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PERMIAN CONODONT BIOSTRATIGRAPHY OF JAPAN

By
Hisaharu Igo

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All Communications relating to this publication should be addressed to
THE EDITOR
c/o Department of Geology, Faculty of Science, Kyushu University, Fukuoka 812

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By

Hisaharu Igo

Department of Astronomy and Earth Sciences,
Tokyo Gakugei University

Abstract

Fourteen genera and thirty species including nineteen unidentified species of conodont elements are discriminated in the Japanese Permian System. Among them, fortyfour conodont elements are described and illustrated herein. Ten new species and one new subspecies are proposed. Two conodont faunas, and two conodont assemblage zones are established in the Sakamotozawan and Nabeyaman Series and their biostratigraphic value is discussed.

Contents

I. Introduction and Acknowledgements

Permian System is the most extenively distributed Paleozoic rocks in the Japanese Islands. Biostratigraphical investigations of the Japanese Permian have been mainly done by the zonation of fusulinaceans in the calcareous facies. Stratigraphical and geochronological studies of the Permian non-calcareous facies were almost ignored by most Japanese geologists. Since 1967, Hisayoshi Igo, Koike and the author have been studying the geologic structure and stratigraphy of these so-called Permian rocks. We have found many Triassic and Permian conodonts in the noncalcareous rocks and also in the limestones. As a result of our studies, the distribution of the Permian and Triassic sediments in the Japanese Islands is considerably revised.

During the past decade, our investigation and some other studies brought many noteworthy new data concerning the geologic history as well as stratigraphy of the Upper Paleozoic to Lower Mesozoic deposits in Japan. Remarkable contributions are the following: Nakazawa and Nogami (1967), Sakagami *et al.* (1969), Koike *et al.* (1970), (1971), Murata and Sugimoto (1971), Hisayoshi Igo (1972), Hisayoshi Igo *et al.* (1973), Sugimoto (1974), Kano (1975), Toyohara (1975, 1977), Makino (1976), Ishida (1977, 1979), Matsuda (1978, 1980), Matsuda and Sato (1979), Koike (1979) and Isozaki and Matsuda (1980).

Recent investigations of the Triassic conodont biostratigraphy have been progressed by the mentioned contributors, but there still remained many unsolved problems concerning the Permian conodonts biostratigraphy. Therefore, the author tried to collect Permian conodonts from limestones and cherts distributed in the various regions of Japan.

In this paper, the author described Permian conodonts collected from the Mino-Hida, Kiso, Kwanto and Ashio Massifs and discussed their biostratigraphic value. This is the first comprehensive study of Permian conodonts in Japan.

Acknowledgements: The author acknowledges the comments and suggestions of Professor Emeritus Mosaburo Kanuma and Professor Tatsuaki Kimura of Tokyo Gakugei University. He expresses appreciation to my elder brother, Dr. Hisayoshi Igo, Professor of the University of Tsukuba, for his continuous guidance, cooperation in the field and help with the preparation of this paper. Acknowledgements are due to Dr. Toshio Koike, Assistant Professor of Yokohama National University, for his cooperation in the field and valuable suggestions. Particular thanks are expressed to Dr. Kagetaka Watanabe, Professor Emeritus of the University of Tsukuba, for suggesting the preparation of this paper. The author is much indebted to Dr. Tsugio Shuto, Professor of Kyushu University, for his many helpful suggestions and critical reading of the manuscript.

II. Historical Review of Permian Conodont Studies

Permian conodonts are still poorly known compared with those from other geologic systems. Recently, Clark (1972, 1974, 1979), Clark and Behnken (1971, 1979) and Behnken (1975) summarized the history of Permian conodont studies and described several species collected from western and southwestern United States and discussed their stratigraphic value and evolutionary relationship. Kozur (1975, 1978) contributed to our knowledge of Permian conodont fauna in Europe. In Asia, Permian conodonts were first described by Ching (1960) from China. Lower Permian conodonts were described from Northern Thailand by Hisayoshi Igo (1974). Sweet (1970a, b) described Upper Permian to Lower Triassic conodonts from the Salt Range and Trans-Indus Ranges, Pakistan and discussed the Permian-Triassic boundary.

In Japan, the existence of Permian conodonts was first reported by Hisayoshi Igo and Koike (1966). Previous to their paper, Hayashi (1963, 1964a, b) briefly reported the occurrence of Permian conodonts from the shales distributed in the Ashio and Kwanto mountains. Hisayoshi Igo and Koike (1966), however, pointed out Hayashi's misidentification of the conodonts. These conodonts are really of the Triassic. Hayashi (1968) also described conodonts from the Adoyama Formation distributed in the Kuzuu district, Tochigi Prefecture and he thought that the conodonts are of the Permian age. However, Koike *et al.* (1970) and Hisayoshi Igo (1972) proved that the conodont fauna is identical with the standard European and North American Triassic conodont faunas. Hayashi (1971) also described Permian conodonts collected from the *Parafusulina*-bearing Nabeyama Formation outcropping in the same area, and he erroneously identified distinct Permian species as Lower Carboniferous ones. Sobajima (1972) collected some conodonts from the *Pseudodoliolina ozawai* Zone of the Permian Akasaka Limestone, Central Japan and identified them as *Gnathodus commutatus commutatus* (Branson and Mehl). This species is identified as *Diplognathodus nodosus* Igo, n. sp. in this paper.

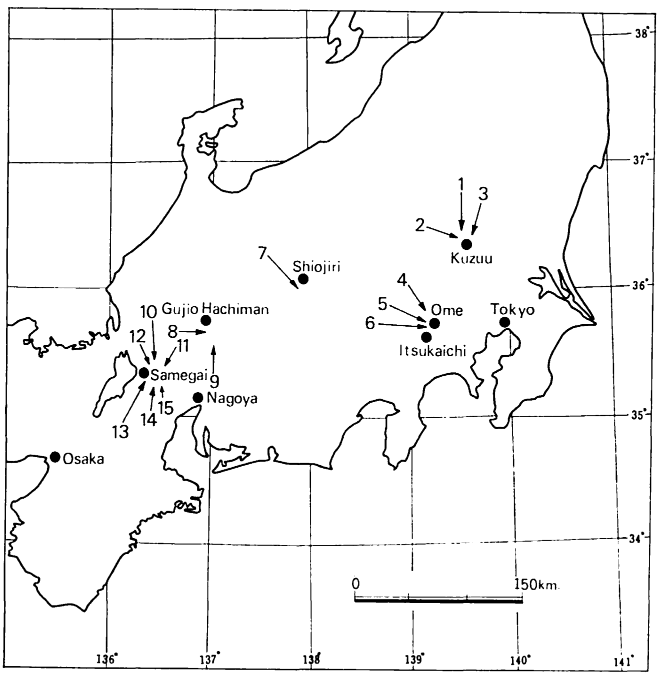
Hisayoshi Igo (1972) briefly mentioned the occurrence of some Permian conodonts in several localities in Japan. Up to date our specimens of Permian conodonts came from more than 150 localities. Most of these specimens were obtained from cherts, which lack other reliable index fossils, such as fusulinaceans and corals. Conodonts preserved in limestones are frequently associated with fusulinaceans or interbedded with fusulinacean-bearing strata, and thus their geochronology can be clearly settled.

The present paper deals mainly with conodonts discovered from limestones to establish Permian conodont biostratigraphy of the Japanese Islands. Conodonts preserved in cherts and shales will be described on another occasion.

III. Geological Setting

As the standard succession of Permian rocks in Japan the following series have been proposed in descending order; they are the Mitaian, Kuman, Akasakan, Nabeyaman and Sakamotozawan Series.

The author collected many limestone samples from the type sections of these series, but conodonts were commonly found only in the type section of the Nabeyaman Series.

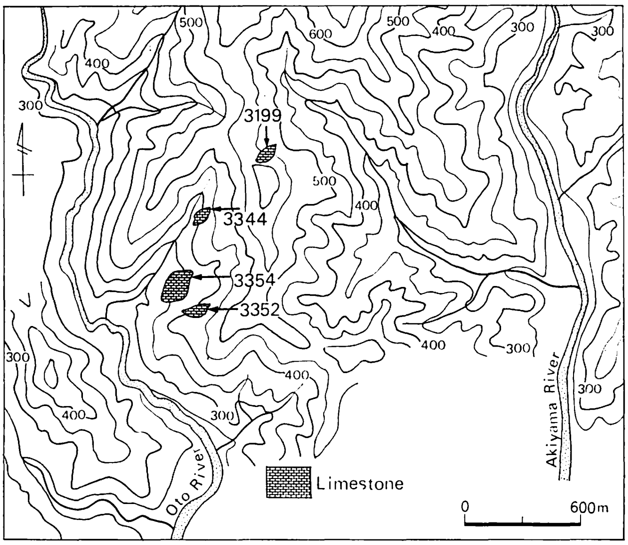


Text-fig. 1. Map of collecting localities. 1: Akiyama, Kuzuu Town, Aso County, Tochigi Prefecture. 2: Yamasuge (Quarry of the Tokyo Lime Industry Co. Ltd.), Kuzuu Town, Aso County, Tochigi Prefecture. 3: Nagaami (Quarry of the Miyata Lime Industry Co. Ltd.), Kuzuu Town, Aso County, Tochigi Prefecture. 4: Shiraiwa (Shiraiwa Limestone), Ome City, Tokyo. 5: Minokuchi, Hinode Village, Nishitama County, Tokyo. 6: Tamanouchi, Hinode Village, Nishitama County, Tokyo. 7: Uto-Pass, Shiojiri City, Nagano Prefecture. 8: Gujio Hachiman, Hachiman Town, Gujio County, Gifu Prefecture. 9: Nukui, Mugi Village, Mugi County, Gifu Prefecture. 10: Ibukiyama (Ibukiyama Limestone), Ibuki Village, Sakata County, Shiga Prefecture. 11: Akasaka (Akasaka Limestone), Akasaka Town, Ogaki City, Gifu Prefecture. 12: Samegai (Sg. 4), Maibara Town, Sakata County, Shiga Prefecture. 13: Samegai (Sg. 3), Maibara Town, Sakata County, Shiga Prefecture. 14: Ichinose, Kamiishizu Village, Yoro County, Gifu Prefecture. 15: Yoro, Yoro Town, Yoro County, Gifu Prefecture.

The type section of the Akasakan Series yields a few conodonts. The type sections of the Kuman and Sakamotozawan Series are entirely in barren of conodonts. The Kuma Formation is composed mainly of small limestone lenses, conglomertes, sandstones, and shales which are considered to be the deltaic origin (Kanmera, 1953). The Sakamotozawa Limestone is regarded as very shallow water deposits, probably in sedimentary environment with restricted circulation (Kanmera and Mikami, 1965). The depositional environment of the Kuma Formation and the Sakamotozawa Limestone was probably not appropriate for conodont-bearing animals. Conodonts described in this paper were collected from the Permian sediments distributed mainly in the Kwanto and Chubu regions. Text-fig. 1 shows the localities of Permian conodonts described in this paper. Geologic setting of these localities is summarized as follows.

