fauna. Recent paleontological studies have revealed the presence of diverse mollusks, which previously received little attention (Kase *et al*., 1985, gastropod; Kase *et al*., 1987, hyolithid; Niko, 1990, 1991, 1993, cephalopods). The results have not merely taxonomic but also paleobiogeographic importance because of their being the only records of this age in Japan. This report describes seven cephalopod species belonging to the family Pseudorthoceratidae as a part of the study of the molluscan fauna from the Fukuji Formation. Devonian pseudorthoceratids are poorly known in Japan. Previously, only a single Middle Devonian (Eifelian) species *Geisonocerella nakazatoensis* Niko, 1989, from the Kitakami Mountains, northeast Japan has been recorded. Because of the fragile nature of orthoconic cephalopods, generic and specific diagnosis has usually been based upon fragmentary phragmocones. The discovery of this new material provides knowledge of early growth stages together with adult shells of four genera: *Fukujiceras* gen. nov., *Spyroceras, Hamadaites* gen. nov., and *Mitorthoceras* ?.

All specimens studied are deposited either in the University Museum, University of Tokyo (UMUT), or the Hida Museum of Natural History, Fukuji, Gifu Prefecture (HMNH).

Geologic setting and paleontologic significance

The material was collected from black to dark-gray calcareous shale, exposed in three localities on the southern flanks of the Ozako valley (FH-1) and eastern slope of Mt. Sora (FH-4 and FH-5) in the Fukuji area of Yoshiki-gun, Gifu Prefecture (Figure 1). Of these localities, FH-1 is situated in the type section of the D1 member (Niikawa, 1980), which is more than 60 m thick and represents the lowest part of the Fukuji Formation. Lithologically, cephalopod-bearing beds of the other two localities also can be referred to this member. The calcareous shale includes thin matrix-supported limestone lenses indicating a shallow neritic environment (Niko and Hamada, 1988). According to Kuwano (1987), intercalated limestone in the upper portion of this shale contains early to middle Lochkovian (Early Devonian) conodonts, such as *Icriodus postwoschmidti* Mashkoba, *I*. cf. *woschmidti woschmidti* Ziegler, and *Ozarkodina* spp.

Carbonate is the main component of the Fukuji Formation; however, its maximum thickness is only 60 m and it lacks carbonate ooids and/or aggregated grains. No evaporites have been recognized in the formation. Shallow-water conditions prevailed during deposition of the Fukuji Formation; however these strata are notably lacking in dasycladacean and/or codiacean green algae. Boundstones consisting of colonial corals, favositids, and tube-like stromatoporoids are common in the formation, but do not form large reefal buildups. Thus, the paleoclimate of Fukuji area was somewhat cooler compared with the tropical to subtropical provinces of the major Old World Realm of Boucot *et al*. (1988).

The Fukuji cephalopod fauna has no species in common with other regions. Of the 12 genera firmly recorded by Niko

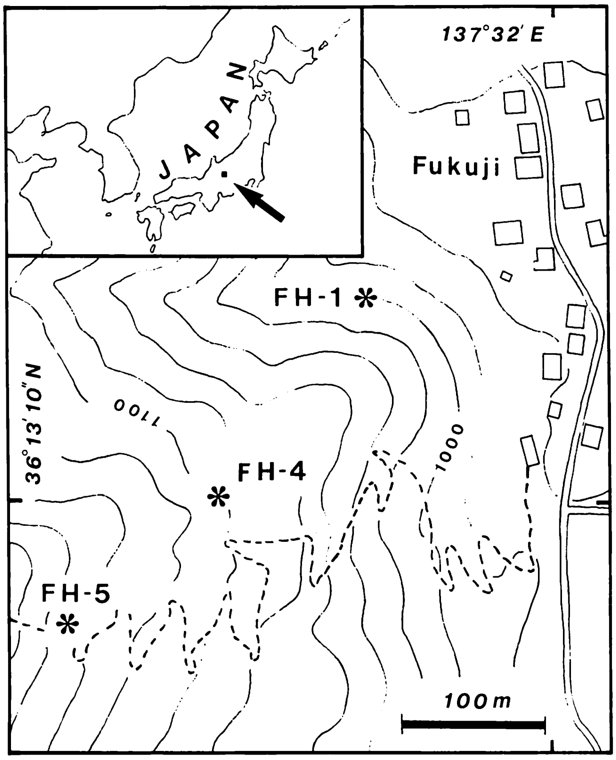

Figure 1. Index map of study area and fossil localities in the Fukuji Formation, Gifu Prefecture, central Japan.

(1990, 1991, 1993, and this report), *Fukujiceras*, *Hamadaites*, and *Plicatoceras* are endemic at the generic level. As noted by Crick (1990), this regional provincialism of Lochkovian age may be the result of habitat separation caused by a eustatic drop in sea level. The Fukuji cephalopod fauna is dominated by orthocerids with subordinate actinocerids, which are unusual for Early Devonian faunas. It is possible that this assemblage is typical of warm-temperate sea conditions in Early Devonian time (Hamada, 1961).

Systematic paleontology

Family Pseudorthoceratidae Flower and Caster, 1935
Subfamily Pseudorthoceratinae Flower and Caster, 1935
Genus ***Fukujiceras*** gen. nov.

Type species.—*Fukujiceras kamiyai* sp. nov., by monotypy.

Diagnosis.—Moderately expanding orthocones with exgastric early juvenile shell; adoral surface markings consist of flattened lirae; sutures straight, transverse; siphuncle nearly central, pyriform with suborthochoanitic septal necks in apical shell, then cylindrical form with suborthochoanitic to orthochoanitic septal necks, adoral siphuncle of expanded connecting rings and cyrtochoanitic septal necks; cameral deposits mural, episeptal-mural, hyposeptal; endosiphuncular deposits originated in mid-length of segments.

Etymology.—The generic name is derived from the Fukuji Formation, where the type species occurs.

Fukujiceras kamiyai sp. nov.

Figures 2-1—13

Diagnosis.—As for the genus.

Description.—Large-sized orthocones with moderate shell expansion, angle of expansion of juvenile shell 5.8 degrees, decreasing to 4.3-5.5 degrees adorally, cross section of shell circular, largest specimen (UMUT PM 19122) of body chamber attains approximately 50 mm (reconstructed) in diameter; early juvenile shell exhibits slightly exogastric curvature; ornamentation of transverse coarse lirae in juvenile shell, adorally becomes flat topped transverse lirae separated by narrow striae with weak sinuations and salients, this change occurs at shell of approximately 4 mm in diameter; sutures straight, transverse; body chamber long, at least 149.5 mm in length, having approximately 37 mm (reconstructed) shell diameter at last septum; cameral length approximately 2.3 mm in apical shell of holotype, width/length ratio approximately 1.7 in exogastric part, adorally increasing to 2.1-3.5; septa relatively shallow in juvenile shell, but adorally exhibiting moderately strong curvature; siphuncular position nearly central, shifting slightly towards venter; siphuncular segments exhibit three distinct types ontogenetically: 1) pyriform connecting rings with suborthochoanitic septal necks in early juvenile shell (up to 2.8 mm shell diameter), 2) cylindrical connecting rings with suborthochoanitic to orthochoanitic septal necks, 3) inflated, subcylindrical connecting rings, strongly contracted at septal foramen, with cyrtochoanitic septal necks (more than approximately 12 mm shell diameter); length of septal necks relatively short, 0.23 mm in orthochoanitic necks of holotype; except for ventral camerae of juvenile shell which have mural deposits, dominant cameral deposits episeptal-mural with mammiform growth,

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Figure 2. *Fukujiceras kamiyai* gen. et sp. nov. **1.** Paratype, UMUT PM 19113, lateral view of juvenile shell, venter on right, ×5, showing transverse coarse lirae. **2.** Paratype, UMUT PM 19117, lateral view of juvenile shell, venter on left, ×5. **3.** Paratype, UMUT PM 19112, ventral view, ×1.5. **4.** Paratype, UMUT PM 19116, ventral view, ×1.5. **5.** Paratype, UMUT PM 19115, ventral view, ×1.5. **6.** Paratype, UMUT PM 19143, ventral view, ×1. **7, 11, 12.** Holotype, UMUT PM 19111, 7: ventral view, silicone rubber cast, ×1.5, 11: dorsoventral thin section, venter on left, ×5, 12: detail of siphuncle, ×10, illustrating suborthochoanitic to orthochoanitic septal necks and endosiphuncular deposits. **8, 13.** Paratype, UMUT PM 19114, 8: detail of surface ornamentation, ×10, showing flat topped lirae, 13: dorsoventral thin section of adoral phragmocone, venter on right, ×10, showing cyrtochoanitic septal necks. **9, 10.** Paratype, UMUT PM 19117, early juvenile shell, venter on right, 9: dorsoventral thin section, ×20, showing suborthochoanitic septal necks and endosiphuncular doposits, 10: dorsoventral polished section, ×10, showing exogastric nature.


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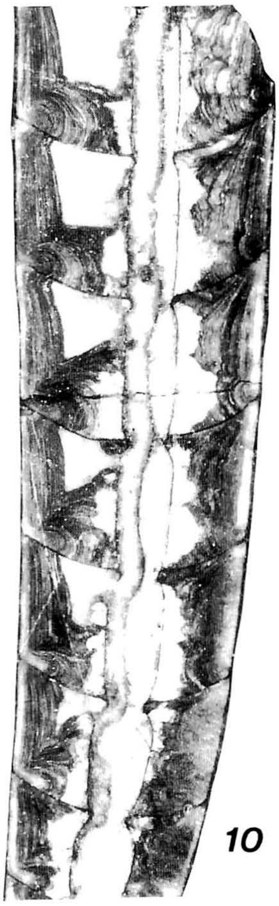
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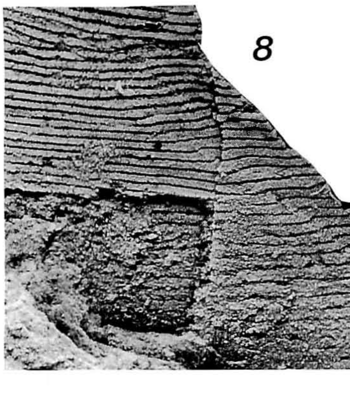
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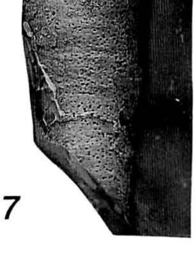
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additional hyposeptal deposits occur in adoral camerae; endosiphuncular deposits well developed, but restricted to ventral siphuncular wall, fusing, originating mid-length along segments and growing apically and adorally, forming broadly arched periphery in longitudinal section.

Discussion.—The morphology of the endosiphuncular deposits of *Fukujiceras kamiyai* gen. et sp. nov. is unusual for the Pseudorthoceratidae. A similar structure was recognized only in the type species of the genus *Pseudorthoceras* Girty, 1911, *P. knoxense* (McChesney, 1859) from the Pennsylvanian of the United States by Fisher and Teichert (1969, Pl. 2, fig. 4, text-fig. 1). In addition, the possession of an exogastric apical shell and the suborthochoanitic to orthochoanitic stages shifting to cyrtochoanitic stages of the septal necks in the siphuncular ontogeny of *Fukujiceras* suggest a relationship to *Pseudorthoceras*. However, *Fukujiceras* can be distinguished from this genus by its longer exogastric part of the shell, less inflated adoral siphuncular segments, and particularly by possession of the characteristic surface lirae.

Schindewolf (1944) erected the genus *Pseudocyrtoceras* based on *Cyrtoceras acus* (de Koninck, 1880, Pl. 35, figs. 6, 7, Pl. 36, fig. 3) from the Lower Carboniferous of Belgium, which has a similar apical shell shape to *Fukujiceras kamiyai* and ventrally restricted endosiphuncular deposits. It differs from *Fukujiceras kamiyai* in the subglobular siphuncular segments in the adoral shell, greater angle of expansion of the shell, and lack of surface ornamentation.

The Lochkovian species *Fukujiceras kamiyai* is one of the earliest known member of the Pseudorthoceratinae.

Etymology.—The specific name honors T. Kamiya (Kasugai, Aichi Prefecture), who discovered this cephalopod.

Material.—The holotype, UMUT PM 19111, is an incomplete phragmocone. The following 13 paratypes of incomplete shells are assigned: UMUT PM 19112-19119, 19143, phragmocone; UMUT PM 19120-19122, phragmocone with apical body chamber; UMUT PM 19123, body chamber. In addition, 19 reference specimens (UMUT PM 19124-19142) were also examined.

Occurrence.—Localities FH-1 (UMUT PM 19111-19142) and FH-4 (UMUT PM 19143).

Genus and species indeterminate

Figures 3-1, 2

Discussion.—A single fragmentary specimen represented by a thin section in the dorsoventral plane of the phragmocone is assigned to the subfamily Pseudorthoceratinae, because of its inflated segments with cyrtochoanitic septal necks and the possession of annulosiphonate deposits.

Material.—UMUT PM 19144.

Occurrence.—Locality FH-4.

Subfamily Spyroceratinae Shimizu and Obata, 1935

Genus **Spyroceras** Hyatt, 1884

Type species.—*Orthoceras crotalum* Hall, 1861.

Spyroceras fukujiense sp. nov.

Figures 3-3—11; 4-1—5

Diagnosis.—Large-sized *Spyroceras* with low angle of expansion; 25-33 longitudinal ribs, transverse coarse lirae changing to subdued broad lirae in adoral shell, additional reticulate ornamentation occurs on body chamber; siphuncle slightly dorsal.

Description.—Annulated large orthocones with gradual shell expansion, angle of expansion ranges from 4.0 to 4.4 degrees in juvenile shell, then decreases to 2.7-3.8 degrees adorally; circular cross section; largest specimen (UMUT PM 18515) of body chamber attains approximately 80 mm (reconstructed) in diameter; early juvenile shell slightly cyrtoconic, lacks annulations which appear at approximately 5 mm in shell diameter and disappear in body chamber; annulations transverse, low, but relatively broad; ornamentation composed of 25-33 (usually 26-28) longitudinal ribs throughout shell, and coarse transverse lirae changing to transverse subdued broad lirae in adoral shell, additionally reticulate ornamentation consisting of fine longitudinal and transverse lirae occurs in body chamber; sutures straight, slightly oblique, towards aperture on venter; camerae relatively short, approximately 1.2-1.7 mm in length in apical shell of holotype, width/length ratio ranges from 2.0 to 5.0; septal curvature weak; siphuncle shifting slightly dorsally from center; septal necks relatively short, 0.24 mm in length in holotype, suborthochoanitic; connecting rings weakly inflated in early juvenile shell (approximately 2.9 mm shell diameter), adorally nearly cylindrical with weak constriction at septal foramen; ventral cameral deposits mural with mammiform growth in their later stages, dorsally forms L-shaped episeptal-mural deposits; endosiphuncular deposits thin rings, restricted to apical shell.

Discussion.—Although the siphuncular structure of known species of *Spyroceras* is rarely observed, *S. fukujiense* sp. nov. is clearly distinguished in its external morphology from most previously described species of the genus by its fewer longitudinal ribs. Only *Spyroceras suave* Zhuravleva (1978, Pl. 9, figs. 1-4), from the Middle Devonian of the Urals, possesses surface ornamentation somewhat similar to that of *S. fukujiense*. However, it is distinguished from the Fukuji species by its moderately large angle of shell expansion (9-10 rather than 2.7-4.4 degrees) and the less eccentric siphuncular position.

Even in fragmentary specimens, the low and relatively broad annulations and prominent longitudinal ribs immediately distinguish the species from the associated annulated species *Spyroceras melolineatum* sp. nov.

Etymology.—The specific name is taken from the Fukuji Formation, where the type specimens occur.

Material.—The holotype, UMUT PM 18505, is an incomplete phragmocone. The following 16 paratypes of incomplete shells are assigned: UMUT PM 18506, 18507, 18512-18514, 18516, 18517, 19145-19150, HMNH-N098, phragmocone; UMUT PM 18515, 19151, body chamber. In addition, 15 reference specimens (UMUT PM 18508-18511, 18518, 19152-19161) were also examined.

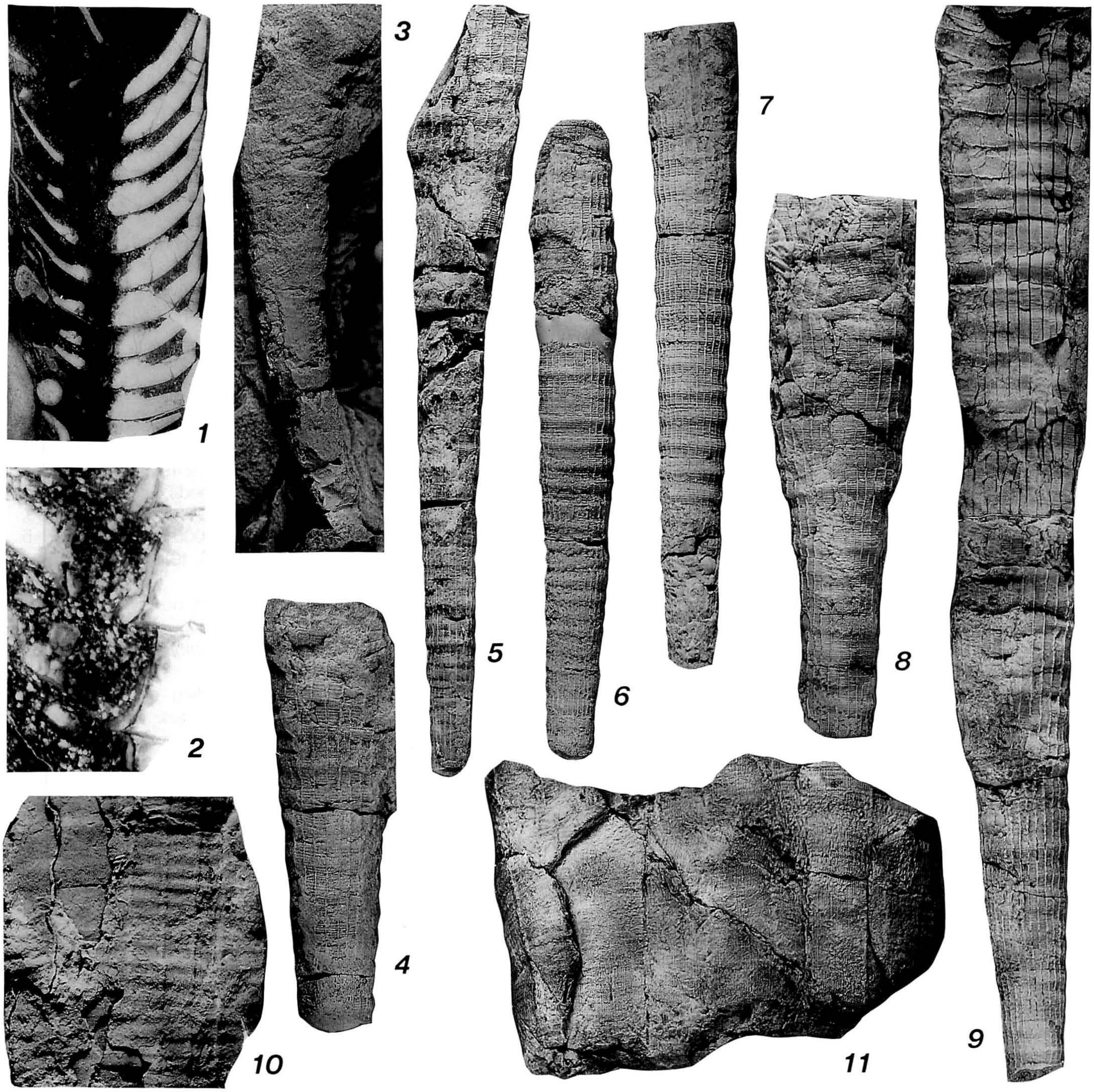


Figure 3. **1, 2.** Pseudorthoceratine genus and species indeterminate, UMUT PM 19144, dorsoventral thin section, venter on right, 1 : ×5, 2 : enlarged view shows siphuncular structure, ×20. **3-11.** *Spyroceras fukujiense* sp. nov., 3 : paratype, UMUT PM 18516, early juvenile shell, venter on left, ×3, showing cyrtoconic nature, 4 : paratype, UMUT PM 18507, ventral view, ×1.5, 5 : holotype, UMUT PM 18505, ventral view, ×1.5, 6 : paratype, UMUT PM 19145, dorsal view, ×1.5, 7 : paratype, UMUT PM 18512, side view, ×1.5, 8 : paratype, UMUT PM 18514, ventral view, ×1, 9 : paratype, UMUT PM 18513, ventral view, ×1, 10 : paratype, HMNH-N098, side view, ×1.5, showing longitudinal ribs and transverse subdued lirae, 11 : paratype, UMUT PM 18515, side view of body chamber, ×0.8, showing reticulate ornamentation.

Occurrence.—Localities FH-1 (UMUT PM 18505-18507, 18509, 18510, 18512-18518, 19145-19158; HMNH-N098), FH-4 (UMUT PM 19159, 19160) and FH-5 (UMUT PM 18508, 18511, 19161).

Spyroceras melolineatum sp. nov.

Figures 4-6—11; 5-1—5

Diagnosis.—*Spyroceras* with alternating prominent and less prominent longitudinal ribs up to 66 in number.

Description.—Moderate-sized orthocones with gradual shell expansion, angle of expansion ranges from 3.0 to 3.9 degrees, circular cross section; largest specimen (UMUT PM 18485) of body chamber attains approximately 24 mm (reconstructed) diameter; early juvenile shell exhibits endogastric curvature with apical angle of 8.5 degrees, nonannulated, endogastric portion approximately 20 mm in length; initial camera bluntly cone-shaped with small bulbous inflation in apex; transverse, close annulations occur in adoral juvenile phragmocone to body chamber with rounded crests; longitudinal ornamentation composed of alternating prominent and less prominent ribs, which diminish into body chamber, rib number attains 66; transverse lirae fine, becoming finer on body chamber; sutures transverse, straight in juvenile shell, adorally slightly sinuate; cameral length moderate, approximately 1.7 mm in apical shell of holotype, width/length ratio of initial camera approximately 0.8, this ratio increasing with shell growth, 1.5-2.9 in early juvenile shell (up to approximately 2.3-3.0 mm shell diameter) to 3.3-4.5 in adoral shell (more than 6.0 mm shell diameter); septal curvature moderately weak; siphuncle nearly central, but slightly towards dorsum in adoral shell, weakly curved suborthochoanitic to orthochoanitic septal necks, approximately 0.42 mm in length in holotype, and cylindrical connecting rings with weak constriction at septal foramen; cameral deposits of L-shaped episeptal-mural deposits; endosiphuncular parietal deposits well developed, fusing to form thick, continuous lining on ventral siphuncular wall in adoral shell.

Discussion.—*Spyroceras thoas* (Hall, 1861; 1879, Pl. 41, figs. 1-9; Pl. 78B, fig. 5; Pl. 79, fig. 13; Pl. 80, figs. 7, 10, 11; Pl. 112, figs. 7, 8; Collins, 1969, Pl. 6, figs. 1-4, text-fig. 3) from the Lower to Middle Devonian of North America and Middle Devonian of Novaya Zemlya (Kuzmin, 1965, Pl. 1, figs. 5a, b, described as *Spyroceras* ? *nuntium*; Zhuravleva, 1978, Pl. 8, figs. 5, 6a, b) also has cylindrical connecting rings and well developed endosiphuncular annuli. This species differs in having uniform and more numerous longitudinal ribs than *Spyroceras melolineatum*.

The Upper Silurian genus *Palaeospyroceras* Chen (in Chen *et al*., 1981; type species, *P. crassicostatum* Chen, 1981, Pl. 38, figs. 8-10) known only from Yunnan, China, possesses a prominent annulation and nearly cylindrical connecting rings which suggest a relationship to this species. *Palaeospyroceras*, however, lacks the continuous lining of the endosiphuncular deposits. In addition the sutures and annulations are oblique to the long axis of the shell and the siphuncle is subcentral in position.

Etymology.—The specific name is derived from the Latin *melos* (tune) and *linea* (line) referring to the rhythmic alternation of longitudinal ridges.

Material.—The holotype, UMUT PM 18493, an incomplete phragmocone. The following 12 paratypes of incomplete shells are assigned: UMUT PM 18483, 18484, 18486-18490, 18494, 19163, HMNH-N005, phragmocone; and UMUT PM 18485, 19164, body chamber. In addition, 22 reference specimens (UMUT PM 18482, 18495, 18496, 18504, 19165-19181; HMNH-N015) were also examined.

Occurrence.—Localities FH-1 (UMUT PM 18482-18490, 18493, 18494, 19163-19179; HMNH-N005, N015) and FH-5 (UMUT PM 18495, 18496, 18504, 19180, 19181).

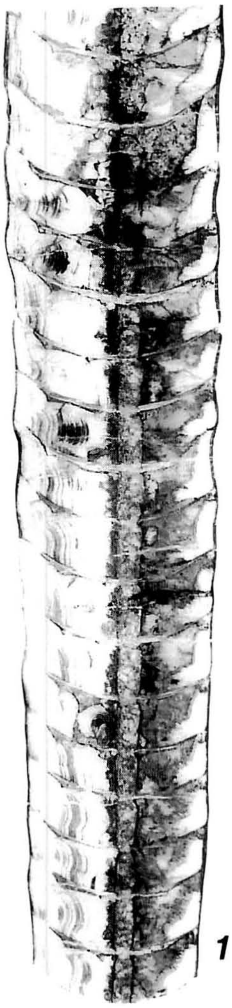
Genus **Hamadaites** gen. nov.

Type species..—*Hamadaites labyrinthus* sp. nov., by monotypy.

Diagnosis.—Relatively rapid expanding orthocones with simple peristome, broad hyponomic sinus, dorsal furrows, constrictions in body chamber; early juvenile shell orthoconic; ornamentation of transverse lirae, anastomosing; sutures straight, slightly oblique; siphuncle nearly central with suborthochoanitic to orthochoanitic septal necks; connecting rings cylindrical to subcylindrical; cameral deposits mural, episeptal-mural; endosiphuncular deposits form thick lining.

Etymology.—The generic name refers to T. Hamada (University of the Air), in recognition of his contributions to the study of the Japanese Paleozoic invertebrates.

Figure 4. 1-5. *Spyroceras fukujiense* sp. nov., 1, 2: holotype, UMUT PM 18505, dorsoventral thin section, venter on left, 1, ×5; 2, enlarged view shows siphuncular structure, ×20, illustrating suborthochoanitic septal necks, 3: paratype, UMUT PM 18516, dorsoventral polished section, venter on left, ×10, showing inflated connecting rings in early juvenile shell, 4: paratype, UMUT PM 18506, dorsoventral thin section, venter on right, ×5, 5: paratype, UMUT PM 18517, dorsoventral thin section, venter on left, ×5. **6-11.** *Spyroceras melolineatum* sp. nov., 6: paratype, UMUT PM 18494, longitudinal thin section, ×5, 7: holotype, UMUT PM 18493, dorsoventral thin section, venter on right, ×5, 8, 10: paratype, UMUT PM 18484, dorsoventral thin section, venter on left, 8, ×5; 10, detail of siphuncle, ×10, showing suborthochoanitic to orthochoanitic septal necks and well-developed endosiphuncular deposits, 9: paratype, UMUT PM 18483, dorsoventral thin section of apical shell, venter on left, ×10, showing endogastric nature, 11: paratype, UMUT PM 18487, dorsoventral polished section of early juvenile shell, venter on left, ×10.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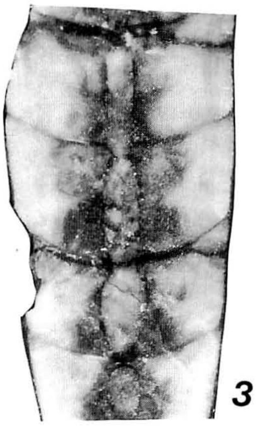
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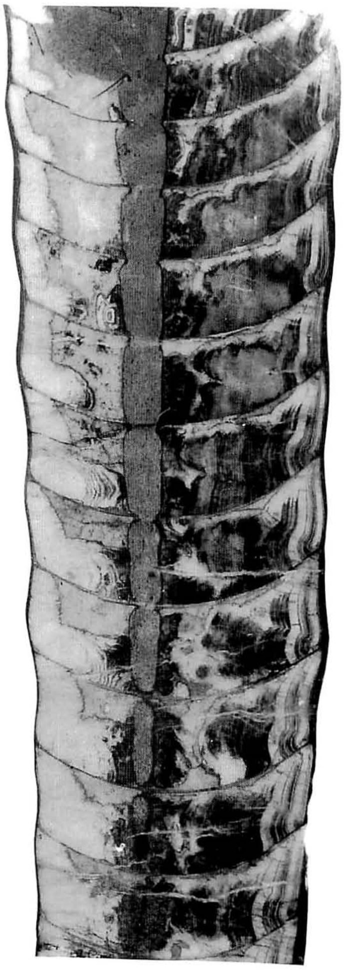
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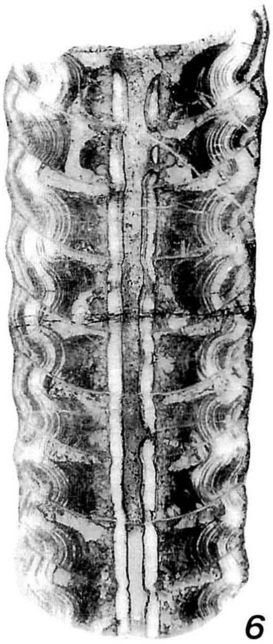
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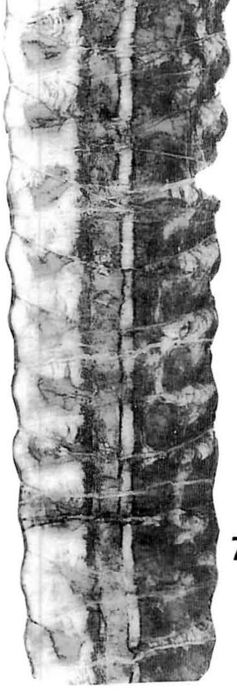
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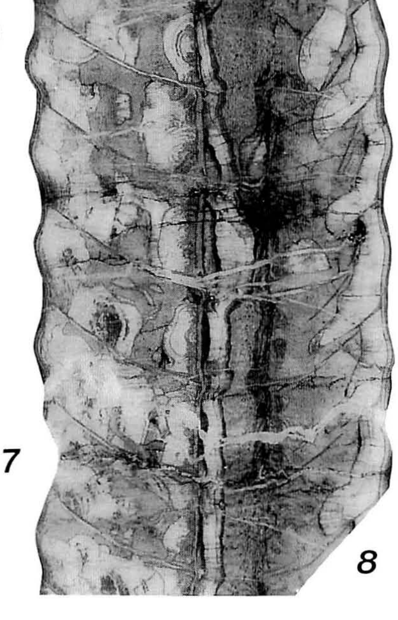
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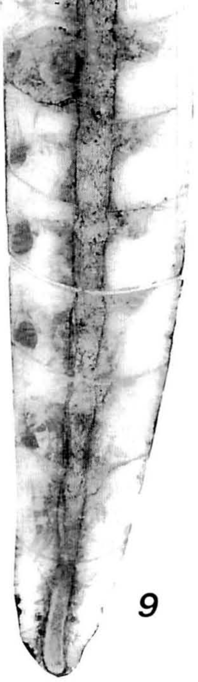
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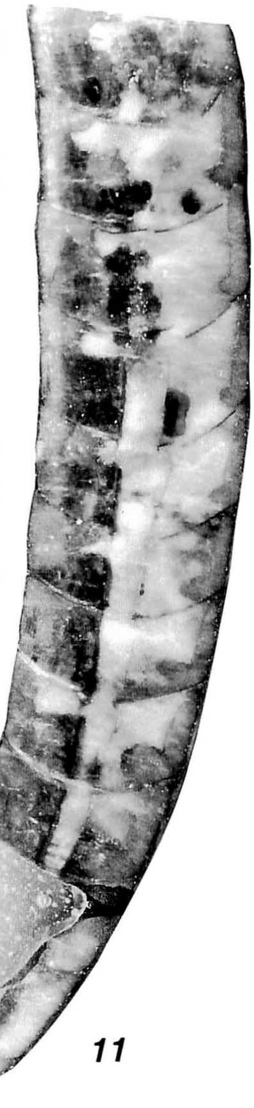
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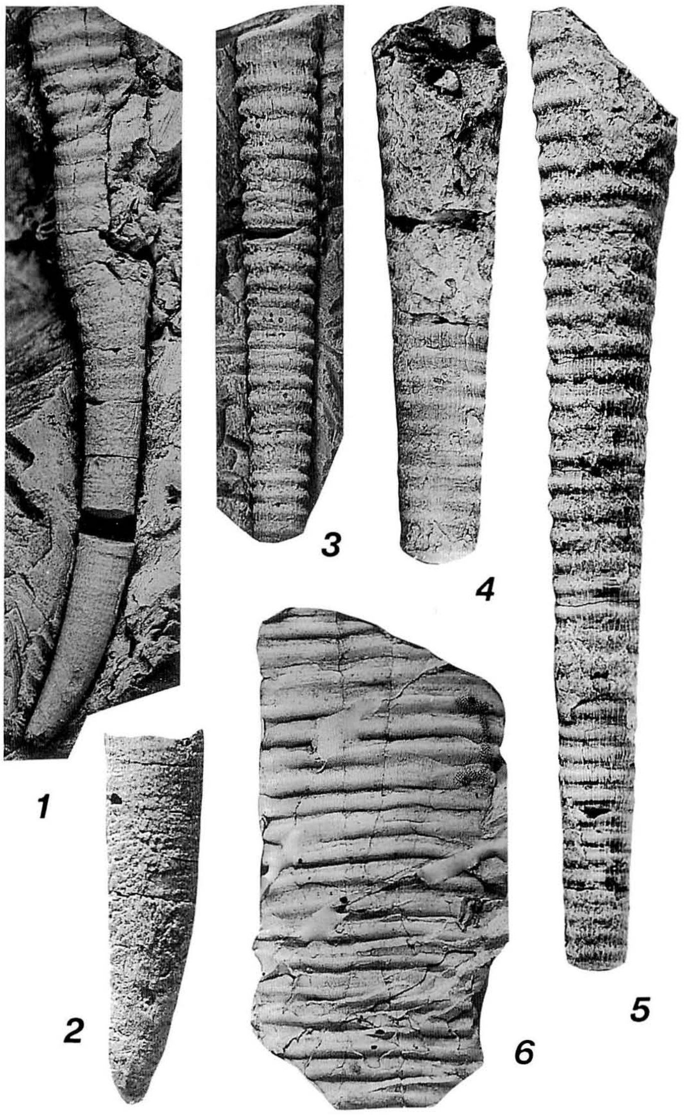

Figure 5. *Spyroceras melolineatum* sp. nov. **1.** Paratype, UMUT PM 18486, lateral view of early juvenile shell, venter on left, ×3, showing endogastric nature. **2.** Paratype, UMUT PM 18483, lateral view of apical shell, venter on left, ×5. **3.** Paratype, UMUT PM 19163, side view, ×1.5. **4.** Paratype, UMUT PM 18494, dorsal view, ×1.5. **5.** Holotype, UMUT PM 18493, ventral view, ×1.5. **6.** Paratype, UMUT PM 18485, side view of body chamber, ×1.

Hamadaites labyrinthus sp. nov.

Figures 6-1—15

Diagnosis.—As for the genus.

Description.—Moderate-sized orthocones with relatively rapid shell expansion, angle of expansion ranges from 7.5 to 7.8 degrees, then decreases to approximately 6.5 degrees adorally; circular cross section; largest specimen (UMUT PM 19201) of body chamber attains approximately 21 mm (reconstructed) diameter; early juvenile shell orthoconic with faint shell inflation forming a bullet shape; body chamber long, not less than 44 mm in length with diameter at last septum approximately 11 mm (reconstructed); growth lines exhibit simple peristome with broad but shallow hyponomic sinus; phragmocone bears dorsal furrows; juvenile shell (up to approximately 8 mm shell diameter) lacks surface ornamentation, adoral shell surface possesses slightly sinus transverse lirae, which anastomose somewhat irregularly and give labyrinthian appearance in part, this labyrinthian pattern spreads over body chamber; internal mold of body chamber with series of weak transverse constrictions produced by thickening of shell wall; sutures straight, slightly oblique, towards aperture on venter; septal curvature moderately deep; cameral length ranges from 0.5 to 2.7 mm in holotype, width/length ratio of early juvenile shell (up to 1.5 mm shell diameter) approximately 1.9, adorally it ranges from 2.1 to 4.2; siphuncle nearly central, shifting faintly ventrally from center; septal necks suborthochoanitic in apical shell, approximately 0.25 mm length at 5.3 mm shell diameter in holotype; connecting rings cylindrical to subcylindrical, weakly inflated on dorsal side, weak constriction at septal foramen; adoral septal necks at more than 8 mm shell diameter orthochoanitic with cylindrical connecting rings; cameral deposits mural in juvenile shell, adorally episeptal-mural; endosiphuncular deposits well developed, but absent in apical shell, fusing to form thick continuous lining on ventral siphuncular wall.

Discussion.—Based on its siphuncular morphology mentioned above it is clear that this species belongs in the subfamily Spyroceratinae. Furthermore, the early juvenile shell shape of the Fukuji specimens is quite similar to that of some primitive species of the genus *Dolorthoceras* Miller (1931; type species, *D. circulare* Miller, figs. 1, 2 from the Carboniferous of the Karakorum Mountains) such as *D. parlinense* (Williams in Williams and Breger, 1916, Pl. 13, figs. 21, 25; Flower, 1939), from the Lower Devonian of Maine. Gordon (1964) reported a bullet-shaped early juvenile shell in the Mississippian species, *Dolorthoceras tenuifilosum* Gordon from Arkansas. The diagnostic features of *Hamadaites labyrinthus* gen. et sp. nov. appear in the adult shell, i.e. labyrinthian surface ornamentation and transverse constrictions formed by shell thickening, which are unique in the subfamily. Judging from the juvenile shell morphology, *Hamadaites* probably originated from species of *Dolorthoceras*.

The Permian genus *Bitaunioceras* Shimizu and Obata (1936; type species, *Orthoceras bitauniense* Haniel, 1915, Pl. 56, figs. 5a-c from Timor) is also characterized by surface constrictions and well-developed endosiphuncular deposits (Miller and Youngquist, 1949; Niko and Nishida, 1987). *Bitaunioceras* has a more slender shell than that of *Hamadaites*, however, and lacks the labyrinthian ornamentation. Furthermore, the surface constrictions occur early in the phragmocone in all known *Bitaunioceras* in contrast to *Hamadaites labyrinthus*, where they are restricted to the body chamber.

Hamadaites labyrinthus is the most abundant cephalopod in the Fukuji Formation. To date 137 specimens have been obtained, which exhibit morphological variations in the mode of development of anastomosing pattern in the surface ornamentation.

Epizoans of a dimple-like boring (*Cyclopuncta* ? sp.) are usually concentrated on the ventral surface of the shell (Figures 6-2, 3, 5), suggesting that those forms drifted necroplanktonically in horizontal and venter-down orientation.

Etymology.—The specific name is derived from the Latin *labyrinthus* (labyrinth), referring to the surface ornamentation.

Material.—The holotype, UMUT PM 19182, is an incomplete phragmocone. The following 23 paratypes of incomplete shells are assigned: UMUT PM 18499, 18500, 19183-19198, 19307, phragmocone; 19199, phragmocone with apical body chamber; and 19200, 19201, 19308, body chamber. In addition, 113 reference specimens (UMUT PM 18501-18503, 19202-19306, 19309-19312, HMNH-N013) were also examined.

Occurrence.—Localities FH-1 (UMUT PM 18499-18503, 19182-19306, HMNH-N013) and FH-4 (UMUT PM 19307-19312).

Genus ***Mitorthoceras*** Gordon, 1960

Type species.—*Mitorthoceras perfilosum* Gordon, 1960.

Mitorthoceras*? *kamitakarense sp. nov.