(1) Kuzuu district, southern part of the Ashio Massif

It has long been thought that the Upper Paleozoic rocks constitute this mountainous region. As already mentioned earlier, however, recent conodont investigations demonstrated that the Triassic sediments are rather widely distributed in this district. In the Akiyama area located about 10 km north of Kuzuu Town, the Upper Permian deposits is narrowly distributed in fault contact with the Middle and Upper Triassic rocks. These Upper Permian rocks contain limestone lenses on a tributary of the Oto river (Text-fig. 2). These limestones yield abundant *Colaniella parva* (Colani) and a few specimens of *Reichelina* sp. These limestones also contain some conodonts. *Anchignathodus minutus permicus* Igo, n. subsp., *Diplognathodus* sp., *Neogondolella* sp. and hindeodellid elements were obtained from the locality 3199. *Anchignathodus typicalis* Sweet and *Enantiognathus tribulosus* (clark and Behnken) were obtained from the locality 3352. *Anchignathodus minutus permicus* Igo, n. subsp., *Anchignathodus typicalis* Sweet, *Neogondolella* sp. and hindeodellid elements were obtained from the locality 3354. *Anchignathodus typicalis* Sweet, *Diplognathodus* sp. and hindeodellid elements were

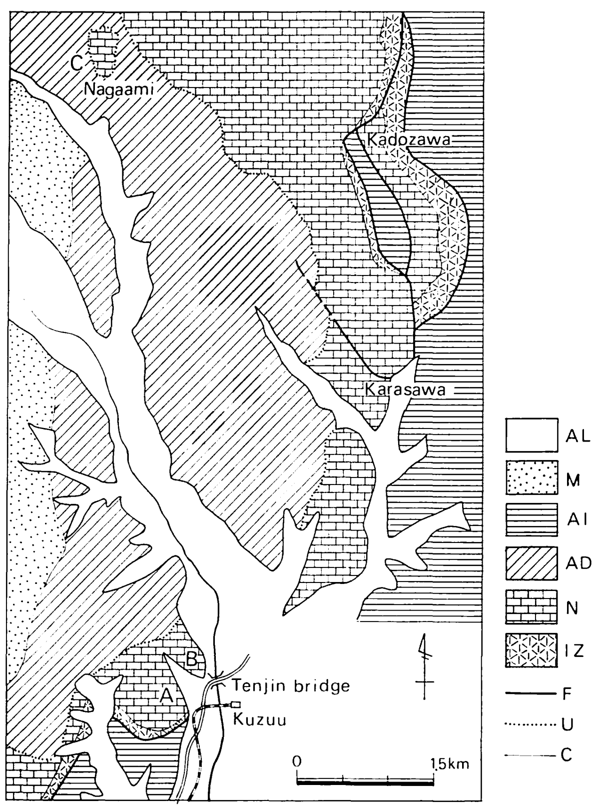


Text-fig. 2. Map showing the collecting localities of the Akiyama, Kuzuu Town, Aso County, Tochigi Prefecture.

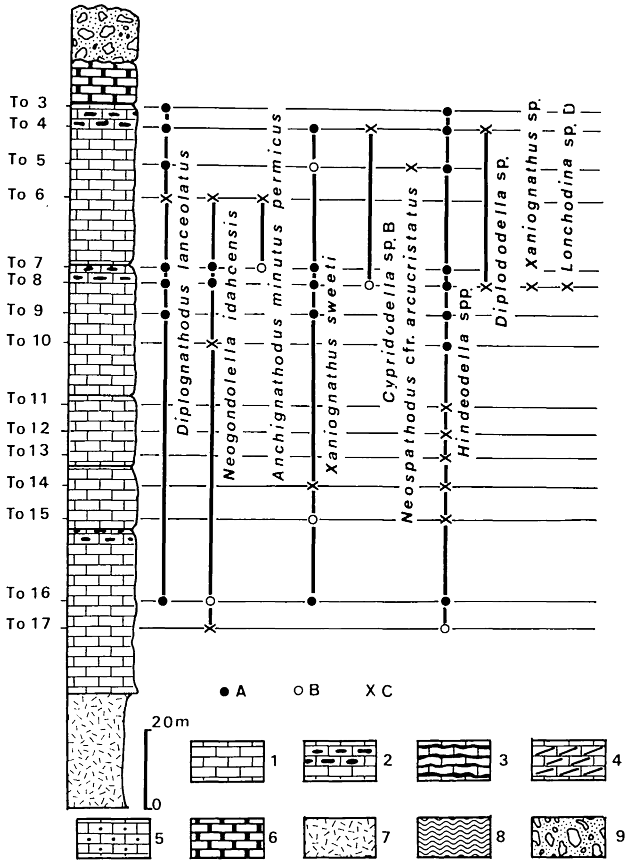
obtained from the locality 3344 (Koike *et al.*, 1974 and Koike, 1979). The *Colaniella-Reichelina* fauna is a clear indicator of the Tethyan Upper Permian. Based upon smaller foraminifers and fusulinaceans, this Upper Permian can be correlated with the upper part of the Maizuru Group of the Maizuru belt and the Mitai Formation of Kyushu (Ishii, Okimura and Nakazawa, 1975).

The Permian carbonate and volcanics are widely distributed in Kuzuu town and they are grouped into two formations, namely the Nebeyama and Izuru Formations in descending order. The Upper Triassic Adoyama Formation unconformably overlies the Middle Permian Nabeyama Formation with basal conglomerate. The Nabeyama Formation yielding *Parafusulina, Neoschwagerina* and others is subdivided into three members in descending order, the Karasawa Limestone, Hanezuru Dolostone and Yamasuge Limestone Members (Fujimoto, 1961). Recently, Kobayashi (1979) has studied the petrography and sedimentary environment of this formation.

The Karasawa Limestone Member consists mainly of gray to white massive limestones and contains black chert concretions in the upper part of this member. The Hanezuru Dolostone Member consists mainly of gray to white and massive dolostones. These dolostones are secondary in origin and almost barren in fossils (Kobayashi, 1979).



Text-fig. 3. Geological map of the Kuzuu area and conodont collecting localities. AL: Alluvial deposits. M: Maki Formation (sandstone). Ad: Adoyama Formation (chert), AI: Aisawa Formation (sandstone), N: Nabeyama Formation (limestone and dolostone), IZ: Izuru Formation (basic tuff and lava), F: Fault, U: Unconformity and C: Conformity. A: Quarry of the Tokyo Lime Industry Co. Ltd, B: Yamasuge and C: Quarry of the Miyata Lime Industry Co. Ltd.



Text-fig. 4. Columnar section of the Yamasuge Limestone Member of the Quarry of the Tokyo Lime Industry Co. Ltd., showing stratigraphic distribution of conodonts. 1: limestone, 2: limestone with chert concretions, 3: limestone with chert layers 4: limestone breccia, 5: coquinoid limestone, 6: dolostone, 7: basic tuff and lava 8: chert, 9: conglomerate, A: abundant, B: common and C: rare The above symbols are used in all of the following Text-figures.

The Yamasuge Limestone Member is now typically exposed at the quarry of Tokyo Lime Industry Co. Ltd., near Yamasuge (Text-fig. 3). The Yamasuge Limestone Member consists mainly of black or dark gray bedded limestones and frequently intercalates dolomitic and encrinal facies. The Izuru Formation consists mainly of green and purple pyroclastic rocks and intercalates gray limestone lenses. The following succession in descending order can be observed along the artificial outcrop in the quarry (Text-fig. 4).

Conglomerate; comprising various sized pebbles of chert, shale, limestone and dolostone (basal conglomerate of the Triassic Adoyama Formation) ..more than 15 m thick

.... Unconformity ....

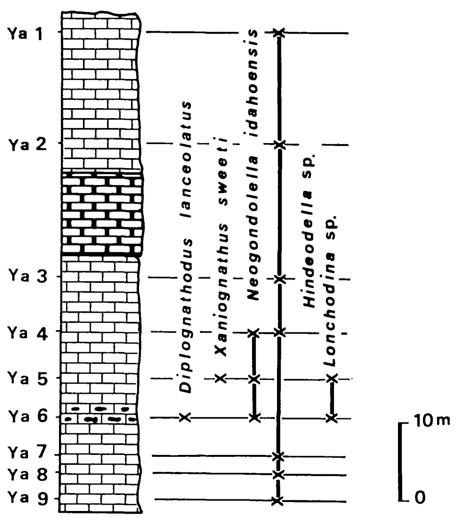
Yamasuge Limestone Member

Dolostone; light yellow and massive ....12 m thick

Limestone; buff, dolomitic with fusulinaceans (contains chert concretions in the upper part)...40 m thick

Limestone; buff, well-bedded, dolomitic, alternates with thin tuffaceous shales, contains chert concretions in the upper part ....10 m thick
Limestone; gray, dolomitic with fusulinaceans..........................35 m thick
Limestone; buff, dolomitic with fusulinaceans ....10 m thick
Limestone; gray well-bedded, bioclastic, alternates with buff thin tuffaceous shales .... 29 m thick
Limestone; gray to buff, dolomitic, with fusulinaceans, chert concretions in the upper part ....27 m thick

Izuru Formation
Pyroclastic rocks; green and purple, intercalate gray limestone lenses ....more than 50 m thick



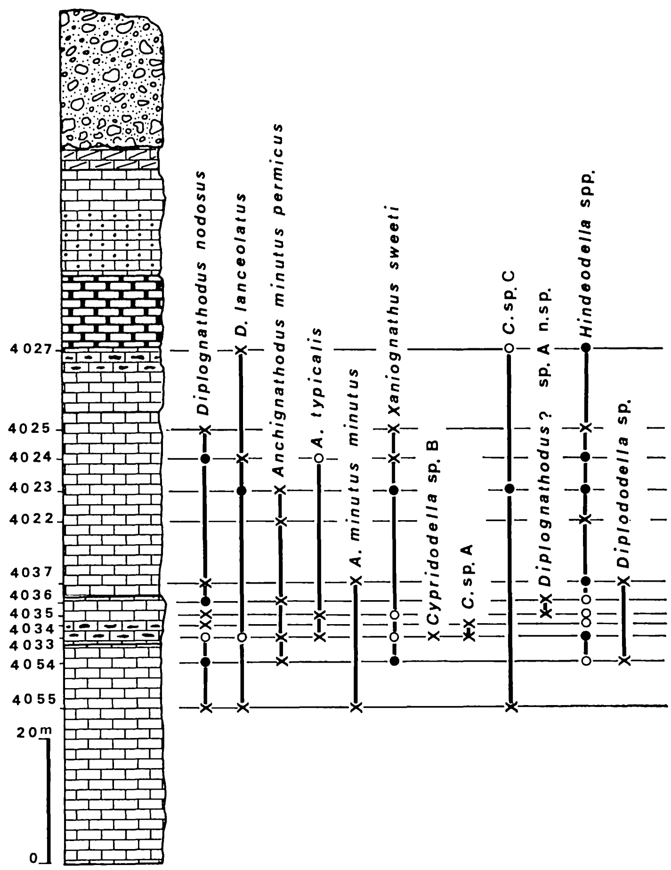
Text-fig. 5. Columnar section of the Yamasuge Limestone Member near the Tenjin Bridge at Yamasuge, showing the stratigraphic distribution of conodonts.

Conodont elements are found throughout this carbonate succession and are particularly abundant in the upper and middle levels. The other conodont locality is situated near the Tenjin Bridge at Yamasuge and the following succession was observed in descending order (Text-fig. 5).

Yamasuge Limestone Member
Limestone; buff, thickly bedded, with bioclasts ......20 m thick
Dolostone; buff, with relics of fusulinacean tests and other fossils ....10 m thick
Limestone; gray, well-bedded, dolomitic with fusulinaceans and other fossil fragments .... 20 m thick
Limestone; buff, well-bedded with fusulinaceans and other fossil fragments, alternates with yellow thin tuffaceous shales and contains chert concretions in the upper part ....10 m thick

The lower and middle parts of this sequence yield conodont elements. The following conodonts are discriminated from the above mentioned sections, namely:—*Anchignathodus minutus permicus* Igo, n. subsp., *Cypridodella* sp. B, *Diplododella* sp., *Diplognathodus lanceolatus* Igo, n. sp., *Lonchodina* sp. D, *Neogondolella idahoensis* (Youngquist, Hawley and Miller), *Neospathodus* cfr. *arcucristatus* (Clark and Behnken), *Xaniognathus sweeti* Igo, n. sp. and fragmental hindeodellid elements.

Other localities with prolific conodonts is the quarry of the Miyata Lime Industry Co., Ltd. (Text-figs. 3, 6) at Nagaami, north of Kuzuu Town. The Karasawa Limestone Member and the Adoyama Formation are exposed in this quarry. The Triassic Adoyama Formation overlies the Karasawa Limestone Member with pronounced unconformity. Stratigraphic significance of this unconformity and detailed succession were



Text-fig. 6. Columnar section of the Quarry of the Miyata Lime Industry Co., Ltd., showing the stratigraphic distribution of conodonts.

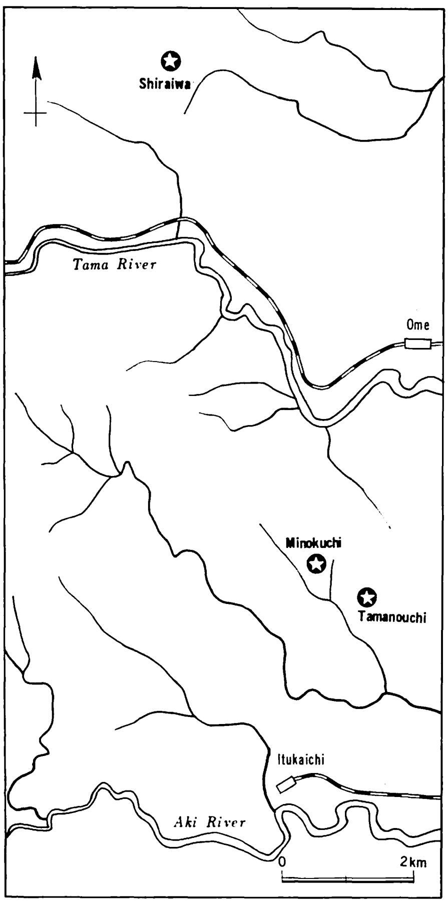
already discussed by Koike *et al.* (1971) and Hisayoshi Igo and Hisaharu Igo (1977). The Karasawa Limestone Member in this quarry yields conodonts, such as, *Anchignathodus minutus minutus* (Ellison), *Anchignathodus minutus permicus* Igo, n. subsp., *Anchignathodus typicalis* Sweet, *Cypridodella* sp. A, *Cypridodella* sp. B, *Cypridodella* sp. C, *Diplododella* sp., *Diplognathodus lanceolatus* Igo, n. sp., *Diplognathodus nodosus* Igo, n. sp., *Diplognathodus*? sp. A n. sp., *Xaniognathus sweeti* Igo, n. sp. and indeterminable hindeodellid elements. Some of these conodonts were reworked and are contained within both the matrix and pebbles of the basal conglomerate of the Adoyama Formation. The type section of the Karasawa Limestone Member at Karasawa yields the same conodont fauna with Nagaami (Text-fig. 3).

As mentioned above, the Nabeyama Formation contains one of the richest Middle Permian conodont faunas in Japan.

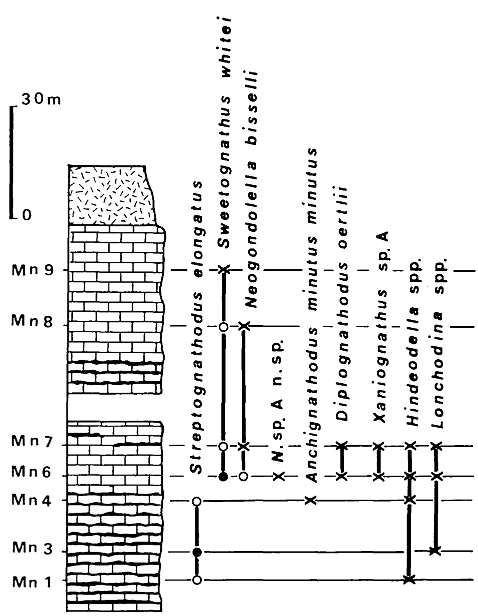
(2) Kwanto Massif

Fossiliferous Carboniferous, Permian and Triassic rocks are exposed along the Tama River and its tributaries about 50 km west of Tokyo. These rocks are narrowly separated from each other by intense folding and faulting and distributed repeatedly showing complicated zonal distribution. The Kitaosoki Formation is one of the lithologic units of the Paleozoic in this area (Ozawa, 1975). It is about 200 m thick and divided into the lower and upper subformations. The lower subformation yields rich Upper Carboniferous fusulinaceans in lenticular limestone. The upper subformation intercalates frequently lenticular limestones. The Shiraiwa Limestone of about 50 m in thickness, exposed at Shiraiwa near Ome City (Text-fig. 7) yields Lower Permian fusulinaceans, such as, *Triticites*? *langsonensis* Saurin, *Pseudoschwagerina minatoi* Kanmera, *Paraschwagerina shimodakensis* Kanmera and many others. This limestone is gray to white, massive to thickly bedded and highly fossiliferous in fusulinaceans and algae. The following conodonts are identified from this limestone, such as :—*Streptognathodus elongatus* Gunnell and *Idiognathodus* cfr. *ellisoni* Clark and Behnken and indeterminable hindeodellid elements but they are rather rare in number of specimens.

Bedded green chert exposed near Tamanouchi (Text-fig. 7), about 5 km northwest of Itukaichi Town in Tokyo, contains many conodonts. *Diplognathodus* sp. B, *Enantiognathus tribulosus* (Clark and Ethington), *Lonchodina* sp. E, *Neogondolella bisselli* (Clark and Behnken), *Sweetognathus whitei* (Rhodes), *Xaniognathus* sp. A and indeterminable hindeodellid elements were recovered by dissolving the rock in dilute hydrofluoric acid.



Text-fig. 7. Map showing the collecting localities of the Ome and Itukaichi districts.



Text-fig. 8. Columnar section of Minokuchi, showing the stratigraphic distribution of conodonts.

The stratigraphic relation among this conodont-bearing chert and other formations is uncertain. This chert, however, is intercalated with thin and discontinuous limestone breccia which contains *Pseudofusulina* sp. Thus, the geologic age of this conodont-bearing chert is probably late Early Permian.

Other conodont-bearing strata are exposed at Minokuchi, northwestern part of Itukaichi Town (Text-fig. 7). The following succession can be observed along the slope of the mountain in descending order (Text-fig. 8).

Tuff; green and partly laminated ....more than 15 m thick
Limestone; gray, tuffaceous, thickly bedded, intercalates thin chert layers in the lower part ....45 m thick
Covered..7 m thick
Limestone; gray with thin chert layers ....6 m thick
Limestone; gray and tuffaceous..10 m thick
Limestone; gray with thin chert layers ....20 m thick
Limestone; gray dolomitic with chert layers ....10 m thick

The following conodonts were yielded in the above mentioned section namely:—*Anchignathodus minutus minutus* (Ellison), *Diploghathodus oertlii* Kozur, *Neogondolella bisselli* (Clark and Behnken), *Neogondolella* n. sp. A, *Lonchodina* spp., *Streptognathodus elongatus* Gunnell, *Sweetognathus whitei* (Rhodes), *Xaniognathus* sp. A and fragmental hindeodellid elements.

(3) Kiso Massif

Permian and Triassic rocks are widely distributed in the Kiso Massif. Some Permian conodonts were collected from the limestone exposed at Uto-Pass near Shiojiri City, Nagano Prefecture (Text-fig. 1). This limestone is recrystallized and almost barren in fossils. Kamei *et al.* (1962) discovered *Waagenophyllum indicum* (Waagen and Wentzel) in this limestone. This coral was very poorly preserved, but Kamei *et al.* correlated the limestone with the upper Middle Permian. The author made a field survey in collaboration with Hisayoshi Igo and Koike in this area. The following poorly preserved conodonts were found; *Diplognathodus* cfr. *movschovitschi* Kozur and Pjatakova, *Diplognathodus*? sp., *Lonchodina* sp. and *Neogondolella* cfr. *orientalis* (Barskov and Koroleva).

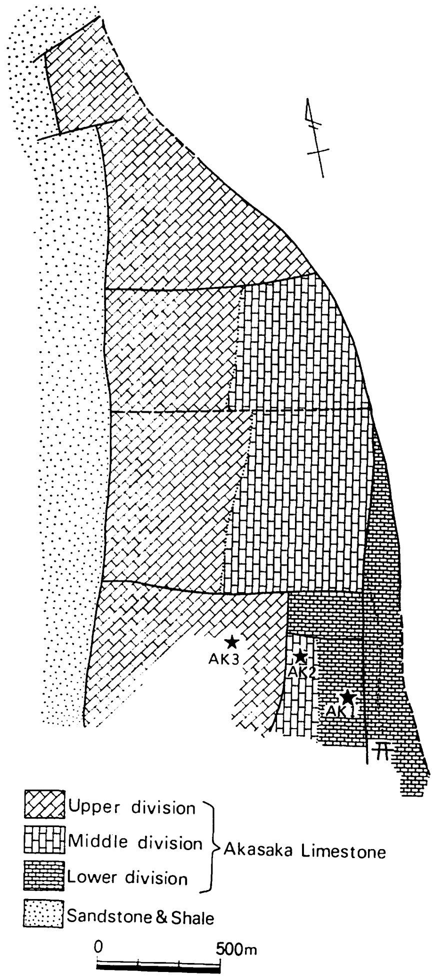
(4) Hida-Mino Massif

Permian and Triassic strata are also widely distributed in this massif.

The Akasaka Limestone exposed in Akasaka, Ogaki City, Gifu Prefecture is one of the most important Permian fossil localities in Japan (Text-figs. 1, 9). It yields abundant fusulinaceans, corals, gastropods, pelecypods, calcareous algae and many others. Fusulinaceans have been repeatedly studied by many investigators. Fifteen fusulinacean zones are established in this limestone (Morikawa 1958). Many limestone samples from various levels of this limestone were collected and dissolved. However, conodont elements are scarce. Conodonts are found in three localities (AK1, AK2, AK3). Limestone collected from AK1 is characterized by the occurrence of *Pseudodoliolina ozawai* Yabe and Hanzawa and correlated with the Nabeyaman Series. Limestone obtained from AK2 is the type of Akasakan Series and contains the various species of *Neoschwagerina*. Samples of AK3 yield *Yabeina*. and represent the Kuman Series. *Diplognathodus nodosus* Igo, n. sp. and *Neostreptognathodus pequopensis* Behnken are found in

AK1. *Diplognathodus* sp. and *Lonchodina muelleri* Tatge are obtained from AK2. *Xaniognathus* sp., indeterminable hindeodellid elements, and gen. et sp. indet. are found in AK3.

Limestone distributed in Nukui, Mugi Village, Mugi County, Gifu Prefecture, situated about 45 km north of Nagoya City (Text-fig. 1), attains about 50 m in thickness and 500 m in lateral extent. According to Kano (1976), this limestone is surrounded by the Wadano conglomerate consisting of chert and shale breccia and seems to be an olistolith. This limestone yields *Pseudodoliolina ozawai* Yabe and Hanzawa (Kanuma, 1958, Mizutani, 1964) and, furthermore, the author identified *Verbeekina verbeeki* (Geinitz), and *Neoschwagerina craticulifera* (Schwager). This limestone contains *Diplognathodus* sp. C and other indeterminable hindeodellid elements.



Text-fig. 9. Geological map (after Morikawa et al., 1956) and conodont collecting localities of the Akasaka Limestone.

The Upper Carboniferous and Permian rocks are widely distributed around Gujio Hachiman, Hachiman Town, Gujio County, Gifu Prefecture (Text-fig. 1). The stratigraphy and paleontology of this district were studied in detail by Kanuma (1958). The Permian conodonts are found in limestone distributed in the southern part of this town. The stratigraphic succession of this area was established by Kanuma (1958) as follows in descending order; The Kayugawa, Shimadani, Kuchibora and Akuda Formations. The Kayugawa Formation consists mainly of sandstones, shales, cherts and small lenticular limestones. Recently, many Triassic conodonts were found from the various levels of this formation by the author. Based on this fact, larger part of this formation is apparently Triassic. The following stratigraphic succession can be obseved along the road cut of Horikoshi-Pass to vicinity of Akuda in descending order (Text-figs. 10, 11).