Figures 7-1—10

Diagnosis.—Orthocones with very fine transverse surface lirae; moderately shallow septa forming slightly oblique sutures; camerae relatively short, width/length ratio 1.6-3.6; cameral deposits dominantly episeptal-mural.

Description.—Small-sized orthocones with moderate shell expansion, angle of expansion ranges from 6.5 to 6.8 degrees, then decreases to approximately 5 degrees adorally, circular cross section; largest specimen (UMUT PM 19316) of body chamber attains approximately 9 mm (reconstructed) shell diameter; early juvenile shell simple orthocone; surface ornamentation absent up to approximately 2.3 mm in shell diameter; body chamber long, length of preserved body chamber at least 51.6 mm; surface ornamentation of very fine, weakly sinuate transverse lirae separating nearly flat interspaces, additional low annular ornamentations parallel to lirae occur in shell surface of body chamber; septa moderately shallow; sutures straight, slightly oblique, towards aperture on venter; camerae relatively short for genus, their length somewhat variable, 0.7-1.5 mm in holotype, width / length ratio ranges from 1.6 to 3.6, usually 1.6-2.5; siphuncle subcentral, shifting slightly ventrally; septal necks suborthochoanitic, short, approximately 0.14 mm in length in apical holotype; connecting rings subcylindrical with constrictions at septal foramen, weak dorsal inflations; cameral deposits episeptal-mural, excepting apical ventral camerae which have mural deposits; weak endosiphuncular deposits occur in apical shell (up to 2 mm shell diameter), restricted to ventral siphuncular wall, fusing.

Discussion.—The morphological combination of the *Dolorthoceras*-like siphuncular structure described above and the transverse lirae of the surface ornamentation of the present species is the most diagnostic character of the genus *Mitorthoceras*. The tentative assignment of this species to *Mitorthoceras* is owing to *M.* ? *kamitakarense* being clearly distinguished from most species of the genus by the absence of hyposeptal deposits. *"Mitorthoceras" aktjubense* Zhuravleva (1978, Pl. 15, figs. 4-9) from the Upper Devonian of the southern Urals also lacks hyposeptal deposits, but has a smaller angle of expansion (4-5 degrees) and longer camerae (cameral length/shell diameter 1.3-1.8) than those of *M.* ? *kamitakarense* sp. nov.

The type specimens of *Mitorthoceras perfilosum* Gordon (1960, Pl. 27, figs. 1-4, 8; the type species of the genus) are known to possess hyposeptal deposits. Crick (1982), how-


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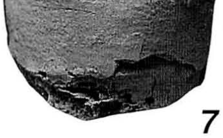
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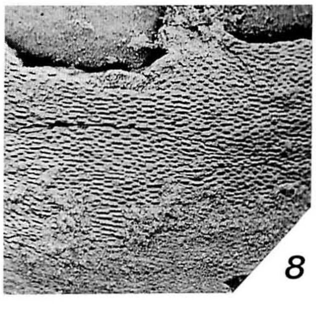
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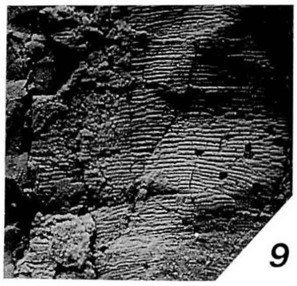
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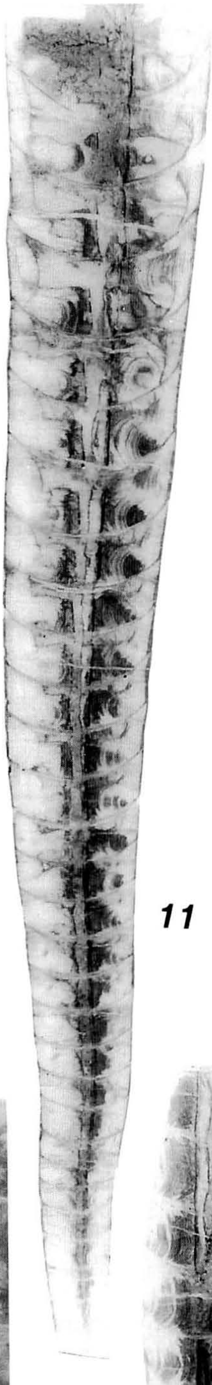
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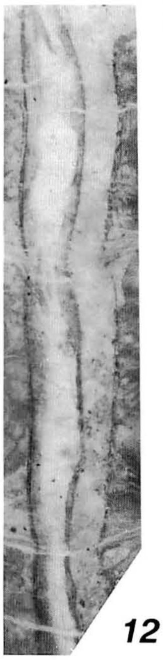
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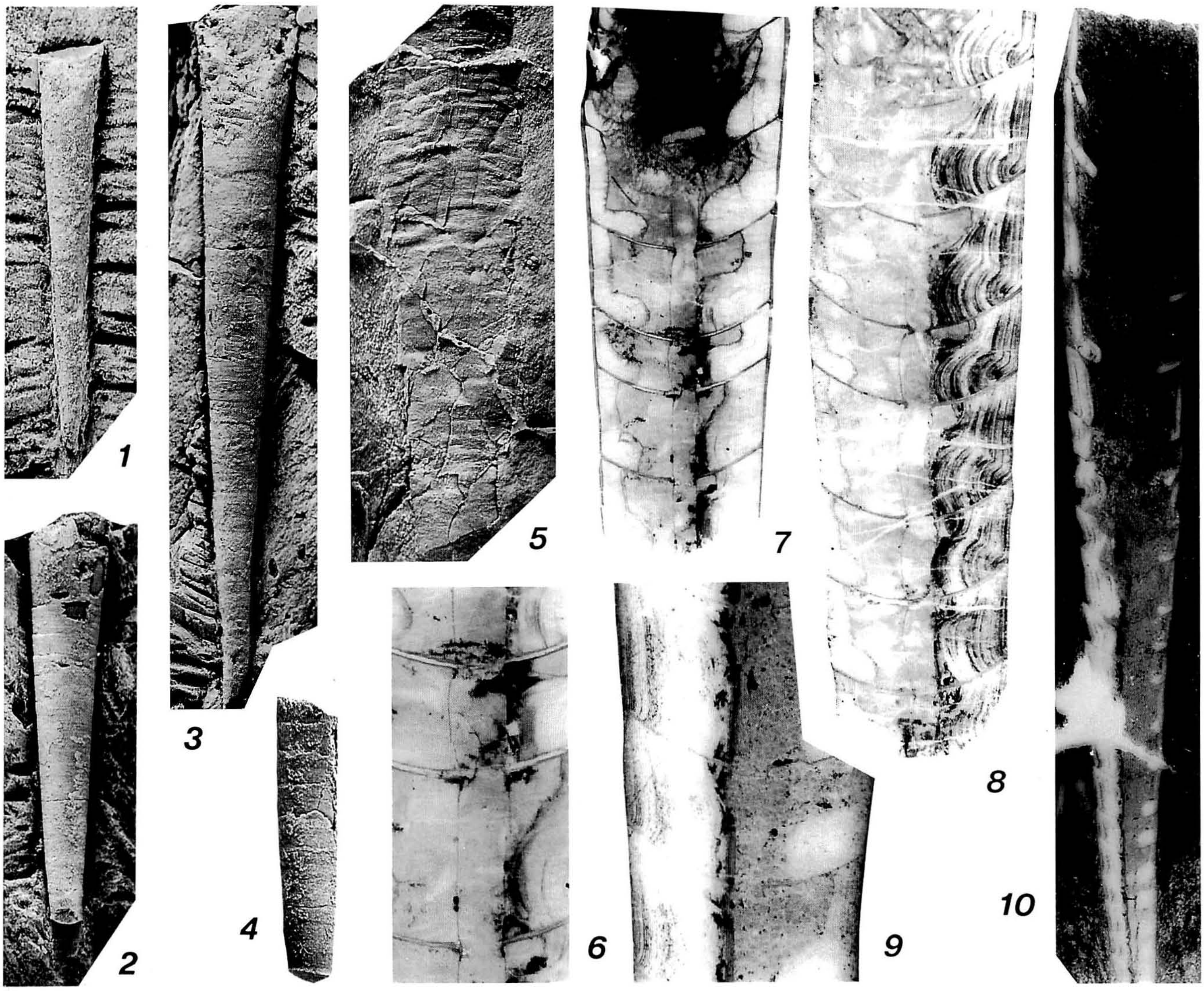

Figure 7. *Mitorthoceras ? kamitakarense* sp. nov. **1.** Paratype, UMUT PM 19315, side view of early juvenile shell ×3. **2.** Paratype, UMUT PM 19314, dorsal view, ×3. **3.** Paratype, UMUT PM 19313, dorsal view, ×3. **4, 6, 7.** Holotype, UMUT PM 18497, 4 : lateral view, venter on left, ×3, 6 : detail of siphuncle, dorsoventral thin section, venter on right, ×20, showing suborthochoanitic septal necks, 7 : dorsoventral thin section, venter on right, ×10. **5.** Paratype, UMUT PM 19316, side view of body chamber, ×1.5, showing transverse lirae and annular ornamentations. **8.** Paratype, UMUT PM 18498, dorsoventral thin section, venter on right, ×10. **9, 10.** Paratype, UMUT PM 18519, dorsoventral thin section, venter on left, 9 : detail of siphuncle of juvenile shell, ×20, showing weak siphuncular deposits, 10 : ×5.

Figure 6. *Hamadaites labyrinthus* gen. et sp. nov. **1.** Paratype, UMUT PM 19307, dorsal view of early juvenile shell, ×5, showing bullet-shape apical shell. **2, 3.** Paratype, UMUT PM 18499, 2 : lateral view, venter on left, ×1.5, 3 : ventral view, × 1.5, illustrating broad hyponomic sinus. **4.** Paratype, UMUT PM 19188, side view, ×1.5. **5.** Paratype, UMUT PM 19194, lateral view, venter on right, ×1.5. **6, 11.** Holotype, UMUT PM 19182, 6 : ventral view, ×1.5, 11 : dorsoventral thin section, venter on right, ×5. **7, 8.** Paratype, UMUT PM 19200, 7 : side view of body chamber, ×1.5, 8 : detail of shell surface, × 5, illustrating anastomose ornamentation. **9.** Paratype, UMUT PM 19199, detail of surface ornamentation, ×5. **10.** Paratype, UMUT PM 18500, dorsoventral thin section, venter on left, ×5. **12, 13.** Paratype, UMUT PM 18499, dorsoventral thin section, venter on left, 12 : detail of siphuncle, ×20, showing suborthochoanitic to orthochoanitic septal necks and well-developed siphuncular deposits, 13 : ×5. **14.** Paratype, UMUT PM 19187, dorsoventral thin section of adoral phragmocone, ×5, showing orthochoanitic septal necks. **15.** Paratype, UMUT PM 19186, dorsoventral thin section, venter on left, ×5.

ever, insisted that the three species of *Mitorthoceras* (*M. crebriliratum, M. girtyi*, and *M. perfilosum*) from the Boggy Formation of Oklahoma have only mural and episeptal deposits. Notwithstanding, justification of Crick's assignment is difficult since no morphological information other than description of the cameral deposits is given by him; this suggests that the form of the cameral deposits may not be so suitable as a generic and even specific level criterion in *Mitorthoceras*. The specimens from the Boggy Formation differ from *Mitorthoceras* ? *kamitakarense* in the possession of a more gradually expanding shell and longer camerae.

Etymology.—The specific name is derived from Kamitakara, which is the village name of the type locality.

Material.—The holotype, UMUT PM 18497, is an incomplete phragmocone. The following six paratypes of incomplete shells are assigned: UMUT PM 18498, 18519, 19313-19315, phragmocone; and UMUT PM 19316, body chamber. In addition, five reference specimens (UMUT PM 19317-19321) were also examined.

Occurrence.—Localities FH-1 (UMUT PM 19321) and FH-4 (UMUT PM 18497, 18498, 18519, 19313-19320).

Subfamily Cayutoceratinae Flower, 1939
Genus **Buchanoceras** Teichert and Glenister, 1952

Type species.—***Buchanoceras graviventrum*** Teichert and Glenister, 1952.

Buchanoceras sp.

Figures 8-1—4

Description.—Moderately large-sized orthocones with gradual shell expansion (angle approximately 3 degrees), circular cross section, smooth shell surface; septal curvature moderate to moderately deep in apical shell, but becomes shallower adorally; sutures straight, nearly transverse; width/length ratio of camerae ranges from 3.3 to 4.8; siphuncle relatively large, ratio of septal foramen width to shell diameter attains 0.16; apical siphuncle subcentral,

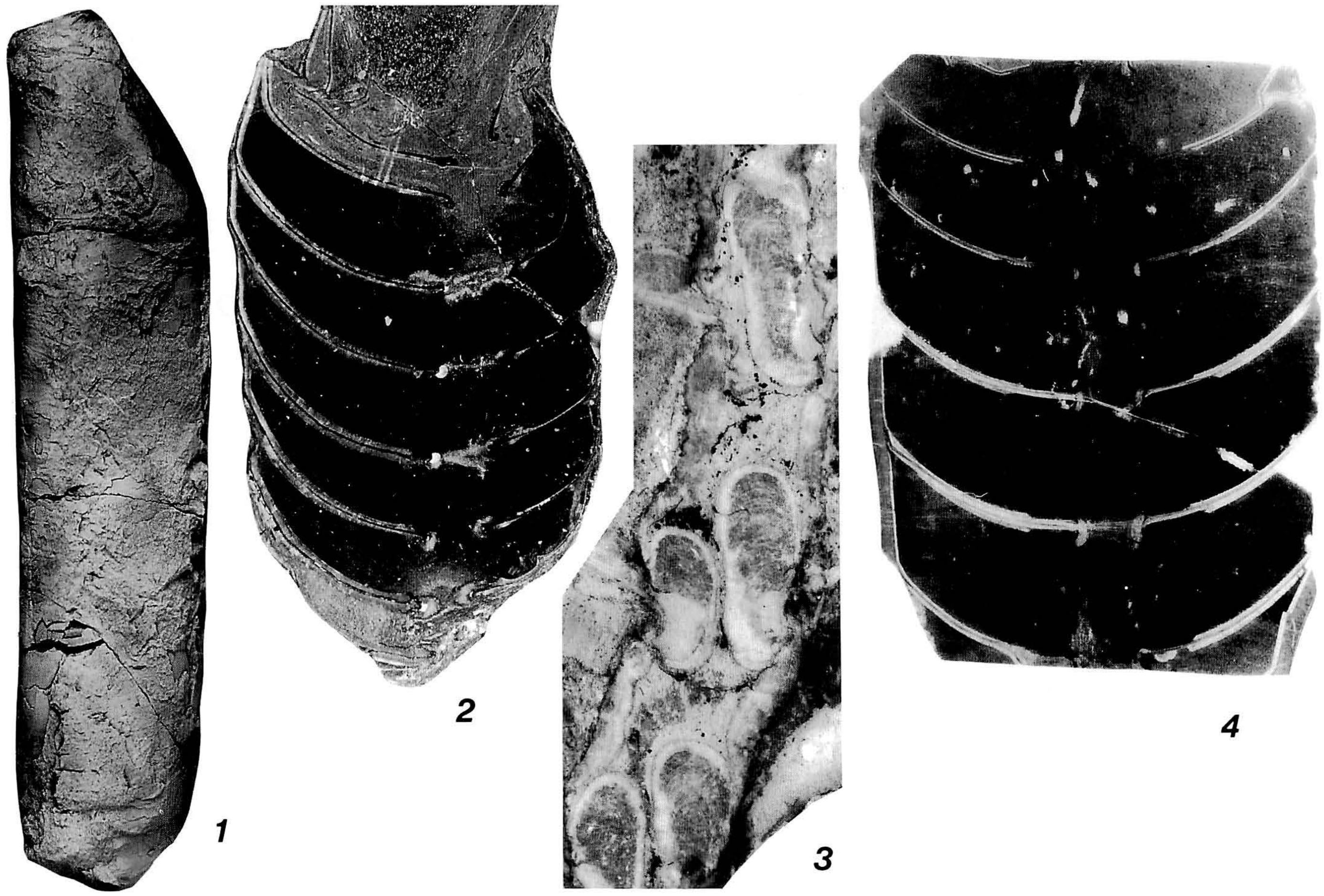

Figure 8. *Buchanoceras* sp. **1.** UMUT PM 19322, side view, ×1. **2.** UMUT PM 18522, dorsoventral polished section, venter on left, ×3. **3.** UMUT PM 18521, dorsoventral thin section, venter on right, ×10, showing well-developed endosiphuncular bullettes. **4.** UMUT PM 18520, longitudinal thin section of adoral phragmocone, ×3.

slightly dorsal from center with cyrtochoanitic septal necks, adorally shifts to central position with suborthochoanitic septal necks, 0.67-0.92 mm in length; connecting rings inflated in camerae; cameral deposits consisting of thin episeptal-mural, hyposeptal deposits; thick bullettes differentiated into outer annuli and inner laminated deposits, inner layer of deposits also developed on connecting rings, and absent in adoral shell.

Discussion.—The differentiated and well-developed endosiphuncular bullettes, moderately large shell with low angle of expansion, and lack of surface ornamentation of the Fukuji species are definitive characters of the genus *Buchanoceras*. This species appears to approach *Buchanoceras seretense* (Balashov, in Balashov and Kisselev, 1968, Pl. 3, figs. 1a-d, Pl. 4, figs. 3a-d) from the Lochkovian of Podolia and *B. frequens* Zhuravleva (1990, Pl. 2, fig. 6) from the Lower Devonian of eastern Gobi, Mongolia, but the poorly preserved apical portion of the material precludes strict specific assignment. This is the first record of the subfamily Cayutoceratinae in Japan.

Material.—Four specimens of incomplete shells, UMUT PM 18520-18522 (phragmocone) and 19322 (body chamber), were examined. In addition, four deformed specimens (UMUT PM 19323, 19324, HMNH-N007, N011) are questionably assigned to this species.

Occurrence.—Locality FH-1.

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References cited

Balashov, Z.G. and Kisselev, G.N., 1968: Nekotorye golovonogie mollyuski Malinovecekogo, Skalskogo, Borchovskogo i Chortkovskogo gorizontov Podolii (Some cephalopod molluscs of the Malinovecekiy, Skalskiy, Borchovskiy and Chortkovskiy Formations of Podolia). *In*, Balashov, Z.G. *ed., Siluriysko-devonskaya fauna Podolii (Silurian-Devonian fauna of Podolia)*, p. 7-29. Izdatelstvo Leningradskogo Universiteta. (*in Russian*)

Boucot, A.J., Rohr, D.M. and Blodgett, R.B., 1988: A marine invertebrate faunule from the Tawil Sandstone (basal Devonian) of Saudi Arabia and its biogeographic-paleogeographic consequences. *New Mexico Bureau of Mines and Mineral Resources, Memoir* 44, p. 316-372.

Chen, J., Gengwn, L. and Tingen. C., 1981: Silurian nautiloid faunas of central and southwestern China. *Memoirs of Nanjing Institute of Geology and Palaeontology, Academia Sinica*, no. 13, p. 1-104, pls. 1-40. (*in Chinese with English abstract*)

Collins, D.H., 1969: Devonian nautiloids from northern Canada. *Geological Survey of Canada Bulletin*, vol. 182, p. 31-75.

Crick, R.E., 1982: The mode and tempo of cameral deposit formation: evidence of orthoconic nautiloid physiology and ecology. *Third North American Paleontological Convention, Proceedings*. vol. 1, p. 113-118.

Crick, R.E., 1990: Cambro-Devonian biogeography of nautiloid cephalopods. *In*, Mckerrow W.S. and Scotese C.R. *eds., Palaeozoic Palaeogeography and Biogeography. Geological Society, Memoir* 12, p. 147-161.

Fisher, A.G. and Teichert, C., 1969: Cameral deposits in cephalopod shells. *The University of Kansas, Paleontological Contributions*, Paper 37, 30 p., 4 pls.

Flower, R.H. 1939: Study of the Pseudorthoceratidae. *Palaeontographica Americana*, vol. 2, 215 p., 9 pls.

Flower, R.H. and Caster, K.E., 1935: The cephalopod fauna of the Conewango Series of the Upper Devonian in New York and Pennsylvania. *Bulletins of American Paleontology*, vol. 22, p. 199-271.

Girty, G.H., 1911: On some new genera and species of Pennsylvanian fossils from the Wewoka Formation of Oklahoma. *Annals New York Academy of Science*, vol. 21, p. 119-156.

Gordon, M. JR., 1960: Some American Midcontinent Carboniferous cephalopods. *Journal of Paleontology*, vol. 34, p. 133-151, pls. 27, 28.

Gordon, M. JR., 1964: Carboniferous cephalopods of Arkansas. *U.S. Geological Survey, Professional Paper* 460, 322 p., 30 pls.

Hall, J., 1861: Descriptions of new species of fossils from the Upper Helderberg, Hamilton, and Chemung Group, Albany. *New York State Cabinet of Natural History Fifteenth Annual Report*, p. 1-52.

Hall, J., 1879: Description of the Gastropoda, Pteropoda and Cephalopoda of the Upper Helderberg, Hamilton, Portage and Chemung Groups. *New York Geological Survey, Paleontology of New York*, vol. 5, part 1, 492 p., part 2, 113 pls.

Hamada, T., 1961: The Middle Palaeozoic group of Japan and its bearing on her geological history. *Journal of the Faculty of Science, University of Tokyo, Section II, Geology, Mineralogy, Geography, Geophysics*, vol. 13, p. 1-80.

Haniel, C.H., 1915: Die Cephalopoden der Dyas von Timor. *Paläontologie von Timor, Lieferung 3, Abhandlung 6*, p. 1-153, pls. 46-56.

Hyatt, A., 1883-84: Genera of fossil cephalopods. *Proceedings of the Boston Society of Natural History*, vol. 22, p. 253-338.

Kase, T., Hamada, T. and Niko, S., 1987: First record of a hyolith (Paleozoic Mollusca) from Japan. *Bulletin of the National Science Museum, Series C, Geology*, vol. 13, p. 29-34.

Kase, T., Nishida, T. and Niko, S., 1985: *Boiotremus fukujiensis*, n. sp. from Fukuji, Gifu Prefecture: first recorded Devonian gastropod from Japan. *Memoirs of the National Science Museum Tokyo*, no. 18, p. 29-34.

Koninck, L.G. de, 1880 : Faune du calcaire Carbonifère de la Belgique. *Annales du Musée Royal d'histoire Naturelle de Belgique, Série Paléontologique*, vol. 5, 133 p., pls. 32-50.

Kuwano, Y., 1987 : Early Devonian conodonts and ostracodes from central Japan. *Bulletin of the National Science Museum, Series C, Geology*, vol. 13, p. 77-105.

Kuzmin, A.M., 1965 : Devonskiye tsefalopody (Nadotryad Nautiloidea) yuzhnogo ostrova Novoi Zemlii (Devonian cephalopods (Superorder Nautiloidea) from southern island of Novaya Zemlya). *Nauchno-Issledovatel'spii Institut Geolgii Arktiki* (*NIIGA*), *Uchenye zapiski, Paleontologii i Stratigrafii*, no. 9, p. 8-40, pls. 1-8. (*in Russian*)

McChesney, J.H., 1859 : Descriptions of new species of fossils from the Palaeozoic rocks of the Western States. *Transactions of Chicago Academy of Science*, vol. 1, p. 1-76. (*not seen*)

Miller, A.K., 1931 : Two new genera of late Paleozoic cephalopods from Central Asia. *American Journal of Science, 5th series*, vol. 22, p. 417-425.

Miller, A.K. and Youngquist, W., 1949 : American Permian nautiloids. *Geological Society of America, Memoir* 41, 218 p., 59 pls.

Niikawa, I., 1980 : Geology and biostratigraphy of the Fukuji district, Gifu Prefecture, central Japan. *Journal of the Geological Society of Japan*, vol. 86, p. 25-36. (*in Japanese with English abstract*)

Niko, S., 1989 : A new Devonian cephalopod from the Nakazato Formation of the southern Kitakami Mountains. *Transactions and Proceedings of the Palaeontological Society of Japan, New series*, no. 156, p. 291-295.

Niko, S., 1990 : Early Devonian (Gedinnian) actinocerid cephalopods from the Fukuji Formation, central Japan. *Journal of Paleontology*, vol. 64, p. 595-600.

Niko, S., 1991 : *Plicatoceras*, a new lamellorthoceratid cephalopod genus from the Gedinnian (Early Devonian) of central Japan. *Journal of Paleontology*, vol. 65, p. 917-919.

Niko, S., 1993 : Orthoceratid cephalopods from the Early Devonian Fukuji Formation of Gifu Prefecture, central Japan. *Journal of Paleontology*, vol. 67, p. 210-216.

Niko, S. and Hamada, T., 1988 : Early Devonian receptaculitid (*Ischadites*) from the Fukuji Formation, central Japan. *Journal of the Geological Society of Japan*, vol. 94, p. 337-342, pl. 1.

Niko, S. and Nishida, T., 1987 : Early Permian cephalopods from the Mizuyagadani Formation, Fukuji district, central Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 146, p. 35-41.

Schindewolf, O.H., 1944 : Über das Apikalende der Actinoceren (Cephal., Nautil.). *Jahrbuch des Reichsamts für Bodenforschung für das Jahr 1941*, vol. 62, p. 207-247, pls. 8-11.

Shimizu, S. and Obata, T., 1935 : New genera of Gotlandian and Ordovician nautiloids. *The Journal of the Shanghai Science Institute, Section 2, Geology, Palaeontology, Mineralogy, and Petrology*, vol. 2, p. 1-10.

Shimizu, S. and Obata, T., 1936 : Remarks on Hayasaka's *Protocycloceras* cfr. *cyclophorum* and the Permian and Carboniferous orthoconic nautiloids of Asia. *Journal of the Geological Society of Japan*, vol. 43, p. 11-29. (*in Japanese with English abstract*)

Teichert, C. and Glenister, B.F., 1952 : Fossil nautiloid faunas from Australia. *Journal of Paleontology*, vol. 26, p. 730-752, pls. 104-108.

Williams, H.S. and Breger, C.L., 1916 : The fauna of the Chapman sandstone of Maine, including descriptions of some related species from the Moose River sandstone. *U.S. Geological Survey Professional Paper* 89, 347 p., 27 pls.

Zhuravleva, F.A., 1978 : Devonskiye ortocerody, nadotryad Orthoceratoidea (Devonian orthocerids, superorder Orthoceratoidea). *Akademia Nauk SSSR, Trudy Paleontologicheskogo Instituta*, vol. 168, 223 p. (*in Russian*)

Zhuravleva, F.A., 1990 : Novye paleozoiskiye tseflopody Mongolii (New Paleozoic cephalopods from Mongolia). *Paleontologicheskii Zhurnal*, no. 2, p. 37-46, pl. 2. (*in Russian*)

Fukuji 福地, Kitakami 北上, Ozako 大迫, Mt. Sora 空山, Yoshiki-gun 吉城郡, Yunnan 云南.

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 181, pp. 361-374, 2 Figs., April 30, 1996

1005 Fossil Mollusca of the Lower Miocene Yotsuyaku Formation in the Ninohe district, Iwate Prefecture, Northeast Japan
Part 2 (2). Gastropoda

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Abstract. Fifteen species of Gastropoda, obtained from the Koiwai Mudstone, Sandstone and Conglomerate Member of the Yotsuyaku Formation, are described herein. Of these, two, *Tateiwaia chinzeii* and "*Ocenebra*" *katayamai*, are described as new species.

Key words : Yotsuyaku Formation, Lower Miocene, Gastropoda, systematic descriptions, *Tateiwaia chinzeii* and *"Ocenebra" katayamai* sp. nov.

Introduction

In this article, the writer describes Gastropoda including two new species from the Yotsuyaku Formation in the same manner as in Part 2 (1).

Systematic descriptions and remarks

Class Gastropoda
Subclass Prosobranchia
Order Archaeogastropoda
Family Trochidae
Genus ***Cantharidus*** Montfort, 1810

Cantharidus sp. indet.

Figure 1-3

Remarks.—Several incomplete specimens were obtained. These specimens are characterized by its small, low, conical shell with a surface sculpture of low, fine, numerous, flat-topped spiral cords and fine, oblique, well impressed growth lines.

Locality.—1, 5, 7, 12 (No. 102633), 18.

Family Turbinidae
Genus ***Homalopoma*** Carpenter, 1864

Homalopoma aff. ***ena*** (Itoigawa, 1955)

Figure 1-4

Resembles.—

Leptothyra ena Itoigawa, 1955b, p. 140, pl. 6, fig. 8.

Homalopoma ena (Itoigawa). Itoigawa in Itoigawa *et al*., 1974, p. 126, pl. 39, figs. 8a-c ; Itoigawa *et al*., 1981, 1982, p. 149, 150, pl. 27, figs. 5a-c ; Kanno *et al*., 1988, pl. 3, fig. 15.

Description.—Shell small in size, thick, trochiform, with 5 and a half whorls ; umbilicus closed ; nuclear whorls about two in number, smooth, but not distinctly defined ; whorls roundly inflated and defined by fine suture ; shell surface sculptured with spiral cords and growth lines ; 7 primary spiral cords, fine, rather round-topped, broader than their interspaces, variable in width on penultimate whorl intercalated with one or two threads in each interspace ; periphery with many fine spiral threads ; growth lines fine, distinct, inclined 40 degrees to axis ; aperture transversely elongate-oblong in outline ; inner lip smooth, with nodular ridge anteriorly ; outer lip broken.

Remarks.—A single incomplete specimen was examined.

Comparison.—*Homalopoma ena* (Itoigawa, 1955b) closely resembles this specimen, but is distinguished from it in having more regularly arranged spiral cords. *Homalopoma hidaensis* Itoigawa, 1960, is distinguished by its more numerous primary spiral cords and less rounded whorls.

Locality.—1 (No. 102612).

Order Mesogastropoda
Family Littorinidae
Genus ***Littorina*** Brainville, 1825

Littorina sp. indet.

Figures 1-1a, b, 2a, b

Description.—Shell small, thick, turbinate ; apical angle about 60 degrees ; apex worn ; spire weakly rounded and distinguished by fine, distinct suture ; whorls with spiral

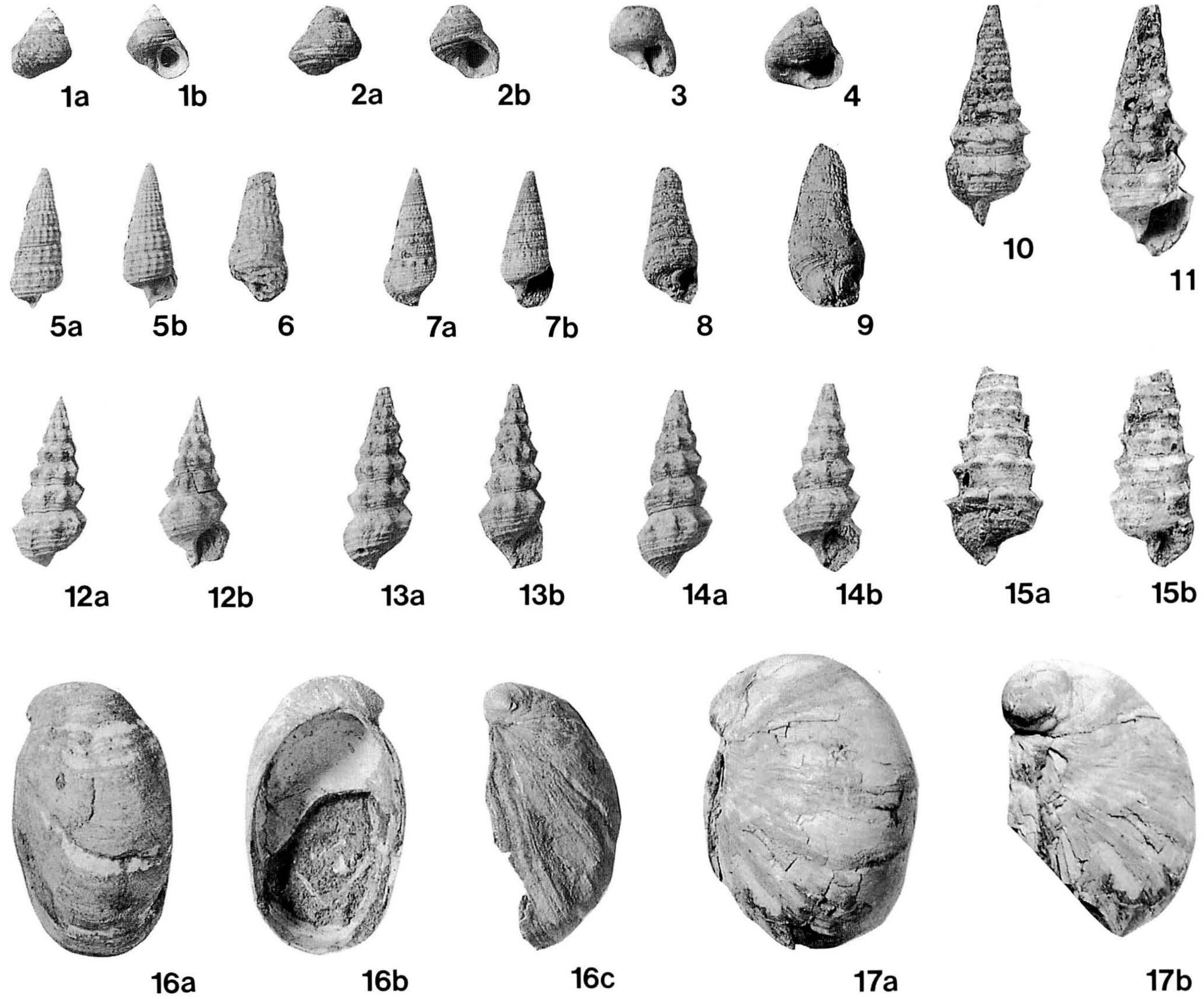

Figure 1. (All figures natural size, unless otherwise stated).
1a-b, 2a-b. *Littorina* sp., Loc. 12, IGPS coll. cat. no. 102613. **3.** *Cantharidus* sp., Loc. 12, IGPS coll. cat. no. 102633, ×1.5. **4.** *Homalopoma* aff. *ena* (Itoigawa), Loc. 1, IGPS coll. cat. no. 102612, ×1.5. **5a-b, 6.** *Cerithideopsilla* aff. *minoensis* (Itoigawa), 5a-b : Loc. 11, IGPS coll. cat. no. 102583, 6 : Loc. 9, IGPS coll. cat. no. 102617, silicon rubber cast. **7a-b, 8.** *Vicaryella otukai* (Nomura), 7a-b : Loc. 18, IGPS coll. cat. no. 102627, 8 : Loc. 2, IGPS coll. cat. no. 102624. **9.** *Vicaryella* sp., Loc. 2, IGPS coll. cat. no. 102627, silicon rubber cast. **10, 11, 15a-b.** *Vicaryella* "*bacula*" (Yokoyama), Loc. 10, IGPS coll. cat. no. 102623. **12a-b, 13a-b, 14a-b.** *Tateiwaia chinzeii* sp. nov., Loc. 18, 12a-b : IGPS coll. cat. no. 102618, holotype, 13a-b, 14a-b : IGPS coll. cat. no. 102619, paratypes. **16a-c, 17a-b.** *Crepidula jimboana* Yokoyama, 16a-b : Loc. 18, IGPS coll. cat. no. 102616, 17a-b : Loc. 3, IGPS coll. cat. no. 102615.

cords and growth lines ; cords round-topped, numerous, not defined distinctly, unequal in width, broader than their interspaces and branching with shell growth ; smallest specimens possess 3 spiral cords on penultimate whorl ; base nearly flat, sculptured with two strong and many finer cords ; uppermost of the two cords is in contact with posterior of aperture large and smooth, with thick inner and outer lips ; growth lines fine, distinct and inclined about 40 degrees to whorl axis.

Remarks.—Three well-preserved specimens were examined.

Comparison.—The species somewhat resembles *Littorina* (*Ezolittorina*) *squalida* Brodelip and Sowerby, a Recent species distributed from Northeast Honshu to the Okhotsk

Sea coast (Habe and Okutani, 1975), in general feature, but differs in having a larger shell with more indistinct spiral cords.

Locality.—7 (No. 102614), 11 (No. 102613).

Measurements (in mm).—

IGPS Coll. Cat. No.	Height	Diameter
102613-1	10.5	8.3
102613-2	11.0+	10.3
102614	6.0+	6.3

Family Calyptraeidae
Genus ***Crepidula*** Lamarck, 1799

Crepidula jimboana Yokoyama, 1931

Figures 1-16a-c, 17a, b

Crepidula jimboana Yokoyama, 1931, p. 194, pl. 11, fig. 1; Otuka, 1934, p. 626, pl. 51, fig. 112; Nomura and Hatai, 1936, p. 144, 145, pl. 17, fig. 17; Itoigawa, 1956, pl. 1, fig. 7; Makiyama, 1959, pl. 80, figs. 1a, b; Mizuno, 1964, pl. 1, figs. 11, 12; Itoigawa in Itoigawa *et al.,* 1974, p. 144, 145, pl. 44, figs. 7a-11; Itoigawa *et al.,* 1981, 1982, p. 189, pl. 33, figs. 15a-c, 16; Amano, 1983, p. 32, pl. 8, fig. 7; Akamatsu, 1984, pl. 1, fig. 4; Amano, 1986, pl. 18, fig. 6.

?*Crepidula jimboana* Yokoyama. Muramatsu, 1992, pl. 50, fig. 10.

not *Crepidula jimboana* Yokoyama. Nomura and Ônishi, 1940, p. 192, pl. 19, fig. 8.

Remarks.—*Crepidula jimboana* is characterized by its large size, rather thick, inflated shell with a blunt incurved beak. *Crepidula jimboana* figured by Nomura and Ônishi (1940) is not conspecific with the present species judging from its less convex shell.

Comparison.—*Crepidula nidatoriensis sogabei* Kamada, 1962, from the Numanouchi Formation in Fukushima Prefecture, is distinguished from this species in possessing a smaller shell with a more strongly incurved apex.

Locality.—1, 3 (No. 102615), 4, 7, 16, 18 (No. 102616).

Distribution.—Ishiizawa, Takinoue and Furanui Formations of Hokkaido, Isomatsu Formation in Aomori Prefecture, Kubota Formation in Fukushima Prefecture, Tôyama and Akeyo Formations of the Mizunami Group in Gifu Prefecture, Okuyamada and Yuantani Formations of the Tsuzuki Group in Kyoto Prefecture, Kurokawa Formation of the Ayugawa Group in Shiga Prefecture.

Measurements (in mm).—

IGPS Coll. Cat No.	Height	Width	Depth
102615-1	40.8+	27.3	20.2
102615-2	40.9+	28.1	21.5
102616-1	38.7	22.7	16.8
102616-2	34.6	20.1	16.1
102616-3	30.4	17.8	16.8
102616-4	33.8+	23.8	17.1

Family Potamididae
Genus ***Tateiwaia*** Makiyama, 1936

Tateiwaia chinzeii sp. nov.

Figures 1-12a, b, 13a, b, 14a, b

Batillaria yamanarii Makiyama. Mizuno, 1964, pl. 1, figs. 1-3 [not of Makiyama, 1926]

Tateiwaia yamanarii (Makiyama). Itoigawa in Itoigawa *et al.,* 1974, p. 134-135, pl. 40, figs. 23, 24a, b [not of Makiyama, 1926]

Tateiwaia sp. Itoigawa *et al.,* 1981, 1982, p. 174, pl. 30, figs. 9a, b.

Type locality.—Loc. 11; upper reaches of the Koida River, about 1.6 km east of Chayaba, Ichinohe town, Ninohe County, Iwate Prefecture.

Type specimens.—IGPS Coll. Cat. No. 102618 (holotype), No. 102619 and 102620 (paratypes).