Shimadani Formation

Chert; well-bedded, green and red ....more than 80 m thick as far as exposed

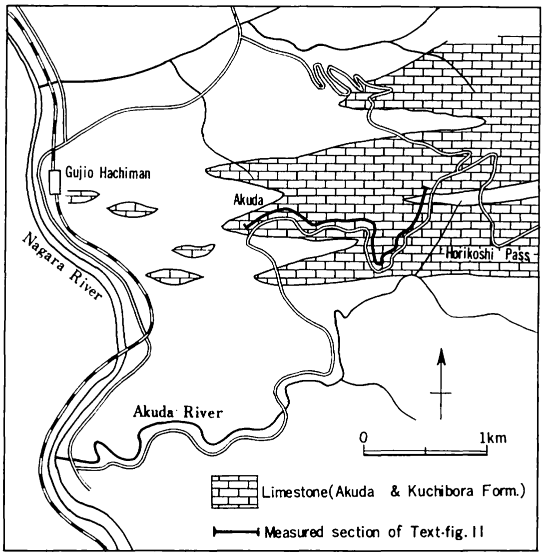
Kuchibora Formation

Tuff; green and purple and basic...............................about 23 m thick

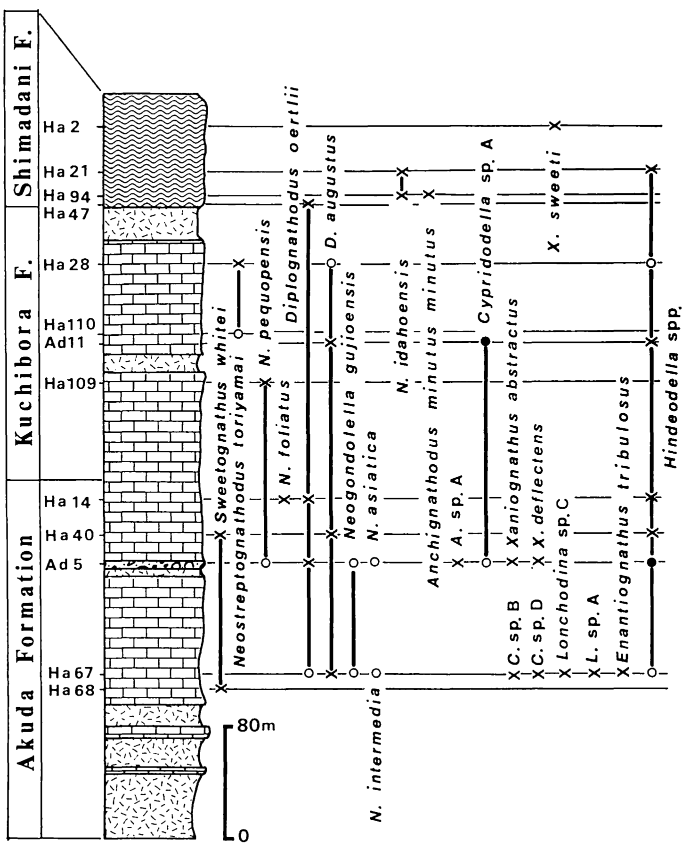
Limestone; black to brown, well-bedded, alternating with thin calcareous shale in the lower part ....80 m thick

Tuff; green and purple and basic.......................................13 m thick

Limestone; black to gray, well-bedded, alternating with thin calcareous shale in



Text-fig. 10. Map showing the collecting localities of Horikoshi-Pass to Akuda section of the Gujio Hachiman district.



Text-fig. 11. Columnar section of the Gujio Hachiman district, showing the stratigraphic distribution of conodonts.

the upper prat ....70 m thick

Akuda Formation

Limestone; white and thickly bedded ....54 m thick

Conglomerate; various sized pebbles of limestone and chert contained in matrix of buff dolomitic limestone ....4 m thick

Tuff; purple and basic ....6 m thick

Limestone; white and thickly bedded ....80 m thick

Tuff; purple and basic ....15 m thick

Limestone; white and massive.....................................8 m thick

Tuff; purple, intercalating limestone pebbles in the upper level ....18 m thick

Limestone; white and massive.....................................3 m thick

Tuff; purple, intercalating limestone pebbles in the upper level ..about 40 m thick

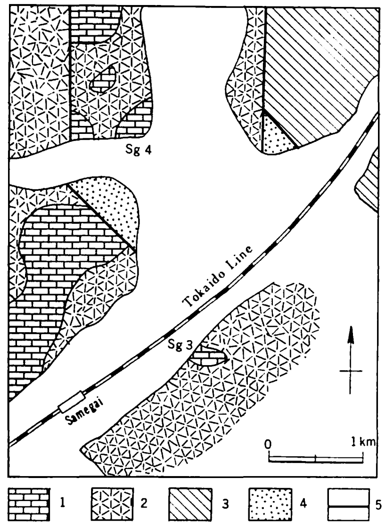
Conodonts were recovered from chert beds in the Shimadani Formation and at various levels of limestone of the Kuchibora and Akuda Formations. It is interesting that many conodonts were recovered from dolomitic limestone which consistutes matrix of conglomerate of the Akuda Formation. Conodont elements are condensed in thin-bedded limestone of the middle part of the Kuchibora Formation. The following conodonts were identified in the above mentioned section; *Anchignathodus minutus minutus* (Ellison), *Anchignathodus* sp. A, *Cypridodella* sp. A, *Cypridodella* sp. D, *Diplognathodus augustus* Igo, n. sp., *Diplognathodus oertlii* Kozur, *Enantiognathus tribulosus* (Clark and Ethington), *Lonchodina* sp. A, *Lonchodina* sp. C, *Neogondolella asiatica* Igo, n. sp., *Neogondolella gujioensis* Igo, n. sp., *Neogondolella idahoensis* (Youngquist, Hawley and Miller), *Neogondolella intermedia* Igo, n. sp., *Neostreptognathodus foliatus* Igo, n. sp., *Neostreptognathodus pequopensis* Behnken, *Neostreptognathodus toriyamai* Igo. n. sp., *Sweetognathus whitei* (Rhodes), *Xaniognathus abstractus* (Clark and Ethington), *Xaniognathus deflectens* Sweet, *Xaniognathus sweeti* Igo, n. sp., and indeterminable hindeodellid elements.

Important Permian fusulinaceans from the various levels of the Akuda and Kuchibora Formations are as follows; *Cancellina nipponica* Ozawa, *Maklaya pamirica* (Leven), *Minojapanella elongata* Fujimoto and Kanuma, *Misellina claudiae* (Deprat), *Neofusulinella paraecursor* Deprat, *Parafusulina* (*Skinnerella*) cfr. *sappeli* (Staff), *Paraschwagerina yanagidai* Igo, *Pseudofusulina horadaniensis* Igo, *Pseudofusulina krotowi* (Schellwien) and *Schwagerina*? *annamitica* (Deprat).

The large limestone mass constituting Mt. Ibuki, is situated in Shiga Prefecture (Text-fig. 1). The stratigraphy and paleontology of the Ibukiyama Limestone have been studied by Kobayashi (1957). The stratigraphy and geological structure have been studied by Miyamura (1967). Kobayashi (1957) divided the Ibukiyama Limestone into four fusulinacean zones and six subzones. The Ibukiyama Limestone intercalates chert beds at many different levels. Conodonts were obtained from thin-bedded limestone immediately above the chert beds in the lower level of *Neoschwagerina craticulifera* subzone. The conodonts discriminated from this thin-bedded limestone are *Neogondolella gujioensis* Igo, n. sp. and indeterminable hindeodellid elements. This conodont assemblage is very meager, but its occurrence from the Middle Permian limestone is important.

The Permian rocks are widely distributed around the foot of Mt. Ibuki. Those in the southern part of Mt. Ibuki consist of cherts, shales, pyroclastic rocks and small limestone masses. The geological study of this area has been done by Miyamura (1967).

These Permian rocks were designated as the Samegai Group and divided into the Samegai and Kiyotaki Formations in descending order. The Kiyotaki Formation is composed mainly of cherts with some intercalations of siliceous shales. The Samegai Formation consists mainly of pyroclastic rocks with intercalation of lenticular limestones. The limestone which yields the conodonts is located at about 1 km east of the Samegai Station of the Tokaido Line of Japan National Railway, Shiga Prefecture (Text-fig. 12). The limestone is well-bedded and tuffaceous, and is correlated with the lower part of the Samegai Formation. The identified conodonts were *Diplognathodus oertlii* Kozur, *Neogondolella bisselli* (Clark and Behnken) and indeterminable hindeodellid elements. *Pseudofusulina* cfr. *krotowi* (Schellwien) occurs in this limestone. The other limestone which yields conodonts is found at about 2 km north of the Samegai Station (Text-fig. 12). The following conodonts were discriminated from this limestone, namely :—*Diplognathodus oertlii* Kozur, *Lonchodina* sp. C, *Neogondolella bisselli* Clark and Behnken), *Neospathodus divergens* (Bender and Stoppel), *Neostreptognathodus pequopensis* Behnken, *Sweetognathus whitei* (Rhodes) and *Xaniognathus abstractus* (Clark and Ethington).



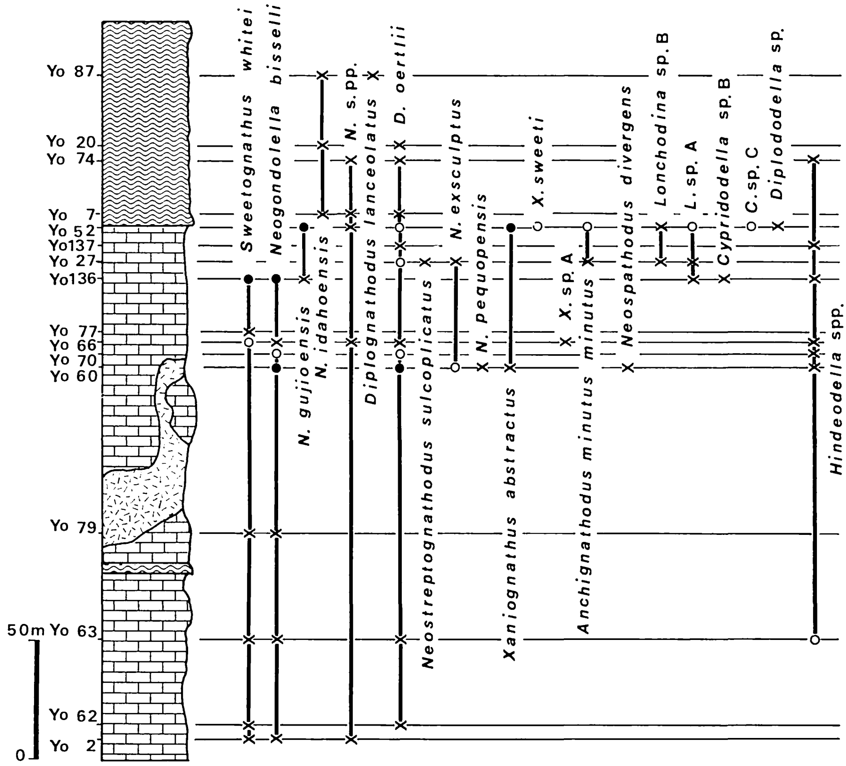
Text-fig. 12. Map showing the collecting localities of the Samegai district. (Geological map is after Miyamura 1967). 1 : Limestone, 2 : basic tuff, 3 : chert, 4 : sandstone and 5 : fault

The Yoro Massif in Gifu Prefecture is constituted by the Permian and Triassic rocks. The geology of this region was studied by Kanuma and Irie (1962). They divided the Yoro Group into the lower and upper subgroups and considered it to be Permian.

Recently, Middle to Upper Triassic conodonts were found from the upper subgroup by the author. Therefore, the upper subgroup should be assigned to not Permian but Triassic in age. The following stratigraphic succession is observed in the northeastern part of this massif, in descending order (Text-Fig. 13).