Description.—Shell of medium size for genus *Tateiwaia*, highly turreted, and with moderate thickness; apical angle about 30°. Nuclear whorl smooth; whorls delimited by fine, distinct suture; holotype specimen has about 7 whorls except for protoconch. Shell surface with fine growth lines and sculptured with nodular axial ribs crossed by fine spiral cords; axials well elevated, shouldered, extending over whole of whorl height and 8 to 10 on body and penultimate whorls; interspaces broader than axials; spiral cords 4, fine, strong, round-topped, equidistant from each other; interspaces of nearly equal width to or slightly broader than the cords; upper two cords become nodulous or spinous as they cross longitudinal ribs; lowermost cord contacts suture; upper area of whorl sculptured by numerous fine spiral threads. Growth lines with shallow sinus on the shoulder; aperture small, inclined, oblong, with short canal and weakly developed inner lip; outer lip not thickened.

Remarks.—The species is named in honour of Prof. Kiyotaka Chinzei of Kyoto University.

It is conspecific with *Batillaria yamanarii* Makiyama by Mizuno (1964) from the Isomatsu Formation of the Kita-tsugaru district, Aomori Prefecture, *Tateiwaia yamanarii* by Itoigawa (1974) and *Tateiwaia* sp. by Itoigawa *et al.* (1981, 1982) from the Tsukiyoshi Member of the Akeyo Formation, Mizunami Group, of Gifu Prefecture judging from details of the longitudinal ribs and spiral cords.

Comparison.—*Tateiwaia yamanarii* (Makiyama, 1926), a well-known species from upper Lower-lower Middle Miocene deposits resembles this species, but differs in having a stronger shell shoulder sculptured only by fine spiral threads. *Tateiwaia toshioi* (Masuda, 1956), originally described from the Lower Miocene Higashi-innai Formation of Ishikawa Prefecture, is another allied species, but is distinguished by the possession of more rounded longitudinal ribs and spiral cords on the upper area of the whorl.

Locality.—2, 4, 5, 7, 8a, 8b, 10, 11 (No. 102618, 102619), 12, 13, 16 and 18 (No. 102620).

Distribution.—Isomatsu Formation in Aomori Prefecture, Tsukiyoshi Member of the Akeyo Formation of the Mizunami Group in Gifu Prefecture.

Measurements (*in mm, unless otherwise stated*).—

IGPS Coll. Cat. No.	Height	Maximum diameter	Number of axial ribs	
			Body whorl	Penultimate whorl
102618	24.5+	10.6	8	9
102619-1	26.8+	11.1	10	8
102619-2	27.0+	9.6	8	8
102619-3	24.6+	10.2	10	11
102619-4	19.5+	17.6	10	10
102619-5	21.4+	8.6	9	8
102619-6	21.9+	8.4	9	9
102619-7	27.0+	10.2	10	10
102619-8	20.5+	9.3	9	9
102619-9	15.8+	6.3	9	9
102619-10	19.3+	7.6	8	8
102619-11	—	9.3	9	9
102619-12	11.7	5.2	8	8

Genus **Cerithideopsilla** Thiele, 1929

Cerithideopsilla aff. **minoensis** (Itoigawa, 1960)

Figures 1-5a, b, 6

Resembles.—

Cerithidea (Cerithideopsilla) minoensis Itoigawa, 1960, p. 279, 280, pl. 3, figs. 13a, b, 14 ; Itoigawa *et al.,* 1974, p. 134, pl. 40, figs. 20-23.

Cerithideopsilla minoensis (Itoigawa). Itoigawa *et al.,* 1981, 1982, p. 167, 168, pl. 29, figs. 1a-b ; Noda *et al.,* 1994, figs. 7-3, -4.

Description.—Shell medium in size for genus *Certhideopsilla*, rather thin, turreted, of 10 whorls ; spire not inflated, outline nearly straight ; protoconch lost ; shell surface sculptured with 3 flat-topped spiral cords crossing axial ribs ; spiral cords equally distributed and separated by distinct interspaces ; interspaces flat-bottomed and nearly equal to or slightly broader than cords ; axial ribs less elevated than cords, nearly parallel to shell axis and narrower than their interspaces ; ribs less elevated with growth ; junctions of spiral cords and axial ribs nodulous ; a complete specimen shows 18 ribs on body and penultimate whorls ; suture fine, distinct ; lowermost part of whorl depressed like a band ; body whorl has 5 spiral cords the lower two of which are fine ; aperture tilted, oblong with short canal ; inner lip thin, smooth ; outer lip rather extended outwards ; varix not observed.

Comparison.—*Cerithideopsilla minoensis* (Itoigawa, 1960), originally described from the Akeyo Formation of the Mizunami Group in Gifu Prefecture, closely resembles these specimens, but differs in possessing fewer axial ribs with much broader interspaces, and narrower spiral cords on the body whorl. *Cerithideopsilla djadjariensis* (v. Martens), a living species, resembles this material, but is distinguished by having broader spiral cords. *Cerithideopsilla cingulata* (Gmelin), an another living species, is distinguished from the present species by its broader spiral cords, stronger axial ribs and body whorl with well developed outer lip and a distinct varix. The present species differs from *C. yatsuoensis* (Tsuda, 1959), originally described from the Miocene Kurosedani Formation of Toyama Prefecture, in possessing narrower and fewer axial ribs.

Locality.—8b, 9 (No. 102617), 11 (No. 102584), 13, 18.

Measurements.—

IGPS Coll. Cat. No.	Height (mm)	Diameter (mm)	Number of axial ribs	
			Body	Penultimate
102584	20.5+	7.4	18	18
102617-1	30.0+	9.2	—	—
102617-2	24.4+	ca. 8.2	—	—

Family Cerithidae

Genus **Vicaryella** Yabe and Hatai, 1938

Vicaryella "bacula" (Yokoyama, 1923)

Figures 1-10, 11, 15a, b

?*Cerithium baculum* Yokoyama, 1923b, p. 52, pl. 6, fig. 12.

?*Vicaryella bacula* (Yokoyama). Yabe and Hatai, 1938, pl. 21, fig. 26 ; Makiyama, 1957, pl. 7, fig. 12.

?*Clava bacula* (Yokoyama). Takeyama, 1930, p. 104.

Vicaryella bacula (Yokoyama). Shikama, 1954, pl. 6, figs. 6a-b ; Okamoto and Terachi, 1974, pl. 41, fig. 10 ; Itoigawa in Itoigawa *et al.,* 1974, p. 137, pl. 42, figs. 4a-b ; Itoigawa and Nishikawa, 1976, pl. 35, fig. 12 ; Itoigawa, 1978, pl. 2, fig. 2 ; Yoon, 1980, p. 74, pl. 8, fig. 6 ; Itoigawa *et al.,* 1981, 1982, p. 170-171, pl. 30, figs. 13a-b ; Mizuno *et al.,* 1994, fig. 3-D, E in p. 41.

not *Cerithium baculum* Yokoyama. Yokoyama, 1925b, [*Vicaryella ishiiana* (Yokoyama)].

not *Vicarya bacula* (Yokoyama). Yokoyama, 1926b, [*Vicarya yokoyamai* Takeyama, 1933]

not *Vicaryella bacula* (Yokoyama). Yabe and Hatai, 1938, p. 168-169, pl. 21, figs. 33-35, 38 ; Taguchi *et al.,* 1979, pl. 3, figs. 29, 30 [*Vicaryella ishiiana* (Yokoyama)].

not *Vicaryella* cf. *bacula* (Yokoyama). Hatai, 1940, p. 136 [*Tateiwaia tateiwai* (Makiyama)].

Description.—Shell highly turreted, moderately thick, rather small ; shell surface sculptured with 4 or 5 spiral cords ; subsutural cord strongest, platy and spinous ; other cords fine and very finely beaded ; worn specimen show smooth spiral cords ; spines of subsutural cord 8 to 9 in number on body and 7 to 8 on penultimate whorls ; canal short, but distinct ; outer lip thickened on several specimens ; suture distinct.

Remarks.—*Vicaryella bacula* was originally described from the lower Middle Miocene Kanayama Formation of Wakayama Prefecture by Yokoyama (1923b) based on a single, incomplete specimen under the genus *Cerithium*. Takeyama (1930) reexamined topotype specimens and pointed out that *Cerithium baculum* of Yokoyama (1925b) from the Lower Miocene Nakayama Formation in Fukushima Prefecture and *Vicarya bacula* of Yokoyama (1926b) from the Tsukiyoshi Member of the Akeyo Formation of the Mizunami Group in Gifu Prefecture are not identical with this species ; the former specimens are *Vicaryella ishiiana* (Yokoyama, 1926) and the latter was later given the new name of *Vicarya verneuili yokoyamai* by Takeyama (1933). However, he did not describe the morphologic characters of the spiral cords of *V. bacula*. Although Yabe and Hatai (1938) referred specimens from the Tsukiyoshi Member of the Akeyo Formation to this species, their specimens were later considered to be conspecific with *V. ishiiana*. Oyama and Saka (1944) listed the morphological characters of species belonging to

Vicaryella, including *V. bacula*, in the remarks on *V. ishiiana* from the Tsukiyoshi Member of the Akeyo Formation of the Mizunami Group, but it is uncertain what specimens they examined for *V. bacula*. In fact, the morphologic features, especially of the spiral cords and aperture, of true *V. bacula* are still unclear.

Shikama (1954) figured *Vicaryella bacula* from the Tomikusa Group of Nagano Prefecture, and specimens from the Yotsuyaku Formation are considered to be conspecific on the basis of the above-mentioned characters. Therefore, the writer uses the name *V. bacula* provisionally, in the sense of Shikama (1954), but the species should be revised based on topotype specimens.

Vicaryella cf. *bacula* reported from the Kadonosawa Formation by Hatai (1940) is conspecific with *Tateiwaia tateiwai* (Makiyama, 1926), based on the writer's reexamination of the specimen registered and deposited in the Tohoku University (IGPS) collection.

Comparison.—*Vicaryella jobanica* Kamada, 1960, from the Kunugidaira Formation in Fukushima Prefecture, closely resembles this species in having a platy, spinous subsutural cord and distinct suture, but is distinguished by having more strongly beaded spiral cords except for the subsutural cord. *Vicaryella ishiiana* (Yokoyama, 1926a) is easily distinguished from the present species in possessing low, rounded subsutural spiral cords with many tubercles and an indistinct suture.

Locality.—2 (No. 102621), 8a (No. 102622), 8b, 10 (No. 102623), 11.

Distribution.—Arakida, Ôshimojo, Nukuta and Awano Formations of the Tomikusa Group in Nagano Prefecture, Akeyo Formation of the Mizunami Group in Gifu Prefecture, Ayugawa Group in Shiga Prefecture, ?Kanayama Formation in Wakayama Prefecture, "lower formation" of the Bihoku Group in Hiroshima and Okayama Prefectures, Nishiichi Formation in Yamaguchi Prefecture, Japan. Sinhyeon Formation in the Ulsan district, Korea.

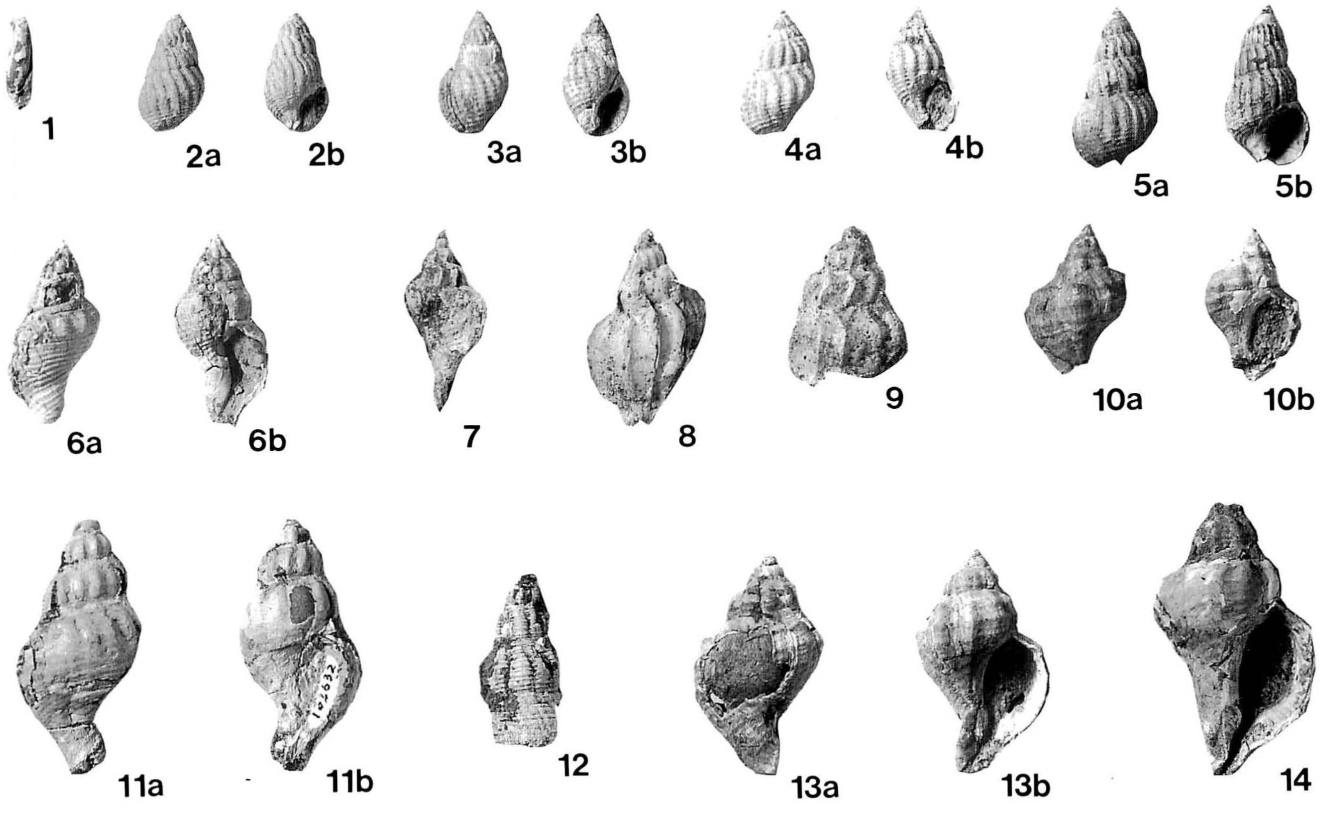

Figure 2. (All figures natural size, unless otherwise stated)

1. *Adamnestia* sp., Loc. 19, IGPS coll. cat. no. 102589, ×1.5. **2a-b, 5a-b.** *Phos (Phos) notoensis* Masuda, 2a-b : Loc. 11, IGPS coll. cat. no. 102631, ×1.5, 5a-b : Loc. 13, IGPS coll. cat. no. 102628, ×1.5. **3a-b, 4a-b.** *Nassarius* (*Zeuxis*) sp., Loc. 12, IGPS coll. cat. no. 102634, ×1.5. **6a-b, 11a-b, 12.** *Searlesia kurodai* Makiyama, 6a-b : Loc. 13, IGPS coll. cat. no. 102639, 11a-b : Loc. 15, IGPS coll. cat. no. 102632, 12 : Loc. 12, IGPS coll. cat. no. 102638. **7, 8, 9.** *Boreotrophon* sp., 7 : Loc. 19, IGPS coll. cat. no. 102634, 8, 9 : Loc. 14b, IGPS coll. cat. no. 102635. **10a-b, 13a-b, 14.** "*Ocenebra*" *katayamai* sp. nov., Loc. 18, 10a-b, 14 : IGPS coll. cat. no. 102630, paratypes, 13a-b : IGPS coll. cat. no. 102629, holotype.

Vicaryella otukai (Nomura, 1935)

Figures 1-7a, b, 8

Cerithium aff. *ishiianum* (Yokoyama). Otuka, 1934, p. 624, 625, pl. 49, figs. 72, 73. [not of Yokoyama, 1926a].
Cerithium (*Proclava*) *otukai* Nomura, 1935, p. 227.
?*Cerithium* cf. *otukai* Nomura. Itoigawa, 1956, pl. 2, figs. 6, 8.
Vicaryella tyosenica otukai (Nomura). Kamada, 1960, pl. 31, figs. 3a, b; Mizuno, 1964, p. 10, 11, pl. 1, figs. 8-10; Kanno and Ogawa, 1964, text-fig. 5b.
Batillaria cf. *toshioi* Masuda. Ogasawara, 1973, pl. 13, fig. 21 (not of Masuda, 1956).
Proclava otukai (Nomura). Itoigawa in Itoigawa *et al.,* 1974, p. 138, 139, pl. 43, figs. 12a, b, 14.
Rhinoclavis (*Proclava*) *otukai* (Nomura). Houbrick, 1978, p. 79, pl. 48.
"*Proclava*" *otukai* Nomura. Itoigawa *et al.,* 1981, 1982, p. 181, 182, p. 181, 182, pl. 31, figs. 23a, b.
not *Cerithium* (*Proclava*) *otukai* Nomura, 1935d, pl. 2, figs. 7. [*Vicaryella ishiiana* (Yokoyama)].

Remarks.—*Vicaryella otukai* is characterized by its highly turreted shell and shell surface sculptured with distinctly beaded spiral cords, initially three in number and equidistant with narrower interspaces; secondarily, the subsutural one becomes stronger and nodular with shell growth and a few, very finely beaded cords are intercalated in each interspace. Specimens from the Yotsuyaku Formation are smaller in size than the holotype specimen, but possess the same features of the spiral cords and are therefore referable to *V. otukai*. *Batillaria* cf. *toshioi* Masuda reported by Ogasawara (1973) from the Nishikurosawa Formation in Akita Prefecture is considered to be conspecific with the present species judging from the spiral cords.

Comparison.—*Vicaryella tyosenica* Yabe and Hatai, 1938, closely resembles this species, but is distinguishied by having a strongly spinous subsutural cord. This species is also similar to *Vicaryella ancisa* (Yokoyama, 1926) [=*Batillaria atukoae* Otuka as pointed out by Otuka (1938)], but is distinguished by having a narrower apical angle, more whorls and weaker subsutural cords on younger whorls.

Locality.—2 (No. 102624), 3, 8a, 11, 12, 13, 15, 18 (No. 102627).

Distribution.—Furanui Formation of Hokkaido, Isomatsu Formation in Aomori Prefecture, Nishikurosawa Formation in Akita Prefecture, Kadonosawa Formation in Iwate Prefecture, Okuyamada and Yuantani Formations of the Tsuzuki Group in Kyoto Prefecture, Nenobi Granule Conglomerate and Hiramatsu Sandstone and Siltstone Formations of the Awa Group in Mie Prefecture.

Vicaryella sp. indet.

Figure 1-9

Remarks.—Although only a single mould was obtained, this specimen is characterized by its four finely beaded spiral cords which are rather broader than their interspaces, and by subsutural cords stronger than the other and also finely beaded.

Locality.—2 (No. 102627).

Family Buccinidae
Genus ***Phos*** Montfort, 1810
Subgenus ***Phos*** s.s.

Phos (***Phos***) ***notoensis*** Masuda, 1967

Figures 2-2a, b, 5a, b

Phos notoensis Masuda, 1967, p. 7, 8, pl. 2, figs. 6a, b.

Description.—Shell small, rather thin, turreted, with rounded base and oblong aperture; apex rather rounded; whorls weakly inflated; the largest specimen has 6 and a half whorls; protoconch of 3 whorls, smooth; suture fine, distinct, slightly undulating; shell surface sculptured by axial ribs and spiral cords; axial ribs nearly equal to or slightly narrower than their interspaces, rounded, weakly curved; ribs 18 to 20 on body whorl and 16 to 20 on penultimate whorl, respectively; spiral cords flat-topped, much broader than their interspaces, and 15 to 16 on the body and 8 to 9 on penultimate whorls; varix rather distinct; aperture with smooth inner lip and short canal; inner lip covered by thin callus; outer lip lacking; posterior canal small, distinguished by a small ridge; columella smooth; fasciole weakly developed, with more than 4 folds and not sharply defined.

Comparison.—*Phos* (*Coraeophos*) *tsukiyoshianus* Itoigawa, 1960, originally described from the Akeyo Formation of the Mizunami Group in Gifu Prefecture, resembles this species in outline and in morphology of the aperture, but is distingushed by having fewer, broader spiral cords. As pointed out in the original description, this species is distinguished from *Phos* (*Phos*) *minoensis* Itoigawa, 1960, from the Akeyo Formation of the Mizunami Group in Gifu Prefecture, in having less inflated whorls, fewer and broader spiral cords and fewer axial ribs.

Locality.—10, 11 (No. 102631), 13 (No. 102628), 19.

Measurements.—

IGPS Coll. Cat. No.	Height (mm)	Diameter (mm)	Number of axial ribs		Number of spiral cords	
			body	penultimate	body	penultimate
102628-1	13.8+	7.2	20	18	15	10
102628-2	10.3	5.1+	—	21	—	—
102628-3	10.6	5.5	20	17	16	9
102628-4	11.6	5.5+	17	17	15	8
102628-5	16.2+	6.2+	—	20	—	8
102628-6	9.9+	5.5+	—	16	15	8
102628-7	9.1	5.0	18	18	—	—
102628-8	8.9	4.7+	20	17	—	10

Genus ***Searlesia*** Harmer, 1915

Searlesia kurodai Makiyama, 1936

Figures 2-6a, b, 11a, b, 12

Searlesia kurodai Makiyama, 1936, p. 223-224, pl. 5, figs. 13, 14.

Remarks.—One nearly complete specimen lacking shell surface of body whorl and some broken specimens were obtained. Specimens from the Yotsuyaku Formation are characterized by their rather small size and fusiform shells, the surface sculptured with 10 to 13 nodular axial ribs and 11 rather irregular spiral cords on the penultimate whorl, intercalated by a number of secondary threads. The species was originally described from the Pyonryug (Heiroku) Formation of the Meongcheon (Meisen) Group of North Korea, and has been subsequently little reported.

Distribution.—Pyonryug (Heiroku) Formation of the Meongcheon (Meisen) Group in North Korea.

Locality.—2, 5, 6, 7, 10, 11 (No. 102639), 12 (No. 102638), 13, 15 (No. 102632).

Family Nassariidae
Genus ***Nassarius*** Duméril, 1806
Subgenus ***Zeuxis*** H. & A. Adams, 1853

Nassarius (***Zeuxis***) sp. indet.

Figures 2-3a, b, 4a, b

Description.—Shell small, rather thick, low-turreted, rather inflated; base large; aperture large oblong in form, with short canal, rather distinct inner lip and thickened outer lip; canal broadly open, strongly inclined; inner lip smooth, distinctly defined by callus; outer lip with more than 6 denticulations; columella with five folds; posterior canal short, angular and distinguished by a parietal ridge; shell surface ornamented by axial ribs and spiral cords; axial ribs much stronger than spiral cords, well elevated, round-topped, narrower than their round-bottomed interspaces and weakly folded; ribs 14 to 15 on body whorl and 12 to 14 on penultimate whorl; spiral cords less elevated, flat-topped, broader than their interspaces except on periphery, 11 to 13 on the body and 5 to 6 on penultimate whorls; subsutural cord rather broader than the others and distinguished by a shallow spiral furrow; varix distinct on body whorl; fasciole distinct, with 4 folds.

Comparison.—*Nassarius* (*Zeuxis*) *notoensis* (Masuda, 1955) from the Higashi-innai Formation in Ishikawa Prefecture, resembles the present materials, but is distinguished in having a smaller shell with indistinct spiral cords and strongly elevated axial ribs.

Nassarius (*Zeuxis*) *minoensis* (Itoigawa, 1960), originally described from the Mizunami Group in Gifu Prefecture, is distinguished by its broader axial ribs.

Locality.—1, 2, 3, 8a, 8b, 10, 12 (No. 102634), 13, 14a, 14b, 15, 16, 18, 19.

Order Neogastropoda
Family Muricidae
Genus ***Ocenebra*** Gray, 1847

"***Ocenebra***" ***katayamai*** sp. nov.

Figures 2-10a, b, 13a, b, 14

Type locality.—Loc. 18; upper reaches of the Nesori River about 3 km east of Nosokei, Ichinohe town, Ninohe County, Iwate Prefecture.

Type specimens.—IGPS Coll. Cat. No. 102629 (Holotype), No. 102630 and 102631 (Paratypes).

Description.—Shell of medium size, moderately thick, fusiform, with large aperture; apical angle about 50°; holotype specimen of about 4 whorls; protoconch not distinguished because of wear; aperture occupies about half the shell height; periphery smoothly rounded and continues to canal; whorl inflated, shouldered, and sculptured by axial ribs, spiral cords, and fine growth lines; varix not distinct; axial ribs stronger than spiral cords, nodular, 9 on body and penultimate whorls on holotype specimen, and separated by interspaces rather broader than the ribs; axial ribs become obsolete near aperture of the larger specimen; two strongly elevated spiral cords associated with fine, numerous subsidiary cords; junction of axial ribs and spiral cords becomes nodular or spinous; aperture with rather long, weakly curved canal and angulated anterior canal; outer lip rather thickened, but not extending outwards and with 9 to 12 denticulations; inner lip narrow, smooth and defined by thin callus; columella with no fold; fasciole distinct and curved.

Remarks.—The species is dedicated to the late M. Sc. Toshio Katayama who studied the geology and micropaleontology of the Ninohe-Sannohe district in 1978-1980.

Judging from features of the apertural area, axial ribs and spiral cords, this species belongs to the family Muricidae. However, the writer could find no genus entirely suitable for this species, and the reference to the genus *Ocenebra* is made provisionally.

Locality.—2 (No. 102631), 7, 8a, 11, 12, 18 (No. 102629, 103630).

Measurements.—

IGPS Coll. Cat. No.	Height (mm)	Diameter (mm)	Number of whorls
102629 (Holotype)	29.0	16.8	4
102630-1 (Paratype)	36.1+	—	3+
102630-2 (Paratype)	26.2±	27.3	2+
102630-3 (Paratype)	16.5	17.2	4
102630-4 (Paratype)	20.0+	13.5	4
102630-5 (Paratype)	15.4+	15.5	4

Genus ***Boreotrophon*** Fischer, 1884

Boreotrophon sp. indet.

Figures 2-7, 8, 9

Remarks.—Some external moulds were obtained. These specimens have small fusiform shells with laminar axial ribs and a rather curved canal. Although determination of the species is difficult, these features indicate that it is a member of the genus *Boreotrophon*.

Locality.—14a (No. 102635), 14b, 19 (No. 102636).

Subclass Opistobranchia
Order Cepharaspida
Family Scaphandriadae
Genus ***Adamnestia*** Iredale, 1937

Adamnestia sp. indet.

Figure 2-1

Remarks.—This species is characterized by its small, cylindrical shell with a slit-like aperture of which the anterior part is rounded and rather broadly opening, and a depressed apex. The specimens are too poorly preserved to identify the species.

Locality.—14a, 20 (No. 102589).

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References cited

Akamatsu, M., 1984: Paleoenvironment of the *Desmostylus*-bearing formations in Hokkaido—with a special reference to the Hobetsu specimen. *Monograph of the Association of Geological Collaboration in Japan*, no. 28, p. 63-68, pl. 1. (*in Japanese with English abstract*)

Amano, K., 1980: Miocene molluscan fossils from the Yudoro Formation in the east Rumoi, Hokkaido. *Prof. S. Kanno Memorial Volume*, p. 99-120, pl. 13.

Amano, K., 1983: Paleontological study of the Miocene Togeshita molluscan fauna in the Rumoi district, Hokkaido. *Science Report of the Institute of Geoscience, the University of Tsukuba, Section B* (*Geological Science*), vol. 4, p. 1-72, pls. 1-8.

Amano, K., 1986: Age and characteristics of the so-called "Atsunai-Togeshita Fauna" in Hokkaido. *Palaeontological Society of Japan, Special Papers*, no. 29, p. 187-198, pl. 18.

Amano, K., 1992: *Cypraea ohiroi* and its associated molluscan species from the Miocene Kadonosawa Formation, Northeast Japan. *Bulletin of the Mizunami Fossil Museum*, no. 19 (*Dr. J. Itoigawa Memorial Volume*), p. 405-411, pl. 57.

Amano, K., 1994: Pliocene molluscan fauna and its paleoenvironment in Matsunoyama-machi, Niigata Prefecture. *Journal of Geography*, vol. 103, no. 6, p. 653-673, pls. 1-3. (*in Japanese with English abstract*).

Aoki, S., 1954: Mollusca from the Miocene Kabeya Formation, Jôban Coal-field, Fukushima Prefecture, Japan. *Science Reports of the Tokyo University of Education, Section C*, vol. 3, no. 17, p. 23-41, pls. 1, 2.

Aoki, S., 1959: Miocene Mollusca from the southern part of the Shimokita Peninsula, Aomori Prefecture. *Science Reports of the Tokyo University of Education, Section C*, vol. 6, no. 57, p. 255-280, pls. 1-3.

Araki, Y., 1959: On some marine Miocene Mollusca from Mie Prefecture, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 36, p. 161-167, pl. 18.

Araki, Y., 1960: Geology, paleontology and sedimentary structures (including Problematica) of the Tertiary formations developed in the environs of Tsu City, Mie Prefecture. *Bulletin of the Liberal Art Department, Mie University, Special Volume*, no. 1, 118 p., 11 pls.

Baba, K., 1990: *Molluscan Fossil Assemblages of the Kazusa Group, South Kwanto, Central Japan*. 445 p., 40 pls., Keio Yochisha, Tokyo. (*in Japanese with English description of new species*)

Bito, A., Hayakawa, T., Kaseno, Y., Ogasawara, K. and Takayama, T., 1980: Neogene stratigraphy around Kaga City, Ishikawa Prefecture, Japan. *Annals of Science, College of Liberal Arts, Kanazawa University*, p. 45-77, pls. 1-3.

Chijiwa, K. and Tomita, S., 1985: On the Onuma Formation of the Kumano Group (A study of the Tertiary formation of the Kumano Coal-field in the Kii Peninsula, Southwest Japan, Part 3). *Memoirs of the Faculty of Science, Kyushu University, Series D* (*Geology*), vol. 25, no. 3, p. 319-336, pl. 41.

Chinzei, K., 1958: On the Neogene formations in the vicinity of Fukuoka-machi, Iwate Prefecture; Cenozoic geology of the northern margin of the Kitakami Mountains, I. *Journal of Geography,* vol. 67, no. 1, p. 1-30. (*in Japanese with English abstract*)

Chinzei, K., 1959: Molluscan fauna of the Pliocene Sannohe Group of Northeast Honshu, Japan. 1. The faunule of the Kubo Formation. *Journal of Faculty of Science, the University of Tokyo, Section 2*, vol. 12, pl. 1, pls. 9-11.

Educational Committee of Fukushima Prefecture *ed.*, 1983: Report on the fossils from the mountains in the western margin of Aizu Basin, Fukushima Prefecture—with a special reference to the Yama Fauna (Mollusca). *Research Reports of the Fukushima Prefectural Museum*, no. 2, p. 21, pls. 1-4. (*in Japanese, title translated*)

Fujie, T., 1958: Illustrated Cenozoic fossils (28). Molluscan fossils from the Pleistocene Shishinai Formation, Hokkaido. *Shinseidai-no-Kenkyû* (*Cenozoic Research*), no. 28, p. 28-44, pls. 27, 28. (*in Japanese, title translated*)

Fujie, T. and Uozumi, S., 1957: Illustrated Cenozoic Fossils (25). Faunal succession of Neogene molluscan fauna of Hokkaido (preliminary report)—No. 1. Outline of the faunas and their distributions. *Shinseidai-no-Kenkyû* (*Cenozoic Research*), no. 23, p. 32-37, pl. 24. (*in Japanese, title translated*)

Habe, T., 1953: Pinnidae, Placunuidae, Anomiidae. *In*, T. Kuroda *ed.*, *Illustrated Catalogue of Japanese Shells*, no. 24, p. 185-200, pls. 24-28.

Habe, T., 1955: Fauna of Akkeshi Bay, 21. Pelecypoda and Scaphopoda. *Publications from the Akkeshi Marine Biological Station*, no. 4, p. 1-31, pls. 1-7.

Habe, T., 1960: Fauna of shell-bearing molluscs of the sea around Shirikishinai, Hokkaido (1), Pelecypoda. *Fauna and Flora of the Sea around Shirikishinai Marine Station*, no. 2, p. 1-10, pls. 1-5. (*in Japanese with English abstract*)

Habe, T., 1977: *Systematics of Mollusca in Japan*: *Bivalvia and Scaphopoda*, 372 p. Zukan-no-Hokuryukan, Tokyo. (*in Japanese*)

Habe, T. and Okutani, T., 1975: *The Mollusks of Japan*. (*The Snails*), 306 p., Gakken, Tokyo.

Hata, Y., 1967: Cenozoic sequences in the Komono area, Mie Prefecture. *Reports of Resources Exploitational Institute*, no. 4, p. 77-107, pls. 1-6. (*in Japanese, title translated*).

Hatai, K., 1940 : On some fossils from the Ninohe district, Mutu Province, Northeast Honsyû, Japan (No. 1). *Bulletin of the Biogeographical Society of Japan*, vol. 10, no. 9, p. 119-137, pl. 1.

Hatai, K. and Nisiyama, S., 1949 : New Tertiary Mollusca from Japan. *Journal of Paleontology*, vol. 23, no. 1, p. 87-94, pls. 23, 24.

Hatai, K. and Nishiyama, S., 1952 : Check list of Japanese Tertiary marine Mollusca. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), *Special Volume*, no. 3, 464 p.

Hayakawa, N., Funayama, Y., Saito K. and Kitamura, N., 1954 : Geology of the Tertiary deposits distributed between eastern end of Kitakami Mountains and Ou Backbone Range in Iwate Prefecture. *Journal of the Tohoku Mining Society*, no. 10, 97 p. (*in Japanese, title translated*)

Hayasaka, S., 1960 : Large sized oysters from the Japanese Pleistocene and their paleoecological implications. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), *Special Volume*, no. 4 (*Prof. S. Hanzawa Memorial Volume*), p. 356-370, pls. 37, 38.

Hayasaka, S., 1961 : The geology and paleontology of the Atsumi Peninsula, Aichi Prefecture, Japan. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), vol. 33, no. 1, p. 1-103, pls. 1-12.

Hayasaka, S., 1969 : Molluscan fauna of the Kukinaga Group in Tané-ga-shima, south Kyûshû, Japan. *Reports of the Faculty of Science, Kagoshima University*, no. 2, p. 33-52, pls. 1-3.

Hayashi, T. and Miura, Y., 1973 : The Cenozoic sediments in the southern part of Okazaki City, central Japan. *Bulletin of the Aichi University of Education*, vol. 22, p. 133-149, pls. 1, 2.

Hirayama, K., 1954 : Miocene Mollusca from the Arakawa Group, Tochigi Prefecture, Japan. *Science Reports of the Tokyo University of Education, Section C.*, vol. 3, no. 18, p. 43-76, pls. 3-5.

Hirayama, K., 1956 : Tertiary Mollusca from Hikoshima, Yamaguchi Prefecture, Japan, with remarks on the geological age of the "Ashiya Fauna". *Science Reports of the Tokyo University of Education, Section C*, vol. 5, no. 45, p. 81-127, pls. 6-13.

Houbrick, R.S., 1978 : The family Cerithidae in the Indo-Pacific ; part 1 : The genera *Rhinoclavis, Pseudovertagus* and *Clavocerithium. Monograph of Marine Mollusca*, no. 1, p. 1-130.

Ikebe, N., 1941 : On *Katelysia* (*Nipponomarcia*) *nakamurai*, subgen. et sp. nov., from the Togarian Miocene of Japan. *Venus*, vol. 11, nos. 2-3, p. 49-53, pl. 2.

Itoigawa, J., 1955a : On the variation of *Katelysia* (*Nipponomarcia*) *nakamurai* Ikebe. *Venus*, vol. 18, no. 3, p. 176-183.

Itoigawa, J., 1955b : Molluscan fauna of the Mizunami Group in Iwamura Basin. *Memoirs of the College of Science, the University of Kyoto, Series B*, vol. 22, no. 2, p. 127-143, pls. 5, 6.

Itoigawa, J., 1956 : Molluscan fauna of the Tsuzuki Group in Kyoto Prefecture, Japan. *Venus*, vol. 23, no. 2, p. 179-192, pls. 1, 2.

Itoigawa, J., 1957 : On the Miocene Lucinidae from the Mizunami Group, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 25, p. 1-6, pl. 1.

Itoigawa, J., 1960 : Paleoecological studies of the Miocene Mizunami Group, Central Japan. *Journal of Earth Sciences, Nagoya University*, vol. 8, no. 2, p. 246-299, pls. 1-6.

Itoigawa, J., 1978 : Evidence of subtropical environments in the Miocene of Japan. *Bulletin of the Mizunami Fossil Museum*, no. 5, p. 7-21, pls. 2, 3.

Itoigawa, J. and Nishikawa, I., 1976 : A few problems on the Miocene Setouchi Series in the northern part of Okayama-Hiroshima Prefectures, southwest Japan. *Bulletin of the Mizunami Fossil Museum*, no. 3, p. 127-149, pls. 33-35. (*in Japanese with English abstract*)

Itoigawa, J. and Shibata, H., 1986 : Molluscan fauna of the Setouchi Miocene Series, southwest Japan. *Palaeontological Society of Japan, Special Papers*, no. 29, p. 149-159, pls. 16-17.

Itoigawa, J., Shibata, H. and Nishimoto, H., 1974 : Molluscan fossils from the Mizunami Group, central Japan. *Bulletin of the Mizunami Fossil Museum*, no. 1 (Geology and Paleontology of Mizunami City), p. 43-203, pls. 1-63. (*in Japanese, title translated*)

Itoigawa, J., Shibata, H., Nishimoto, H. and Okumura, Y., 1981 : Miocene fossils from the Mizunami Group, central Japan. 2. Molluscs. *Monograph of the Mizunami Fossil Museum*, no. 3-A, p. 1-53, pls. 1-52. (*in Japanese*)

Itoigawa, J., Shibata, H., Nishimoto, H. and Okumura, Y., 1982 : Miocene fossils from the Mizunami Group, central Japan. 2. Molluscs. *Monograph of the Mizunami Fossil Museum*, no. 3-B, p. 1-330. (*in Japanese*)

Iwai, T., 1960 : A new locality of the *Vicarya* fauna from Aomori Prefecture. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 37, p. 201-208, pl. 24.

Iwai, T., 1961 : The Miocene molluscan fossils from the area southwest of Hirosaki City, Aomori Prefecture. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series,* no. 41, p. 1-8, pl. 1.

Iwai, T., 1965 : The geological and paleontological studies in the marginal area of the Tsugaru Basin, Aomori Prefecture, Japan. *Bulletin of the Faculty of Education, Hirosaki University*, no. 15, p. 1-68, pls. 12-20.

Iwai, T. and Shiobara, T., 1969 : Pleistocene Mollusca from Kamikita-gun, Aomori Prefecture. *Bulletin of the Faculty of Education, Hirosaki University*, no. 20, p. 1-7, pls. 1-3.

Iwamura Research Group, 1989 : New localities of *Vicarya* in the Iwamura Basin, Gifu Prefecture, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 16, p. 117-120, pl. 21. (*in Japanese*)

Iwasaki, Y., 1970 : The Shiobara-type Molluscan Fauna ; an ecological analysis of fossil molluscs. *Journal of the Faculty of Science, the University of Tokyo, Section 2,* vol. 17, pt. 3, p. 351-444, pls. 1-7.

Kamada, Y., 1952 : On some species of *Cyclina* from Japan and Korea. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 6, p. 167-173, pl. 15.

Kamada, Y., 1954 : *Patinopecten kobiyamai*, a new Miocene scallop from the Joban Coal-field, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 15, p. 173-178, pl. 23.

Kamada, Y., 1960 : On the associated occurrence of *Vicarya* and *Vicaryella* in the Japanese Tertiary, with the first occurrence of a Paleogene species of *Vicarya* from Japan. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), *Special Volume*, no. 4 (*Prof. S. Hanzawa Memorial Volume*), p. 281-295, pls. 30, 31.

Kamada, Y., 1962 : Tertiary marine Mollusca from the Joban Coal-Field, Japan. *Palaeontological Society of Japan, Special Volume*, no. 5, 187 p., 21 pls.

Kanno, S., 1956 : Fossil and Recent species of the Cultellid molluscs from Japan. *Science Reports of the Tokyo University of Education, Section C*, vol. 4, no. 34, p. 209-218 pls. 5, 6.