Chert ; green and gray, well-bedded ....more than 80 m thick
Limestone ; white and gray, well-bedded ....20 m thick
Limestone ; gray, well-bedded with thin chert layers....................10 m thick
Limestone breccia ; buff, changed laterally into tuff and lava ....20 m thick
Limestone ; white, massive and changed laterally into tuff and lava ....25 m thick
Tuff ; green, intercalating basic lava and changed laterally into limestone ....
.... about 30 to 60 m thick
Limstone ; gray and greenish gray, tuffaceous.............. about 10 to 20 m thick
Chert ; red and brown, well-bedded ....5 m thick
Tuff ; green and basic ....10 m thick
Limestone ; gray and white, massive ....20 m thick
Limestone ; gray, intercalated with tuffaceous limstone..................55 m thick

The uppermost part of this succession is a fault contact with Triassic chert. Cono-



Text-fig. 13. Columnar section of the lower subgroup of the Yoro Group, showing the stratigraphic distribution of conodonts.

donts are found throughout this limestone sequence and chert beds, especially in the upper levels. The following conodonts were identified in the above mentioned section, namely :—*Anchignathodus minutus minutus* (Ellison), *Cypridodella* sp. B, *Cypridodella* sp. C, *Diplododella* sp., *Diplognathodus lanceolatus* Igo, n. sp., *Diplognathodus oertlii* Kozur *Lonchodina* sp. A, *Lonchodina* sp. B, *Neogondolella bisselli* (Clark and Behnken), *Neogondolella gujioensis* Igo, n. sp., *Neogondolella idahoensis* (Youngquist, Hawley and Miller), *Neospathodus divergens* (Bender and Stoppel), *Neostreptognathodus exsculptus* Igo, n. sp., *Neostreptognathodus pequopensis* Behnken, *Neostreptognathodus sulcoplicatus* (Youngquist, Hawley and Miller), *Sweetognathus whitei* (Rhodes), *Xaniognathus abstractus* (Clark and Ethington), *Xaniognathus sweeti* Igo, n. sp., *Xaniognathus* sp. A and hindeodellid elements.

The fusulinaceans are not well preserved and not numerous, but such species as *Paraschwagerina* sp., *Pseudofusulina* sp. and *Pseudofusulina vulgaris* (Schellwien) were identified in three levels of this limestone.

Permian rocks are distributed in the northern part of the Suzuka Mountains. Limestone, chert, basic tuff and sandstone are distributed in Ichinose Village, Yoro County, Gifu Prefecture, situated at about 10 km west of Yoro Town. The geological structure of this area was studied by Mizutani (1964). Paleontological study was not done in this area. Limestone beds yielding Permian conodonts are distributed on western mountain slope of Ichinose Village. The following succession can be observed in descending order.

Tuff; green and basic ....more than 20 m thick
Limestone; gray, well-bedded and tuffaceous ....5 m thick
Limestone; buff, alternating with dolostone ....17 m thick
Chert; red and brown, well-bedded ....3 m thick
Limestone; white and gray, thickly bedded..............................7 m thick
Tuff; green and basic ....more than 20 m thick

The following conodonts were identified from the upper part of tuffaceous limestone; *Cypridodella* sp. A, *Lonchodina* sp. B, *Neogondolella bisselli* (Clark and Behnken), *Neogondolella gujioensis* Igo, n. sp., *Neogondolella intermedia* Igo, n. sp., *Neostreptognathodus* aff. *prayi* Behnken, *Neostreptognathodus sulcoplicatus* (Youngquist, Hawley and Miller), *Sweetognathus whitei* (Rhodes), *Xaniognathus abstractus* (Clark and Ethington) and many fragments of conodonts. The fusulinaceans found in the lower part of this limestone are *Paraschwagerina* sp. and *Robustoschwagerina hidensis* Igo.

IV. Conodont Biostratigraphy

On the basis of the stratigraphic distribution of conodont species, the Japanese Lower to Middle Permian is subdivded into four biostratigraphic units. These units are recognized in the Sakamotozawan and also in the Nabeyaman Series. The biostratigraphic zonation of the Akasakan, Kuman and Mitaian Series are almost impossible because they are barren in reliable guide species of conodonts.

The following Faunas and Assemblage zones are established in the Sakamotozawan and Nabeyaman Series in descending order.

Nabeyaman *Diplognathodus lanceolatus-Diplognathodus nodosus* Assemblage Zone

Sakamotozawan
- *Diplognathodus oertlii-Neostreptognathodus pequopensis* Fauna
- *Neogondolella bisselli-Sweetognathus whitei* Assemblage Zone
- *Streptognathodus elongatus* Fauna

1) *Streptognathodus elongatus* Fauna

The *Streptognathodus elongatus* Fauna is recognized typically in limestone cropped out at Minokuchi, northwest of Itukaichi Town and at Shiraiwa, northwest of Ome City, Tokyo. As already mentioned, the stratigraphic position of these limestones are in the upper subformation of the Kitaosoki Formation.

The lower part of the Shiraiwa Limestone at Shiraiwa is characterized by the joint occurrence of *Streptognathodus elongatus* Gunnell and *Idiognathodus* cfr. *ellisoni* Clark and Behnken. Conodont-bearing beds include *Pseudoschwagerina minatoi* Kanmera and other Lower Permian species of fusulinaceans, and thus their geologic age is clearly settled.

Streptognathodus elongatus Gunnell and *Anchignathodus minutus minutus* (Ellison) are found in the lower part of the sequence cropped out at Minokuchi. The sequence is about 30 m thick and consists of limestone and dolostone in alternation with cherts. The conodont fauna from this sequence is entirely monospecific and without any other platform type conodonts. *Pseudofusulina vulgaris*, *Rugosofusulina*? sp. and *Triticites* sp. are found in a particular level of this sequence.

Streptognathodus elongatus was first described by Gunnell from the Americus Limestone of the Virgilian Wabaunsee Group, Upper Pennsylvanian of Kansas. The occurrence of this species has been recorded from the Middle to Upper Pennsylvanian rocks elsewhere in the United States. Rhodes (1963) reported this species in association with *Sweetognathus whitei* (Rhodes) from the top of the Tensleep Sandstone, Wyoming and thought it to be Lower Permian. *Idiognathodus ellisoni* Assemblage zone was defined as a faunal zone in the lower Wolfcampian by Clark and Behnken (1971). This assemblage Zone contains the following conodonts, such as, *Adetognathus gigantus* (Gunnell), *Adetognathus latus* (Gunnell), *Gnathodus bassleri* (Harris and Hollingsworth), *Gnathodus roundyi* Gunnell, *Gondolella bella* Stuffer and Plummer, *Ozarkodina delicatula* (Stuffer and Plummer) and *Spathognathodus minutus minutus* (Ellison). They referred the age of this assemblage zone to late Pennsylvanian? (Desmoinesian?) to early Wolfcampian.

Clark (1974) recognized two conodont faunas namely Fauna A and Fauna B in the Moorman Ranch sequence. Faunas A and B correspond respectively to the *Idiognathodus ellisoni* Assemblage Zone and *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone. Clark stated that these faunas are stratigraphically separated from each other and the evolutionary differences between them are underscored by the subtle ecologic factor. Fauna A thrived in very shallow, nutrient rich water of moderate energy and normal salinity, whereas Fauna B preferred deeper water, perhaps at the limit of the photic zone.

Based upon the above mentioned evidence, the author defines the *Streptognathodus elongatus* Fauna in Japan as extending from the Upper Carboniferous to the first appearance of *Sweetognathus whitei* (Rhodes). Upper part of this Fauna is equivalent to the lower part of the Zone of *Pseudoschwagerina*, *Pseudoschwagerina morikawai* subzone. It is also correlated with the *Idiognathodus ellisoni* Assemblage Zone of the United States.

2) *Neogondolella bisselli—Sweetognatus whitei* Assemblage Zone

This zone is recognized in the upper sequence immediately above the *Streptognathodus elongatus* Fauna at Minokuchi near Itukaichi Town, Tokyo. It is also recognized in green chert distributed in Tamanouchi, north of Itukaichi. The lower division of the Yoro Group, about 210 m thick, and the Ichinose Limestone, both distributed in Yoro Town, Yoro County, Gifu Prefecture yield the fauna belonging to this assemblage zone. The lower part of the Samegai Formation distributed near Samegai, Shiga Prefecture and the Akuda Formation of Gujio Hachiman, Hachiman Town, Gujio County, Gifu Prefecture also contain conodonts belonging to this zone. The characteristic species of this assemblage zone are as follows:

Anchignathodus sp. A
Cypridodella sp. A
Cypridodella sp. B
Cypridodella sp. C
Cypridodella sp. D
Diplognathodus augustus Igo, n. sp.
Diplognathodus oertlii Kozur
Diplognathodus sp. B
Enantiognathus tribulosus (Clark and Ethington)
Lonchodina sp. A

Lonchodina sp. B
Lonchodina sp. C
Lonchodina sp. E
Neogondolella asiatica Igo, n. sp.
Neogondolella bisselli (Clark and Behnken)
Neogondolella gujioensis Igo, n. sp.
Neogondolella intermedia Igo, n. sp.
Neogondolella sp. A, n. sp.
Neostreptognathodus exsculptus Igo, n. sp.
Neostreptognathodus foliatus Igo, n. sp.
Neostreptognathodus pequopensis Behnken
Neostreptognathodus aff. *prayi* Behnken
Neostreptognathodus sulcoplicatus (Youngquist, Hawley and Miller)
Neospathodus divergens (Bender and Stoppel)
Sweetognathus whitei (Rhodes)
Xaniognathus abstractus (Clark and Ethington)
Xaniognathus deflectenus Sweet
Xaniognathus sp. A

This zone is defined by the range of *Neogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes).

Characteristic species of this zone is *Sweetognathus whitei* (Rhodes) which was first described from the Tensleep Sandostone, Wyoming. Behnken (1975) also recorded this species from the lowest 90 feet of the Pequop Formation of Nevada. This formation has been correlated with the Upper Wolfcampian of Texas. *Diplognathodus oertlii* Kozur is also an important species in this zone. This species was originally introduced as the early growth stage of *Gnathodus sicilianus* Bender and Stoppel from the Socio Stage of Sicily. This species is rather widely distributed in Japan. Its range extends into the overlying *Diplognathodus oertlii—Neostreptognathodus pequopensis* Fauna.

Anchignathodus sp. A is only recorded from the upper part of the Akuda Formation in Gujio Hachiman. *Diplognathodus augustus* Igo, n. sp. is found in the uppermost division of the Akuda Formation and throghout the overlying Kuchibora Formation. *Diplognathodus* sp. A occurs in a chert cropped out near Tamanouchi. This species denotes the lower to middle part of this zone.

Lonchodina sp. A and *Lonchodina* sp. B are recovered from chert layers in Tamanouchi, the Akuda Formation in Gujio Hachiman and the Lower Subgroup of the Yoro Group in Yoro. These two species of *Lonchodina* are characteristic of the middle and upper parts of this zone.

Neogondolella asiatica Igo, n. sp. is found in the middle part of the Akuda Formation of Gujio Hachiman. This species has a characteristic shape of platform and with very small basal cavity. It will be a reliable index fossil after a detailed examination of its lateral distribution. *Neogondolella intermedia* Igo, n. sp. is an important species in this zone and is found in Gujio Hachiman in association with *Neogondolella asiatica* and also from Ichinose. These two species of *Neogondolella* are confined within the upper part of this zone.

Neogondolella bisselli (Clark and Behnken) is known from several regions of Japan and is associated with *Sweetognathus whitei* (Rhodes). This species was originally reported from the Riepetown Sandostone of Nevada by Clark and Behnken (1971). Behnken (1975) pointed out the occurrence of this species from the lower 250 feet of the Pequop Formation of Nevada. Kozur (1978) recorded the occurrence of this species from the Ural Mountains and others. The author collected this species from the lower part of the Samegai Formation, near Samegai, lower part of the Yoro Group, Ichinose, and 30 m above the base of the sequence in Minokuchi and chert layers in Tamanouchi. Therefore, the range of this species comprises the entire zone of *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone.

Neogondolella sp. A, n. sp. is only recovered from the level situated 35 m above the base in the Minokuchi section. This species is characterized by a very small basal cavity, posteriorly pointed slender loop, keel expanded at the middle of platform and other remarkable features. The proposal of a new specific name is suspended until many complete specimens will be accumulated. The unidentified species is characterized by similar biocharacters to *Neogondolella asiatica* Igo, n. sp. and *Neogondolella gujioensis* Igo, n. sp. which appear in the upper part of this zone. The author became aware of evolutionally change from *Neogondolella* sp. A, n. sp. to *Neogondolella gujioensis* through *Neogondolella asiatica*. Descendant of *Neogondolella gujioensis* is obscure because any allied species does not occur in the younger levels. Behnken (1975) concluded that *Neogondolella bisselli* is an ancestral species of all the subsequent species of *Neogondolella*. The author came to conclude that the other *Neogondolella* lineage, *Neo gondolella* sp. A, n. sp.—*Neogondolella asiatica—Neogondolella gujioensis* existed during the Permian. This problem will be discussed in detail on another occasion.

Neostreptognathodus foliatus Igo, n. sp. is also an important species in the Japanese Permian and is found in the upper part of the Akuda Formatin of Gujio Hachiman. *Neostreptognathodus pequopensis* Behnken is recorded from the upper part of the Akuda Formation, upper part of the lower division of the Samegai Formation and ranges up into the next younger *Diplognathodus oertlii—Neostreptognathodus pequopensis* Fauna. This species was described from the Ferguson Mountain Formation and the Arcutus Limestone in Nevada. These units are equivalent to the Upper Wolfcampian to Leonardian, therefore, the stratigraphic occurrence of this species in Japan is quite identical with that in the United States.

Neostreptognathodus sulcoplicatus (Youngquist, Hawley and Miller) was found from the Phosphoria Formation of Idaho. Behnken's (1975) stratigraphic study showed that the species occurs from the Middle to Upper Leonardian and extends to the Middle Guadalupian. In Japan this species occurs in the Lower Subgroup of the Yoro Group, the *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone, associated with *Neogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes). This evidence shows that this species appears earlier in Japan than in the United States.

Neostreptognathodus aff. *prayi* Behnken collected from Ichinose coexists with *Neogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes). This species is recorded from the Upper Leonardian to Lower Guadalupian in North America. Therefore, this species also occurs in earlier beds in Japan compared with those of the United States.

Neospathodus divergens (Bender and Stoppel) occurs in the lower subgroup of the

Yoro Group, upper part of the *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone, distributed in the Yoro Massif. This species was originally described from the Zechstein I in Germany (Bender and Stoppel, 1965). Several species belonging to *Xaniognathus* appear from the middle to upper part of the Lower Permian in Japan as mentioned below.

Xaniognathus deflectens Sweet was recovered from the upper part of this zone in the lower part of the Yoro Group. This interesting species was originally reported from the Lower Triassic Minawai Formation, Salt Range, Pakistan. This is the first record of the occurrence of this species from the Permian.

Xaniognathus abstractus (Clark and Ethington) was recovered from the upper division of the Akuda Formation and from limestone near Ichinose Village. It is associated with *Neogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes). This species was originally reported from the Bone Springs Formation (Leonardian) by Clark and Ethington.

Xaniognathus sp. A came from the chert beds exposed near Tamanouchi, the middle part of Minokuchi section and the lower subgroup of Yoro Group. This species is somewhat similar to *Xaniognathus tortilis* (Tatge).

As mentioned above, there are some differences in stratigraphic occurrences of conodont species in Japan, North America and Europe. The geuns *Diplognathodus* appears in this zone. *Diplognathodus oertlii* Kozur appears earlier than in Europe. On the other hand, some species have the same range as in North America. *Neogondolella bisselli* (Clark and Behnken), *Sweetognathus whitei* (Rhodes) and *Neostreptognathodus pequopensis* Behnken have almost similar stratigraphic distribution in Japan as in North America. These species seem to be excellent guide species for intercontinental correlation.

The *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone in the Japanese Lower Permian can be correlated with the same zone in the United States. As clearly defined in Minokuchi, the first appearance of the above mentioned two species is the same as the first appearance of a characteristic fusulinacean species, *Pseudofusulina vulgaris* which is widespread in Japan as well as in the Tethyan realms. *Neogondolella bisselli* and *Sweetognathus whitei* disappear abruptly at the upper limit of the Akuda Formation in Gujio Hachiman. *Misellina claudiae* (Deprat) occurs at the base of the Kuchibora Formation which conformably overlies the Akuda Formation. The above mentioned evidence shows that the present conodont zone is equivalent to the middle part of the Zone of *Pseudoschwagerina*, that is the *Pseudofusulina vulgaris* Subzone.

3) *Diplognathodus oertlii—Neostreptognathodus pequopensis* Fauna

This faunal unit is recognized in the entire part of the Kuchibora Formation about 160 m in thickness in Gujio Hachiman, Hachiman Town, Gifu Prefecture. It is also recognized in bed, only 5 m thick, 220 m above the base of the upper division of the lower formation of the Yoro Group cropped out near Yoro Town, Yoro County, Gifu Prefecture. This faunal unit is proposed for the interval between the *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone and the *Diplognathodus lanceolatus—Diplognathodus nodosus* Assemblage Zone.

The following species are characteristic:

Anchignathodus minutus minutus (Ellison)

Cypridodella sp. A
Diplognathodus augustus Igo, n. sp.
Diplognathodus oertlii Kozur
Lonchodina sp. A
Lonchodina sp. B
Lonchodina sp. C
Neogondolella gujioensis Igo, n. sp.
Neostreptognathodus pequopensis Behnken
Neostreptognathodus toriyamai Igo, n. sp.
Xaniognathus abstractus (Clark and Ethington)
Xaniognathus sweeti Igo, n. sp.

This fauna is characteristic of the joint occurrence of *Diplognathodus oertlii* Kozur and *Neostreptognathodus pequopensis* Behnken and entirely lacks the association of *Sweetognathus whitei, Neogondolella bisselli* and *Diplognathodus lanceolatus* Igo, n. sp.

Diplognathodus oertlii Kozur is not confined to this fauna. It appeared in the underlying zone and further survived in the *Diplognathodus lanceolatus—Diplognathodus nodosus* Assemblage Zone. This species occurs in the lower part of the Kuchibora Formation and Lower Subgroup of the Yoro Group. *Lonchodina* sp. A ranges from the underlying *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone to the middle part of this faunal unit. *Cypridodella* sp. A occuring in the upper part of Akuda Formation, ranges throughout this zone and extends to the next younger zone.

Neostreptognathodus pequopensis Behnken also ranges through this faunal unit and is recorded from the upper Akuda Formation to the middle part of the Kuchibora Formation. However, this species is restricted to the previous zone in the lower subgroup of the Yoro Group.

The stratigraphic relation between this conodont faunal unit and fusulinacean zone of the Kuchibora Formation is as follow. Limestone sequence, about 100 m thick, in the lower part of Kuchibora Fromation yields *Misellina claudiae* (Deprat). *Maklaya pamirica* (Leven) yields from 45 m above the last occurrence of *Misellina claudiae. Misellina claudiae* indicates the Upper Sakamotozawan and *Maklaya pamirica* denotes the Lower Nabeyaman. Therefore, the *Diplognathodus oertlii—Neostreptognathodus pequopensis* Fauna is correlated with the upper part of the Zone of *Pseudoschwagerina*, i.e. *Misellina claudiae* Subzone. The upper part of this faunal unit may correspond to the lower part of *Maklaya pamirica* Subzone in Japan and other Tethyan realms. This conodont faunal unit seems to be correlated with Behnken's *Neostreptognathodus pequopeesis* Assemblage Zone in North America.

4) *Diplognathodus lanceolatus—Diplognathodus nodosus* Assemblage Zone

This zone is defined by the range of *Diplognathodus lanceolatus* Igo, n. sp.. *Diplognathodus nodosus* Igo, n. sp. appears from the middle part of this zone and it disappears at the top of this zone. This zone is recognized in the Shimadani Formation and chert beds of the upper part of the lower subgroup of the Yoro Group. The lower limit of this zone coincides with the base of the Shimadani Formation and also the base of chert beds overlying the limestones of lower subgroup of the Yoro Group. The Nabeyama Formation of the Kuzuu district, Tochigi Prefecture is almost equivalent to this biostratigarphic unit.

This zone is characterized by the following species:

Anchignathodus minutus minutus (Ellison)
Anchignathodus minutus permicus Igo, n. subsp.
Anchignathodus typicalis Sweet
Cypridodella sp. A
Cypridodella sp. B
Cypridodella sp. C
Diplododella sp.
Diplognathodus lanceolatus Igo, n. sp.
Diplognathodus nodosus Igo, n. sp.
Diplognathodus? sp. A, n. sp.
Lonchodina sp. D
Neogondolella idahoensis (Youngquist, Hawley and Miller)
Neospathodus cfr. *arcucristatus* Clark and Behnken
Xaniognathus sweeti Igo, n. sp.

Anchignathodus minutus permicus Igo, n. subsp. and *Anchignathodus typicalis* Sweet are found in this zone, but the latter species is known from the higher zones in the United States and Pakistan. *Diplognathodus lanceolatus* Igo, n. sp. occurs abundantly in the Yamasuge Limestone Member of the Lower Nabeyama Formation in the quarry of the Tokyo Lime Industry Co. Ltd. This species occurs throughout the section of the Yamasuge Limestone Member in the quarry, but it is confined to one level in the type section of this member. This species is also recovered from the chert layers overlying the limestones of Lower Subgroup of the Yoro Group.

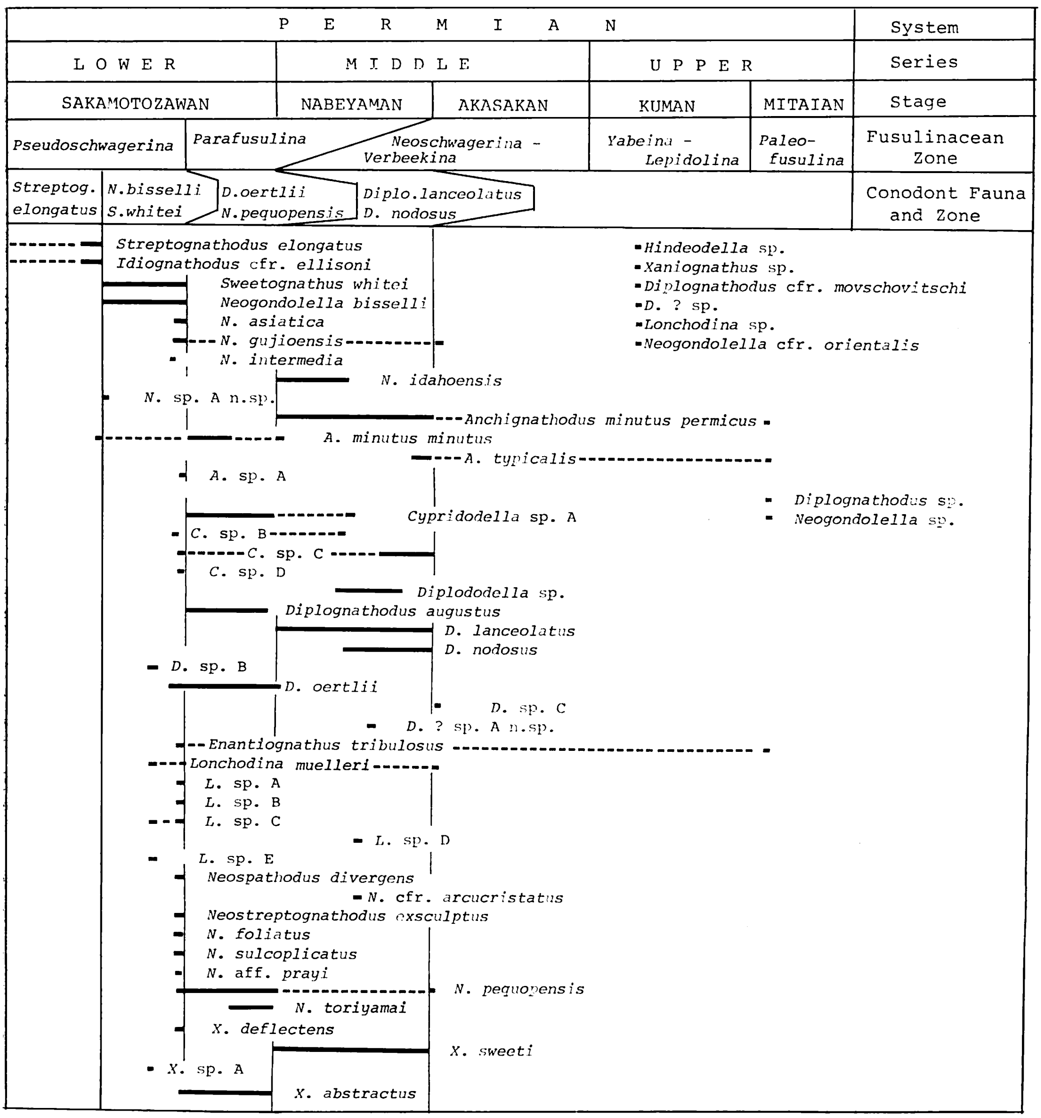
Diplognathodus nodosus Igo, n. sp. occurs successively in limestone beds from about 20 m above the base of the Karasawa Limestone Member of the Upper Nabeyama Formation exposed in the quarry of the Miyata Lime Industry Co. Ltd. in Nagaami, north of Kuzuu. *Diplognathodus nodosus* and *Diplognathodus lanceolatus* occur jointly in the Karasawa Limestone Member distributed in Karasawa, type section of this member, and Kadozawa in Kuzuu Town.