Kanno, S., 1957 : On some new species of *Patinopecten* from the Chichibu Basin, Saitama Prefecture. *Bulletin of the Chichibu Museum of Natural History*, no. 7, p. 101-114, pls. 1-3.

Kanno, S., 1960 : The Tertiary System of the Chichibu Basin, Saitama Prefecture, Central Japan. Part 2. Palaeontology. *Publications of the Japan Society of Promotion of Science*, p. 123-396, pls. 31-51.

Kanno, S. and Akatsu, K., 1972 : Tertiary System developed in the Taiki-machi, Biroo-gun, Hokkaido. *Memoirs of the National Science Museum,* no. 5, p. 227-236, pls. 8, 9 (*in Japanese with English abstract*)

Kanno, S., Amano, K. and Noda, H., 1988 : *Vicarya* and its associated molluscan fauna from the Kunnui Formation in Oshamanbe, Southwest Hokkaido. *Saito Ho-on Kai Special Publications* (*Prof. T. Kotaka Commemorative Volume*), p. 373-389, pls. 1-3.

Kanno, S. and Ogawa, H., 1964 : Molluscan fauna from the Momijiyama and Takinoue districts, Hokkaido, Japan. *Science Reports of the Tokyo University of Education, Section C*, vol. 8, no. 81, p. 269-294, pls. 1-4.

Kaseno, Y., 1956 : 2. Molluscan fossils from the environs of Ayukawa. *Fukui-ken-san Kaseki Zu-fu* (*Illustrated Catalogue of Fossils from Fukui Prefecture*), no. 1, p. 4-16, pls. 1-4. (*in Japanese, title translated*)

Kaseno, Y. and Matsuura, N., 1965 : Pliocene shells from the Omma Formation around Kanazawa City, Japan. *Science Reports of the Kanazawa University*, vol. 10, no. 1, p. 27-62, pls. 1-20.

Katto, J. and Masuda, K., 1978 : Tertiary Mollusca from the southern part of Kii Peninsula, Wakayama Prefecture, Southwest Japan. *Research Reports of the Kochi University*, vol. 27, p. 97-111, pls. 1-5.

Kim, B. K., Noda, H. and Yoon, S., 1974 : Molluscan fossils from the Miocene Eoil Formation, Gampo and Ulsan districts, southeastern-side of Korea. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 93, p. 266-285, pls. 38, 39.

Kim, B. K. and Yoon, S., 1978 : Some molluscan fossils from the uppermost part of the Neogene deposits of the Pohang Basin, Korea. *Journal of the Geological Society of Korea*, vol. 14, no. 2, p. 1-12, pls. 1, 2.

Kobayashi, I., 1986 : Character and development of the Omma-Manganji Fauna in Niigata Oil-field, Central Japan. *Palaeontological Society of Japan, Special Papers,* no. 29, p. 245-255, pl. 21.

Kobayashi, I. and Ueda, T., 1991 : Early Middle Miocene molluscan assemblages from the Orito Formation, Sado Island, Central Japan. *Science Reports of the Niigata University, Series E (Geology and Mineralogy)*, no. 8, p. 125-149.

Kobayashi, Y., 1987 : Molluscan assemblage from the Otanoshike Formation, Kushiro area. *Prof. M. Matsui Memorial Volume*, p. 113-129, pls. 1-4.

Kotaka, T., 1955 : Molluscan fauna from the Oligocene Isomatsu Formation, Aomori Prefecture, Northeast Japan. *Saito Ho-on Kai Museum Research Bulletin*, no. 24, p. 23-31, pl. 2.

Kuroda, T., 1929-1935 : Illustrated Catalogue of Japanese Shell-bearing Mollusca. *Venus*, vol. 1, nos. 3-6, vol. 2, nos. 1-6, vol. 3, nos. 1-5, vol. 4, nos. 1, 3, vol. 5, no. 4, appendix, p. 1-154, figs. 1-165.

Kuroda, T., Habe, T. and Oyama, K., 1971 : *The Sea Shells of Sagami Bay.* 741 p. (*in Japanese*) +489 p. (*in English*), 121 pls., Maruzen, Tokyo.

Lee, Y.G., 1992 : Paleontological study of the molluscan fauna in Korea. *Science Reports of Institute of Geoscience, the University of Tsukuba, Section B*, vol. 13, p. 15-125.

Majima, R., 1989 : Neogene stratigraphy along Arakawa River near Yorii, and of the Ogawa Basin, Hiki Hills and Iwadono Hills, central Saitama Prefecture. *Geoscience Reports of the Shizuoka University*, vol. 15, p. 1-24. (*in Japanese with English abstract*)

Makiyama, J., 1926 : Tertiary fossils from North Kankyô-dô, Korea. *Memoirs of the College of Science, Kyoto Imperial University, Series B,* vol. 2, no. 3, p. 143-160, pls. 12, 13.

Makiyama, J., 1927 : Molluscan fauna of the lower part of the Kakegawa Series in the province of Tôtômi, Japan. *Memoirs of the College of Science, Kyoto Imperial University, Series B,* vol. 3, no. 1, p. 1-147, pls. 1-6.

Makiyama, J., 1936 : The Meisen Miocene of North Korea. *Memoirs of the College of Science, Kyoto Imperial University, Series B*, vol. 11, no. 4, p. 193-227, pls. 4, 5.

Makiyama, J., 1957 : Matajiro Yokoyama's Tertiary fossils from various localities in Japan. Part 1. *Palaeontological Society of Japan, Special Papers*, no. 3, pls. 1-24.

Makiyama, J., 1958 : Matajiro Yokoyama's Tertiary fossils from various localities in Japan. Part 2. *Palaeontological Society of Japan, Special Papers*, no. 4, pls. 25-57.

Makiyama, J., 1959 : Matajiro Yokoyama's Tertiary fossils from various localities in Japan. Part 3. *Palaeontological Society of Japan, Special Papers*, no. 5, pls. 58-86.

Marincovich, L. Jr., 1988 : Recognition of an earliest Middle Miocene warm-water event in a southwestern Alaskan molluscan fauna. *Saito Ho-on Kai Special Publications* (*Prof. T. Kotaka Commemorative Volume*), p. 1-24, pls. 1-3.

Masuda, K., 1955 : Miocene Mollusca from Noto Peninsula, Japan. Part 1 (1). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 20, p. 119-127, pl. 19.

Masuda, K., 1956 : Miocene Mollusca from Noto Peninsula, Japan. Part 1 (2). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 21, p. 161-167, pl. 26.

Masuda, K., 1963a : The so-called *Patinopecten* of Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 52, p. 145-153, pls. 22, 23.

Masuda, K., 1963b : Three Miocene *Dosinia* from near Sendai City, Miyagi Prefecture, Northeast Honshu, Japan, with reference to some Miocene *Dosinia*. *Saito Ho-on Kai Museum Research Bulletin*, no. 32, p. 18-29, pls. 3, 4.

Masuda, K., 1967: Molluscan fauna of the Higashi-innai Formation of Noto Peninsula, Japan-3. Description of new species and remarks on some species. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 65, p. 1-18, pls. 1, 2.

Masuda, K., Handa, M., Kanno, M., Miyasaka, Y., Nemoto, J., Sasaki, T., Takaizumi, Y. and Wako, K., 1990: Remarks on molluscan fauna from the Dainenji Formation, Sendai, Miyagi Prefecture, Japan. *Saito Ho-on Kai Museum of Natural History Research Bulletin*, no. 58, p. 1-10, pls. 1-4.

Masuda, K., Hayasaka, S. and Noda, H., 1983: Shell bearing molluscs in Sendai Bay, Northeast Honshu, Japan. *Saito Ho-on Kai Museum of Natural History Research Bulletin*, no. 51, p. 1-39, pls. 1-5.

Matsui, S., 1985: Recurrent molluscan associations of the Omma-Manganji Fauna in the Gojome-Oga area, Northeast Honshu. Part. 2. Systematic notes on Bivalve species. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series,* p. 225-239, pls. 31-34.

Matsui, S., 1990: Pliocene-Pleistocene molluscan associations in north-central Japan and their relationship to environments. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 160, p. 641-662.

Matsukuma, A., Ozawa, T. and Yoosukh, W., 1988: *Paphia* (*Protapes*) *irrediviva* Makiyama, an extinct tropical embayment element of Japanese Cenozoic molluscs, and allied species from Indo-West Pacific. *Saito Ho-on Kai Special Publication* (*Prof. T. Kotaka Commemorative Volume*), p. 405-415, pls. 1-4.

Matsushima, Y., 1969: On the molluscan fossils from the Alluvial deposits in Yokohama City. *Bulletin of the Kanagawa Prefectural Museum*, vol. 1, no. 2, p. 79-96, pls. 10-13. (*in Japanese with English abstract*)

Matsushima, Y., 1982a: The radiocarbon age of the molluscan fossils from the Alluvial deposits along Pashikuru-numa, the Pacific coast of Hokkaido. *Memoirs of the Kushiro Municipal Museum*, no. 9, p. 1-3, pls. 1-3. (*in Japanese*)

Matsushima, Y., 1982b: Radiocarbon age of the Holocene marine deposits along Kucharo Lake, northern Hokkaido. *Bulletin of the Kanagawa Prefectural Museum*, no. 13, p. 51-66, pls. 1-4. (*in Japanese with English abstract*)

Matsushima, Y. and Nara, M., 1987: Radiocarbon ages of the molluscan shells from the Holocene marine deposits in the Tanabu Plain, Shimokita Peninsula, Northeast Japan, with contributions on their related problems. *Bulletin of the Kanagawa Prefectural Museum*, no. 17, p. 57-72, pl. 5.

Matsuura, N., 1977: Molluscan fossils from the Late Pleistocene marine terrace deposits of Hokuriku Region, Japan Sea side of Central Japan. *Science Reports of the Kanazawa University*, vol. 22, no. 1, p. 117-162, pls. 1-20.

Matsuura, N., 1985: Successive change of the marine molluscan faunas from Pliocene to Holocene in Hokuriku Region, Central Japan. *Bulletin of the Mizunami Fossil Museum*, no. 12, p. 71-158, pls. 32-42. (*in Japanese with English abstract*)

Mizuno, A., 1964: A study of the Miocene molluscan faunas of the Kitatsugaru and Nishitsugaru districts, North Honshu. *Bulletin of the Geological Survey of Japan*, vol. 15, no. 10, p. 1-28, pls. 1-4.

Mizuno, A., 1965: Tertiary molluscan fauna from the environs of Hanawa Basin, North Honshu. *Bulletin of the Geological Survey of Japan*, vol. 17, no. 6, p. 31-36, pls. 1, 2. (*in Japanese*)

Mizuno, A., Yamanoi, T. and Fukudomi, T., 1994: The Tertiary Nishiichi Formation in western Honshu: Its late Early Miocene marine molluscan fauna and palynoflora, and discussions on their geologic age and related paleogeographical problem. *Bulletin of the Kitakyushu Museum of Natural History*, vol. 13, p. 37-49.

Muramatsu, K., 1992: Geology and molluscan assemblages of the Ayugawa Group, Shiga Prefecture, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 19 (*Dr. J. Itoigawa Memorial Volume*), p. 301-317, pls. 18-50. (*in Japanese with English abstract*)

Nakada, Y. and Amano, K., 1991: Pliocene molluscan associations in the Tomikura district, extended over Niigata and Nagano Prefectures, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 19 (*Dr. J. Itoigawa Memorial Volume*), no. 12, p. 27-47, pls. 15-24. (*in Japanese with English abstract*)

Nakagawa, T., 1989: Intertidal molluscan assemblages in the Miocene Kunimi Formation, Fukui Prefecture, Central Japan. *Bulletin of the Fukui Prefectural Museum*, no. 3, p. 23-45, pls. 1-3. (*in Japanese with English abstract*)

Nakagawa, T., Fukuoka, O., Fujii, S., Chiji, M. and Nakamura, T., 1993: Fossil shell assemblages in the Holocene Takahama Shell Bed discovered at Takahama-Cho, western part of Fukui Prefecture, Central Japan. *Monograph of the Fukui City Museum of Natural History*, no. 1 (*Takahama Shell Bed*), 113 p., 34 pls. (*in Japanese with English abstract*)

Nakagawa, T. and Takeyama, K., 1985: Fossil molluscan associations and paleo-environment of the Uchiura Group, Fukui Prefecture, central Japan. *Bulletin of the Mizunami Fossil Museum*, no. 12, p. 27-47, pls. 15-24.

Noda, H., 1973: Additional notes on the Miyagian marine fauna from the Gobansyoyama Formation, Ojika Peninsula, Miyagi Prefecture. *Saito Ho-on Kai Museum Research Bulletin*, no. 42, p. 31-45, pls. 4, 5.

Noda, H. and Amano, K., 1986: Preliminary report on the geology and paleontology of the environs of Teshio, Hokkaido. Part. 7. *Anadara* (*Anadara*) *uozumii* and some associated molluscan fossils from the Pliocene "Yuchi" Formation. *Human Culture and Environmental Studies in Northern Hokkaido* (the University of Tsukuba), no. 7, p. 1-12, pls. 4, 5.

Noda, H., Koda, Y. and Suzuki, S., 1989: Molluscan fossils from the Taki Formation, Fukushima Prefecture. *Iwaki-shi Maizô Bunka-zai Chôsa Hôkoku-sho* (*Research Reports on Buried Cultural Properties of Iwaki City, Fukushima Prefecture*), no. 22, p. 211-214, pls. 25, 26. (*in Japanese, title translated*)

Noda, H., Kikuchi, Y. and Nikaido, A., 1993: Molluscan fossils from the Pliocene Kume Formation in Ibaraki Prefecture, northeastern Kanto, Japan. *Science*

Reports of the Institute of Geoscience, the University of Tsukuba, Section B, vol. 14, p. 115-204.

Noda, H., Kikuchi, Y. and Nikaido, A., 1994: Middle Miocene molluscan fauna from the Tamagawa Formation in Ibaraki Prefecture, northern Kanto, Japan; Arcid-Potamid Fauna in the Tanakura Tectonic Zone. *Science Reports of the Institute of Geoscience, the University of Tsukuba, Section B*, vol. 15, p. 81-102.

Noda, H., Watanabe, R. and Kikuchi, N., 1995: Pliocene marine molluscan fauna from the Hitachi Formation in the northeastern part of Ibaraki Prefecture, Japan. *Science Reports of the Institute of Geoscience, the University of Tsukuba, Section B*, vol. 16, p. 39-93.

Noda, Y., 1992: Neogene molluscan faunas from the Haboro Coal-field, Hokkaido, Japan. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), vol. 62, nos. 1-2, p. 1-140, pls. 1-16.

Noda, Y. and Hoyanagi, K., 1993: Molluscan fauna from the Miocene Meshikuni Formation on Rebun Island, northern Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 172, p. 311-327.

Nomura, S., 1935a: On some Mollusca from Northeast Honsyû, Japan. Part 1. Fossil Mollusca from the vicinity of the Narusawa Hot Spring northeastern part of the Kurikoma Volcano, Iwate-ken. *Saito Ho-on Kai Museum Research Bulletin,* no. 5, p. 71-99, pls. 3, 4.

Nomura, S., 1935b: On some Mollusca from Northeast Honsyû, Japan. Part 2. Fossil Mollusca from the vicinity of Ogino, Yama-gun, Hukusima-ken. *Saito Ho-on Kai Museum Research Bulletin*, no. 5, p. 101-130, pls. 5-7.

Nomura, S., 1935c: Miocene Mollusca from the Nisi-Tugaru district, Aomori-ken, Northeast Honsyû, Japan. *Saito Ho-on Kai Museum Research Bulletin*, no. 6, p. 19-81, pls. 2-8.

Nomura, S., 1935d: Miocene Mollusca from Siogama, Northeast Honsyû, Japan. *Saito Ho-on Kai Museum Research Bulletin*, no. 6, p. 193-294, pls. 16, 17.

Nomura, S., 1938: Molluscan fossils from the Tatunokuti Shell Bed exposed at Gôroku Cliff in the western border of Sendai. *Science Reports of the Tohoku Imperial University, 2nd Series* (*Geology*), vol. 19, no. 2, p. 235-275, pls. 33-36.

Nomura, S., 1940: Molluscan fauna of the Moniwa Shell Bed exposed along the Natori-gawa in the vicinity of Sendai, Miyagi Prefecture, Japan. *Science Reports of the Tohoku Imperial University, 2nd Series* (*Geology*), vol. 21, no. 1, p. 1-46, pls. 1-3.

Nomura, S. and Hatai, K., 1935: Catalogue of the shell-bearing Mollusca collected from the Kesen and Motoyosi districts, Northeast Honsyû, Japan, immediately after the Sanriku Tunami, March 3, 1933. *Saito Ho-on Kai Museum Research Bulletin*, no. 5, p. 1-47, pls. 1, 2.

Nomura, S. and Hatai, K., 1936: Fossils from the Tanagura Beds in the vicinity of the Town Tanagura, Hukusima-ken, Northeast Honsyû, Japan. *Saito Ho-on Kai Museum Research Bulletin*, no. 6, p. 109-155, pls. 13-17.

Nomura, S. and Hatai, K., 1937: A list of the Miocene Mollusca and Brachiopoda collected from the region lying north of the Nanakita River in the vicinity of Sendai, Rikuzen Province, Japan. *Saito Ho-on Kai Museum Research Bulletin*, no. 13, p. 121-145, pls. 17-21.

Nomura, S. and Hatai, K., 1938: On some fossils from Akita Prefecture, Northeast Honshu, Japan. *Japanese Journal of Geology and Geography*, vol. 16, nos. 1-2, p. 39-64.

Nomura, S. and Ônishi, H., 1940: Neogene Mollusca from the Sennan district, Miyagi Prefecture, Japan. *Japanese Journal of Geology and Geography*, vol. 17, nos. 3-4, p. 181-194, pls. 17-19.

Nomura, S. and Zinbô, N., 1935: Fossil Mollusca from the vicinity of Hurukuti, Mogami-gun, Yamagata-ken, Northeast Honsyû, Japan. *Saito Ho-on Kai Museum Research Bulletin*, no. 6, p. 1-17, pl. 1.

Ogasawara, Kenshiro, 1973: Molluscan fossils from the Nishikurosawa Formation, Oga Peninsula, Akita Prefecture, Japan. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), *Special Volume*, no. 6, (*Prof. K. Hatai Memorial Volume*), p. 137-155, pls. 12, 13.

Ogasawara, K., 1976: Miocene Mollusca from Ishikawa, Toyama area, Japan. *Science Reports of the Tohoku University, 2nd Series* (*Geology*), vol. 46, no. 2, p. 33-78, pls. 11-15.

Ogasawara, K., Ijima, S. and Kaseno, Y., 1989a: Miocene molluscs from the Tenguyama Formation, Toyama Prefecture, Hokuriku district, Japan. *Science Reports of the Kanazawa University*, vol. 34, no. 2, p. 67-93, pls. 1-4.

Ogasawara, K., Masuda, K. and Matoba, Y. *eds*., 1986: *Neogene Molluscs from the Akita Oil-field, Japan*. 310 p., 85 pls. (*in Japanese*)

Ogasawara, K. and Nagasawa, K., 1992: Tropical molluscan association in the Middle Miocene marginal sea of the Japanese Islands: An example of molluscs from the Oyama Formation, Tsuruoka City, Northeast Honshu, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 167, p. 1224-1246.

Ogasawara, K. and Noda, H., 1978: Arcid-Potamid Fauna (Mollusca) from the Tsukinoki Formation, Sennan district, Miyagi Prefecture, Northeast Japan. *Saito Ho-on Kai Museum of Natural History Research Bulletin*, no. 46, p. 21-47, pls. 3, 4.

Ogasawara, K. and Nomura, R., 1980: Miocene fossils from the Fujina Formation, Shimane Prefecture, San-in district, Japan. *Prof. S. Kanno Memorial Volume*, p. 79-98, pls. 9-12.

Ogasawara, K., Sasaki, O. and Nemoto, J., 1989b: The Otokawa Fauna of the Hokuriku Neogene and its geohistorical significance. *Prof. M. Matsui Memorial Volume*, p. 65-74, pls. 1-3.

Ogasawara, K. and Yashima, R., 1981: Miocene molluscs from the Date Formation, Fukushima Prefecture, Northeast Japan. *Saito Ho-on Kai Museum of Natural History Research Bulletin*, no. 49, p. 37-50, pl. 3.

Ogasawara, Kenzo and Tanai, T., 1952: The discovery of new Miocene fauna in the northern part of Nishitagawa Coal-field, Yamagata Prefecture, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 7, p. 205-212, pl. 19.

O'Hara, S. and Nemoto, N., 1984: Molluscan fossils from the type Goyasu Formation of the Joban Coalfield. *Journal of the College of Arts and Sciences, Chiba University*, B-17, p. 45-61, pls. 1, 2.

Ôinomikado, T., 1934: On the morphology of pallial sinus of the genus *Macoma*. *Venus*, vol. 4, no. 6, p. 353-356, pl. 8. (*in Japanese, title translated*)

Okamoto, K., Hayashi, Y. and Katsuhara, M., 1989: Fossil Mollusca from the Miocene at Myoga, Shobara City, a new locality of *Geloina* in Shobara, and relationship between *Tateiwaia* species and substrata—Study of the Bihoku Group 2—. *Bulletin of the Mizunami Fossil Museum*, no. 16, p. 43-53, pls. 5-7. (*in Japanese with English abstract*)

Okamoto, K., Katsuhara, M., Ueno, Y. and Sumiyoshi, O., 1990: Molluscan assemblage from the Miocene Bihoku Group in the Kaisekidani area, Miyauchi-cho, Shobara City, Southwest Japan—Study of the Bihoku Group III—. *Bulletin of the Mizunami Fossil Museum*, no. 17, p. 35-49, pls. 9-11. (*in Japanese with English abstract*)

Okamoto, K., Suyama, Y., Matsuda, I., Nishimoto, Y. and Kakegawa, K., 1983: The Miocene Susa Group in the northeastern area of Yamaguchi Prefecture, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 10, p. 85-102, pls. 20-27. (*in Japanese with English abstract*)

Okamoto, K. and Terachi, M., 1974: Miocene molluscs from the Bihoku Group at Miyauchi-cho, Shobara City, Southwest Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 95, p. 341-357, pl. 47.

Okumura, K. and Koyanagi, T., 1989: Molluscan fossils from the Ashigara Group, southwestern part of the Kanto Region, Central Japan. *Bulletin of the Mizunami Fossil Museum*, no. 16, p. 65-83, pls. 8, 9.

Okumura, K. and Takei, T., 1993: Molluscan assemblage from the Late Pliocene Ananai Formation, Kochi Prefecture, Southwest Japan. *Bulletin of the Mizunami Fossil Museum*, no. 20, p. 133-183, pls. 27-40.

Otuka, Y., 1934: Tertiary structures of the northwestern end of the Kitakami Mountainland, Iwate Prefecture. *Bulletin of the Earthquake Research Institute*, vol. 12, p. 566-638, pls. 45-51.

Otuka, Y., 1935: The Oti Graben in southern Noto Peninsula, Japan. (Part 3). *Bulletin of the Earthquake Research Institute*, vol. 13, pt. 5, p. 846-909, pls. 53-57.

Otuka, Y., 1938: Mollusca from the Miocene of Tyûgoku, Japan. *Journal of Faculty of Science, the Imperial University of Tokyo, Section 2*, vol. 5, pt. 2, p. 21-45, pls. 1-4.

Otuka, Y., 1941: Fossil Mollusca from Tazima, Hyôgo Prefecture, Japan. *Japanese Journal of Geology and Geography*, vol. 18, nos. 1-2, p. 21-24.

Oyama, K., 1950: Remarks on Japanese fossil molluscan name. *Mineral and Geology*, vol. 3, no. 6, p. 1-4. (*in Japanese*)

Oyama, K., 1973: Revision of Matajiro Yokoyama's type Mollusca from the Tertiary and Quaternary of the Kanto Area. *Palaeontological Society of Japan, Special Papers*, no. 17, 148 p., 57 pls.

Oyama, K., Noshimoto, H. and Naruse, A., 1994: New fossil molluscs indicating tropical sea elements from the Miocene Bihoku Group, southwest Honshu, Japan. Part 2. Description of *Cancilla hirosei* n. sp., with notes on some molluscs from the Bihoku Group of Shobara City, Hiroshima Prefecture. *Bulletin of the Mizunami Fossil Museum*, no. 21, p. 19-28, pl. 7.

Oyama, K. and Saka, K., 1944: Fossil molluscs from the Tsukiyoshi Formation. *Bulletin of the Shigenkagaku Kenkyusyo*, vol. 1, no. 2, p. 137-144, pls. 14, 15. (*in Japanese with German abstract*)

Ozaki, H., 1958: Stratigraphical and paleontological studies on the Neogene and Pleistocene formations of the Tyosi district. *Bulletin of the National Science Museum*, vol. 4, no. 1, p. 1-182, pls. 1-24.

Ozawa, T., Nakagawa, T. and Takeyama, K., 1986: Middle Miocene molluscan fauna of the Uchiura Group, Wakasa Province, Southwest Japan. *Palaeontological Society of Japan, Special Papers*, no. 29, p. 135-148, pls. 12-15.

Sasaki, O. and Ogasawara, K., 1986: Intertidal molluscan assemblage from the Miocene Sunakozaka Formation, Ishikawa-Toyama area, Hokuriku district, Japan. *Memoirs of the National Science Museum*, no. 19, p. 79-90, pls. 5, 6.

Shibata, H., 1970: Molluscan faunas of the First Setouchi Miocene Series, Southwest Japan. Part 1. Fauna of the Ichishi Group. *Journal of the Earth Sciences, Nagoya University*, vol. 18, no. 1, p. 27-84, pls. 1-4.

Shibata, H., 1978: Molluscan paleoecology of the Miocene First Setouchi Series in the eastern part of the Setouchi Geologic Province, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 5, p. 23-110.

Shibata, H. and Ina, H., 1983: Molluscs and plants from the Shitara Group (Miocene), Central Japan. *Monograph of the Mizunami Fossil Museum*, no. 4, p. 1-88, pls. 1-24.

Shibata, H. and Kato, S., 1975: Miocene molluscs from Totomi, Shizuoka Prefecture, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 2, p. 75-84, pl. 16. (*in Japanese with English abstract*)

Shibata, H. and Kato, S., 1988: Miocene molluscs from the Oga Formation of Shimada City, Shizuoka Prefecture, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 15, p. 7-38, pls. 2, 3.

Shibata, H., Kato, Y. and Assefa, G., 1987: Miocene molluscs from Neba-mura, Nagano Prefecture, Japan. *Research Bulletin of the College of General Education, Nagoya University*, no. 31, p. 85-94, pl. 1.

Shikama, T., 1954: On the Tertiary formations of Tomikusa in south Nagano Prefecture. *Science Reports of the Yokohama National University, 2nd Series*, vol. 3, p. 71-108, pls. 4-8. (*in Japanese with English abstract*)

Suzuki, A., Nojo, A., Inaki, H., Kusaka, H. and Togo, Y., 1994: The Arcid-Potamid Fauna (Mollusca) from the Miocene Babagawa Formation in the Setana area, southwestern Hokkaido. *Journal of the Geological Society of Japan*, vol. 100, no. 3, p. 263-266. (*in Japanese*)

Taguchi, E., 1981: *Geloina/Telescopium* bearing molluscan assemblages from the Katsuta Group, Okayama Prefecture—with special reference to brackish faunal zonation in the Miocene of Japan. *Bulletin of the Mizunami Fossil Museum*, no. 8, p. 7-20, pls. 2-4.

Taguchi, E., Ono, N. and Okamoto, K., 1979: Fossil molluscan assemblages from the Miocene Bihoku Group in Niimi City and Ohsa-chô, Okayama Prefecture, Japan. *Bulletin of the Mizunami Fossil Museum*, no. 6, p. 1-15, pls. 1-4. (*in Japanese with English abstract*)

Takahashi, H., 1984: Molluscan assemblages from the Miocene Nakayama Formation in the Kadono district, Joban Coal-Field, Fukushima Prefecture. *Fossils* (*Palaeontological Society of Japan*), no. 36, p. 1-17, pl. 1.

(*in Japanese with English abstract*)

Takahashi, H., 1986: Characteristics of the molluscan assemblages in the Pliocene Kume Formation in the Hitachi-Ota area, Ibaraki Prefecture, central Japan. *Monograph of the Mizunami Fossil Museum*, no. 6, p. 91-103, pls. 12-14. (*in Japanese with English abstract*)

Takayasu, K., 1981: Fossil Mollusca from the Miocene Masuda Group at Okuda, Masuda City—Molluscan fossils from various localities in Shimane Prefecture, Part 2. *Memoirs of the College of Science, Shimane University*, vol. 15, p. 89-108, pls. 1-3.

Takayasu, K., 1985: Miocene molluscs from Sai, Shinji-cho, Shimane Prefecture—Molluscan fossils from various localities in Shimane Prefecture, Part 4. *Memoirs of the College of Science, Shimane University*, vol. 19, p. 135-145, pls. 1, 2.

Takeyama, T., 1930: Tertiary stratigraphy of the environs of Tanabe, Kii. *Chikyû* (*Globe*), vol. 13, no. 2, p. 92-106, pl. 4. (*in Japanese, title translated*)

Takeyama, T., 1933: Notes on the genus *Vicarya*, with description of two Japanese forms. *Japanese Journal of Geology and Geography*, vol. 10, nos. 3-4, p. 129-144, pl. 13.

Tanaka, K., 1961: Studies on the molluscan fossils from central Shinano, Nagano Prefecture, Japan (Part 6)—Molluscan fossils from the Moriya Formation. *Bulletin of the Faculty of Education, Shinshu University*, no. 12, p. 61-97, pls. 1, 2.

Tokunaga, S., 1906: Fossils from the environs of Tôkyô. *Journal of the College of Science, Imperial University of Tokyo*, vol. 11, art. 2, p. 1-96, pls. 1-6.

Torigoe, K., 1981: Oysters in Japan. *Journal of Science, Hiroshima University, Series B, Division 1*, vol. 29, no. 2, p. 291-347, pls. 1-36.

Tsuda, K., 1959: New Miocene molluscs from the Kurosedani Formation in Toyama Prefecture, Japan. *Journal of the Faculty of Science, Niigata University, Series 2,* vol. 3, no. 2, p. 67-110, pls. 1-7.

Tsuru, T., 1983: Middle Miocene molluscan fauna from the Tôgane Formation in Hamada City, Shimane Prefecture, Southwest Japan. *Bulletin of the Mizunami Fossil Museum*, no. 10, p. 29-83, pls. 8-19. (*in Japanese with English abstract*)

Uchimura, R. and Majima, R., 1992: The mixed sea area of warm- and cold-water molluscs of the Japanese early Middle Miocene; the case study in the Furanui Formation, mid-Hokkaido, Japan. *Journal of the Geological Society of Japan*, vol. 98, no. 12, p. 1129-1144. (*in Japanese with English abstract*)

Uozumi, S., 1957: Studies on the molluscan fossils from Hokkaido. Part 2. Genera *Yoldia* and *Portlandia. Journal of the Faculty of Science, Hokkaido University, Series 4* (*Geology and Mineralogy*), vol. 9, no. 4, p. 539-596, pls. 1-7.

Uozumi, S. and Fujie, T., 1966: Neogene molluscan fauna in Hokkaido; part 2. Description of the Okushiri fauna associated with *Vicarya*, from Okushiri Island, southwest Hokkaido. *Journal of the Faculty of Science, Hokkaido University, Series 4* (*Geology and Mineralogy*), vol. 15, p. 139-163, pls. 11-13.

Yabe, H. and Hatai, K., 1938: On the Japanese species of *Vicarya. Science Reports of the Tohoku Imperial University, 2nd Series* (*Geology*), vol. 19, no. 2, p. 149-172, pl. 21.

Yamamoto, G. and Habe, T., 1959: Fauna of shell-bearing molluscs in Mutsu Bay; Lamellibranchia (2). *Bulletin of the Marine Biological Station of Asamushi*, vol. 9, no. 3, p. 85-122, pls. 6-14.

Yokoyama, M., 1920: Fossils from the Miura Peninsula and its immediate north. *Journal of the College of Science, Tokyo Imperial University*, vol. 44, art. 1, p. 1-186, pls. 1-20.

Yokoyama, M., 1923a: On some fossil mollusca from the Neogene of Izumo, Japan. *Japanese Journal of Geology and Geography*, vol. 2, no. 1, p. 1-9, pl. 1.

Yokoyama, M., 1923b: Tertiary fossils from Kii. *Japanese Journal of Geology and Geography*, vol. 2, no. 3, p. 47-58, pls. 6, 7.

Yokoyama, M., 1924: Molluscan remains from the lowest part of the Jô-ban Coal-field. *Journal of the College of Science, Tokyo Imperial University*, vol. 25, art. 3, p. 1-22, pls. 1-5.

Yokoyama, M., 1925a: Molluscan remains from the uppermost part of the Jô-ban Coal-field. *Journal of the College of Science, Tokyo Imperial University*, vol. 45, art. 5, p. 1-23, pls. 1-34, pls. 1-6.

Yokoyama, M., 1925b: Mollusca from the Tertiary basin of Chichibu. *Journal of the Faculty of Science, the Imperial University of Tokyo, Section 2*, vol. 1, p. 111-126, pls. 14, 15.

Yokoyama, M., 1926a: Molluscan fossils from the Tertiary of Mino. *Journal of the Faculty of Science, the Imperial University of Tokyo, Section 2*, vol. 1, p. 213-227, pl. 28.

Yokoyama, M., 1926b: Fossil Mollusca from the Oil-fields of Akita. *Journal of the Faculty of Science, the Imperial University of Tokyo, Section 2*, vol. 1, p. 377-389, pls. 44, 45.

Yokoyama, M., 1931: Neogene shells from Karafto and Hokkaido. *Journal of the Faculty of Science, Imperial University of Tokyo, Section 2,* vol. 3, p. 186-196, pl. 11.

Yoon, S., 1976a: Geology and paleontology of the Tertiary Pohang Basin, Pohang district, Korea. Part 2, Paleontology (Mollusca); no. 1, Systematic description of Bivalvia. *Journal of the Geological Society of Korea*, vol. 12, no. 1, p. 1-22, pls. 1-3.

Yoon, S., 1976b: Geology and paleontology of the Tertiary Pohang Basin, Pohang district, Korea. Part 2, Paleontology (Mollusca); no. 2, Systematic description of Scaphopoda and Gastropoda with descriptions of fossil localities. *Journal of the Geological Society of Korea*, vol. 12, no. 2, p. 63-78, pl. 1.

Yoon, S., 1979: The Tertiary deposits of the Ulsan Basin, No. 2, Molluscan fossils. *Journal of the Geological Society of Korea*, vol. 15, no. 1, p. 1-36, pls. 1-5.

Yoon, S., 1980: Additional notes on Miocene molluscs of the Tertiary Ulsan Basin, Korea. *Prof. S. Kanno Memorial Volume*, p. 71-77, pl. 8.

Yoon, S., 1988: The Seoguipo molluscan fauna of Jeju Island, Korea. *Saito Ho-on Kai Special Publication* (*Prof. T. Kotaka Commemorative Volume*), p. 539-545, pls. 1-5.

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1006 An early Turonian (Cretaceous) new species of *Inoceramus* (Bivalvia) from Hokkaido

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Abstract. In this paper *Inoceramus kamuy* n. sp. is established on a fairly large number of specimens from Hokkaido. It ranges throughout the lower Turonian strata and is certainly useful for correlation. In its juvenile growth stages, *I. kamuy* closely resembles *I. nodai* of late Cenomanian age, but differs in later growth stages in that its valve is extended straight to the ventral extremity and tends to be differentiated into a moderately inflated main part and a somewhat flattened posterior part. Although there are some differences, *I. kamuy* has affinities with *I. atlanticus*, *I. nodai* and probably *I. rutherfordi* of middle to late Cenomanian age. These species may be affiliated with a group originated from *I. virgatus* and, thus, belong to *Inoceramus* in a broad sense. On the other hand, *I. kamuy* is not likely to be ancestral to the *I.* (*I.*) *hobetsensis* and *I.* (*I.*) *lamarcki* groups of middle Turonian age. In view of some similarity and variability in shell shape and ornament, we suggest that *I. kamuy* may be an indirect source from which, in the late Turonian, *I. teshioensis*, *I. costellatus*, and *I. perplexus* (with rather uniformly convex valves) and *I. longealatus* (with posterodorsally flattening) may have been derived. However, the linking forms should be sought in the middle part of the Turonian. Several species of latest Turonian to Coniacian age, such as *I. frechi*, *I. glatziae* and *I. multiformis*, are seemingly similar to *I. kamuy* in some of their particular characters, but their phylogenetic relationships with *I. kamuy* have yet to be worked out.

Key words: *Inoceramus*, Turonian, Hokkaido, correlation, phylogenetic relationships.

Introduction

In early Turonian time several species of the inoceramid genus *Mytiloides* were distributed worldwide, whereas very few examples of the genus *Inoceramus* have been reported from the contemporary strata. We have, however, a fairly large number of specimens which have been collected from lower Turonian strata at various localities in Hokkaido. They represent a species of *Inoceramus* which has been provisionally called *Inoceramus* aff. *saxonicus* Petrascheck or *Inoceramus* aff. *teshioensis* Nagao and Matsumoto in a number of stratigraphic reports. In this paper we describe it as a new species of *Inoceramus* and give remarks on its systematic affinities or phylogenetic relationships with previously known species.

The specimens mentioned above have been acquired by a number of our colleagues as well as ourselves from calcareous nodules formed mainly in mudstones and sometimes sandy rocks of a well-defined middle part of the Yezo Group in the Oyubari [=Shuyubari, Siyubari or "Shuparo"] and Ashibetsu areas of the Yubari Mountains, central Hokkaido, and the Obira [=Obirashibe, Opiraushibets or "Tappu"] area of the Teshio Mountains, northwestern Hokkaido. For the sites of fossil localities and stratigraphy, readers may refer to Matsumoto (1942), Matsumoto *et al.* (1991), Hirano *et al.* (1989a, b, c; 1990) and Nishida *et al.* (1993, 1995) for the Oyubari area and Tanaka (1963), Tanabe *et al.* (1977), Sekine *et al.* (1985) and Asai and Hirano (1990) for the Obira area. The localities are numbered independently by T.M. and A.A.; in other words, the same locality may have different numbers of the two authors. The lower Turonian part of the Oyubari area is Member IIn of Matsumoto (1942) and Nishida *et al.* (1993, 1995), to which Member M9 of Hirano *et al.* (1989a, b, c; 1990) is equivalent. Member Mj of Tanaka (1963) is commonly used for the lower Turonian part of the Cretaceous sequence in the Obira area. The described specimens from the Ashibetsu area were collected at two localities that are shown in Figure 6. A particular member name is not used there, but the early Turonian age is evidenced by species of *Mytiloides*.

Although the substages of the Turonian Stage have not been formally defined by the Subcommission on Cretaceous Stratigraphy, we use in this paper provisionally the lower, middle and upper Turonian on the basis of the integrated zones of ammonites, inoceramids and foraminifera (see Matsumoto *et al.*, 1991; Toshimitsu *et al.*, 1995). The three substages in Japan can be approximately correlated with those generally used in western Europe and North America.

The repositories of the specimens enumerated in Material are as follows, with abbreviations at the heading of the register number:

GK. = Type Room, Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, Fukuoka 812-81

WE. = Institute of Earth Science, School of Education, Waseda University, Nishi-Waseda, Tokyo 169-50

Paleontological description

Family Inoceramidae Zittel, 1881
Genus *Inoceramus* Sowerby, 1814

Type species.—*Inoceramus cuvierii* Sowerby, 1814.

Remarks.—In this paper the genus *Inoceramus* is defined in the same sense as in Matsumoto and Tanaka (1988) (see also discussion below). The technical terms and their abbreviations in the description below are the same as those used in that paper and partly shown in Table 1.

Inoceramus kamuy sp. nov.

Figures 1-1—3; 2-1—6; 3-1—5; 4-1—3; 5-1—5

Synonymy.—Provisional names used in stratigraphic papers without paleontologic description are omitted here.

Material.—Holotype is GK. H500 (BV) (Figure 1-1) from the siltstone in the upper part of Member IIn exposed at loc. Y415, right bank of the Hinata-zawa, about 50 m upstream from its confluence with the River Shuparo [=Shuyubari or Siyubari] of the Oyubari area (collected by T.M. in September 1939).

Paratypes are GK. H501 (RV) (Figure 1-3), GK. H502A (BV) (Figure 1-2), H502B (LV) (Figure 2-1), H502C (RV), H502D (BV) and H502E (BV) from the same rock of the type locality Y415; GK. H506 (RV) (Figure 2-2) from Member IIn exposed at loc. Y139, left bank of the Hikage-zawa at its confluence with the River Shuparo; GK. H507A (BV) (Figure 2-4) and H507B (LV) in a nodule derived probably from Member IIn at loc. Y223p on the River Shuparo, somewhat downstream from Y415; GK. H478 (LV) from the lower part of Member IIn at loc. Y139e on the left bank of the Hikage-zawa, 300 m upstream from the confluence with the River Shuparo; GK. H8381A (LV) and H8381B (RV) at loc. Y5109c, GK. H8382 (RV) and H8383 (LV) at loc. 5109b, from the upper part of Member IIn exposed along the forestry road on the right side of the Taki-no-sawa [=Penkemoyuparo]; GK. H8430 (LV) (Figure 2-5), GK. H8431 (LV) and others in a nodule at loc. Y5154a from the uppermost part of Member IIn on the left bank of the same stream; GK. H8440 (RV) (Figure 2-3) and others embedded around a huge macroconch of *Puzosia orientalis* Matsumoto (see Nishida *et al*., 1995, pl. 3, figs. 3, 4; pl. 4, fig. 3) in a bed of greenish sandy siltstone of loc. Y5233a, immediately above the black mudstone (product of OAE), that indicates the Cenomanian-Turonian boundary on a continuous outcrop (see Nishida *et al*., 1993, figs. 2, 3; Toshimitsu *et al*., 1995, fig. 1) along the right side of the Shirakin River [=Hakkin-zawa] and GK. H8432 (LV) (Figure 2-6) and associated specimens in a nodule from the mudstone of Member IIn at loc. Y5228f above the bed with *Mytiloides mytiloides* (Mantell), about 250 m downstream from loc. Y5233a, on the right bank of the same stream, i.e. Shirakin River; all in the Oyubari area (collected by T.M. with assistance of H. Okada at loc. Y5109b, c and Y. Kawashita at locs. Y5228f and Y5233a.)

Paratypes in WE. (collected by Hiromichi Hirano, students of Waseda University and A.A.) are as follows: WE. P106Y (BV) (Figure 3-1) at loc. Y070077d (89); P108Y (LV and RV) and P109Y (LV) at loc. Y070077c (89); WE. P122Y (RV) at loc. Y070091 (78); WE. P123Y (RV) (Figure 3-2) and P124Y (LV and RV) at loc. Y070093b (84); WE. P136Y (LV) at loc. Y070075Y (92); all from Member M9 exposed along the Hakkin-zawa [=Shirakin River] of the Oyubari area; also WE. P125A (RV) (Figure 5-1), P126A (LV) (Figure 5-2), P127A (LV), P128A (LV) (Figure 5-4) and P129A (LV) (Figure 5-3) at loc. As4049a (89) immediately below the rock at loc. As4048d, where *Mytiloides goppelnensis* (Badillet and Sornay) of early Turonian age was obtained along the stream called Hachigetsu-zawa; WE. P134A at loc. As3037a (88), where *Mytiloides subhercynicus* (Seitz) of probably late early Turonian age was obtained, along the stream called Tsukimi-zawa, in the Ashibetsu area (Figure 6).

Paratypes of the WE collection from the Obira area are as follows: WE. P033T (LV) (Figure 4-1), P034T (Figure 3-5), P116T (RV), P117T (RV), P118 (LV), P119T (LV), P120T (RV) and P121T (RV) from one and the same nodule at loc. T4507x (85), as a transported boulder in the Okufutamata-zawa [=Kechikauen-Obirashibe], a tributary of the River Obirashibe, derived probably from Member Mj; WE. P035T (RV) (Figure 3-4), P036T (RV) (Figure 3-3) and P110T (RV) at loc. T6046c (84); WE. P111T (LV), P112T (LV) (Figure 4-2) at loc. T6042c (84); WE. P115T (LV) (Figure 5-5) at loc. T6048a (82); WE. P135T (BV) at loc. Y6047a (89); WE. P138T (RV) (Figure 4-3) at loc. T6038g (83); all from Member Mj of Tanaka (1963) of the Obira area.

Paratypes in GK collection from the Obira area are GK. H8476, H8477 and H8478 from a cliff of loc. R5211 (a, b and e respectively), outcrop of Member Mj, on the left side of the River Obirashibe obtained during joint field work in 1974 by K. Tanabe, H. Hirano and T.M.

Specific name.—Kamuy is God of the Yezo region, i.e., ancient Hokkaido and adjacent areas.

Diagnosis.—Shell small, inequilateral, somewhat inequivalve and moderately inflated, with left valve more inflated and slightly more umbonate than the right. Growth axis weakly concave forward in juveniles and almost straight to oblique to the ventral extremity later, forming angle of 60 to 70 degrees with the hinge line.

Hinge line moderately long, with the ratio $s/l=0.70$ to 0.75 (in the holotype); height somewhat greater than length, with $l/h=0.84$ and 0.88 (in LV and RV of the holotype). Posterior hinge angle obtuse.

Anterodorsal margin short and somewhat concave, passing to gently arcuate or nearly straight anterior margin; anteroventral margin abruptly bent to asymmetrically rounded ventral margin. Posteroventral bending somewhat variable from rather abrupt to gradual. Posterior margin

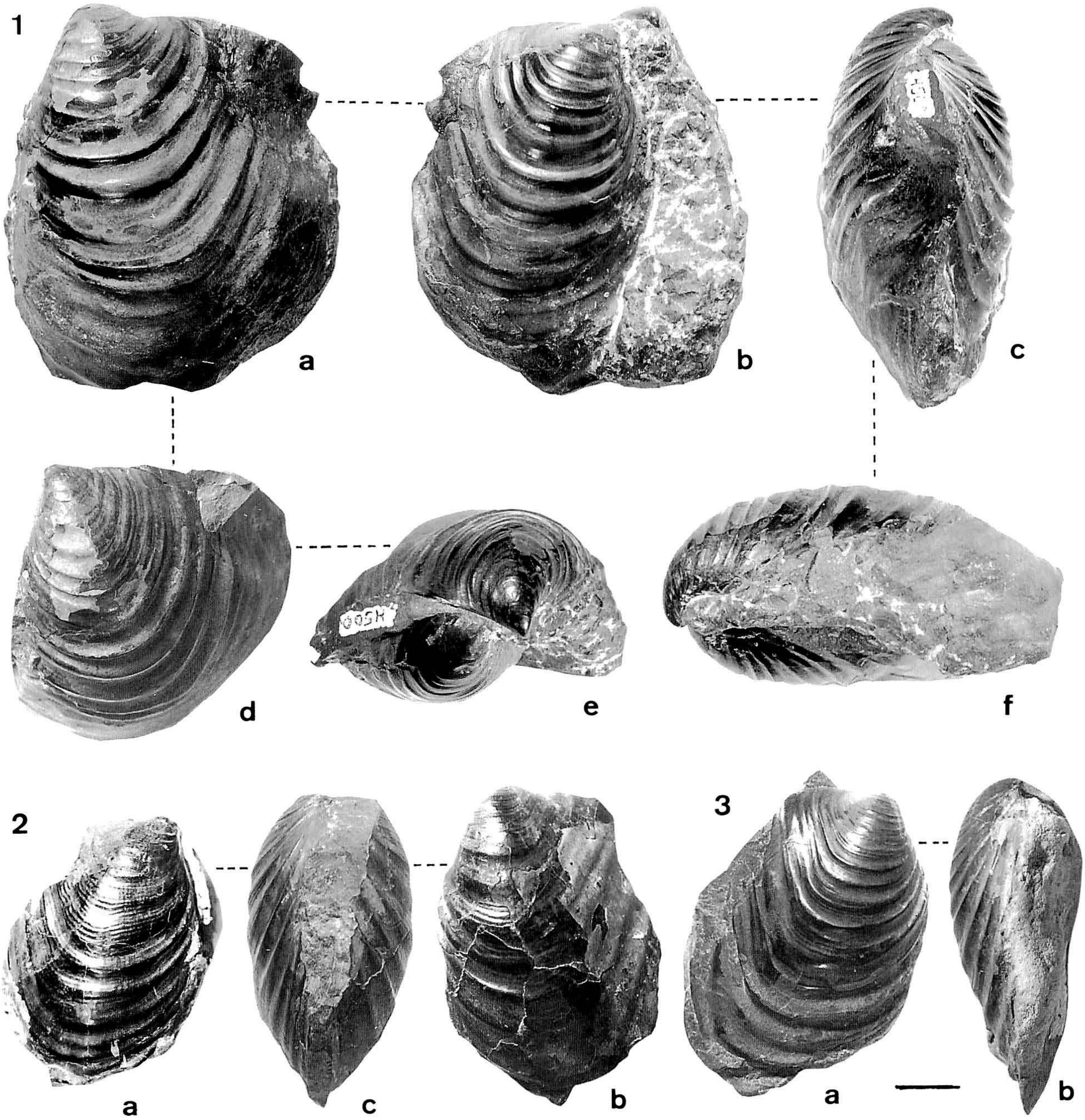

Figure 1. *Inoceramus kamuy* sp. nov. Holotype and two other specimens from the type locality, Y415 of the Oyubari area. **1.** GK. H500, holotype (BV), left (a) and right (b) lateral, anterior (c), dorsal (e) and posterior (f) views and also umbonal to dorsocentral part of LV (d). **2.** GK. H502A (BV), right lateral (a), left lateral (b) and anterior (c) views. **3.** GK. H501 (RV), lateral (a) and anterior (b) views. In this and the succeeding photographic illustrations different views of the same specimen are linked by dotted lines. For the details of stratigraphic levels and collectors readers may refer to Material. Figures are natural size (scale bar=10 mm) unless otherwise stated. Photos by courtesy of M. Noda (Figures 1 and 2) and by A.A. (Figures 3–5), without whitening.

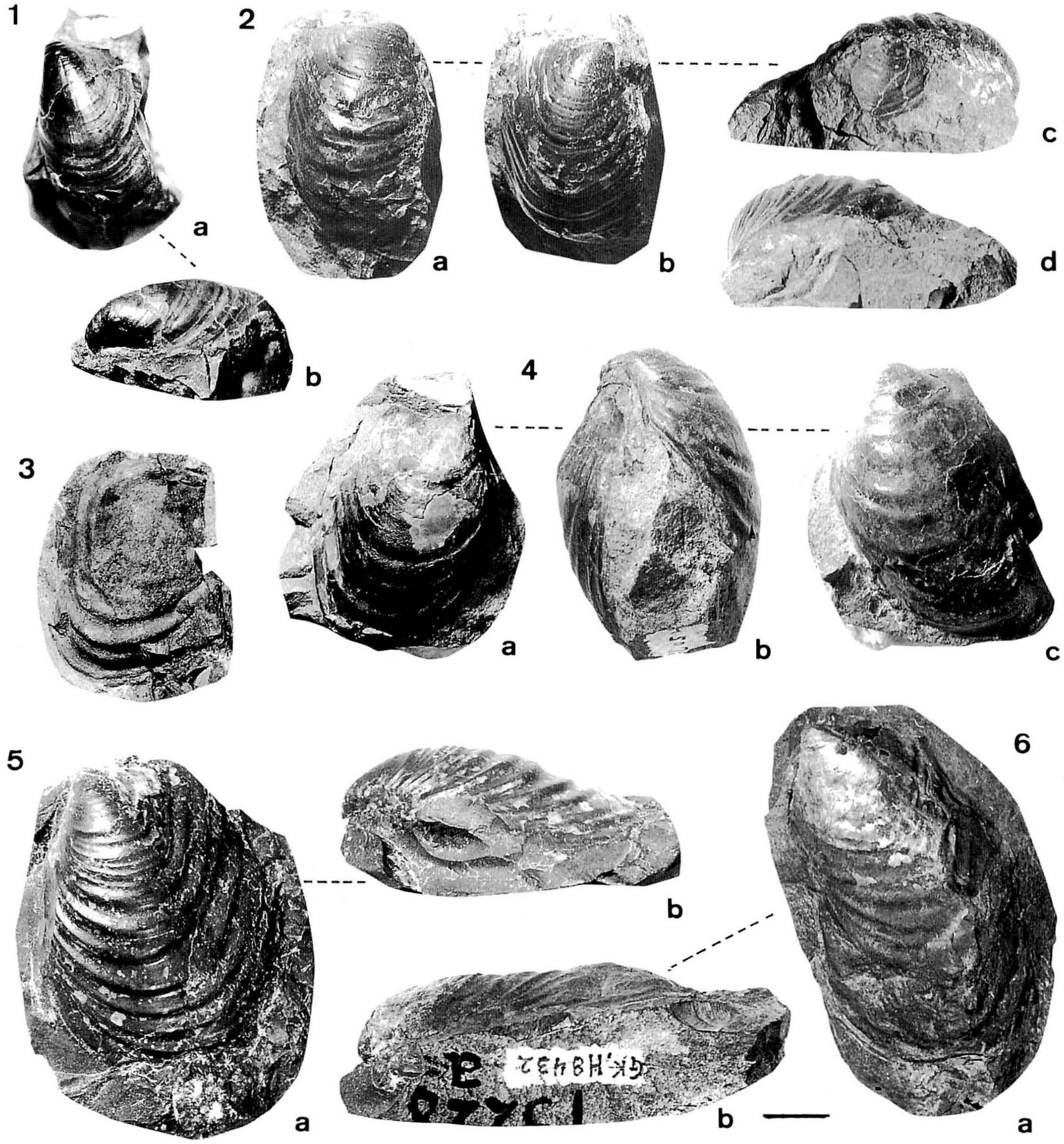

Figure 2. *Inoceramus kamuy* sp. nov. Selected specimens from the Oyubari area. **1.** GK. H502B (LV, probably juvenile) from loc. Y415 (type locality), lateral (a) and anterior (b) views. **2.** GK. H506 (RV, small form or immature) from loc. Y137, two lateral views, of which a is normal and b is disposed to show the umbonal part more clearly than a; anterior (c) and posterior (d) views. **3.** GK. H8440 (RV) from loc. Y5233a, lateral view. **4.** GK. H507A (BV) from loc. Y223p, lateral views of RV (a) and LV (c); anterior view (b). **5.** GK. H8430 (RV) from loc. Y5154a, lateral (a) and anterior (b) views. **6.** GK. H8432 (LV, somewhat distorted) from loc. Y5228f, lateral (a) and anterior (b) views. Figures 2-1 and 2-2 are slightly enlarged (×1.2).

broadly convex or nearly straight or even gently sinuous and bent forward to its posterodoral end at variable angle with the hinge line.

Valves moderately inflated in the main part along the growth axis and more or less flattened in the posterior part. A shallow radial depression may appear, forming an obscure boundary between the two parts.

Comarginal major ribs weak in youth and irregularly interspaced, sooner or later moderately strong, rather sharp-crested and regularly disposed on the main part of the shell, with gradually broadening interspaces, but may become weaker and less distant at the last or gerontic stage. Bifurcation or intercalation may occur occasionally. Under favourable conditions of preservation finer concentric rings or lirae are discernible on the shell surface in combination with the major ribbing. Internal radial striae may be impressed on some specimens.

Measurements.—See Table 1.

Observation.—There is some extent of variation in the convexity or inflation of valves. For instance, in the left valve of the holotype b/h=0.38 to 0.40 and its beak is somewhat projected obliquely forward and incurved, whereas in a smaller paratype (WE. P034T) (LV) b/h=0.30 and its beak is only slightly projected. In the right valve of the holotype, b/h=0.30 and in that of GK. H502A b/h=0.35 to 0.34. The feature may be modified by secondary deformation, as evidently shown by distorted or flattened specimens.

The ratio l/h or L/H also varies to some extent. In small, probably immature specimens, L/H is generally greater than that of mature ones. Even in the small specimens, as exemplified by WE. specimens, there is variation, and thus shell may appear subrounded and evenly convex, except for the flattened posterodorsal part (e.g., WE. P122Y and 123Y as compared with others).

There is also some variation in the strength, density and regularity of ribbing. In the typical form (e.g. GK. H500, H501, H502A and WE. P036T) the ribs are regular in showing the moderate intensity and gradual broadening interspaces with growth on the main part, but on the umbonal part, i.e. on the surface of young shells, the major ribs are weak or undeveloped and minor rings or lirae may predominate. Occasionally, this juvenile ornament persists to the middle growth stage, as seen in WE. P033T, which shows a delayed appearance of major ribs, or in WE. P035T, in which the major ribs occur irregularly.

Occurrence.—For details see the locality records of Material. Summarizing them, this species occurs commonly in lower Turonian strata, ranging from the basal part to the top of the substage as defined by certain species of ammonites and *Mytiloides*. Its distribution is chiefly in the Oyubari and Ashibetsu areas of the Yubari Mountains (central Hokkaido), and the Obira area of the Teshio Mountains (northwestern Hokkaido). More specimens are known to occur in the Ikushunbetsu [i.e. Mikasa] area, but they are not included in the type material, because their locality records will be issued at a later date.

Comparison and discussion.—The present new species has long been indicated provisionally as *Inoceramus* n. sp. aff. *I. saxonicus* Petrascheck or *Inoceramus* aff. *saxonicus* in a number of papers (Matsumoto and Haraguchi, 1978, p. 307; Sekine *et al.*, 1985, p. 6; Hirano and Asai, 1987, p. 62, figs. 1, 2; Hirano *et al.*, 1990, p. 23; Asai and Hirano, 1990, p. 44, table 2a; Matsumoto *et al.*, 1991, table 2; Nishida *et al.*, 1993, p. 16, 24, pl. 6, fig. 2; 1995, p. 184; Hirano, 1995, p. 13 and elsewhere; Toshimitsu *et al.*, 1995, p. 22-23).

Whether *I. kamuy* has true affinity with *Inoceramus sax-*

Table 1. Measurements of *Inoceramus kamuy*.

Specimen	V	h	l	l/h	b	b/h	s	s/l	H	L	L/H	γ	δ
GK. H500	LV	59.0	49.5	.84	23.5	.40	36.0	.73	61.0	52.5	.86	120°	68°
GK. H500	LV	34.0	28.4	.84	~12.5	.38	20.8	.73	36.0	32.5	.90	115°	70°
GK. H500	RV	39.6	33.0	.83	~12.8	.38	–	–	42.0	~36.0	.86	–	–
GK. H500	RV	24.9	22.0	.88	–	–	16.4	.75	25.6	22.8	.89	110°	65°
GK. H501	RV	45.5	32.0	.70	2.6	.28	–	–	50.0	–	–	–	–
GK. H501	RV	23.5	21.2	.90	~ 7.7	.33	15.4	.73	25.0	24.5	.98	110°	70°
GK. H502A	RV	36.6	~31	~.85	12.5	.34	–	–	~40	~30	–	–	–
GK. H502A	RV	22.2	18.8	.85	~ 7.5	.34	13.5	.72	~24	~19	–	118°	60°
WE. P033	LV	32.5	26.8	.82	12.4	.38	18.8	.70	32.0	17.5	.86	110°	62°
WE. P034	LV	27.6	23.0	.83	8.3	.30	~17	.74	27.8	22.8	.82	110°	72°
WE. P035	RV	~38	~34	.89	13.6	.36	–	–	~40	~33	.82	113°	70°
WE. P035	RV	24.0	21.2	.88	–	–	16.0	.75	~29	~24	.82	120°	62°
WE. P106	LV	23.5	22.2	.94	~ 7.5	.32	17.4	.78	23.5	~22	.94	114°	63°
WE. P106	RV	20.0	18.6	.93	–	–	15.0	.76	21.5	~19	.88	112°	62°
WE. P123	RV	17.6	15.8	.90	–	–	12.2	.77	19.7	18.0	.91	124°	63°

Remarks. h=Shell height, l=shell length, b=shell breadth, s=length of hinge line, H=linear dimension from beak to the extremity of ventral margin (i.e. end of growth axis), L=linear dimension perpendicular to H. Because of the curvature the anterior hinge angle (α) and beak angle (β) are hardly measured with precision. γ=posterior hinge angle, δ=angle between hinge line and growth axis. Linear dimension is in mm. ~=approximate or restored. V=valve, LV=left valve, RV=right valve. In the specimen of BV, LV and RV are not necessarily measured at the same growth stage.

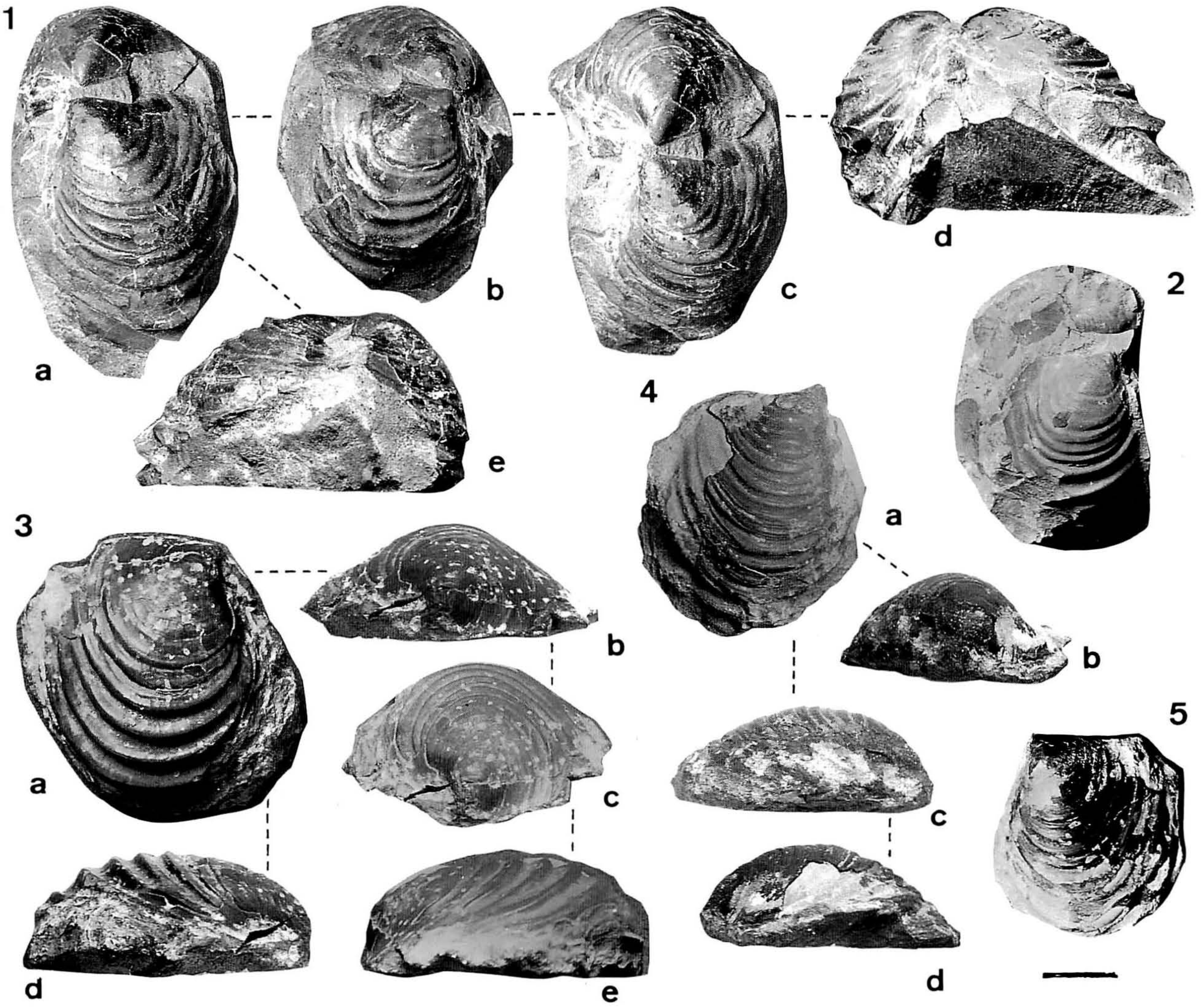

Figure 3. *Inoceramus kamuy* sp. nov. Selected specimens from the Oyubari (1, 2) and Obira (3–5) areas. **1.** WE. P106Y (BV) from loc. Y070077d (89), lateral views of LV (a) and RV (b), with dorsal views of the other valve, dorsolateral (c), anterior (d) and posterior (e) views. **2.** WE. P123Y (RV, juvenile) from loc. Y070093b (84), lateral view. **3.** WE. P036T (RV) from loc. T6046c (84), lateral (a), dorsal (b), dorsolateral (c), anterior (d) and posterior (e) views. **4.** WE. P035T (RV) from loc. T6046c (84), lateral (a), dorsal (b), anterior (c) and posterior (d) views. **5.** WE. P034T (LV, middle-aged or small form) from loc. T4507x (85), lateral view. Note that the dorsolateral view shows about a dorsal half of the disk and may be called dorsocentral.

onicus Petrascheck (1904, p. 158, pl. 8, fig. 5) (redefined by Tröger, 1967, p. 98, pl. 10, fig. 1; draft 20), from Central Europe, is uncertain. *I. saxonicus* differs from *I. kamuy* in having a rounded subhexagonal outline, a more convex valve with a much inflated umbonal part and a more incurved beak, and a less oblique axis of growth. As the material is not numerous and the lectotype is represented by a left valve, with a poorly preserved right valve, *I. saxonicus* is by no means well defined. Its geological age was thought to be early Turonian but is currently revised to middle Turonian on the evidence of a coexisting ammonite species *Collignoniceras woollgari* (Mantell) (see Tröger, 1989, fig. 2).

Inoceramus tuberosus Keller (1982, p. 69, pl. 2, fig. 5), from the lower Turonian of Germany, has a subspherical or knobby umbonal part and a much inflated and well-rounded valve. In these diagnostic features it is discriminated from *I. kamuy*.

Inoceramus kamuy is certainly allied to *Inoceramus nodai* Matsumoto and Tanaka (1988, p. 571, figs. 1–3, 5–13). The latter ranges throughout upper Cenomanian strata in Hokkaido. The early part of *I. kamuy* closely resembles that of *I. nodai*, but they distinctly differ in the character of their later growth stages. While the axis of growth continues to maintain a forward concave curvature in *I. nodai*, its curva-

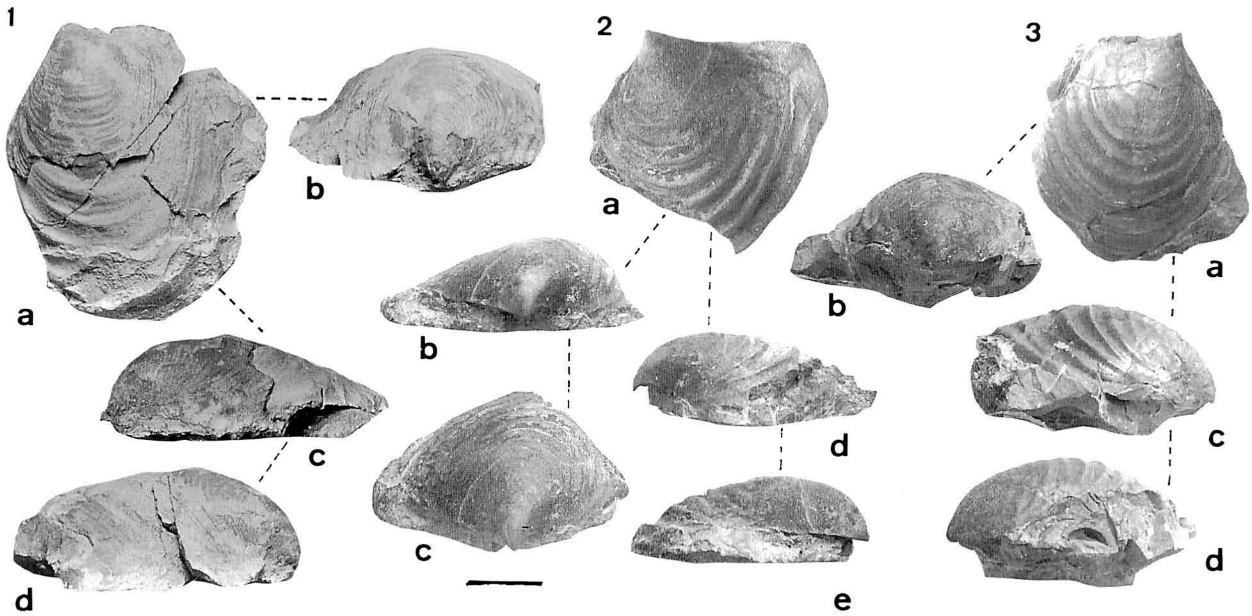

Figure 4. *Inoceramus kamuy* sp. nov. Selected specimens from the Obira area. **1.** WE. P033T (LV) from loc. T4507x (85), lateral (a), dorsocentral (b), anterior (c) and posterior (d) views. **2.** WE. P112T (LV) from loc. T6042c (84), lateral (a), dorsal (b), dorsolateral (c), anterior (d) and posterior (e) views. **3.** WE. P138T (RV) from loc. T6038g (83), lateral (a), dorsocentral (b), anterior (c) and posterior (d) views.

ture decreases gradually with growth, becoming sooner or later straight in *I. kamuy*.

In the typical form of *I. nodai* (see Matsumoto and Tanaka, 1988, fig. 1A–D) the valves are moderately and uniformly convex without notable differences between left and right ones and with gradual changes from the umbonal part to the ventral margin and also from the growth axis to the anterior or posterior margin. In *I. kamuy*, the left valve is somewhat more convex with a little more projected and incurved beak than the right valve. *I. kamuy* is somewhat inequivalve, whereas *I. nodai* is nearly equivalve or subequivalve. However, as there is variation in both species, this difference may appear slight between some variants of the two species.

In *I. kamuy*, the axial zone of the valve is considerably inflated showing fairly steep inclination toward the anterior margin, whereas the rest of the valve flattens in the posterior half and merges into a posterodorsal wing-like part. There is often a very shallow radial sulcus or depressed zone on the posterior side of the convex axial zone. In this regard the ribs as well as the posterior margin often show a gently sinuous or somewhat peculiar curvature.

Inoceramus arvanus Stephenson (1953, p. 65, pl. 12, figs. 6–9; 1955, p. 55, pl. 4, figs. 1–3) and *Inoceramus rutherfordi* Warren (1930, p. 59, pl. 7, figs. 1–3), from middle to early late Cenomanian formations of the Gulf Coast and Western Interior provinces of North America, are somewhat similar to *I. kamuy* in having a weak to moderate radial sulcus on the posterior side of the growth axis with associated sinuosity of the ribs, but their flat posterodorsal wing is typically demarcated from the main part of the valve. Some young forms of *I. kamuy* are fairly similar to the illustrated examples of the North American species, but in later growth stages of our species, the outline of the shell is not so squarish but rather suboval and the major ribs are developed more regularly and sharply, showing better combination with minor rings. Whether the particular musculature characters observed by Kauffman and Powell (1977, p. 71) on the internal mould of *I. arvanus* exist in our species or not remains undetermined.

Matsumoto and Tanaka (1988, p. 574) have given remarks on *Inoceramus atlanticus* (Heinz, 1936) of the middle Cenomanian in comparison with late Cenomanian *I. nodai*. *I. atlanticus* differs from *I. kamuy* in its more gently and rather uniformly convex valves, and its growth axis is slightly convex forward or almost straight. Its hinge line is shorter showing a smaller ratio s/l. It should be noted, however, that the ribs are somewhat sinuous on the posteroventral part in the middle growth stage of the lectotype and another probable example of *I. atlanticus* [="*I. crippsi* var. *reachensis*" of Woods, 1911, pl. 48, fig. 5 and fig. 4]. It can be generally stated that *I. kamuy* may have affinities with *I. atlanticus*, *I. rutherfordi* and *I. nodai* of middle to late Cenomanian age. These species may be affiliated to the group originated from *I. virgatus* Schlüter.

Whether early Turonian *I. kamuy* could be ancestral to middle Turonian *I.* (*Inoceramus*) *hobetsensis* Nagao and Matsumoto, 1939 remains to be seen. The typical form of *I.* (*I.*) *hobetsensis* has a radial sulcus on the posterior side of the zone of the growth axis. Noda (1975) has shown a series of change from its non-sulcate form to the moderately sulcate one in an ascending sequence of strata in his study of samples from the middle Turonian part of the Onogawa Group in Southwest Japan. Further material from various

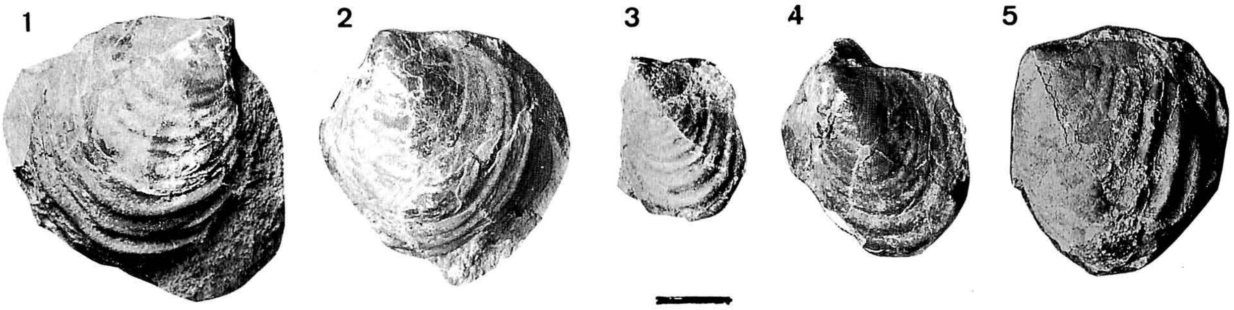

Figure 5. *Inoceramus kamuy* sp. nov. Selected specimens from loc. A54049a (89) of the Ashibetsu (1-4) and loc. T6048a (82) of the Obira (5) area. **1.** WE. P125A (RV). **2.** WE. P126A (LV). **3.** WE. P129A (LV). **4.** WE. P128A (LV). **5.** WE. P115T (LV).

areas in Hokkaido is being studied by Noda, with whom one of us (T.M.) is cooperating. According to the preliminary (but not yet fully described) result of the study of Noda and Matsumoto, there is a form which is probably ancestral to *I.* (*I.*) *hobetsensis*. While the latter occurs mainly in the Zone of *Romaniceras* (*R.*) *deverianum* (upper part of the middle Turonian), the former is associated with *Yubariceras yubarense* Matsumoto, Saito and Fukuda, (regarded by Kennedy *et al.* (1980) as a synonym of *R.* (*Y.*) *ornatissimum* (Stoliczka)), a zonal index of the middle part of the middle Turonian. That probable ancestor of *I.* (*I.*) *hobetsensis* differs from *I. kamuy* in its much higher oval outline with a smaller ratio of L/H, more incurved umbo of the left valve, presence of a well-demarcated posterodorsal wing, and absence of the flattened posterior part of the valve. In other words, *I. kamuy* is not likely to be ancestral to *I.*(*I.*) *hobetsensis*.

I. (*I.*) *hobetsensis* is somewhat allied to the nearly contemporary *I.* (*I.*) *lamarcki* Parkinson. In the latter, including the so-called subspecies (see Tröger, 1967 ; Keller, 1982), the shell is larger, the much inflated main part of the valve is demarcated from the very broad posterior wing, and the beak projects considerably over the hinge line. *I. kamuy* is, hence, undoubtedly distinct from *I.* (*I.*) *lamarcki*. *I.* (*I.*) *apicalis* Woods, 1912, which appears earlier than *I.* (*I.*) *lamarcki* within the middle Turonian, is regarded as ancestral to *I.* (*I*) *lamarcki* (see Keller, 1982). It is smaller than *I.* (*I.*) *lamarcki* and may be comparable in size with some forms of *I. kamuy*, but it has a more inflated main part of the valve, its growth axis is erect, forming a larger angle with the hinge line, and its major ribs are evidently weaker as compared with *I. kamuy*.

Inoceramus (*Inoceramus*) *cuvierii* Sowerby has been interpreted in various ways by authors. Its lectotype is the specimen illustrated by Sowerby (1822, pl. 25, figs. 2, 3 ; 1823, pl. 441, fig. 1) and redrawn by Woods (1912, text-fig. 73). Its specific diagnosis, as concisely given by Keller (1982, p. 90), is considerably different from that of *I. kamuy* in its shorter hinge line, long and gently concave anterior margin, less convex main part of the valve, anteriorly concave growth axis, and lower and less distinct major ribs combined with minor lines or lamellae instead of definite rings. Its extent of variation has not been precisely studied. *I.* (*I.*) *cuvierii* occurs in the Middle Chalk of England and in the middle Cenomanian of Germany and other areas of Europe. North American examples have been shown by Hattin (1962, fig. 15), Hattin and Cobban (1977, figs. 7, 8) and Kauffman (1977, pl. 7, figs. 1, 2) from the Zone of *Collignoniceras woollgari*. We hesitate to comment on variously subdivided forms ("subspecies") of *I. cuvierii* by Pergament (1971), but none of them seems to be related to *I. kamuy*. In middle Turonian strata of Japan *I.* (*I.*) *hobetsensis* predominates and only occasionally *I.* sp. cf. *I.* (*I.*) *cuvierii* is found (Matsumoto *et al.*, 1989, pl. 2, fig. 4).

To sum up the above discussion, *I. kamuy* n. sp. is not referable to the group of *I.* (*I.*) *lamarcki* that represents the main phylogenetic stock of the subgenus *I.* (*Inoceramus*).

The present new species was indicated sometimes as *Inoceramus* n. (?) sp. aff. *I. teshioensis* (e.g. Hirano *et al.*, 1977, p. 9 ; Tanabe *et al.*, 1977, table 2c). *Inoceramus teshioensis* Nagao and Matsumoto (1939, p. 274, pl. 24, figs. 6, 7, 9, pl. 26, figs. 5, 6, 7) was redefined by Noda (1975, p. 251, pl. 35, figs. 2-7, text-fig. 15B) in his study of the material from Southwest Japan. It resembles *I. kamuy* in the weakly inequivalve character, proportion of L/H or l/h with a little higher than long outline, and the ornament consisting typically of regular and sharp major ribs and minor rings on the main part. There are, however, notable differences between the two species ; *I. teshioensis* has a nearly straight or gently concave axis of growth, an evenly rounded ventral margin and rather wholly convex valves, whereas *I. kamuy* has in youth a concave and later straight growth axis, an asymmetrically curved ventral margin that passes to a longly arcuate or often sinuous posterior margin, and a differentiation of a convex anterior to axial main part and a flattened and fairly broad posterior to posterodorsal part.

I. teshioensis, which occurs abundantly in upper Turonian strata in Hokkaido, Sakhalin and Southwest Japan, is regarded as an index species of the late Turonian together with the index ammonite *Subprionocyclus neptuni* (Geinitz).

Inoceramus costellatus Woods (1912, p. 336, pl. 54, figs. 5-7), from the late Turonian Chalk Rock in England and correlative strata in Germany and other regions, closely resembles *I. teshioensis* (see Matsumoto, 1959, p. 84), but so far as the illustrated examples are concerned, the former has less convex valves and more crowded major ribs than the latter. At any rate, it is distinct from *I. kamuy* in the same way as in the case of *I. teshioensis*.

Inoceramus perplexus Whitfield (1877 ; 1880, p. 392, pl. 10, figs. 4, 5 ; pl. 8, fig. 3), from the late Turonian *Scaphites whitfield* Zone and *S. nigricollensis* Zone of North America, is also similar to *I. teshioensis*, as is recorded in a private note by one of us (T.M., April 3, 1957 at USGS, Denver). That comparison was based on plaster casts of the two syntypes, well preserved RV and imperfect LV, which were later designated respectively as the lectotype and paralectotype by Kennedy *et al.* (1989, p. 106, figs. 33 K and O), and also other examples kindly shown by W.A. Cobban. The American species, thus, resembles *I. kamuy* and especially so in that its growth axis is semewhat concave in youth, becoming straight later. It is, however, different from *I. kamuy* in that the convex axial part of the valve inclines gradually to the posterior part and the outline of its young shell is higher than that of a juvenile *I. kamuy*.