Neogondolella idahoensis (Youngquist, Hawley and Miller) is a characteristic species in the lower part of this assemblage zone and is recovered from cherts of the Shimadani Formation in Gujio Hachiman, throughout the Yamasuge Limestone Member in the quarry of the Tokyo Lime Industry Co. Ltd. and also from the same lithostratigraphic unit of Yamasuge, Kuzuu. This species was originally reported from the Phosphoria Formation of Idaho, North America (Youngquist, Hawley and Miller, 1951). Recently, Behnken (1975) has added localities of this species, such as, the Bone Spring Limestone, Victorio Peak Formation in the Guadalupe Mountains of West Texas, and the Phosphoria Formation of Utah and Wyoming. These formations are correlated with the Leonardian of Texas. *Xaniognathus sweeti* Igo, n. sp. occurs throughout this biostratigraphic unit, which occupies the Shimadani Formation in Gujio Hachiman. It is also recorded from the lower division of the Yoro Group and the Yamasuge Limestone Member in the quarry of the Tokyo Lime Industry Co. Ltd. in the Kuzuu district. Based upon the above mentioned field occurrences, this species may represent the lower division of this assemblage zone.

Anchignathodus typicalis Sweet occurs from 35 m above the base of the Karasawa

Limestone Member cropped out in Nagaami north of Kuzuu. It is also recovered from the limestome containinig the Upper Permian *Colaniella—Reichelina* fauna exposed in the Akiyama area of Kuzuu Town. This species was described from the uppermost Permian to the lowermost Triassic in the Salt and Trans Indus Ranges, Pakistan (Sweet, 1970b).

Anchignathodus minutus permicus Igo, n. subsp. is rather long ranging. It is found in the upper Yamasuge Limestone Member cropped out in the quarry of the Tokyo Lime Industry Co. Ltd., the Karasawa Limestone Member cropped out in the quarry of the Miyata Lime Industry Co. Ltd., and further in the Upper Permian limestone of the Akiyama area north of Kuzuu Town. The present discovery is important because *Anchignathodus typicalis* was thought as an index species of the Upper Permian and



Text-fig. 14. Distribution of stratigraphically important Permian conodonts in Japan.

Lower Triassic (Sweet, 1970b; Kozur, 1975). The *Diplognathodus lanceolatus—Diplognathodus nodosus* Assemblage Zone is correlated with the *Neostreptognathodus pequopensis* Assemblage Zone established by Behnken (1975) in the United States.

5) Conodont Faunas of the Akasaka Series

Conodonts from the Akasakan Series are rather poor and detailed zonation remains to be done. *Diplognathodus* sp. C occuring in the Nukui Limestone, Mugi Village, Mugi County, Gifu Prefecture is one of the most important conodonts in the Akasakan. *Neogondolella gujioensis* Igo, n. sp. from the Ibukiyama Limestone Group and *Lonchodina muelleri* Tatge and *Diplognathodus* sp. from the Akasaka Limestone are also representatives of this series. *Neogondolella gujioensis* appears from the upper part of the *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone and extends into the Akasakan. *Lonchodina muelleri* Tatge is a long ranging species and has been known from the Triassic.

6) Conodont Eaunas of the Kuman and Mitaian Series

Conodont faunas of these series are also poorly known in Japan. *Hindeodella* sp., *Xaniognathus* sp. and other unidentified fragments are recovered from the Akasaka Limestone associated with *Yabeina globosa* (Yabe).

Diplognathodus cfr. *movschovitschi* Kozur and Pjatakova, *Diplognathodus*? sp., *Lonchodina* sp. and *Neogondolella* cfr. *orientalis* (Barskov and Koroleva) occur in the limestone cropping out at Uto-Pass, near Shiojiri City, Nagano Prefecture. Other conodont fauna represented in the Mitaian Series occurs in a limestone lens cropped out in the Akiyama area of Kuzuu, Tochigi Prefecture. The following species are recovered in association with *Colaniella* and *Reichelina*:—*Anchignathodus minutus permicus* Igo, n. subsp., *Anchignathodus typicalis* Sweet, *Diplognathodus* sp., *Enantiognathus tribulosus* (Clark and Ehtington), *Neogondolella* sp. and indeterminable hindeodellid elements. Conodont faunas from the *Neoschwagerina margaritae* Zone and the *Yabeina* Zone consist of a few taxa and individuals. There is a tendency, however, to increase the diversity and number of individuals of conodonts in the *Colaniella—Reichelina* fauna compared with the mentioned underlying zone.

V. Conclusion

As a result of the investigation of the Japanese Permian conodonts, the author discriminated 13 genera and 44 species including 12 new species and one new subspecies. Based upon the stratigraphic occurrence of these conodonts and previously known fusulinaceans, the author has attempted to establish biostratigraphic subdivisions of the conodont faunas.

Two assemblage zones and two faunal units are newly proposed in the Lower and Middle Permian, they are the *Streptognathodus elongatus* Fauna, *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone and *Diplognathodus oertlii—Neostreptognathodus pequopensis* Fauna in the Sakamotozawan and the *Diplognathodus lanceolatus —Diplognathodus nodosus* Assemblage Zone in the Nabeyaman.

The *Streptognathodus elongatus* Fauna is characterized by species surviving from the Upper Carboniferous. The Upper Carboniferous species entirely disappeared in the *Neogondolella bisselli—Sweetognathus whitei* Assemblage Zone and are replaced by such

Permian elements, as *Sweetognathus* and *Neostreptognathodus*.

The species of *Sweetognathus* became extinct at the beginning of the *Diplognathodus oertlii—Neostreptognathodus pequopensis* Fauna. Some species of *Neostreptognathodus*, however, still persisted to the upper levels.

Many species of *Diplognathodus* flourished in the *Diplognathodus lanceolatus—Diplognathodus nodosus* Assemblage Zone. *Anchignathodus typicalis* which characterizes the Uppermost Permian to Lowest Triassic first appeared in the mentioned zone.

Conodonts decrease both in number of species and individuals in the Akasakan and Kuman Series, but they became slightly abundant in the Mitaian Series.

VI. Description of Species

Genus *Anchignathodus* Sweet, 1970

Anchignathodus minutus minutus (Ellison), 1941

Pl. 10, Figs. 5, 8, 11

Spathodus minutus Ellison, 1941, p. 120, pl. 20, figs. 50-52.
Spathognathodus minutus (Ellison), Merrill, 1973, pl. 1, figs. 1-15, pl. 2, figs. 1-28.
Anchignathodus minutus (Ellison), Kozur, 1975, (partim), pp. 5-7, pl. 1, figs. 1-15, (non fig. 16).

Remarks:—Merrill (1973) discussed the Pennsylvanian *Spathognathodus* element and recognized three distinct phylogenic lineages. Based upon many specimens of *Spathognathodus minutus* (Ellison), he fully described this subspecies. Detailed synonymy list was also given by Merrill (1973). This subspecies closely resembles *Anchignathodus minutus permicus* Igo, n. subsp.

Occurrence:—Gujio Hachiman (Shimadani Formation) and Yoro (Lower Subgroup of Yoro Group), Gifu Prefecture. Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member of the Nabeyama Formation) and Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member of the Nabeyama Formation) in Kuzuu Town and Akiyama (Awano Group) north of Kuzuu Town, Tochigi Prefecture. Minokuchi (Raidenyama Formation) near Itukaichi Town, Tokyo.

Geologic age:—Early Sakamotozawan to Mitaian.

Reg nos. TGU. 1965, 1568, 1570.

Anchignathodus minutus permicus Igo, n. subsp.

Pl. 10, Figs. 1-4

Anchignathodus minutus (Ellison), Behnken, 1975, p. 297, pl. 1, figs. 16-18; Kozur, 1975, (partim), pp. 5-7, pl. 1, fig. 16, (non figs. 1-15).

Diagnosis:—In lateral view, aboral margin is moderately concave in region occupied by basal cavity which is posteriorly situated at half length of element. Aboral margin of anterior to basal cavity is straight. Anterior and posterior margins are subparalell. Anterior edge forms an angle of about 80 degrees with aboral margin and slightly concave or straight. Posterior edge forms an angle of about 90 degrees with the posterior aboral margin. Anterior outline rarely has three or two tiny coalesced denticles. About ten subequal, laterally compressed, short and coalesced denticles are developed throughout cusp, except for posterior one or two tiny denticles. Cusp is high, pointed and trianglar in shape, occupying a quarter length of element at base, generally twice as long as other denticles and up to two or three times as wide. Denticles are confluent near base. In oral view, outline of cup is elliptical to cardioid. Widest position located posteriorly to the center of unit.

Remarks:—Lateral view of *Anchignathodus minutus permicus* is rectangular to trapezoid, but *Anchignathodus minutus minutus* has subtriangular outline. *Anchignathodus minutus permicus* Igo, n. subsp. has fewer denticles (10-11) than those of *Anchignathodus minutus minutus* (Ellison) (13). *Anchignathodus minutus minutus* has an angle of 45 degrees between aboral margin and anterior edge, but *Anchignathodus minutus permicus* has an angle of about 80 degrees. Total heights of blade and denticles of *Anchignathodus minutus permicus* are higher than those of *Anchignathodus minutus minutus.*

Occurrence:—Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member of the Nabeyama Formation) and Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member of the Nabeyama Formation) in Kuzuu Town and Akiyama (Awano Group) north of Kuzuu Town, Tochigi Prefecture.

Geologic age:—The Late Nabeyaman to Mitaian.

Reg. nos. TGU. 1561, 1562 (Holotype), 1563, 1564.

Anchignathodus typicalis Sweet, 1970

Pl. 10, Figs. 6, 7, 9, 12

Anchignathodus typicalis Sweet, 1970a, pp. 7, 8, pl. 1, figs. 13, 22; Sweet, 1970b, p. 222, pl. 1, figs. 13, 20; Behnken, 1975, p. 297, pl. 2, fig. 12; Wang, 1978, p. 215, pl. 1, figs. 26-28.

Remarks:—This sepcies is characterized by slightly arched and gradually decreasing height of unit toward posterior end. In lateral profile, this species can thereby be differentiated from *Anchignathodus minutus minutus* (Ellison). Blade of this species is shorter than that of *Anchignathodus minutus permicus.* The stratigraphical occurrence of *Anchignathodus typicalis* extends into the Upper Leonardian and further younger units in Japan. Behnken (1975) reported this species from the South Wells Member of the Cherry Canyon Formation through the Radar Member of the Bell Canyon Formation of Texas.

Occurrence:—Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member) in Kuzuu Town and Akiyama (Awano Group) north of Kuzuu, Tochigi Prefecture.

Geologic age:—Late Nabeyaman to Mitaian.

Reg. nos. TGU. 1566, 1567, 1569, 1571.

Anchignathodus sp. A

Pl. 10, Fig. 10

Description:—Minute spathognathodid element consists of anteriorly compressed, high blade, large cusp and elliptical basal cavity. In lateral view, outline of oral margin forms a straight line except for cusp. Anterior half of element is a blade consisting of discrete minute denticles, half fused together posteriorly. Anterior cusp is four times wider and more than three times higher than adjacent denticles. Aboral outline strongly curved at anterior part of basal cavity. In oral view, cusp is symmetrical with smooth surface. In aboral view, deepest point of basal cavity is at posterior one-third of length of unit and continues anteriorly as a slit along aboral surface of blade.