Inoceramus longealatus Tröger, 1967 (see Elder and Box, 1992, p. 21) appears similar to *I. kamuy* in the flattened posterior part, but its wing is more produced (i.e. "flared") posterodorsally, and it has a more convex anterior margin, smaller beak angle, and longer hinge line.

In spite of the differences mentioned above, it should be noted that *I. kamuy* could possibly be a source from which in the late Turonian, *I. teshioensis*, *I. costellatus*, and *I. perplexus* (with rather uniformly convex valves) and *I. longealatus* (posterodorsally flattened and produced) may have been derived. The above is presumed by some similarity to these species and also by the variability observed in *I. kamuy* (see Observation). As there is a gap in the geological age and also in the morphological characters, the derivation is probably indirect. The so-called linking species or demes should be searched for from the middle part of the Turonian. In fact, such a species as *I. saxonicus* could link *I. kamuy* with *I. teshioensis*, although that species in our present knowledge is too incomplete to clarify the problem. In the middle Turonian the group of *I.* (*I.*) *lamarki*, including *I.* (*I.*) *hobetsensis* and related species, was so predominant that representatives of the group of *I. kamuy*, if present, may have been confined to a few sheltered environments. There is a sketch in T.M.'s private file of an interesting specimen from loc. K304 of T. Suekane (personal communication, 1983) along the forestry road of Kaneobetsu (Oyubari area) that looks like an "intermediate form" between *I. kamuy* and *I. longealatus*. The strata cropping out at loc. K304 is just

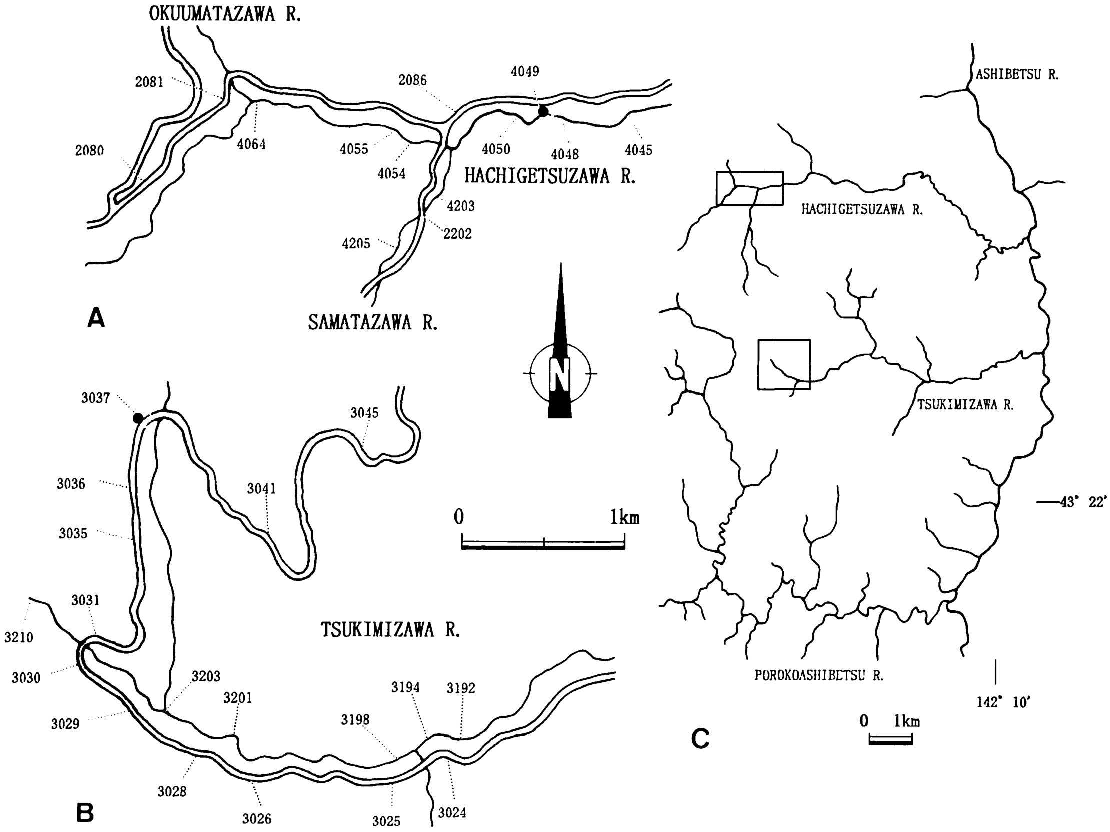

Figure 6. Route maps of the Hachigetsu-zawa (A) and the Tsukimi-zawa (B), showing localities of *Inoceramus kamuy* by larger solid circles. Map (C) on the right side is the drainage system of the upper reaches (part) of the Ashibetsu River to indicate the site of the two route maps. For the general geology of the area readers may refer to Shimizu *et al.* (1953). Note that the official name Hachigatsu-zawa is locally called the Hachigetsu-zawa. (Maps prepared by A.A.) For the sites of the Oyubari, Ashibetsu and Obira areas readers may refer to the map of Matsumoto, 1995, fig. 2.

above the stratigraphic level of loc. K305 where *Mytiloides* sp. occurs with typical examples of *I. kamuy*. K304 may belong to the higher part of lower Turonian or to the lower part of the middle Turonian sequence along this route. At any rate that specimen, as well as some others, should be reexamined more carefully.

A flared posterior wing develops in the late Turonian to early Coniacian *Inoceramus frechi* Flegel, 1904 (see Andert, 1934, p. 120, pl. 5, figs. 5-9, pl. 6, fig. 1; Kauffman, 1977 pl. 9, figs. 21; Keller, 1982, p. 96, pl. 7, fig. 1; Elder and Box, 1992, pl. 23, figs. 12-5, 12-9—15) and also in "*Inoceramus lusatiae*" Andert, 1911. As Kauffman (*in* Herm *et al*., 1979) pointed out, "*I. lusatiae*" includes two species, one of which (Andert, 1911, pl. 8, figs. 3, 4; 1934, pl. 7, figs. 1, 2) belongs to the *I.* (*I.*) *lamarcki* group and the other (Andert, 1911, pl. 3, fig. 3; 1934, pl. 7, fig. 3; Tröger, 1967, p. 73, pl. 8, figs. 2, 3) belongs to *Mytiloides*. *I. frechi* was referred to *Mytiloides* by Kauffman (1977) and Kauffman *et al*. (1978), but it is more probably related to *I. longealatus* as Elder and Box (1992, p. 23) remarked. Thus, the flattened and flared posterior wing may occur in species of different systematic positions. Furthermore, *I. kuskokwimensis* Elder and Box (1992, p. 26, figs. 13-8—13; 14-1—9), from Alaska of uncertain but presumably middle (?) to latest Turonian or earliest Coniacian age, has a very large, broad, flexuous posterior wing.

GK. H8432 (Figure 2-6) from loc. Y5228f is surprisingly similar to some specimens of *Inoceramus glatziae* Flegel, 1904 (see Andert, 1934, pl. 6, fig. 4) from the latest Turonian or early Coniacian in central Europe. This is caused by secondary distortion, as evidenced by several less deformed specimens from the same bed, which is located above the layer with abundant *Mytiloides mytiloides* (Mantell) (loc. Y5228h) and somewhat lower than the bed with *M. labiatus* (Schlotheim) (loc. Y5228a).

Inoceramus multiformis Pergament, 1971, from the highest Turonian to lower Coniacian strata of Kamchatka and Sakhalin, is somewhat similar to *I. kamuy*. This species was subdivided into three subspecies, *I. multiformis multiformis* Pergament (1971, p. 61, pl. 9, figs. 2, 3; pl. 10, figs. 2, 3; pl. 11, figs. 1, 2; pl. 12, figs. 1-5; pl. 33, fig. 3), *I. multiformis sectilis* Pergament (1971, p. 65, pl. 13, figs. 3, 4; pl. 14, figs. 2, 3; pl. 16, figs. 1-3; pl. 17, figs. 2-4) and *I. multiformis subangustus* Pergament (1971, p. 67, pl. 19, figs. 2-7; pl. 20, figs. 3, 4). The coexistence of three subspecies in the strata of the same time interval in the same province is biologically questionable, if not impossible. They may be merely morphotypes within a variable species. The similarity between the two species is in the small size and the shell shape, which often shows a gently sinuous posterior margin and more or less flattened posterior or posterodorsal part with a shallow radial sinus running sometimes on the posterior side of the convex main part of the valve. *I. multiformis*, however, differs from *I. kamuy* in having a straight growth axis throughout life without a concave curvature in young forms, and the shell extends less obliguely, forming a larger angle between the growth axis and the hinge line. The umbo of the left valve of *I. multiformis* projects considerably forward and inward with a smaller beak angle; the major ribs are not so regular in spacing and mode of combination with fine rings as those of our species.

To sum up, it is a future problem to determine what kind of species had an actual phylogenetic relationship with early Turonian *I. kamuy*. It would be also interesting to make clear the functional implications of variously developed flared wings.

Appendix

A biostratigraphic result.—*Inoceramus kamuy* is not only useful for correlating the lower Turonian strata between separate regions but also valuable in marking the base of the Turonian Stage. The stratigraphic level of loc. Y5233a is in the continuous outcrop of about a 300 m thick sequence of late Cenomanian to early Turonian strata along the Shirakin River (Oyubari area), and just 4 m above the upper peak of the carbon isotope spike, which marks the Cenomanian-Turonian boundary (see Hasegawa, 1995, fig. 1; Toshimitsu *et al*., 1995, fig. 1). At this loc. Y5233a, in the upper part of the sandy siltstone bed, several specimens of *I. kamuy* were obtained together with a large shell of *Puzosia orientalis* Matsumoto (see Nishida *et al*., 1995, pl. 3, figs. 3, 4; pl. 4, fig. 3) and one of them, GK. H8440 is illustrated in this paper (Figure 2-3). In addition to them, a tiny inoceramid specimen, probably a juvenile of *Mytiloides* cf. *sackensis* (Keller) is present in the rock matrix of the umbilical part of a *Puzosia*, although more distinct specimens should be searched for in this bed. It is furthermore noted that *Pseudaspidoceras flexuosum* Powell (identified by T.M.) was obtained by H. Hirano at the level 8 m above the level of Y5233a and another example of *I. kamuy* was obtained at the level 1.5 m below this ammonite. On the other hand, *Inoceramus nodai* was found at the level about 10 m below the second spike mentioned above, i.e. about 5 m below the first spike (Hirano, 1995, figs. 2, 3; Toshimitsu *et al*., 1995, fig. 1). The three inoceramid species, *I. nodai*, *I. kamuy* and *M. sackensis*, are, thus, important to recognition of the C/T boundary.

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References cited

Andert, H., 1911 : Die Inoceramen des Kreibitz-Zittauer Sandsteingebirges. *Festschrift des Humboldtvereins zur Feier seines 50 jahrigen Bestehens am 22 Oktober, 1911*, p. 33-64, 9 pls., Ebersbach.

Andert, H., 1934 : Die Kreideablagerungen zwischen Elbe und Jeschken. Teil III. Die Fauna der obersten Kreide in Sachsen, Böhmen und Schlesien. *Abhandlungen der Preussischen Geologischen Landesanstalt, Neue Folge*, vol. 159, p. 7-477, 19 pls.

Asai, A. and Hirano, H., 1990 : Stratigraphy of the Upper Cretaceous in the Obira area, northwestern Hokkaido. *Gakujutsu Kenkyu, School of Education, Waseda University, series Biology and Geology*, vol. 39, p. 27-50. (*in Japanese*)

Elder, W.P. and Box, S.E., 1992 : Late Cretaceous inoceramid bivalves of the Kuskokwin Basin, southwestern Alaska, and their implication for basin evolution. *The Paleontological Society Memoir* 26 (*Journal of Paleontology*, vol. 66, no. 2, supplement), 39 p.

Flegel, K., 1904 : Heuseheuer und Andersbach-Weckelsdorf. Eine Studie über die obere Kreide im böhmisch-schlesischen Gebirge. *In Jahresbericht der Schlesischen Gesellschaft für Vaterlandische Kultur*, III, p. 123-158.

Hasegawa, T., 1995 : Correlation of the Cenomanian/Turonian boundary between Japan and Western Interior of the United States. *Journal of the Geological Society of Japan*, vol. 101, p. 2-12.

Hattin, D.E., 1962 : Stratigraphy of the Carlile Shale (Upper Cretaceous) in Kansas. *State Geological Survey of Kansas, Bulletin* 156, 1-155.

Hattin, D.E. and Cobban, W.A., 1977 : Upper Cretaceous stratigraphy, paleontology and paleoecology of western Kansas. *The Mountain Geologists*, vol. 14, nos. 3-4, p. 175-217.

Heinz, R., 1936 : Inocerámidos de Alicante, Valencia y Baleares. *Boletin de la Sociedad Española de Historia Natural*, vol. 36, p. 91-99, pl. 13.

Herm, D., Kauffman, E.G. and Wiedmann, J., 1979 : The age and depositional environment of the "Gosau"-Group (Coniacian-Santonian), Brandenberg/Tirol, Austria. *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie*, vol. 19, p. 27-92.

Hirano, H., 1995 : Correlation of the Cenomanian/Turonian boundary between Japan and Western Interior of the United States in relation with oceanic anoxic events. *Journal of the Geological Society of Japan*, vol. 101, p. 13-18.

Hirano, H. and Asai, A., 1987 : Biostratigraphy and correlation of the Cenomanian and Turonian of Japan. *Journal of Geography*, (Tokyo), vol. 96, no. 5, p. 61-64. (*in Japanese*)

Hirano, H., Matsumoto, T. and Tanabe, K., 1977 : Mid-Cretaceous stratigraphy of the Oyubari area, central Hokkaido. *Palaeontological Society of Japan, Special Papers*, no. 21, p. 1-10.

Hirano, H., Takizawa, K. and Tsuchida, S., 1989a ; 1989b ; 1989c ; 1990 : Biostratigraphy of the Upper Cretaceous in the Oyubari area, central Hokkaido, Japan. I ; II ; III ; IV. *Bulletin of the Science and Engineering Research Laboratory, Waseda University*, no. 123, p. 13-34 (1989a) ; no. 125, p. 14-36 (1989b) ; no. 126, p. 1-21 (1989c) ; no. 127, p. 8-26 (1990).

Kauffman, E.G., 1977 : Illustrated guide to biostratigraphically important Cretaceous macrofossils, Western Interior Basin, U.S.A. *The Mountain Geologists*, vol. 14, nos. 3-4, p. 225-274.

Kauffman, E.G., Cobban, W.A. and Eicher, D.L., 1978 : Albian through Coniacian strata. Biostratigraphy and principal events in Western Interior United States. *Annals du Museum d'Histoire Naturelle de Nice*, vol. 4 (for 1976), p. xxxiii, 1-12.

Kauffman, E.G. and Powell, J.D., 1977 : Paleontology. *In* Kauffman, E.G., Hattin, D.J. and Powell, J.D., Stratigraphic, paleontologic and paleoenvironmental analysis of the Upper Cretaceous rocks of Cimarron County, northwestern Oklahoma. *Geological Society of America, Memoir* 149, p. 47-150, pls. 1-12.

Keller, S., 1982 : Die Oberkreide der Sack-Mulde bei Alfeld (Cenoman-Unter-Coniac). Lithologie, Biostratigraphie und Inoceramen. *Geologisches Jahrbuch, Reihe A*, Heft 64, p. 3-171, pls. 1-8.

Kennedy, W.J., Cobban, W.A., Hancock, J.M. and Hook, S.C., 1989 : Biostratigraphy of the Chipsa Summit Formation at the type locality : a Cenomanian through Turonian reference section for Trans-Pecos Texas. *Bulletin of the Geological Institutions of the University of Uppsala, New Series*, vol. 15, p. 39-119.

Kennedy, W.J., Wright, C.W. and Hancock, J.M., 1980 : The European species of the Cretaceous ammonites *Romaniceras* with a revision of the genus. *Palaeontology*, vol. 23, p. 325-362, pls. 39-50.

Matsumoto [Matumoto], T., 1942 : Fundamentals in the Cretaceous stratigraphy of Japan. Part I. *Memoirs of the Faculty of Science, Kyushu Imperial University, Series D*, vol. 1, no. 3, p. 129-280.

Matsumoto, T., 1959 : Zonation of the Upper Cretaceous in Japan. *Memoirs of the Faculty of Science, Kyushu University, Series D*, vol. 9, no. 2, p. 55-93, pls. 6-11.

Matsumoto, T., 1995 : Notes on gaudryceratid ammonites from Hokkaido and Sakhalin. *Palaeontological Society of Japan, Special Papers*, no. 35, p. i-vi, 1-152.

Matsumoto, T. and Haraguchi, Y., 1978 : A new texanitine ammonite from Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 110, p. 306-318, pl. 42.

Matsumoto, T., Noda, M. and Maiya, S., 1991 : Towards an integrated ammonoid-inoceramid- and foraminiferal biostratigraphy of the Cenomanian and Turonian (Cretaceous) in Hokkaido. *Journal of Geography*, (Tokyo), vol. 100, p. 378-398. (*in Japanese with English abstract*)

Matsumoto, T., Noda, M. and Toshimitsu, S., 1989 : Gigantic ammonite held in the Hobetsu Museum. Its record of occurrence and its stratigraphic position. *The Bulletin of the Hobetsu Museum*, no. 5, p. 13-35. (*in Japanese with English abstract*)

Matsumoto, T. and Tanaka, K., 1988: Some inoceramids (Bivalvia) from the Cenomanian (Cretaceous) of Japan-IV. An interesting new species from Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, no. 151, p. 570-581.

Nagao, T. and Matsumoto [Matumoto], T., 1939: A monograph of the Cretaceous *Inoceramus* of Japan. Part I. *Journal of the Faculty of Science*, *Hokkaido Imperial University*, *Series IV*, vol. 5, nos. 3-4, p. 241-299, pls. 23-34.

Nishida, T., Matsumoto, T., Maiya, S., Hanagata, S., Yao, A. and Kyuma, Y., 1993: Integrated mega-and micro-biostratigraphy of the Cenomanian Stage in the Oyubari area, Hokkaido-with special reference to its upper and lower limits-Part 1. *Journal of the Faculty of Education*, *Saga University*, vol. 41, no. 1, part 2, p. 11-57. (*in Japanese with English abstract*)

Nishida, T., Matsumoto, T., Maiya, S., Hanagata, S., Yao, A., Uematsu, K., Kawashita, Ỹ. and Kyuma, Y., 1995: Integrated mega-and micro-biostratigraphy of the Cenomanian Stage in the Oyubari area, Hokkaido — with special reference to its upper and lower limits — Part 2. *Journal of the Faculty of Education*, *Saga University*, vol. 42, no. 2, p. 179-199. (*in Japanese with English abstract*)

Noda, M., 1975: Succession of *Inoceramus* in the Upper Cretaceous of Southwest Japan. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, vol. 23, no, 2, p. 211-261, pls. 32-37.

Pergament, M.A., 1971: Biostratigraphy and inocerams of Turonian-Coniacian deposits of the Pacific regions of the USSR. *Transactions of the Academy of Science USSR*, *Geological Institute*, vol. 212, p. 1-202. (*in Russian*)

Petrascheck, W., 1904: Ueber Inoceramen aus der Kreide Böhmens und Sachsens. *Jahrbuch der Königlich-Kaiserisches Geologisches Reichsanstalt*, no. 53, p. 153-168, pl. 8.

Sekine, H., Takagi, A. and Hirano, H., 1985: Biostratigraphical study of the Upper Cretaceous of the north-east part of the Obira area, Hokkaido. *Fossils* (*Palaeontological Society of Japan*), no. 38, p. 1-15. (*in Japanese with English abstract*)

Shimizu, I., Tanaka, K. and Imai, I., 1953; Kami-Ashibetsu. *Explanatory Text of the Geological Map of Japan*, *scale 1:50,000*, p. 1-78 (*in Japanese*); p. 1-23 (*résumé in English*), folded tables 1-2, folded figs. 1-6, route maps 1-8, quadrangle map. Geological Survey of Japan.

Sowerby, J., 1822: *Inoceramus cuvierii*. *Transactions of the Linnean Society*, vol. 13, p. 453, pl. 25.

Sowerby, J., 1823: *The Mineral Conchology of Great Britain*, vol. 5, p. 59-62, pls. 440-442. Richard Taylor, London.

Stephenson, L.W., 1953 (for 1952): Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas. *U.S. Geological Survey Professional Paper*, 242, p. 1-226, pls. 1-59.

Stephenson, L.W., 1955: Basal Eagle Ford Fauna (Cenomanian) in Johnson and Tarrant Counties, Texas. *U.S. Geological Survey Professional Paper* 274-c, p. 53-67, pls. 4-7.

Tanabe, K., Hirano, H., Matsumoto, T. and Miyata, Y., 1977: Stratigraphy of the Upper Cretaceous deposits in the Obira area, northwestern Hokkaido. *Science Reports of the Department of Geology*, *Kyushu University*, vol. 12, no. 3, p. 181-202. (*in Japanese with English abstract*)

Tanaka, K., 1963: A study on the Cretaceous sedimentation in Hokkaido, Japan. *Report of the Geological Survey of Japan*, no. 197, p. 1-122, 2 maps, pls. 1-3.

Toshimitsu, S., Matsumoto, T., Noda, M., Nishida, T. and Maiya, S., 1995: Towards an integrated mega-, micro- and magnetostratigraphy of the Upper Cretaceous in Japan. *Journal of the Geological Society of Japan*, vol. 101, P. 19-29. (*in Japanese with English abstract*)

Tröger, K.-A., 1967: Zur Paläontologie, Biostratigraphie und faziellen Ausbildung der unteren Oberkreide (Cenoman bis Turon). Teil I, Paläontologie und Biostratigraphie der Inoceramen des Cenomans bis Turons Mitteleuropas. *Abhandlungen des Staatlichen Museum für Mineralogie und Geologie zur Dresden*, vol. 12, p. 13-207.

Tröger, K.-A., 1989: Problems of Upper Cretaceous inoceramid biostratigraphy and paleobiogeography in Europe and western Asia. *In*, Wiedmann, J. (*ed.*): *Cretaceous of the Western Tethys*. Proceedings of the 3rd International Cretaceous Symposium, Tübingen, 1987, p. 911-930. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Warren, P.S., 1930: New species of fossils from Smoky River and Dunvegan formations, Alberta. *Alberta Research Council of Geological Survey Report*, vol. 21, p. 57-68, pls. 3-7.

Whitfield, R.P., 1877: Preliminary report on the paleontology of the Black Hills, containing descriptions of new species of fossils from the Potsdam, Jurassic, and Cretaceous formations of the Black Hills of Dakota. *U.S. Geographical and Geological Survey of the Rocky Mountain Region Report* (Powell), 49 p.

Whitfield, R.P., 1880: Paleontology of the Black Hills of Dakota. *In*, Newton, Henry, and Jenney, W.P., Report on the geology and resources of the Black Hills of Dakota. *U.S. Geographical and Geological Survey of the Rocky Mountain Region* (Powell), p. 325-468, 16 pls.

Woods, H., 1911: A monograph of the Cretaceous Lamellibranchiata of England, vol. 2, part 7, *Inoceramus*. *Palaeontographical Society*, 1910, p. 261-284, pls. 45-50.

Woods, H., 1912: A monograph of the Cretaceous Lamellibranchia of England, vol. 2, part 8, *Inoceramus* (continued). *Palaeontographical Society*, 1911, p. 285-340, pls. 51-54.

Aichi 愛知，Anjo 安城，Ashibetsu 芦別，Fukuoka 福岡，Hachigetsu [Hachigatsu]-zawa 八月沢，Hakkin-zawa 白金沢，Hikage-zawa 日陰沢，Hinata-zawa 日向沢，Hokkaido 北海道，Ikushunbetsu 幾春別，Imaike-cho 今池町，Kaneobetsu カネオベツ[金尾別]，Kechikauen-obirashibe ケチカウエン-オビラシベ，Mikasa 三笠，Obira 小平，Obirashibe [Opiraushibets] 小平蘂 [オビラシベ＝オピラウシベツ]，Okufutamata-zawa 奥二股沢，Okuumata-zawa 奥右股沢，Oyubari 大夕張，Penkemoyubari [Penke-moyuparo] ペンケモユーバリ [ペンケモユーパロ]，Porokoashibetsu 幌子芦別，Saga 佐賀，Samata-zawa 左股沢，Shirakin River [the same stream as Hakkin-zawa] 白金川，Shiyubari [Siyubari, Shuparo] 主夕張 [シユーバリ，シューパロ]，Takino-sawa [the same stream as Penkemoyubari] 滝の沢，Tappu 達布，Tsukimi-zawa 月見沢，Yezo [ancient Hokkaido and adjacent area; not written as Ezo] 蝦夷 [イェゾ＝エゾ]（正しい発音はイェゾ）. Note: sawa or zawa＝small river or tributary of the main river

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1007 Miocene pinniped *Allodesmus* (Mammalia : Carnivora) ; with special reference to the "Mito seal" from Ibaraki Prefecture, Central Japan

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Abstract. A partial cranium of a fossil pinniped from late Middle Miocene rocks (ca. 12.0-13.6 Ma) in Mito City, Ibaraki Prefecture, Central Japan, is described as a new species, *Allodesmus naorai*. The holotype of *A. naorai* was previously known only by a plaster cast of the "lost specimen" in the collections at the U.S. National Museum of Natural History, but recently the original specimen was rediscovered in the Naora collection at the National Museum of Japanene History. A phylogenetic analysis indicates that *A. naorai* is the sister taxon of *A. packardi*, and they form a "broad head" subgroup within the genus. The "broad head" subgroup is placed as the sister group to the *A. kernensis*-*A. sinanoensis* species group, which forms a "long head" subgroup within the genus. *Allodesmus courseni* is the most generalized species among five species known within the genus. These five species and other material referred to the Allodesminae described herein from the western North Pacific indicate that the Allodesminae dominated along the shore of the North Pacific Ocean during the late Middle Miocene and became extinct by the end of the Middle Miocene, probably because of the change to a cooler marine climate.

Key words : Phylogeny, *Allodesmus*, Pinnipedia, Miocene, North Pacific, paleobiogeography

Introduction

The extinct Miocene pinniped genus *Allodesmus* Kellogg, 1922 is the most interesting taxa among the Pinnipedia, and its phylogenetic position is a focal point in the current debate of pinniped phylogeny (e.g., Wyss, 1987 ; Barnes, 1989 ; Berta, 1991 ; Wyss and Flynn, 1993 ; Berta and Wyss, 1994). Although allodesmines are known in both the western and eastern North Pacific in Middle Miocene time, the western records still remain poorly known and are alluded to only briefly in the literature (e.g., Mitchell, 1968 ; Repenning and Tedford, 1977 ; Hirota *et al*., 1987 ; Tomida, 1990).

In their extensive monograph on the otarioid seals of the Neogene, Repenning and Tedford (1977) reported *Allodesmus courseni* (Downs, 1956) from Japan on the basis of a plaster cast of the cranial fragment that is in the collections at the United States National Museum of Natural History, Smithsonian Institution, where the cast bears the catalog number USNM 24915. According to Repenning and Tedford (1977), Shikama (written communication, 1967) stated that the original specimen of USNM 24915 had been stored in a shrine at Utsunomiya and was probably destroyed during World War II. Based on Shikama's information, this specimen has been known as the "lost specimen" possibly from the Middle Miocene Kanomatazawa Formation in northern Utsunomiya, Tochigi Prefecture (e.g., Hirota *et al*., 1987 ; Tomida, 1990).

Although not cited by Repenning and Tedford (1977), in his treatise on "Natural history of mammals in Japan" Naora (1944) had mentioned the occurrence of the right facial fragment of an "earless seal" from Mito City, Ibaraki Prefecture. As Naora (1944, p. 97) noted :

> "The mammalian fossil assignable to the family Phocidae from tuffaceous rocks in Mito consists of a right facial part of the skull and is slightly deformed by compression, but it has some characters similar to that of the Recent largha seal. However, I can not make further examination because of the distortion. Thus, I tentatively treat it merely as the Mito seal."

The specimen was, however, neither described in detail nor illustrated.

After Naora's death in 1985 some of his research collection was donated to the National Museum of Japanese History (Harunari, 1987), and the "Mito seal" was rediscovered in the collection (Kohno *et al*., 1994), which was unexpectedly identical with USNM 24915, the cast of the "lost specimen" reported by Repenning and Tedford (1977). The attached label on the original specimen indicates that the fossil was found in the vicinity of Mito City, and it was the object of Naora's (1944) account. Therefore, Shikama's belief that the specimen must have been recovered in northern Utsunomiya is incorrect, and consequently the status of the specimen as reported by Repenning and Tedford (1977) needs to be revised.

In this paper, I amend the status of the rediscovered cranium, describe it in detail on the basis of the original specimen as a new species of the genus *Allodesmus*, and discuss the phylogenetic relationships and paleobiogeography of the genus. I also provide here a review of the fossil records of allodesmines in the western North Pacific with reference to their classification and geochronological distribution.

Abbreviations.—The following abbreviations are used to identify the institutions: **CAS**, California Academy of Sciences, San Francisco, California, U.S.A.; **CBM**, Department of Earth Sciences, Natural History Museum and Institute, Chiba, Chiba, Japan; **HSEH**, Higashichikuma Shiojiri Education Hall, Matsumoto, Nagano, Japan; **IPM**, Iwate Prefectural Museum, Morioka, Iwate, Japan; **KU**, Department of Biosphere History, Kyoto University, Kyoto, Japan; **LACM**, Section of Vertebrate Paleontology, Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A.; **NMJH**, National Museum of Japanese History, Sakura, Chiba, Japan; **NSM**, Department of Geology, National Science Museum, Shinjuku, Tokyo, Japan; **SFH**, Shiga-mura Fossil Hall, Higashichikuma, Nagano, Japan; **SICC**, Sado Island Community Center, Sado, Niigata, Japan; **UCMP**, University of California, Museum of Paleontology, Berkeley, California, U.S.A.; **USNM**, Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.

Systematic paleontology

Class Mammalia Linnaeus, 1758
Order Carnivora Bowdich, 1821
Infraorder Arctoidea Flower, 1869
Parvorder Pinnipedia Illiger, 1811
Family Desmatophocidae Hay, 1930

Desmatophocidae Hay, 1930, p. 557, as a family of the suborder Pinnipedia to include *Desmatophoca*; Repenning and Tedford, 1977, p. 10, as a family of the superfamily Otarioidea to include the subfamilies Desmatophocinae and Allodesminae.

Allodesmidae Kellogg, 1931, p. 227, as a family of the suborder Pinnipedia to include *Allodesmus*.

Otariidae Gill, 1866, *s.l.* (part). Mitchell, 1966, p. 39, as a family of the order Pinnipedia to include the subfamily Desmatophocinae; Mitchell, 1968, p. 1839, as a family of the suborder Pinnipedia to include the subfamily Desmatophocinae; Barnes, 1972, p. 5, as a family of the order Carnivora to include the subfamily Desmatophocinae.

Unnamed clade. Berta, 1991, fig. 22, as a clade of the monophyletic Pinnipedia, to include *Desmatophoca*, *Allodesmus*, and *Pinnarctidion*.

Comments.—The higher level taxonomy among the Pinnipedia is currently controversial. The arguments center over whether or not the otarioids (otariids, odobenids, and their fossil allies) are monophyletic (see "Historical Considerations" in Berta and Wyss, 1994). In this respect, the extinct Miocene genera *Desmatophoca* Condon, 1906 and *Allodesmus* Kellogg, 1922 have played a central role. Some writers have united these genera within the subfamily Desmatophocinae in the family Otariidae *s.l.* (Mitchell, 1966; Barnes, 1972), in the family Desmatophocidae in the superfamily Otarioidea (Repenning and Tedford, 1977), or in an unnamed clade having a sister group relationship to the family Phocidae (Berta, 1991). However, the included taxa within the subfamily, family, or the "group" are different among the various writers (see the above family synonymy). In addition, Barnes (1979, 1989) and Barnes *et al.* (1985) have advocated that the genera *Desmatophoca* and *Allodesmus* do not belong to a monophyletic group. Likewise Berta and Wyss (1994) have depicted a polychotomous state of those taxa including the Phocidae within their new concept of the Phocoidea. The phylogenetic analysis of this study demonstrates that the genera *Desmatophoca* and *Allodesmus* form a monophyletic clade (see also Berta, 1994b), and I recognize the family level definition for these taxa.

Subfamily Allodesminae (Kellogg, 1931).
Mitchell, 1968

Desmatophocinae (Hay, 1930). Mitchell, 1966, p. 39, as a subfamily of the family Otariidae *s.l.* to include *Desmatophoca*, *Allodesmus*, and *Dusignathus*; Barnes, 1972, p. 5, to include *Desmatophoca*, *Allodesmus*, Desmatophocines A, B and C.

Allodesminae (Kellogg, 1931). Mitchell, 1968, p. 1839, as a subfamily of the Otariidae *s.l.* to include *Allodesmus*; Repenning and Tedford, 1977, p. 10, as a subfamily of the family Desmatophocidae to include *Allodesmus*, Desmatophocines B and C of Barnes (1972); Barnes, 1979, p. 23, as a subfamily of the family Otariidae *s.l.* to include *Allodesmus*, Desmatophocines B and C of Barnes (1972).

Emended diagnosis of subfamily.—Retracted dorsal bar of the zygomatic root of maxilla; dorsoventrally expanded, mortised squamosal-jugal contact; dorsoventrally thin and laterally broad pterygoid process between palate and braincase; facet for tympanohyal within hyoid fossa; transversely expanded posterior lacerate foramen; no posterior carina on canine; bulbous cheek teeth; procumbent premolars. Dental formula: $I^3 \cdot C^1 \cdot P^4 \cdot M^{1-2}/I_2 \cdot C_1 \cdot P_4 \cdot M_{1-2}$.

Type and only included genus.—*Allodesmus* Kellogg, 1922.

Genus *Allodesmus* Kellogg, 1922

Allodesmus Kellogg, 1922, p. 26.
Atopotarus Downs, 1956 (part), p. 116.

Emended diagnosis of genus.—The same as for the subfamily until additional genera are described.

Type species.—*Allodesmus kernensis* Kellogg, 1922.

Included species.—*Allodesmus kernensis* Kellogg, 1922 (including *A. kelloggi* Mitchell, 1966), Middle Miocene, California and Japan; *A. sinanoensis* (Nagao, 1941), late Middle Miocene, Japan; *A. courseni* (Downs, 1956), Middle Miocene, California; *A. packardi* Barnes, 1972, Middle Miocene, California; and *A. naorai* sp. nov., late Middle Miocene, Japan.

Allodesmus naorai sp. nov.

Figures 1-3; Table 1

Phoca sp. Naora, 1944, p. 144.
Allodesmus courseni (Downs, 1956). Repenning and Tedford, 1977, p. 75, pl. 9, fig. 3.

Diagnosis.—A species of *Allodesmus* distinguished from *A. kernensis* and *A. sinanoensis* by having narrower and less developed prenarial shelf, posteriorly broader and flatter palate, much smaller overall size, and much wider skull shape; distinguished from *A. packardi* by having much broader prenarial shelf, no acute lateral margins of anterior narial opening, posterodorsal margin of anterior narial opening located above P^{3-4}, much smaller and transversely ovoid infraorbital foramen, no lacrimal foramen, far posteriorly located posterior termination of nasals, laterally projected supraorbital process, and broader intertemporal bar; distinguished from *A. courseni* by having distinct prenarial shelf, distinct supraorbital process, and single-rooted cheek teeth.

Holotype.—NMJH N-001, incomplete right dorsal part of the cranium with right canine and second premolar (present in USNM 24915 but now broken away and missing in NMJH N-001); lacking both left and right zygomatic arches, left dorsal and whole ventral part of cranium, posterior part of braincase, and all the teeth except for right C and P^2. Casts are preserved as USNM 24915, LACM 122528, and NSM-PV 17651.

Type locality.—Naora described the locality of the cranium on its label as being "Mito". However, the precise locality of the holotype within Mito City, Ibaraki Prefecture, Japan, is presently uncertain (see also Tanaka *et al*., 1995).

Formation and age.—Exposures of sedimentary rocks in the vicinity of Mito City have been identified as the Mito Formation (Saito, 1959) and are of Middle Miocene age (Tanaka *et al*., 1995). Within the Mito Formation, the lower member consists of blue-gray, fine grained, tuffaceous sandstone and this facies is almost identical to the matrix on the holotype cranium. A sample of this matrix from the holotype, processed for microfossils by Tanaka *et al*. (1995), produced some important calcareous nannofossils which correspond to the CN5a Zone of Okada and Bukry (1980). Thus, the age of the holotype cranium is estimated to be late Middle Miocene, approximately 12.0-13.6 Ma (Young *et al*., 1994), which is within the estimated age of the lower member of the Mito Formation (Tanaka *et al*., 1985). For more details see Tanaka *et al*. (1995).

Etymology.—The species is named in honor of late Dr. Nobuo Naora, former Professor of Waseda University, who first reported the specimen in 1944, in recognition of his longstanding interest and study of fossil vertebrates in Japan.

Description

All preserved cranial sutures on the holotype are closed but not fused. In addition, the nearly absent sagittal crest and relatively small, incompletely erupted canine suggest that the animal represents a young adult female.

Occipitals.—Posteroventral portion of the holotype is not preserved.

Parietal.—Only the dorsal part of the right parietal is preserved in the cast (USNM 24915), but it is broken away on the original specimen (NMJH N-001). It is relatively flat and flares laterally. The sagittal crest is slightly developed as a ridge and continues as far anteriorly as the anterior end of the braincase.

Frontal.—The frontals are elongated between the orbits, and their dorsal surfaces are flattened. The anterolateral part of the braincase is expanded laterally to form a prominent corner. There is a small fossa on the anterodorsal part of the braincase on the frontal. The intertemporal region is relatively broad and extremely short. The dorsal surface of the intertemporal bar of the frontal in *A. naorai* is elevated higher than any part of the braincase, while in *A. packardi* the braincase swells posterodorsally to a higher level than the intertemporal region. The supraorbital processes are small and located far posteriorly from the anterior margins of the orbits. There is no antorbital process. The anterior margins of the frontals (i.e., frontal-nasal sutures) are retracted medially in an acute V-shape, with the penetration of the posterior half of the nasals as in other species of *Allodesmus*.

Squamosal, tympanic, auditory ossicles, pterygoid, vomer. —Not preserved.

Maxilla.—The maxilla forms the anterolateral part of the cheek region and the anterior portion of the orbital rim. There is no indication of the nasolabialis fossa on the lateral surface of the maxilla. The infraorbital foramen is small and transversely oval in outline, while in *A. packardi* it is relatively large and rounded. The anterior opening of the foramen is located above the P^4. The ventral bar of the zygoma under the foramen is flanged anteroventrally anterior to the infraorbital foramen, thus the anterior opening of the foramen is visible dorsally as in all other species of *Allodesmus*. The dorsal bar of the zygoma is rolled and does not make a thin cupped anterior border of the orbit as in species of the Otariidae.

The palatal region of the maxilla is broad and nearly flat as in *A. packardi*, in contrast with the anteroposteriorly long and arched palate of *A. kernensis* and *A. sinanoensis*. The cheek tooth rows diverge posterolaterally and make bulges on the lateral surface of the maxilla, corresponding to each alveolus of the cheek teeth. The anterior palatine foramen is a tiny, single pit, and located anteromedial to P^4. Although the cheek tooth rows diverge posterolaterally, the canine roots form prominent bulges, thus the rostrum does not taper anteriorly but is expanded laterally around the canines.

Premaxilla.—The narial opening is wide and low in anterior view, and located posteriorly along the dorsal margin of the premaxilla. The lateral margin of the narial opening is rounded as in *A. kernensis* and does not form an acute edge as in *A. packardi*. The posterodorsal margin of the narial opening is located above P^3 as in *A. kernensis* and *A. sinanoensis*, while in *A. packardi* it is located above P^2. The anteroventral floor of the narial opening is expanded anteriorly to form a prenarial shelf. The prenarial shelf in *A. naorai* is narrower and less expanded than that of *A. kernensis* and

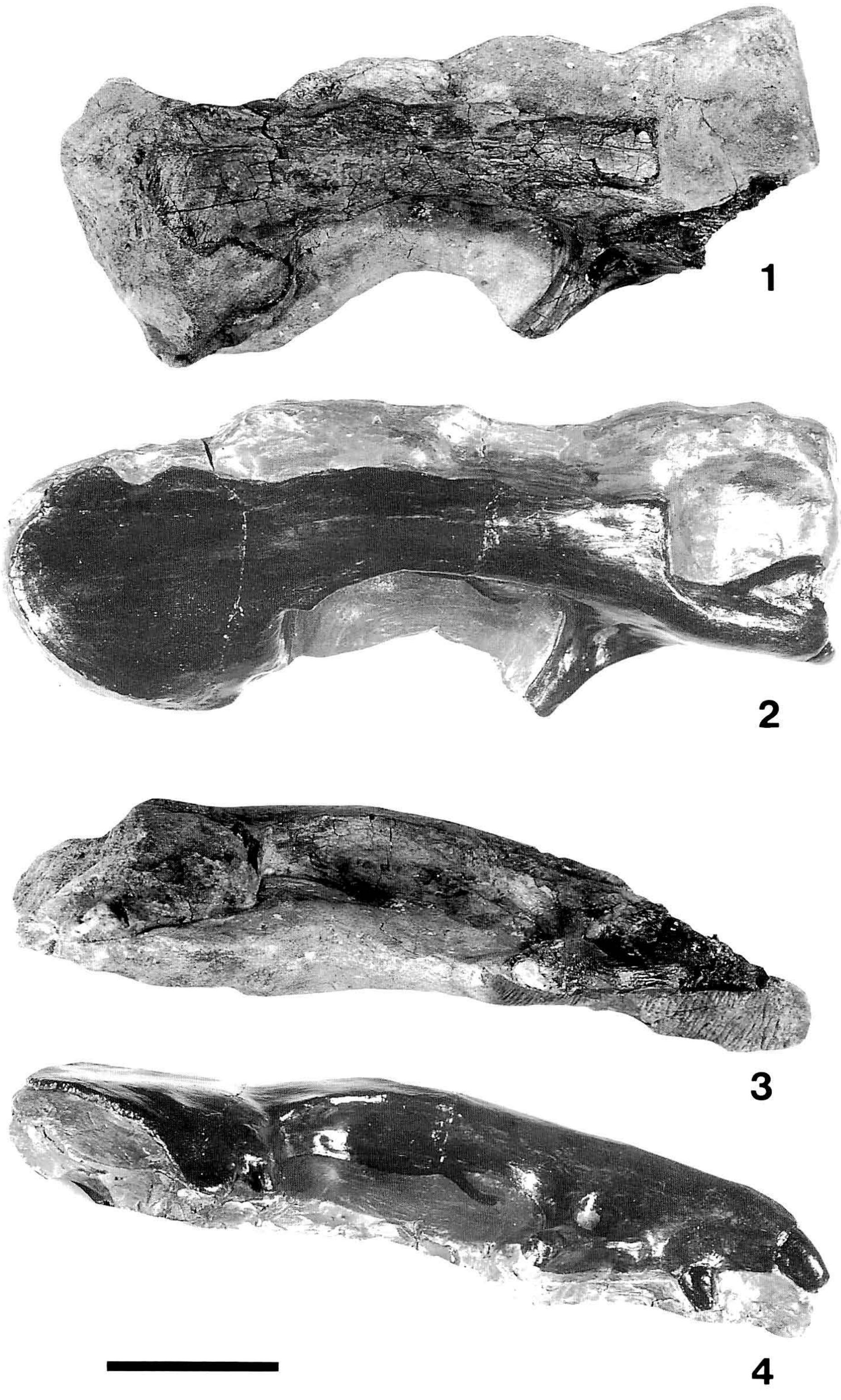

Figure 1. *Allodesmus naorai* sp. nov., holotype cranium. 1. dorsal view, original specimen, NMJH N-001 ; 2. dorsal view, plaster cast, USNM 24915 ; 3. right lateral view, NMJH N-001 ; 4. right lateral view, USNM 24915. Scale bar equals 5 cm.

Table 1. Measurements (in mm) of the cranium of *Allodesmus naorai* sp. nov., holotype, NMJH N-001. Brackets indicate measurements explained by Sivertsen (1954 : 18-20). "R" indicates measurements on the right side. "a" indicates measurements of alveolus. "+" indicates estimated measurements. "*" indicates estimated transverse measurements that are half-skull measurements multiplied by two. "†" indicates measurements from the cast.

Species	*A. naorai*
Specimen	NMJH N-001
Condylobasal length	–
Zygomatic width [17]	–
Prosthion-anterior border of orbit	76.8†
Anterior border of orbit-tip of nasals	39.5
Length of tooth row, C to M^2	–
Length of tooth row, P^1 to M^2	–
Greatest width of anterior nares [3]	27.6*
Greatest height of anterior nares	–
Greatest length of nasals [4]	55.5
Width of rostrum across canines [12]	62.6*†
Width between infraorbital foramina	48.2*
Width of zygomatic root of maxilla [14]	13.3R
Width across antorbital processes [5]	41.2*
Width across greatest interorbital constriction [6]	26.1
Width across supraorbital processes [7]	40.6*
Width across greatest intertemporal constriction	42.8*
Width of braincase at anterior edge of glenoid fossa [8]	104.7+*
Width of palate between anterior root of P^2	54.8*
Width of palate between anterior root of P^4 [15]	81.2*
Transverse diameter of infraorbital foramen	11.0
Vertical diameter of infraorbital foramen	5.1
Auditory width [19]	–
Mastoid width [20]	–
Paroccipital width	–
Greatest width across occipital condyles	–
Greatest height of sagittal crest	1.4+
I^1 anteroposterior diameter of root	–
I^1 transverse diameter of root	–
I^2 anteroposterior diameter of root	–
I^2 transverse diameter of root	–
I^3 anteroposterior diameter of root	12.6+†
I^3 transverse diameter of root	9.5+†
C anteroposterior diameter of root	15.4+†
C transverse diameter of root	–
P^1 anteroposterior diameter of root	–
P^1 transverse diameter of root	–
P^2 anteroposterior diameter of root	–
P^2 transverse diameter of root	–
P^3 anteroposterior diameter of root	13.4a
P^3 transverse diameter of root	9.0a
P^4 anteroposterior diameter of root	12.7a
P^4 transverse diameter of root	9.6a
M^1 anteroposterior diameter of root	–
M^1 transverse diameter of root	9.2+a
C-P^1 septum length	–
P^1-P^2 septum length	–
P^2-P^3 septum length	2.2R
P^3-P^4 septum length	3.9R
P^4-M^1 septum length	6.2+R

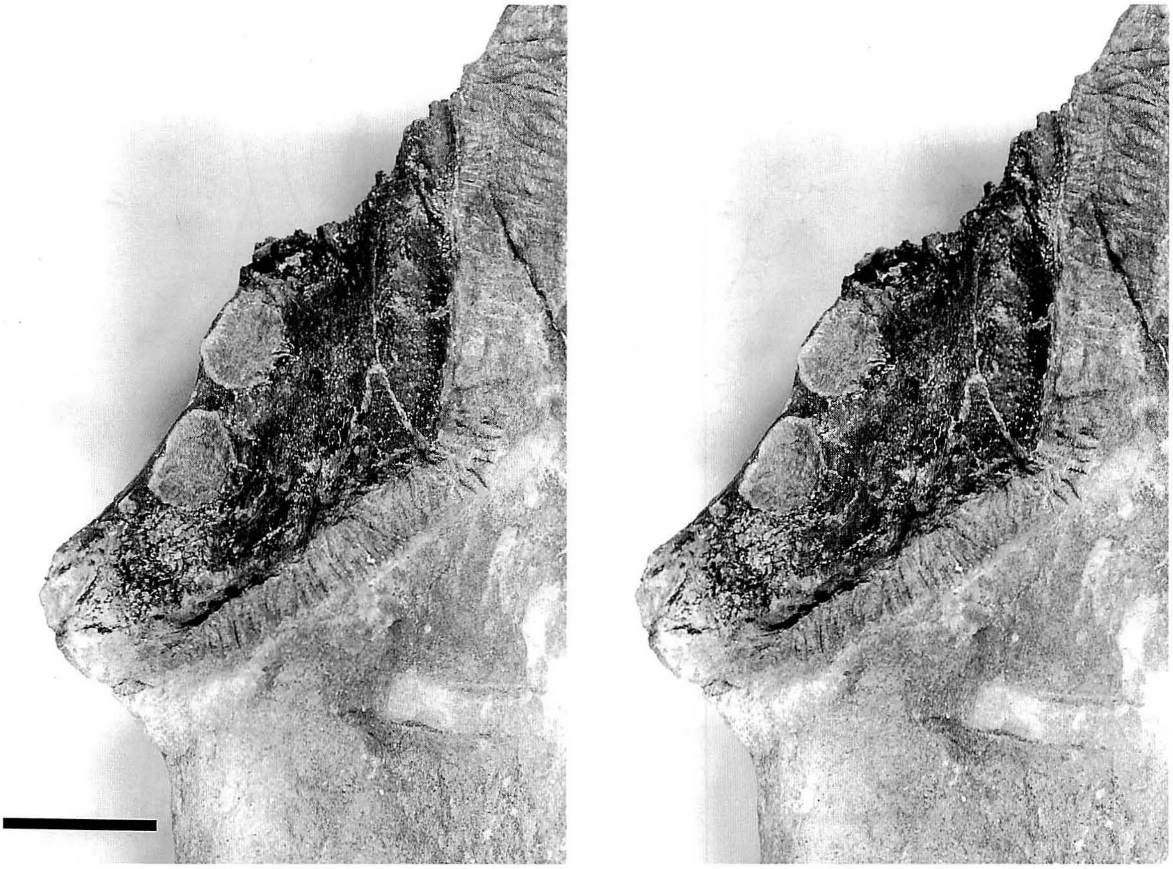

Figure 2. *Allodesmus naorai* sp. nov., holotype cranium, NMJH N-001 ; ventral view, stereophotograph. Scale bar equals 2 cm.

A. sinanoensis, but is broader and more expanded than that of *A. packardi*. The dorsal surface of the premaxilla in *A. packardi* slopes abruptly anterior to the canine, which suggests a small prenarial shelf in that species. The ascending process of the premaxilla extends posterodorsally and contacts the anterior one-fourth of the lateral side of the nasal. The portion of the incisive foramen is broken away, and its shape is not determinable on the holotype.

Nasal.—The nasals are elongate and penetrate the anteromedial margins of the frontals as in other species of *Allodesmus*. The anterior termination of the nasals is nearly straight. The posterior termination of the nasals is marked by an irregular suture in contrast with the smooth outline of the nasal/frontal suture in other species of *Allodesmus*. It is located far posterior to the position of the anterior rim of the orbits on the frontal than in other species of *Allodesmus*.

Palatine.—Not preserved.

Lacrimal.—The lacrimal bone is not detectable on the specimen because of the complete fusion of the sutures. There is no indication of the lacrimal foramen at the position of the lacrimal bone as in other allodesmines except for the holotype of *A. packardi* in which the foramen is distinct just posterior to the anterodorsal margin of the orbital rim.

Jugal.—Most of the jugal is not preserved except for the tip of the anteroventral process of the jugal beneath the zygomatic process of the maxilla. The anteroventral process of the jugal reaches near the anterolateral margin of the alveolus for M^1 as in *A. kernensis* and *A. packardi*.

Dentition.—The right canine and second premolar are preserved in their alveoli on the cast (USNM 24915), but they are now broken off and are missing on the original specimen (NMJH N-001). The rest of the dentition had fallen out before fossilization and is not preserved. The cheek teeth are single rooted unlike those in *A. courseni* in which the cheek teeth except for P^1 are double rooted. The third incisor, which is indicated by its alveolus, is strongly procumbent. Its alveolus is oval in outline and is slightly smaller than that of the canine. The canine is also procumbent, relatively small and round in cross section. P^1 is missing, but its single alveolus is relatively large, cylindrical, and procumbent. P^2 also has a large, single, cylindrical root. The crown of P^2 (now lost) was bulbous and smooth, and had a single cusp as in other species of *Allodesmus*. P^3 alveolus is round in shape and somewhat larger than that of P^2. P^4 alveolus is similar to that of P^3 in shape and has a vestigial septum in its lateral side. There is a narrow diastema between the alveoli of P^4 and M^1. M^1 alveolus is shallow and rounded and slightly smaller in size than those of the

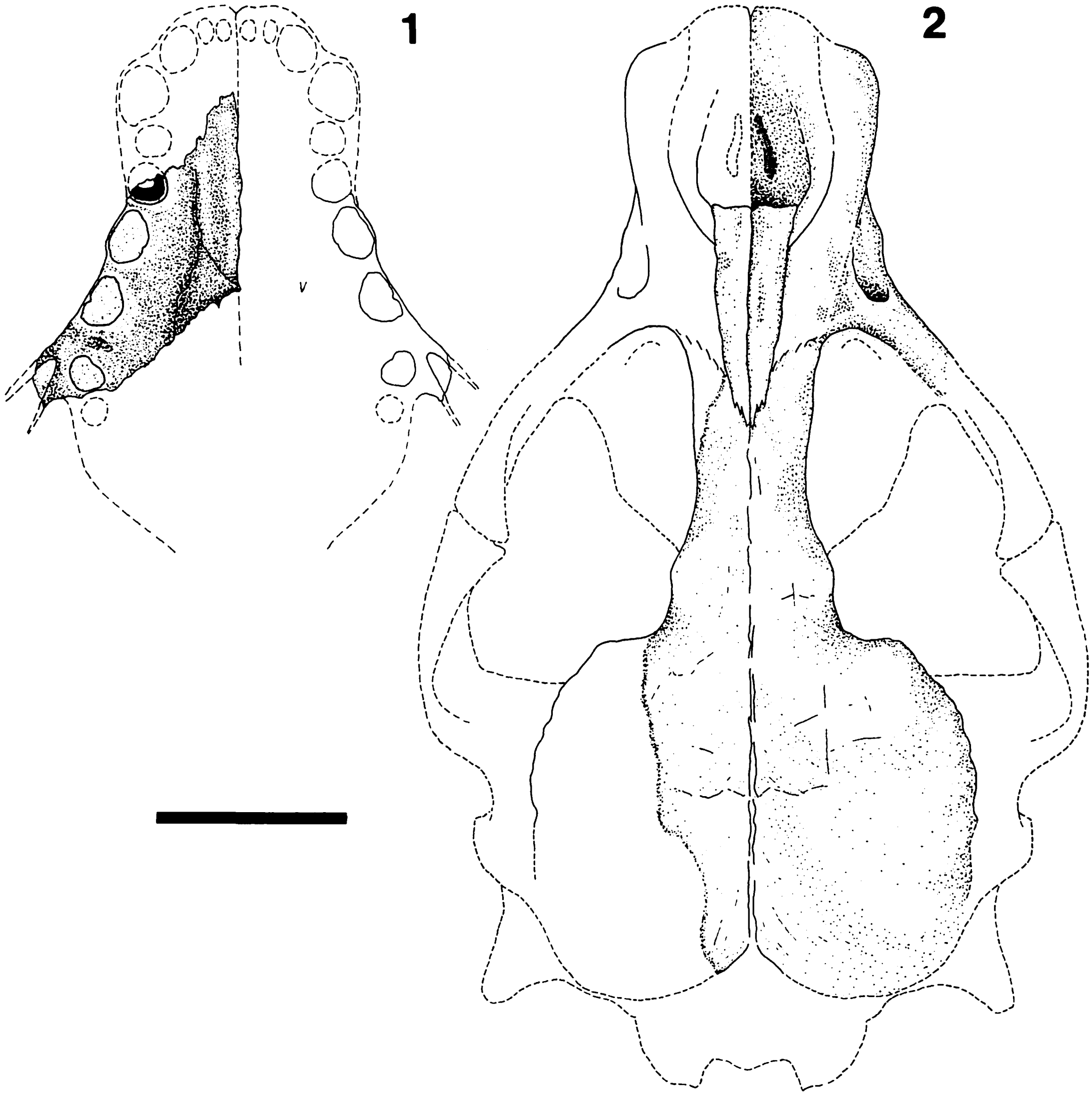

Figure 3. *Allodesmus naorai* sp. nov., restoration of skull based on NMJH N-001 and USNM 24915. 1. ventral view; 2., dorsal view. The stipple represents the preserved elements. The missing left side of the cranium is restored using mirror images from those elements and is represented by solid lines. All other missing parts are represented by dashed lines. Scale bar equals 5 cm.

premolars as in *A. packardi*. In contrast, the size of the alveoli for M^{1-2} in *A. kernensis* is almost one-third the size of the alveolus for P^4.

Relationships

The phylogenetic relationships among five species within the genus *Allodesmus* were considered based on the distribution of 40 cranio-dental characters, of which 24 were binary and 16 were multistate (Table 2). The following taxa were employed as outgroups: *Enaliarctos*, *Pteronarctos*, *Pacificotaria*, *Pinnarctidion*, *Desmatophoca*, Otariidae, Odobenidae (*Imagotaria* and Odobeninae), and Phocidae (Monachinae and Phocinae). Sixty unordered character transformations distributed among 40 characters were scored in the taxon-character matrix (Table 3) and then analyzed using the branch-and-bound algorithm of PAUP 3.1 (Swofford, 1993). As a result of the analysis, a single most parsimonious cladogram was obtained. The tree was 99 steps long, with a consistency index (CI) of 0.667 and a retention index (RI) of 0.791. The proposed relationships among five species within *Allodesmus* are shown in Figure 4.

The genus *Allodesmus* is placed as the sister taxon to the genus *Desmatophoca* and is diagnosed by the following unequivocal derived characters (Figure 4, node 1): retracted dorsal bar of the zygomatic root of maxilla (Character 10), exaggerated mortised squamosal-jugal contact (Character 15), presence of the facet for the tympanohyal within the

Table 2. List of characters and the character matrix used in the phylogenetic analysis. Earlier published discussions in the cladistic framework are listed in parentheses. Character states: 0=primitive states; 1-3=derived states.

Cranium

1. Prenarial shelf: (0) absent; (1) developed; (2) well developed with lateral expansion (Barnes, 1989)
2. Ascending process of premaxilla along nasal: (0) long; (1) short (Wyss, 1987)
3. Nasal posterior end: (0) converging; (1) diverging; (2) penetrating to frontal (Wyss, 1987)
4. Incisive foramen: (0) large; (1) reduced (Berta and Wyss, 1994)
5. Interorbital bar: (0) low and not sloping anteriorly; (1) high and sloping anteriorly (Berta, 1991)
6. Anterior process of frontal: (0) present; (1) absent; (2) retracted, maxilla/frontal suture V-shaped (Deméré, 1994)
7. Antorbital process: (0) small ridge; (1) absent; (2) prominent (Berta and Wyss, 1994)
8. Palate: (0) slightly divergent; (1) strongly divergent; (2) parallel sided (Barnes, 1989)
9. Palate: (0) flat; (1) longitudinally arched (Deméré, 1994)
10. Dorsal bar of zygomatic root of maxilla: (0) not retracted; (1) retracted (Barnes, 1989)
11. Supraorbital process: (0) small; (1) absent; (2) large (Wyss and Flynn, 1994)
12. Supraorbital process: (0) located relatively anterior to orbital rim; (1) far posterior on interorbital bar (this study)
13. Orbital vacuity: (0) absent; (1) present (Wyss, 1987)
14. Anteroventral process of jugal: (0) moderate; (1) long, reaching M^1 alveolus; (2) absent (this study)
15. Squamosal-jugal contact: (0) splint-like; (1) mortised; (2) exaggerated; (3) squamosal process reduced (Wyss, 1987)
16. Pterygoid process of maxilla: (0) small; (1) posteriorly broadened (Barnes, 1989)
17. Optic foramen: (0) located anterodorsally; (1) posteroventrally in front of braincase (Barnes, 1994)
18. Pterygoid strut: (0) slender; (1) dorsoventrally thin and laterally projected; (2) dorsoventrally thick and laterally broad; (3) laterally thin and rolled (Kohno, 1994)
19. Optic foramina: (0) bilateral; (1) merged (Barnes, 1989)
20. Facet for tympanohyal within hyoid fossa: (0) absent; (1) present (Barnes, 1989)
21. Internal acoustic meatus: (0) rounded; (1) bilobed; (2) nerves VII and VIII separated (Wyss, 1987)
22. Epitympanic recess; (0) small; (1) large (Wyss, 1987)
23. Anterior opening of carotid canal: (0) proportionate; (1) retracted (Kohno, 1994)
24. Mastoid process: (0) moderate; (1) enlarged; (2) pachyostotic (Barnes, 1989)
25. Pseudosylvian sulcus: (0) present; (1) absent (Barnes, 1989)
26. Basioccipital: (0) parallel sided; (1) posteriorly broad (Wyss, 1987)
27. Inferior petrosal sinus: (0) present; (1) absent (Barnes, 1989)
28. Posterior lacerate foramen: (0) anteroposteriorly expanded; (1) transversely expanded; (2) fissure (Barnes, 1989)
29. Parocipital process: (0) small and separated from mastoid process; (1) enlarged posteriorly but still separated; (2) moderate size and joined with continuous ridge; (3) thin plate (Kohno, 1994)

Mandible

30. Bony flange below ascending ramus: (0) absent; (1) present (Berta, 1991)

Dentition

31. I^3: (0) vertical; (1) procumbent (Barnes, 1989)
32. Upper canine posterior carina: (0) present; (1) absent (Barnes, 1989)
33. P$^{1-2}$ lingual cingula: (0) distinct but small; (1) well developed; (2) weak and bulbous (Barnes, 1989)
34. P$^{1-4}$: (0) vertical; (1) procumbent (Barnes, 1989)
35. P$^{1-4}$ roots depth: (0) moderate; (1) deep (this study)
36. P^2 and P^3: (0) double rooted; (1) bilobed single rooted; (2) rounded single rooted (Wyss, 1987)
37. P^4: (0) three rooted; (1) double rooted; (2) single rooted (Berta, 1991)
38. M^1: (0) three rooted; (1) double rooted; (2) single rooted (Berta, 1991)
39. M^2: (0) double rooted; (1) single rooted; (2) absent (Barnes, 1989)
40. M$^{1-2}$ relative size to premolars: (0) small; (1) nearly equal (Berta, 1991)

Table 3. Data matrix showing the distribution of 40 characters listed in Table 2. Multistate characters were coded as unordered. Symbols: 0=primitive states; 1-3=derived states; ?=unknown or missing.

Taxon	Character								%
	5	10	15	20	25	30	35	40	
Outgroups									
Enaliarctos	00000	00000	00000	00000	00000	00000	00000	00110	100
Pteronarctos	00000	00000	00000	00000	?0000	0000?	0000?	01110	93
Pacificotaria	00000	00000	00000	00000	??000	0000?	0000?	01110	90
Pinnarctidion	01000	00000	01001	11100	11000	0011?	0010?	00100	95
Otariidae	00100	02200	20100	00010	00001	01020	00000	01111	100
Imagotaria	00000	11200	00103	01200	11111	11030	00100	11001	100
Odobeninae	02010	12210	10103	01201	11111	11030	00100	22322	100
Desmatophoca	01201	21000	01011	11100	11000	10011	10200	01111	100
Phocinae	01200	01100	10122	01300	22021	11201	00300	01121	100
Monachinae	01200	11100	10122	01300	22021	11201	00300	01120	100
Ingroup									
Allodesmus courseni	012?1	21??1	01?12	111??	?????	???11	11210	01???	58
A. kernensis	21211	21011	01112	11111	12101	11111	11211	22210	100
A. sinanoensis	21211	20011	?1112	????1	?????	?????	11211	22???	55
A. packardi	112?1	21101	11112	11101	?2100	0?1??	1121?	22211	85
A. naorai	112?1	21101	0111?	1???1	????0	?????	1121?	222?1	60

hyoid fossa (Character 20), absence of the posterior carina on the upper canine (Character 32), bulbous cheek teeth (Character 33), and procumbent premolars (Character 34). However, characters 15 and 20 are presently not determinable in the holotype of *A. naorai* because of the poor preservation.

Allodesmus courseni, which was originally assigned to the separate genus *Atopotarus* by Downs (1956), is the most generalized and the earliest diverging species within the genus (Figure 4, node 2). *Allodesmus courseni* is distinguishable from other *Allodesmus* species by retention of many primitive characters (primitive states of Characters 1, 36, 37, and 38) and one derived character, the absence of M_2. Other four *Allodesmus* species known (Figure 4, node 3) are, therefore, distinguished from *A. courseni* by having the following derived characters: presence of a prenarial shelf (Character 1) and single rooted premolars and molars (Characters 36, 37, and 38).

Allodesmus naorai and *A. packardi* form a monophyletic clade, the "broad head" subgroup within the genus (Figure 4, node 4). This subgroup is defined by an anteriorly developed prenarial shelf on the rostrum (Character 1), a strongly divergent palate (Character 8) and nearly equal premolar/molar relative size (Character 40). The two species in this subgroup can be distinguished from each other by the extent of the prenarial shelf, presence or absence of acute edges on the lateral margins of the anterior narial opening, locations of the narial opening and the posterior termination of the nasals, size and shape of the infraorbital foramen, and presence or absence of the supraorbital process as discussed in the above section. These differences lie beyond the usual pattern of sexual dimorphism or general individual variation in the living pinnipeds and are similar to those that distinguish other nominal species of living pinnipeds.

Allodesmus kernensis and *A. sinanoensis* form another monophyletic clade, the "long head" subgroup within the genus (Figure 4, node 5). This subgroup is placed as the sister group to the "broad head" subgroup and defined by an anterolaterally expanded, broad prenarial shelf on the rostrum (Character 1'), reduced incisive foramen (Character 4), a longitudinally and transversely arched palate (Character 9), and deep lower premolar roots (Character 35). The two species in this subgroup can also be distinguished from each other by the relative size of the canine teeth and the overall size of the cranium as discussed also in the above section.

Although the differences among the three morphotypes within the genus *Allodesmus* (Figure 4) seem to be equally as great as those among some Recent genera within the Otariidae, as has already been pointed out by Barnes (1972), branch support indices (Bremer, 1994) for nodes 3 to 5 are not high (*b*=2, 1, 1, respectively). In addition, each species known in *Allodesmus* except for *A. kernensis* is still poorly understood and represented only by the holotype (*A. courseni*, *A. packardi* and *A. naorai*) or only two cranial fragments (*A. sinanoensis*). Thus, I do not afford a new generic status for each morphotype in this paper but recognize them as three subgroups within the single genus, *Allodesmus*, until more specimens of each species are obtained.

The western North Pacific Allodesminae

Until recently, only four fossil records of *Allodesmus* including the "Mito seal" have been known from the Japanese Islands (Tanaka *et al.*, 1995). In this paper, I provide some comments for the previously known *Allodesmus* from Japan and describe additional specimens of allodesmines from three different localities.

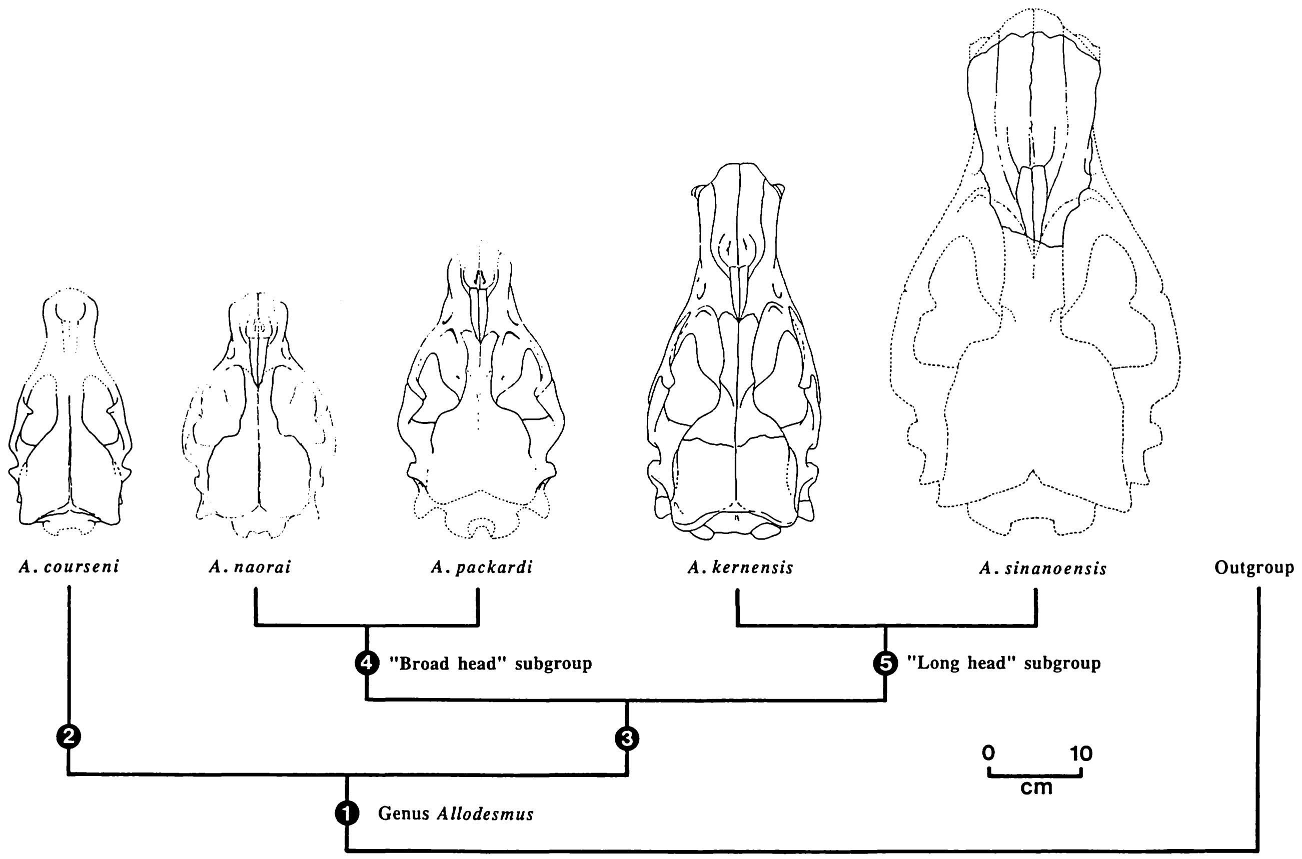

Figure 4. Cladogram showing relationships among the species of *Allodesmus*, with illustrations of the crania of available species reduced to uniform magnification. Numbers refer to nodes supported by derived characters discussed in text. The usage of the categories of subgroups is informal, see text for detail. The illustration of *A. kernensis* is after Barnes (1972) and that of *A. packardi* after Barnes (1979). Others are original illustrations.

Allodesmus sinanoensis (Nagao, 1941)

Eumetopias sinanoensis Nagao, 1941, p. 77, pls. 24-25.
Allodesmus kernensis Kellogg, 1922. Mitchell, 1968, p. 1881.
Allodesmus sinanoensis (Nagao, 1941). Repenning and Tedford, 1977, p. 75.

Holotype.—HSEH unnumbered, very young juvenile individual, rostral and mandibular fragments with upper and lower canines and incompletely erupted cheek teeth; collected in 1920 by Tama Mochizuki.

Type locality.—Aso, Shittako, Shiga-mura, Higashi-chikuma-gun, Nagano Prefecture.

Referred specimen.—SFH unnumbered, old adult male, rostral fragment with very large canines; collected on December 30, 1961 by Masatoshi Seki from Kashiwazawa, Toyoshina-cho, Minamiazumi-gun, Nagano Prefecture.

Formation and Age.—Both the holotype and referred specimens were collected from the lowermost part of the Aoki Formation (Tanaka and Seki, 1962), which corresponds to the base of the *Globorotalia pseudopachyderma-G. woodi* (*s.l.*) Zone of Maiya (1978), indicative of the late Middle Miocene, approximately 12.5-13 Ma (Kosaka *et al*., 1990; Tanaka *et al*., 1995).

Discussion.—The holotype was initially described and illustrated by Nagao (1941) as a new species of the otariid sea lion, *Eumetopias sinanoensis*. Mitchell (1966) later synonymized this species with *A. kernensis* on the basis of the broad prenarial shelf and cheek tooth morphology. Repenning and Tedford (1977), however, pointed out its very large size and robustness and distinguished it specifically from *A. kernensis*. I agree with their assignment.

The holotype consists of a bilaterally compressed rostral and mandibular fragments which has broken at a portion of the P^3. Most of the teeth are almost unworn, having open pulp cavities, and not fully erupted. Therefore, the holotype apparently represents a very young individual. No indication of the anterior narial opening at the posterodorsal surface of the rostrum above the portion of the P^3 indicates that the preserved portion is an anteriorly expanded prenarial shelf like that of *A. kernensis*.

Another huge snout from the Aoki Formation (SFH specimen), which was reported at first as an indeterminate fossil marine mammal by Tanaka and Seki (1962) and later as *A. kernessis* by Hirota *et al*. (1987), closely matches the morphology of the holotype snout of *A. sinanoensis*. The SFH specimen has a very broad prenarial shelf anterior to the narial opening, posteriorly retracted dorsal bar of the zygoma, huge tusk-like upper canines with no enamel remaining, deep alveoli for P^3 and p^4, and arched palate. There are broad diastema between the canine and first postcanine tooth (in this case P^3) in each tooth row and no indication of alveoli for I^1s, P^1s, and P^2s at least on the right tooth row, indicating that this animal lost them during life and must have been a very old individual.

Since the referred specimen has not been distorted in contrast with the bilaterally compressed holotype, it can be compared directly with other allodesmines (Figure 4).

Allodesmus sinanoensis has an anterolaterally very broad prenarial shelf which accommodates very large tusk-like upper canines that are considered to be ever-growing and very large cheek teeth. Based on the calculation from the simple size ratio of some preserved portions of *A. sinanoensis* and *A. kernensis*, the estimated condylobasal length of *A. sinanoensis* reaches 530-590 mm, approximately 1.5 times larger and 3.4 times heavier than in *Allodesmus kernensis* (see also Figure 4).

Allodesmus kernensis Kellogg, 1922

Material.—SICC unnumbered (cast: KU-JC95114), young-adult male, incomplete cranium and left and right dentaries. Collected in the 1910's or 1920's by Rikizo Kanai.

Locality.—Sohama Beach, Donokama, Ogi-machi, Sado-gun, Niigata Prefecture.

Formation and age.—The specimen was collected as "float" from the upper part of the Tsurushi Formation (Hirota *et al.*, 1987). According to Takemura and Hirota (1984), radiolarians from the enclosed matrix indicate that the age of the fossil is early to late Middle Miocene (ca. 13-14 Ma). For more details see Tanaka *et al.* (1995).

Comments.—This specimen was preliminarily reported as *A. kernensis* by Hirota *et al.* (1987) and has been reassessed by L.G. Barnes and K. Hirota (Hirota, 1994). As far as I can see from the illustration of Hirota *et al.* (1987), relatively broad rostrum with large teeth, close appression of the roots of each tooth along the tooth rows, weak sagittal and lambdoidal crests, and incomplete suture closure indicate that this animal belongs to a young-adult male. However, the precise interpretation of these characters must await a full description of this material.

Allodesminae gen. et sp. indet.

Figures 5, 6

Material.—IPM 60023, a right upper canine; IPM 60026, a right lower premolar. Both collected in 1986 by Osamu Fujiwara.

Locality.—Jinguji, Watari-cho, Watari-gun, Miyagi Prefecture.

Formation and age.—Both specimens were collected from the lower part of the Yamairi Formation. According to Oishi *et al.* (1992), the middle part of the Yamairi Formation belongs to N. 13 of Blow (1969), but the lower part has no stratigraphic control from microfossils. Ogasawara (1994) has suggested the age of the lower part of the Yamairi Formation as being approximately 13-14 Ma based on the correlation of shallow-marine molluscan faunas.

Description and discussion.—IPM 60023 and 60026 are described here for the first time. IPM 60023 is similar in size and shape to the upper canine of *A. kernensis*, which has no posterior carina on the rounded crown but has very long root. There is a vertical wear facet on the anterior surface of the crown. It measures 21.5 mm in mesiodistal diameter (as preserved), 17.8 mm in buccolingual diameter (as preserved), and 96.3 mm in root length (buccal side). IPM 60026 is also similar to the lower premolars of *A. kernensis*. The crown of IPM 60026, although most of the lingual side is missing, is bulbous and smooth. The lingual cingulid is reduced and outlined by the shallow groove along the base of the crown. IPM 60026 measures 15.9 mm in mesiodistal diameter and 37.5 mm in root length.

The fossil teeth from the Yamairi Formation are compared

Figure 5. Allodesminae gen. et sp. indet., IPM 60023, right upper canine, from the late Middle Miocene Yamairi Formation. 1. medial view; 2. lingual view. Scale bar equals 1 cm.

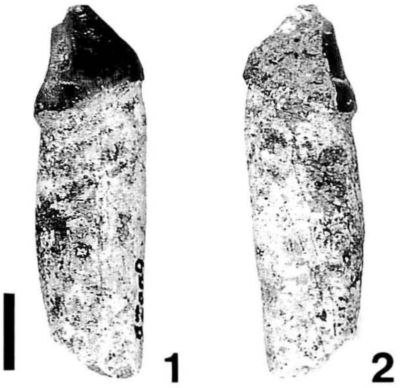

Figure 6. Allodesminae gen. et sp. indet., IPM 60026, right lower premolar, from the Middle Miocene Yamairi Formation. 1. buccal view ; 2. lingual view. Scale bar equals 1 cm.

satisfactorily with the teeth of *Allodesmus kernensis*, but the specimens are represented only by isolated teeth, and no generic and specific information is gained from the teeth. In addition, the cheek teeth of *A. packardi* and *A. naorai* are not well known. Therefore, I identify these teeth merely as Allodesminae gen. et sp. indet.

Allodesminae gen. et sp. indet.

Figures 7-1—4

Material.—CBMPV 530, lower first premolar? ; CBMPV 531, upper premolar? Collected in 1986 by Tatsuya Kaede.

Locality.—Sekinohana, Toki-cho, Hakui-gun, Ishikawa Prefecture.

Formation and age.—The specimens were collected from the Sekinohana Calcareous Sand. According to Kami *et al.* (1981), the Sekinohana Calcareous Sand corresponds to the boundary of CN4 and CN5a Zones of Okada and Bukry (1980), indicative of the late Middle Miocene, approximately between 13.5 and 14 Ma.

Description and discussion.—The specimens, also described here for the first time, have bulbous and smooth crowns with very reduced lingual cingula, typical of species of *Allodesmus*. CBMPV 530 has a single root with a shallow groove on its lateral side. The lingual cingulid of the crown is reduced, and is oblique to the long axis of the root. It measures 9.2 mm in mesiodistal diameter, 6.8 mm in buccolingual diameter, and 23.7 mm in root length. CBMPV 531 is represented only by the bulbous crown with reduced cingulum and measures 12.1 mm in mesiodistal diameter (as preserved) and 10.7 mm in buccolingual diameter.

The fossil teeth from the Sekinohana Calcareous Sand are relatively small and distinguishable from the teeth of known species of *Allodesmus*, but no additional taxonomic information is gained from the teeth. Thus I also identify these teeth merely as Allodesminae gen. et sp. indet.

Allodesminae gen. et sp. indet.

Figures 7-5—8

Material.—NMJH N-002 and NMJH N-003, two cheek teeth belonging to the same individual. No collector and date given.

Locality.—The attached label suggests that the specimens were collected from Sukegawa, Hitachi City, Ibaraki Prefecture.

Formation and age.—The formation that produced the specimens is presently uncertain. According to Y. Yanagisawa of the Geological Survey of Japan (written commun., 1994), the diatom flora from enclosing matrix of the teeth corresponds to the middle part of the *Denticulopsis praedimorpha* Zone of Akiba (1986), indicative of the late Middle Miocene, approximately between 11.8 and 12.5 Ma (Barron and Gladenkov, 1995). The formation which distributes in the vicinity of Sukegawa is the Kokubu Formation or Hase Formation (Yanagisawa *et al.*, 1989), and the age of these formations in that area is almost identical with the estimated age of the specimen.

Description and discussion.—These specimens were found also in the Naora collection at NMJH. Each tooth is relatively large and has bulbous smooth crown with long, bilobed single root, also typical of the allodesmine pinnipeds. In NMJH N-002, the crown is relatively large and low and has

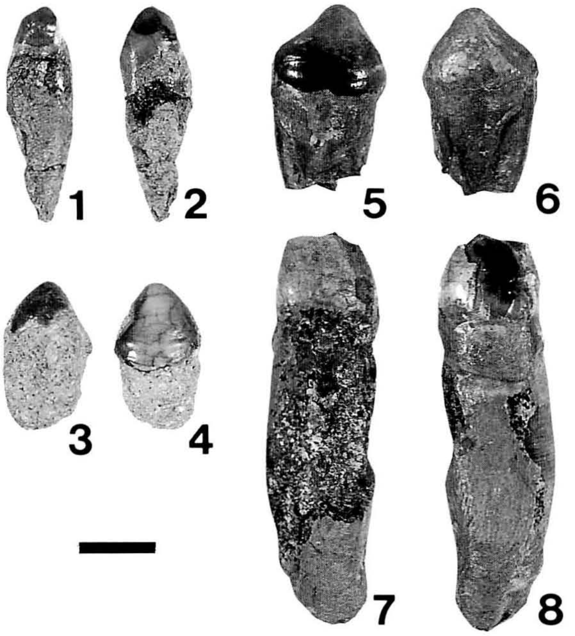

Figure 7. Allodesminae gen. et sp. indet. 1 and 2. CBMPV 530, left lower first premolar ; 3 and 4. CBMPV 531, upper ? premolar ; both from the Middle Miocene Sekinohana Calcareous Sand ; 5 and 6. NMJH N-002, premolar ; 7 and 8. NMJH N-003, premolar ; both from the vicinity of Sukegawa. Odd numbers buccal views, even numbers lingual views. Scale bar equals 1 cm.

deep vertical wear facets on both the anterior and posterior margins. The lingual cingulum of the crown is reduced and its surface is abraded by the contact of food item. NMJH N-002 measures 15.9 mm in mesiodistal diameter and 11.5 mm in buccolingual diameter. In NMJH N-003, the crown is bulbous and low, and the lingual cingulum is almost absent. The root is long and straight, and its lateral surface is badly eroded, showing fine growth lines. NMJH N-003 measures 14.2 mm in mesiodistal diameter, 11.6 mm in buccolingual diameter (as preserved), and 40.3 mm in root length.

The fossil teeth from Sukegawa are somewhat similar to the cheek teeth of *A. sinanoensis* in shape but are slightly smaller. However, again, the isolated teeth have no generic and specific diagnoses as discussed above. Here I identify these teeth as indeterminate genus and species of the Allodesminae.

Biogeographic and chronologic distribution

Allodesmines in the western North Pacific are known to date from seven localities in Japan as described above (see also Figure 8). In addition to these records, though still not described nor illustrated, the occurrences of allodesmines have been announced from the Middle Miocene Fujina Formation, Shimane Prefecture (Hirota *et al.*, 1987) and Okoppezawa Formation, Hokkaido (Sawamura *et al.*, 1994). Therefore, the distribution of allodesmines extends at least along the shore between 35° and 43° north latitudes in the western North Pacific. Based on shallow-marine molluscan faunas (Chinzei, 1986; Ogasawara, 1994) and planktonic microfossils (Takayanagi *et al.*, 1984; Maruyama, 1993), the marine climate in those latitudes of the western North Pacific during the late Middle Miocene (ca. 12-14 Ma) has been reconstructed as mild to warm-temperate (Figure 8), and the condition might have been the living environment of allodesmines at least in the western North Pacific.

Fortunately, almost all the allodesmines in the western North Pacific have biostratigraphic control of microfossils and can be located in the biochronological diagram (Figure 9). The first appearance of allodesmines in the western North Pacific is represented by specimens from the Tsurushi Formation and the Sekinohana Calcareous Sand. The geologic ages of these formations are estimated to be early to late Middle Miocene, approximately 14 Ma. Likewise, the youngest record in the region is the cheek teeth from late Middle Miocene rocks (ca. 12 Ma) in the vicinity of Sukegawa, Hitachi City, as described above. Therefore, the reliable records of allodesmines in the western North Pacific are restricted for the most part to the late Middle Miocene, approximately between 12 and 14 Ma.

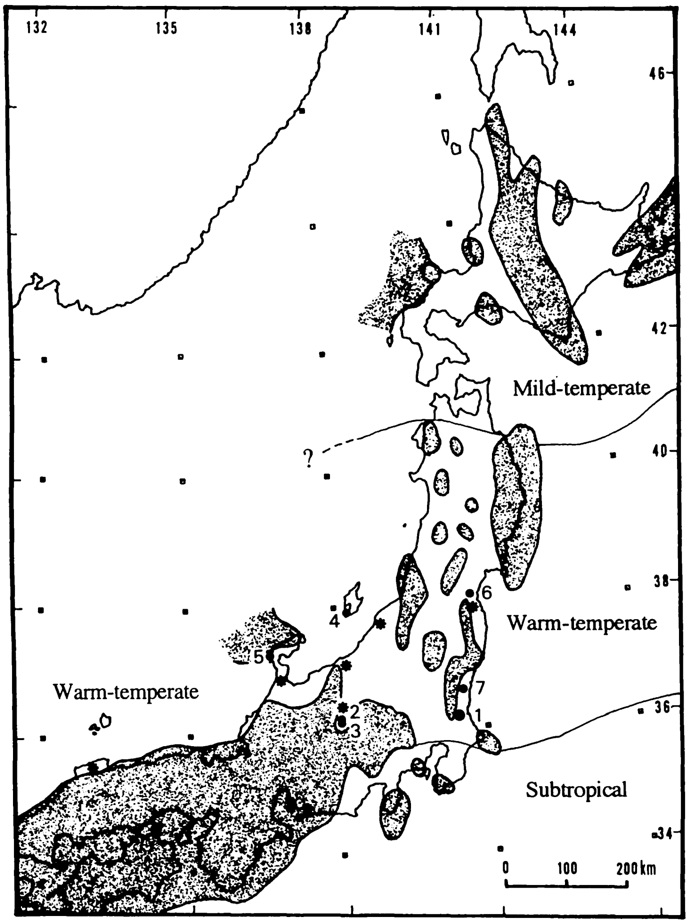

Figure 8. Distribution of the published allodesmines in the western North Pacific, plotted on the map showing the paleogeography and the marine climate during the period between 12 and 14 Ma (modified after Chinzei, 1986, fig. 2, and Ogasawara, 1994, fig. 6). 1. Mito City, Ibaraki; 2. Aso, Shittako, Shiga-mura, Higashichikuma-gun, Nagano; 3. Kashiwazawa, Toyoshina-cho, Minamiazumi-gun, Nagano; 4. Donokama, Ogi-machi, Sado-gun, Niigata; 5. Jinguji, Watari-cho, Watari-gun, Miyagi; 6. Sekinohana, Toki-cho, Hakui-gun, Ishikawa; 7. Sukegawa, Hitachi City, Ibaraki. Asterisks indicate the localities of the planktonic cephalopods in the same geologic age (modified after Yanagisawa, 1990), which is one of the indicators of the warm surface current.

On the other hand, the eastern North Pacific allodesmines are presently recorded from Washington (Bigelow, 1994), Oregon (Hunt and Barnes, 1994), California (Kellogg, 1922; Downs, 1956; Barnes, 1972), and Baja California (Aranda-Manteca, 1990). According to Hunt and Barnes (1994), the oldest record among them is the unpublished specimen from the early Middle Miocene Astoria Formation (ca. 16 Ma) of coastal Oregon. Likewise, the youngest record of the subfamily is the unpublished specimens from the Late Miocene Montesano Formation (ca. 10-11 Ma) in Washington (Bigelow, 1994). Therefore, although almost all these records have no biostratigraphic control from planktonic microfossils as in the western North Pacific, the biogeographical (at least as wide as 30° to 46° north latitudes) and geochronological (approximately 10-16 Ma) distributions of allodesmines in the eastern North Pacific are distinctly wider than in the western North Pacific.

The simplest explanation of the distribution pattern of the allodesmines in the North Pacific is that the Allodesminae might have evolved in the eastern North Pacific by the end of the Early Miocene and migrated to the western North

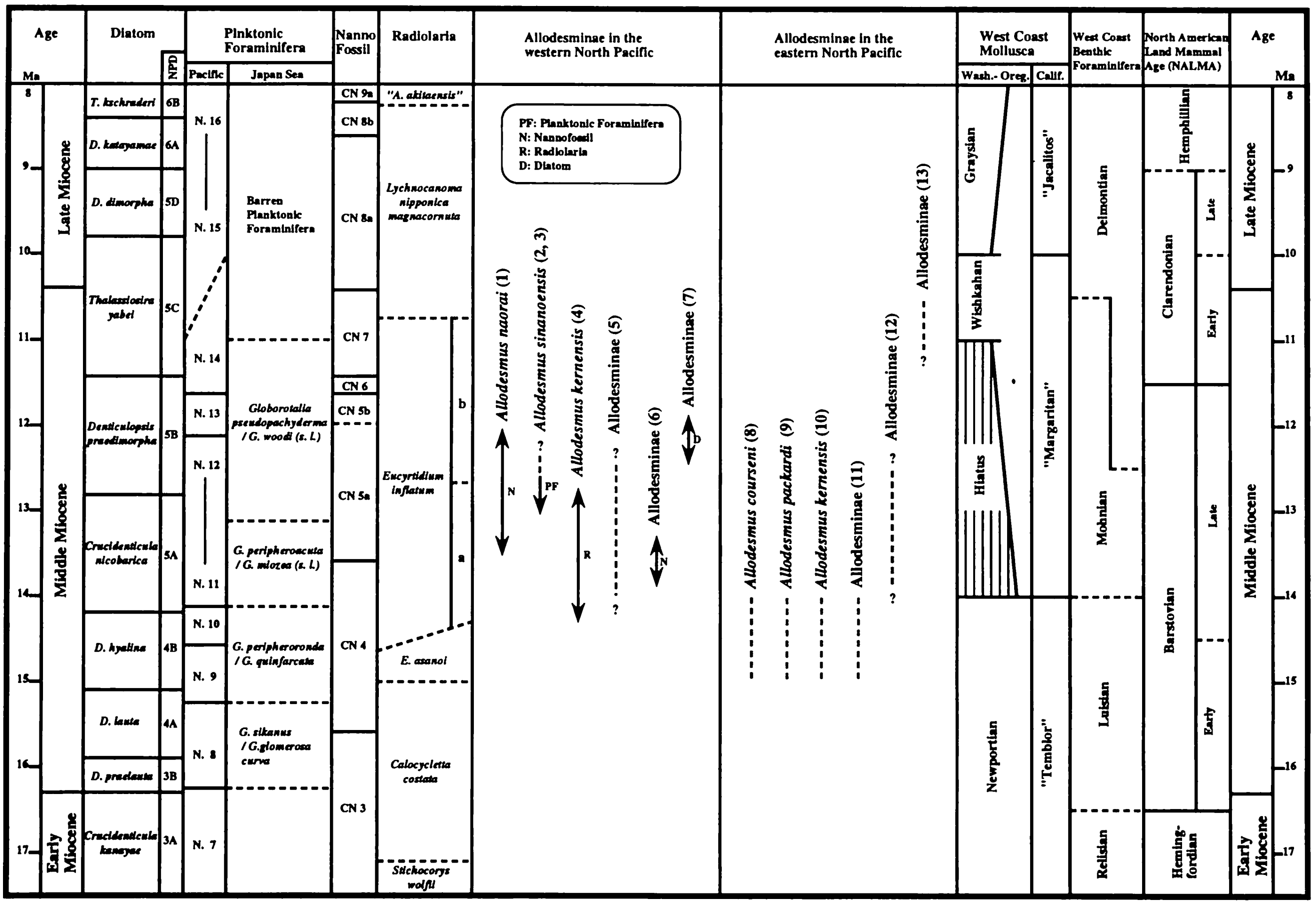

Figure 9. Stratigraphic range of the published allodesmines in the North pacific Ocean. The geologic time scale and correlations of mega- and microfossil zonations follow Armentrout (in Chinzei, 1985), Barron and Gladenkov (1995), Berggren *et al.* (1985), Tedford *et al.* (1987), Tanaka *et al.* (1995), and Young *et al.* (1994). (1) uncertain formation in Mito City, Ibaraki (Tanaka *et al.*, 1995); (2) and (3) lowermost part of Aoki Formation, Nagano (Kosaka *et al.*, 1990; Tanaka *et al.*, 1995); (4) upper part of Tsurushi Formation, Niigata (Takemura and Hirota, 1983); (5) lower part of Yamairi Formation, Miyagi (Ogasawara, 1994); (6) Sekinohana Calcareous Sand, Ishikawa (Kami *et al.*, 1981); (7) uncertain formation in Hitachi City, Ibaraki (this study); (8) Altamira Shale of Montery Formation, California (Repenning and Tedford, 1977); (9) unnamed formation, California (Repenning and Tedford, 1977); (10) upper part of Round Mountain Silt, California (Armentrout, 1981); (11) Rosarito Beach Formation, Baja California (Aranda-Manteca *et al.*, 1994); (12) Santa Margarita Formation, California (Armentrout, 1981); (13) Montesano Formation, Washington (Bigelow, 1994).

Pacific along the shore at some time in the end of the early Middle Miocene. The species of the genus *Allodesmus*, at least, lived almost contemporaneously in the North Pacific during a short period approximately between 12 and 14 Ma. The subfamily became extinct by the end of the late Middle Miocene probably because of the change to the cooler marine climate during that period. Although each species of *Allodesmus* except probably for *A. kernensis* appears to have been endemic, such a judgement needs to be made from many more specimens, which could be obtained both from the western and eastern North Pacific realm.

Conclusions

The Miocene extinct pinniped *Allodesmus* is now represented by five species from the North Pacific coast of Japan as far as 35°-43° north latitudes and of the North America as far as 30°-46° north latitudes.

Allodesmus naorai, described herein as the fifth species of the genus from the vicinity of Mito City, Ibaraki Prefecture of late Middle Miocene age (ca. 12.0-13.6 Ma), has a sister group relationship with *A. packardi*, and these two species form a "broad head" subgroup within the genus. Likewise *Allodesmus kernensis* and *A. sinanoensis* form another monophyletic "long head" subgroup within the genus. The "broad head" and "long head" subgroups are sister taxa with each other. *Allodesmus courseni* is the most generalized, earliest diverging species within the genus. Although the differences among these subgroups seem to represent over-specific grades, the construction of new generic names for them must await support of much better material.

The fossil records of allodesmines in the western North Pacific indicate that they were "immigrants" from the eastern North Pacific and expeditiously diversified during a short interval in the late Middle Miocene. They lived in mild to warm temperate water and decreased as the marine climate grew cooler at least in the western North Pacific. They appear to have become extinct by the end of the late Middle Miocene leaving no Recent descendants.

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References cited

Akiba, F., 1986: Middle Miocene to Quaternary diatom biostratigraphy in the Nankai Trough and Japan Trench, and modified Lower Miocene through Quaternary diatom zones for middle-to-high latitudes of the North Pacific. *In*, Kagami, H., Karig, D.E., Coulbourn, W. *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 87, p. 393-480. U.S. Govt., Printing Office, Washington, D.C.

Aranda-Manteca, F.J., 1990: Aspectos paleoceanograficos y paleoecologicos de los fosiles del Mioceno, La Mesa La Mision, Baja California, Mexico. *Review of the Mexican Paleontology*, vol. 3, no. 1, p. 97-116.

Aranda-Manteca, F.J., Domning, D.P. and Barnes, L.G., 1994: A new Middle Miocene sirenian of the genus *Metaxytherium* from Baja California and California: relationships and paleobiogeographic implications. *In*, Berta, A. and Deméré, T.A. *eds*., Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. *Proceedings of the San Diego Society of Natural History*, no. 29, p. 191-204.

Armentrout, J.M., 1981: Correlation and ages of Cenozoic stratigraphic units in Oregon and Washington. *Geological Society of America Special Paper*, no. 184, p. 137-148.

Barnes, L.G., 1972: Miocene Desmatophocinae (Mammalia: Carnivora) from California. *University of California Publications in Geological Sciences*, vol. 89, p. 1-68.

Barnes, L.G., 1979: Fossil enaliarctine pinnipeds (Mammalia: Otariidae) from Pyramid Hill, Kern County, California. *Contributions in Science*, *Natural History Museum* of Los *Angeles County*, no. 318, p. 1-41.

Barnes, L.G., 1989: A new enaliarctine pinniped from the Astoria Formation, Oregon, and a classification of the Otariidae (Mammalia: Carnivora). *Contributions in Science*, *Natural History Museum of Los Angeles County*, no. 403, p. 1-26.

Barnes, L.G., Domning, D.P. and Ray, C.E., 1985: Status of studies on fossil marine mammals. *Marine Mammal Science*, vol. 1, no. 1, p. 15-53.

Barron, J.A. and A.Y. Gladenkov, A.Y., 1995: Early Miocene to Pleistocene diatom stratigraphy of Leg 145. *In*, Rea, D.K., Basov, I.A., School, D.W. and Allen, J.F. *ed.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 145, p. 3-19.

Berggren, W.A., Kent, D.V., Flynn, J.J. and Van Couvering, J.A., 1985: Cenozoic geochronology. Geological Society of America Bulletin, vol. 96, no. 11, p. 1407-1418.

Berta, A., 1991: New *Enaliarctos** (Pinnipedimorpha) from the Oligocene and Miocene of Oregon and the role of "enaliarctids" in pinniped phylogeny. *Smithsonian Contributions to Paleobiology*, vol. 69, p. 1-33.

Berta, A., 1994a: New specimens of the pinnipediform *Pteronarctos* from the Miocene of Oregon. *Smithsonian Contributions to Paleobiology*, no. 78, p. 1-30.

Berta, A., 1994b: A new species of phocoid pinniped *Pinnarctidion* from the early Miocene of Oregon. *Journal of Vertebrate Paleontology*, vol. 14, no. 3, p. 405-413.

Berta, A. and Wyss, A.R., 1994: Pinniped phylogeny. *In*, Berta, A. and Deméré, T.A. *eds*., Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. *Proceedings of the San Diego Society of Natural History*, no. 29, p. 33-56.

Bigelow, P.K., 1994: Occurrence of a squaloid shark (Chondrichthes: Squaliformes) with the pinniped *Allodesmus* from the Upper Miocene of Washington. *Journal of Paleontology*, vol. 68, no. 3, p. 680-684.

Blow, W.H., 1969: Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In*, Brönnimann, P. and Renz, H.H. *eds*., *Proceedings of the First International Conference on Planktonic Microfossils* (*Geneva, 1967*), vol. 1, p. 199-422. Leiden, E.J. Brill.

Bremer, K., 1994: Branch support and tree stability. *Cladistics*, vol. 10, p. 295-304.

Chinzei, K., 1985: Modes of occurrence, geologic range, and geographic distribution of desmostylians. *Association for Geological Collaboration in Japan*, *Monograph*, no. 30, p. 91-96. (*in Japanese with English abstract*)

Chinzei, K., 1986: Faunal succession and geographic distribution of Neogene molluscan faunas in Japan. *Palaeontological Society of Japan*, *Special Paper*, no. 29, p. 17-32.

Condon, T., 1906: A new fossil pinniped (*Desmatophoca oregonensis*) from the Miocene of the Oregon coast. *University of Oregon Bulletin*, *Supplement* vol. 3, no. 3,

p. 1-14.

Deméré, T.A., 1994: The family Odobenidae: a phylogenetic analysis of fossil and living taxa. *In*, Berta, A. and Deméré, T.A. *eds*., Contribution in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. *Proceedings of the San Diego Society of Natural History*, no. 29, p. 99-123.

Downs, T., 1956: A new pinniped from the Miocene of southern California: with remarks on the Otariidae. *Journal of Paleontology*, vol. 30, no. 1, p. 115-131.

Harunari, H., 1987: Results of the Nishiyagi coast excavation, 1.1. Previous research. *In*, Harunari, H. *ed*., Report on the Excavation of the Nishiyagi Site, Akashi City. *Bulletin of the National Museum of Japanese History*, vol. 13, p. 5-28. (*in Japanese with English summary*)

Hay, O.P., 1930: *Second Bibliography and Catalogue of the Fossil Vertebrata of North America*, 2 volumes, xiv+1074 p.; viii+916 p.

Hirota, K., 1994: A summary of the Miocene pinniped *Allodesmus*. *Association for Geological Collaboration in Japan, Monograph*, no. 43, p. 33-45. (*in Japanese with English abstract*)

Hirota, K., Kobayashi, I., Sasagawa, I., Horikawa, H. and Kamei, T., 1987: On a skull bone of *Allodesmus* (Mammalia: Carnivora) found from Sado Island, central Japan. *Bulletin of the Sado Museum*, no. 9, p. 197-209. (*in Japanese with English abstract*).

Hunt, R.M., Jr. and Barnes, L.G., 1994. Basicranial evidence for ursid affinity of the oldest pinnipeds. *In*, Berta, A. and Deméré, T.A. *eds*., Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. *Proceedings of the San Diego Society of Natural History*, no. 29, p. 57-67.

Kami S., Kato, M., Taguchi, K. and Takayama, T., 1981: Geological ages of calcareous sandstones on the Noto Peninsula. *Bulletin of the Faculty of Liberal Arts, Kanazawa University* (*Natural Sciences*), vol. 18, p. 47-63. (*in Japanese with English abstract*)

Kellogg, A.R., 1922: Pinnipeds from Miocene and Pleistocene deposits of California. University of California Publications, *Bulletin of the Department of Geological Sciences*. vol. 13, no. 4, p. 23-132.

Kellogg, A.R., 1931: Pelagic mammals from the Temblor Formation of the Kern River region, California. *Proceedings of the California Academy of Sciences, 4th Series*, vol. 19, no. 12, p. 217-397.

Kohno, N., 1994: A new Miocene pinniped in the genus *Prototaria* (Carnivora: Odobenidae) from the Moniwa Formation, Miyagi, Japan. *Journal of Vertebrate Paleontology*, vol. 14, no. 3, p. 414-426.

Kohno, N., Tanaka, Y. and Yanagisawa, Y., 1994: Systematic position of the "Mito seal" of Naora (1944), and its geologic age on the basis of the microfossil biochronology. *Abstract of the 101st Annual Meeting of the Geological Society of Japan*, p. 113. (*in Japanese*)

Kosaka, T., Midori, T., Hoyanagi, K., Kubota, M. and Miyahigashi, M., 1990: Late Cenozoic stratigraphy and paleogeographic changes in the Northern Fossa Magna. *Memoirs of the Geological Society of Japan*, no. 37, p. 71-82. (*in Japanese with English abstract*)

Maiya, S., 1978: Late Cenozoic planktonic foraminiferal biostratigraphy of the oil-field region of northeast Japan. *In*, Fujita, K. *et al*. *eds*., *Cenozoic Geology of Japan* (*Prof. N. Ikebe Memorial Volume*), p. 35-60. (*in Japanese with English abstract*)

Maruyama, T., 1993: Diatom temperature index and surface water temperature during the middle and late Miocene along the Pacific side of northeast Japan. *Fossils*, (*Palaeontological Society of Japan*) no. 55, p. 53-64. (*in Japanese with English abstract*)

Mitchell, E.D., 1966: The Miocene pinniped *Allodesmus*. *University of California Publications in Geological Sciences*, vol. 61, p. 1-105.

Mitchell, E.D., 1968: The Mio-Pliocene pinniped *Imagotaria*. *Journal of the Fisheries Research Board of Canada*, vol. 25, no. 9, p. 1843-1900.

Mitchell, E.D. and Tedford, R.H., 1973: The Enaliarctinae, a new group of extinct aquatic Carnivora and a consideration of the origin of the Otariidae. *Bulletin of the American Museum of Natural History*, vol. 151, no. 3, p. 201-284.

Nagao, T., 1941: An occurrence of a fossil sea lion in the Miocene deposits of Sinano, Japan. *Journal of the Faculty of Science, Hokkaido Imperial University, Series* 4, vol. 6, no. 2, p. 75-84.

Naora, N., 1944: *Natural History of Mammals in Japan*. 265 p. Yotokusha. (*in Japanese*)

Ogasawara, K., 1994: Neogene paleogeography and marine climate of the Japanese Islands based on shallow-marine molluscs. *Palaeogeography, Palaeoclimatology*, Palaeoecology, vol. 108, p. 335-351.

Oishi, M., Fujiwara, O. and Ogasawara, K., 1992: A desmostylian humerus from the Miocene Yamairi Formation, Miyagi Prefecture, northeast Japan. *Bulletin of the Iwate Prefectural Museum*, no. 10, p. 1-9. (*in Japanese with English abstract*)

Okada, H. and Bukry, D., 1980: Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). *Marine Micropaleontology*, vol. 5, p. 321-325.

Repenning, C.A. and Tedford, R.H., 1977: Otarioid seals of the Neogene. *United States Geological Survey Professional Paper*, no. 992, p. 1-93, pls. 1-24.

Saito, T., 1959: Geology in the environs of Mito City and Lake Hinuma. (Earth-scientific observations of Lake Hinuma, Part 2). *Bulletin of the Faculty of Arts and Sciences, Ibaraki University* (*Natural Science*), vol. 10, p. 135-143. (*in Japanese with English abstract*)

Sawamura, H., Hirota, K. and Inoue, K., 1994: New occurrence of *Allodesmus* (Pinnipedia, Mammalia) from Urahoro-cho, Hokkaido, Japan. *Abstract of the 101st Annual Meeting of the Geological Society of Japan*, p. 114. (*in Japanese*)

Sivertsen, E., 1954: A survey of the eared seals (family Otariidae) with remarks of the Antarctic seals collected by M/K <<Norvegia>> in 1928-1929. *Det Norske Videnskapo-Akademi i Oslo*, vol. 36, p. 5-76.

Swofford, D.L., 1993: *PAUP: Phylogenetic Analysis Using Parsimony, Version 3.1*. Illinois Natural History Survey, Champaign, Illinois.

Takayanagi, Y., Oda, M., Hasegawa, S., Honda, N., Maruyama, T. and Funayama, M., 1984: Some middle Miocene planktonic microfossil datum planes in northern Honshu, Japan: their paleoceanographic implications. *Palaeogeography, Palaeoclimatology, and*

Palaeoecology, vol. 46, p. 71-84.

Takemura, A. and Hirota, K., 1983: Radiolarian fossils from the vertebrate-bearing dolomite nodule from the Tsurushi Formation, Sado. *NOM*, no. 10, p. 29-38. (*in Japanese with English abstract*)

Tanaka, K. and Seki, M., 1962: Significance of desmostylian-like marine mammal recovered from Toyoshina-cho. *Shinano-kyoiku*, no. 912, p. 55-65. (*in Japanese*)

Tanaka, Y., Yanagisawa, Y. and Kohno, N., 1995: Geologic age of the Miocene extinct pinniped "Mito seal" (Naora, 1944) based on microfossil biostratigraphy, with its presumed horizon and locality in Mito City, Ibaraki Prefecture, Japan. *Journal of the Geological Society of Japan*, vol. 101, no. 3, p. 249-257. (*in Japanese with English abstract*)

Tedford, R.H., 1976: Relationship of pinnipeds to other carnivores (Mammalia). *Systematic Zoology*, vol. 25, no. 4, p. 363-374.

Tedford, R.H., Skinner, M.F., Fields, R.W., Rensberger, J.M., Whistler, D.P., Galusha, T., Taylor, B.E., Macdonald, J.R. and Webb, D., 1987: Faunal succession and biochronology of the Arikareean through Hemphillian interval (Late Oligocene through earliest Pliocene epochs) in North America. *In*, Woodburne, M.E. *ed.*, *Cenozoic Mammals of North America*, p. 153-210. University of California Press.

Tomida, Y., 1990: Classification and evolution of pinnipeds. *In*, Miyazaki, N. *ed.*, *Biology of Marine Mammals*, p. 189-205. (*in Japanese*)

Wyss, A.R., 1987: The walrus auditory region and the monophyly of pinnipeds. *American Museum Novitates*, no. 2871, p. 1-31.

Wyss, A.R. and Flynn, J.J., 1993: A phylogenetic analysis and definition of the Carnivora. *In*, Szalay, F.S., Novacek, M.J. and McKenna, M.C. *eds*., Mammal Phylogeny, p. 32-52. Springer-Verlag, Berlin.

Yanagisawa, Y., 1990: Age of fossil Argonautidae (Cephalopoda) from Hokuriku province (central Honshu, Japan) based on diatom biostratigraphy. *Bulletin of the Geological Survey of Japan*, vol. 41, no. 3, p. 115-127. (in Japanese with English abstract)

Yanagisawa, Y., Nakamura, K., Suzuki, Y., Sawamura, K., Yoshida, F., Tanaka, Y., Honda, Y., and Tanahashi, M., 1989: Tertiary biostratigraphy and subsurface geology of the Futaba district, Joban Coalfield, northeast Japan. *Bulletin of the Geological Survey of Japan*, vol. 40, no. 8, p. 405-467. (*in Japanese with English abstract*)

Young, J.R., Wei, W. and Backman, J., 1994: A summary chart of Neogene nannofossil magnetobiostratigraphy. *Journal of the Nannoplankton Research*, vol. 16, no. 1, p. 21-27.

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 181, pp. 405-406, April 30, 1996

In Memoriam: Teiichi Kobayashi (1901-1996)

TSUNEMASA SAITO

Emeritus Professor Teiichi Kobayashi died of natural causes on January 13, 1996, in Tokyo, at the age of 94. With his passing, the Japanese paleontological community lost one of its most illustrious members, recipient of a chain of scientific accolades including Prize of the Japan Academy (1951), Leopold von Buch Medal of the Deutsche Geologische Gesellschaft (1956), Yokoyama Awards and Medal of the Palaeontological Society of Japan (1966), Fujiwara Foundation Prize and Golden Medal (1969), and Medal and Diploma de Honor al Mérito of Universidad Nacional de La Plata (1977).

Professor Teiichi Kobayashi, known to his students and junior colleagues by the affectionate name of "Kobayashi *sensei*," was born in Osaka, Japan, on August 31, 1901, as the first son of Motomatsu Kobayashi. In 1924, he entered the Imperial University of Tokyo (now University of Tokyo), which would become his center of research activities for the next 40 years. He continued his graduate training at the same university and after completing the course work he joined the faculty, being successively appointed Assistant (1931), Lecturer (1934), and Associate Professor (1937). He received a full professorship in 1947 — an appointment he held until he retired in 1962.

His graduation thesis work on the historical geology of Kangwon-do Province of Korea was said to mark the event which stimulated his life-long interest in early Paleozoic formations and their faunas. In characteristic style, he promptly embarked on a study of Cambro-Ordovician strata and their faunas in Korea and Manchuria (now the northeastern territory of People's Republic of China) for his doctoral dissertation. Soon after becoming a faculty member in 1931, he was given a leave of absence to carry out his overseas research at the National Museum of Natural History in Washington, D.C., where many type specimens of Cambrian fossils from China, especially those studied by Charles D. Walcott, were housed. After staying three years in the U.S., Kobayashi *sensei* returned to Japan in 1934. En route, he spent four months in Europe, visiting Germany, England, Switzerland, and Italy.

His first-hand observation of the structural profile of the eastern Swiss Alps and the geology of the Appalachian Mountains led Kobayashi *sensei* to re-examine the tectonic development of the Japanese Islands from the viewpoint of a large-scale horizontal earth movement such as one which would culminate in the formation of Klippe and Decke structures. Such a re-examination resulted in the publication in 1941 of his much referenced paper entitled "The Sakawa orogenic cycle and its bearing on the origin of the Japanese Islands." Many years ahead of the age of "Plate Tectonics," his papar was quite monumental in that the concept of geosyncline coupled with subsequent orogeny was introduced for the first time to explain in a systematic manner various sedimentational and deformational processes of Paleozoic and Mesozoic strata that make up the core of the island arc.

His three-year stay in the Natural History Museum, where he was able to undertake a detailed comparative analysis of Cambro-Ordovican faunas of the world, enabled the completion of his large monograph, the "Cambro-Ordovican formations and faunas of South Chosen [=Korea]," published in three installments from 1934 to 1935. Although his principal thesis work dealt with the phylogeny of primitive nautiloids, this monograph formed the core of his doctoral thesis, with which he earned his D. Sc. degree in 1936. It has been said of him that one driving discipline he kept for himself in his scientific career was to publish numerous enough papers that their combined total thickness would exceed his own physical height. During the ensuing years of dedicated research spanning some 70 years, including those after his retirement from the university, he authored or coauthored nearly 800 papers. Even casting a casual glance at his lengthy bibliography, one would be awed by the remarkable range of subjects his papers covered. In addition to the tectonic geology of Japan and neighboring Asian mainlands, the subjects ranged over an astonishing array of paleontological taxa including Pteridophyta, pelecypods, cephalopods, trilobites, estherids, and graptolites.

The leadership role of Kobayashi *sensei* in national and international professional societies was also remarkable. In 1933, he helped to organize the International Palaeontological Union and served as its Vice President from 1952 to 1955. He was one of the organizers of the International Union of Geological Sciences and from 1961 to 1964 he was its Vice President. In the home front, he helped to organize the Palaeontological Society of Japan in 1935 and was its Council member from the birth of the society till 1970. He served as President of the Society from 1961 to 1964 and was Honorary President since 1971. Fellow geologists also elected him to the important Science Council of Japan (1962-1968) and the honorable Japan Academy appointed him to be its member from 1970 until his death.

Even after his retirement, he fashioned yet another international project, launching in 1962 collaborative field studies with Southeast Asian countries including Taiwan, the Philippines, Malaysia, Indonesia, Vietnam, and Thailand. Through his skillful leadership and tireless pleading, he succeeded in securing a large sum of research funds as well as the voluntary contribution of a large number of geologists and paleontologists, both from Japan and other Asian countries, which were mobilized towards the preparation of a 25-volume compendium under the cover title of “Geology and Palaeontology of Southeast Asia.” These volumes presented all the geological and paleontological data gathered from the region.

Kobayashi *sensei* will be remembered as a man of extraordinary caliber who published a great number of papers fundamental to the advancement of geology and paleontology of Asia, trained a generation of Japanese paleontologists many of who held influential academic, government and industrial positions in Japan and elsewhere, and devoted service to national and international professional societies.

I extend special thanks to Dr. Itaru Hayami, former professor of the University of Tokyo and who himself is a student of Kobayashi *sensei*, for supplying me with information on the career of Kobayashi *sensei* and locating his portrait.

Palaeontological Society of Japan (PSJ) Council Actions

During its meeting on January 25, 1996, the Council enacted the following changes to its membership.

New members elected ;
Ryuuichi Arakawa, Naomasa Hiraishi, Hideo Horikawa,
Takahisa Ishiyama, Tomoyuki Kaneko, Michiko Miwa,
Kenjiro Mukaiyama, Morihiko Ôfusa, Hiroya Ogata,
Toshiaki Ooi, Shigeru Suzuki, Toyonobu Takei,
Masaaki Taniguchi, Yoshihiro Tsumura, Ryoji Wani,
Paolo Mietto, Mia Mohammad Mohiuddin.

New fellow members ;
Satoshi Chiba, Kazuyoshi Endo, Yoichi Ezaki,
Toshiaki Irizuki, Nobuhiro Kotake, Yuko Kyuma,
Makoto Manabe, Yasunari Shigeta, Yuichiro Tanaka,
Akira Tsukagoshi.

Deceased members ;
(Fellow)
Teiichi Kobayashi, Katsura Oyama, Toshiji Oyama,
Karyu Tsuda, Kinji Tsuruta.
(Ordinary member)
Kahler Franz, Hiroyuki Ikejiri.

Resigned members ;
(Patron member) ;
Mobara Kogyosho, Kanto Tennen-gasu Kaihatsu Company
(Fellow)
Yasufumi Ishiwada, Takashi Miki, Harumi Nishimura.
(Ordinary member)
Richard Dehm, Yu Higuchi, Tetsuro Ichinoseki,
Akiko Iwauchi, Hiroshi Kamada, Yoshio Kasahara,
Jiro Muramatsu, Hideki Okuyama, Kyo Takagi,
Koichi Yamamoto.

Change to overseas member ;
Johann R. Rigor, Shin Jie-Kun, Fe P. Tumanda.

PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本古生物学会　1996年年会・総会

日本古生物学会1996年年会・総会が，1月26日～28日に大阪市立大学で開催された（参加者282名）。

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生体群集と遺骸群集の対応：北太平洋における放散虫
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First announcement and call for papers
PaleoForams '97

Conference: August 17 through 21, 1997, Western Washington University, Bellingham, WA (USA)

Organizers: Charles A. Ross, Department of Geology, Western Washington University, June R.P. Ross, Department of Biology, Western Washington University, and Paul Brenckle, Amoco Production Company, Houston, TX.

Pre-conference Field Trip: August 14-16, 1997, Late Devonian through Permian strata of accreted terranes in southwestern British Columbia (Canada), organized by J.H.W. Moger (Geological Survey of Canada) and others.

Post-conference Field Trip: August 22 to 24, 1997, Carboniferous of Arrow Canyon and the mid-Carboniferous boundary, southern Nevada (USA), organized by Rick Page (US Geological Survey) and Paul Brenckle.

The study of Paleozoic Foraminifera includes a number of general, as well as several unique interests and interpretations that lend themselves well to a specialists meeting. The conference topics are designed to address these, as well as more traditional questions. An initial list of topics for which talks and/or posters are solicited include: Evolution, dispersal, and paleobiogeography; Classification and taxonomy; Biostratigraphy and zonation; Paleoecology and sedimentary environments of deposition; Biological interpretations and significance; Numerical and statistical methods; Composite standard sections and their utility in Foraminifera biostratigraphy; New techniques.

At this time the organizers welcome additional topics that participants wish to have included.

Please address correspondence to:
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Bellingham, WA 98225-9080

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or phone: (360) 650-3634

* *

PaleoForams '97 please return this part to: C.A. Ross, Dept. of Geology, Western Washington Univ.,
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My interest in attending the August 1997 PaleoForams '97 conference in Bellingham, WA.
—— definitely plan to attend
—— probably will be able to attend
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I plan to present (or co-author) a talk ( ) and/or poster ( ) (please check) about:

____

I plan to participate in the:
—— Pre-conference field trip to the Devonian through Permian in southwestern British Columbia.
—— Post-conference field trip to the Carboniferous in Arrow Canyon in Nevada.

行事予定

◎第145回例会は，1996年6月29日〜30日に，新潟大学教養校舎で開催予定です。講演（含ポスターセッション）申し込みは5月10日（必着）締め切りです。講演申し込みの方法や予稿集原稿の書き方については，「化石」48号，54号，または昨年11月1日付で発行した会員名簿をご覧下さい。講演区分の中にはポスターセッションも含まれます。なお，講演予稿集は1996年年会からA4判で，原稿のまま縮小無しです。シンポジウムは「東アジアの中・古生代生物地理とテクトニクス」が予定されております。

◎1997年年会は，1997年1月30日〜2月1日に，京都大学理学部で開催の予定です。講演申し込みは10月5日（必着）締め切りです。シンポジウムを計画されている方は，その概要（開催趣旨，講演者と題目）を5月末までにお申し込み下さい。

◎1997年例会は，1997年6月に，豊橋市自然史博物館で開催の予定です。

◎日本地質学会第104年学術大会（於　福岡；1997年10月10日-12日）は，日本古生物学会ほかの参加した連合学術大会となります。日本古生物学会は会期中にシンポジウムを実施いたします。シンポジウム企画案は1997年3月までにお申し込み下さい。

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