Remarks:—This species strongly resembles *Anchignathodus parvus* Kozur and Pjatakova, but the former is distinguished from the latter in having large and deep basal cavity.

Occurrence:—Gujio Hachiman (Akuda Formation), Gifu Prefecture.

Geologic age:—Upper Middle Sakamotozawan.

Reg. no. TGU. 1658.

Genus *Cypridodella* Mosher, 1968

Cypridodella sp. A

Pl. 12, Figs. 8-10

Description:—Element is composed of laterally compressed posterior bar and main cusp. Usually posterior bar and main cusp meet at about 30 degrees. Posterior bar is slightly robust and very long. Denticles are equal, sharply pointed, discrete and angled about 30 degrees to main cusp. Main cusp without denticles is sharply pointed and slightly bowed inward. It is about twice as long as other denticles and three times as wide as other ones near the base and slightly expanded at base inwardly. Aboral margin of both processes forms a low ridge on inner side of process. Aboral side of both processes is traversed by a fine groove terminating in deep basal cavity.

Occurrence:—Gujio Hachiman (Akuda and Kuchibora Formations) and Ichinose (unnamed formation), Gifu Prefecture. Samegai (Samegai Formation), Shiga Prefecture. Quarry of the Miyata Lime Industry Co. Ltd. (Yamasuge Limestone Member) north of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Late Middle Sakamotozawan to Middle Nabeyaman.

Reg. nos. TGU. 1604, 1605, 1607.

Cypridodella sp. B

Pl. 12, Figs. 3, 4

Description:—Element with long and slightly compressed posterior bar projects downward. Long, slender, and discrete denticles on posterior bar are subparallel or slightly oblique to main cusp. Short anterior bar without denticles projects downward. In lateral profile, posterior bar and main cusp meet at an angle of about 80 degrees. Main cusp slightly bows inward. Aboral side of both bars is traversed by a fine groove terminated in a deep basal cavity.

Remarks:—This species is easily distinguishable from *Cypridodella* sp. C by long and sharply pointed denticles and greater angle between posterior bar and main cusp.

Occurrence:—Gujio Hachiman (Akuda Formation) and Yoro (Lower Subgroup of Yoro Group), Gifu Prefecture. Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge

Limestone Member) of Kuzuu Town, Tochigi Prefecture.

Geologic age :—Late Middle Sakamotozawan to Late Nabeyaman

Reg. nos. TGU. 1610, 1611.

Cypriodella sp. C

Pl. 12, Fig. 15

Description :—Element possesses a long posterior bar which projects strongly downward, slightly arched and bowed inward. Denticles on posterior bar are equal in size, discrete, sharply pointed and rounded in cross section. Short main cusp without denticles projects at an angle of 40 degrees to posterior bar. Main cusp is large, slightly curved inward and slightly compressed. Aboral side of both bars is traversed by a narrow groove continued into deep conical basal cavity below main cusp.

Remarks :—This unidentified species resembles *Synprioniodina microdenta* Ellison, but the former carries discrete and equal sized denticles and does not bear any denticles on main cusp.

Occurrence :—Yoro (Lower Subgroup of Yoro Group), Gifu Prefecture and Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member) north of Kuzuu Town, Tochigi Prefecture.

Geologic age :—Late Middle Sakamotozawan to Late Nabeyaman.

Reg. no. TGU. 1621.

Cypridodella sp. D

Pl. 11, Fig. 14

Description :—This small element is composed of slightly long denticles and an arched posterior bar. Short and fine denticles stand on posterior bar. These denticles are discrete and slightly inclined to main cusp. Posterior bar steeply bows inward. Main cusp is slightly large and steeply bows posteriorly. Aboral edge of main cusp projects downward. Very small nodes appear along left edge of main cusp when viewed from anterior.

Occurrence :—Gujio Hachiman (Akuda Formation), Gifu Prefecture.

Geologic age :—Late Middle Sakamotozawan.

Reg. no. TGU. 1596.

Genus *Diplododella* Bassler, 1925

Diplododella sp.

Pl. 12, Figs. 1, 7

Description :—Element is symmetrical with small basal cavity beneath posteriorly inclined main cusp. Short anterior lateral bars stretch downward and bear subequal four to five denticles inclined posteriorly. Main cusp and denticles of posterior bar incline posteriorly at about 45 degrees to posterior bar. Very fine grooves stretch out on oral side of three bars and joint at basal pit.

Remarks:—This single element species probably coincides with *Ellisonia tribulosa* (Clark and Ethington), LAl-element of multi-element species.

Occurrence:—Yoro (lower subgroup of Yoro Group), Gifu Prefecture. Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member) and Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member) of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Late Middle Sakamotozawan to Late Nabeyaman.

Reg. no. TGU. 1630, 1631.

Genus *Diplognathodus* Kozur and Merrill, 1975

Diplognathodus augustus Igo, n. sp.

Pl. 8, Figs. 1-8

Diagnosis:—Element has a large basal cavity and expanded smooth cup. In oral view, unit consists of a straight and weakly-denticulated carina and vertically extremely compressed, asymmetrically cardioid cup above the basal cavity. Cup is asymmetrical at maturity but symmetrical in early growth stage. Widest part of cup is slightly anterior to its center. Weak growth lines are commonly developed on cup at maturity. In transverse section at a right angle to carina, surface of cup weakly bends but is steep near margin, therefore it forms a ridge parallel to the outline of cup. Posterior end of carina does not reach to posterior end of cup.

In lateral view, oral margin almost straight except for upwardly elevated anterior extremity and downwardly curved posterior part. Aboral margin is straight. Anterior edge of free blade is straight. Free blade has minute denticles in posterior part and large denticle in anterior part. Boundary between sharply ridged carina and denticulated blade is situated at slightly posterior to anterior terminal of basal cavity. In aboral view, basal cavity is large and asymmetrical, deepest in anterior one-quarter and continuing anteriorly as a narrow groove along aboral surface of short anterior blade.

Comparison:—This new species resembles *Diplognathodus oertlii* Kozur but the latter has more convex cup and minute denticles on the carina and its posterior end of carina reaches to the posterior end of cup. This new species is difficult to distinguish from the latter in early growth stage.

Occurrence:—Gujio Hachiman (Akuda and Kuchibora Formations), Gifu Prefecture

Geolagic age:— Late Sakamotozawan to Early Nabeyaman.

Reg. nos. TGU. 1526 (Holotype), 1525, 1527, 1528, 1529, 1530, 1531, 1532.

Diplognathodus lanceolatus Igo, n. sp.

Pl. 9, Figs. 1-5, 7, 8, 13

Diagnosis:—Elongate gnathodid element has a large basal cavity. In oral view, element is almost straight to slighlty bowed and consists of denticulted carina and lanceolate cup. Oral surface of cup is completely lacking ornamentation. Widest part of cup is at anterior one-third or one-quarter of total length of cup. In lateral view, element is slightly arched and anteriorly high. Posterior part of oral margin is curved downward to meet aboral margin at low angle, approaching to 30 degrees. Anterior two or three denticles of blade are high and large, and others gradually decrease their height posteriorly. Denticles of anterior part of carina are confluent, forming a ridge. Anterior and posterior two or three denticles are more or less discrete. In aboral view, basal cavity is symmetrical and large to occupy posterior half of unit. Its deepest portion is situated at anterior one-third of its length. It continues anteriorly as a groove up to one-third length of aboral surface of blade.

Comparison and remarks:—This new species closely resembles *Diplognathodus nodosus* Igo, n. sp., but the former has smooth cup and gently curved oral margin at posterior end of element. Also, this species closely resembles *Gnathodus commutatus* (Branson and Mehl), but the latter is Late Mississippian species. Therefore, *Diplognathodus lanceolatus* Igo, n. sp. and *Gnathodus commutatus* (Branson and Mehl) are thought to be evolutionary homoeomorphs. *Diplognathodus nodosus* is restricted in the upper member of the Nabeyama Formation, but *Diplognathodus lanceolatus* Igo, n. sp. is yielded in the lower to upper members of the Nabeyama Formation. The above mentioned difference in stratigraphic occurrence and morophology of *Diplognathodus lanceolatus* and *Diplognathodus nodosus* shows close resemblance with that of *Gnathodus commutatus* and *Gnathodus nodosus* Bischoff.

Occurrence:—Yoro (lower subgroup of Yoro Group), Gifu Prefecture. Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member) and Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member) of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Nabeyaman.

Reg. nos. TGU. 1541 (Holotype), 1542, 1543, 1544, 1545, 1546, 1548, 1553.

Diplognathodus nodosus Igo, n. sp.

Pl. 9, Figs. 6, 9-12

Diagnosis:—In oral view, unit slightly bows and consists of denticulated carina and elliptical to cardioid cup. Oral surface of cup is relatively flat and is provided with tiny nodes disorderly and its widest part is located near midpoint of unit. Carina consists of confluent node-like denticles. In lateral view, oral and aboral margins are generally parallel to each other. Posterior end of unit has abrupt offset. Denticles of carina are confluent, especially in anterior half, but one or two denticles on posterior end are discrete. Denticles in anterior half of blade are discrete and increase their height anteriorly. In aboral view, basal cavity is slightly asymmetrical and large.

Comparision:—This species closely resembles *Diplognathodus lanceolatus* Igo, n. sp., but the former has many nodes on the cup and abrupt posterior terminus. *Gnathodus nodosus* Bischoff closely resembles this species, but the former has less numerous and larger nodes than those of the present new species.

Occurrence:—Akasaka Limestone (Lower division), Gifu Prefecture and Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member) of Kuzuu Town, Tochigi, Prefecture.

Geologic age:—Upper Nabeyaman.

Reg. nos. TGU. 1547 (Holotype), 1549, 1550, 1551, 1552.

Diplognathodus oertlii Kozur, 1975

Pl. 8, Figs. 9-16

Gnathodus sicilianus Bender and Stoppel, 1965, p. 341, pl. 14, figs. 2a, 2b, (non figs. 1,3; pl. 16, fig. 23).
Diplognathodus oertlii Kozur, 1975, p. 11, (not figured).

Description:—Minute spathognathodid element consists of laterally compressed high blade, large basal cavity and expanded bell-shaped cup. Posterior carina is non-denticulated or has fused denticles. In lateral view, element is small with expanded cup. Posterior carina consists of highly fused denticles and its posterior end terminates at posterior end of cup. Anterior blade is high and provided with five or six discrete denticles gradually increasing in height and width anteriorly. In oral view, element consists of cardioid smooth cup and carina which subdivides the cup into two parts. Anterior denticulated part extends over anterior one-third of basal cavity. In aboral view, element dominated by large, deep basal cavity and its deepest point is at anterior one-half and continues anteriorly as a narrow groove along aboral surface of anterior blade.

Remarks:—While Bender and Stoppel (1965) considered that this species represents an early growth stage of *Gnathodus sicilianus* Bender and Stoppel, Kozur (1975) separated the former from the latter at species-level.

Occurrence:—Gujio Hachiman (Akuda and Shimadani Formations), and Yoro (lower subgroup of Yoro Group), Gifu Prefecture. Samegai (Samegai Formation), Shiga Prefecture. Minokuchi (Raidenyama Formation) near Itukaichi Town, Tokyo.

Geologic age:—Middle to Late Sakamotozawan.

Reg. nos. TGU. 1533, 1534, 1535, 1536, 1537, 1538, 1539, 1540.

Diplognathodus? sp. A, n. sp.

Pl. 9, Fig. 16

Description:—In oral view, element is subtriangular with sharply pointed posterior end. It has nondenticulated straight carina and asymmetrical nodes or ridges. Deep troughs are developed along both side of carina. In lateral view, element is straight, and carina and nodes are of the same height. Posterior end of unit forms an abrupt angle about 90 degrees with oral margin. In aboral view, symmetrical large basal cavity has its deepest point at anterior one-third of its length. Aboral margin of platform is flared.

Remarks:—The specimens obtained were only two elements and lost anterior blade. Therefore, proposal of a new species is suspended.

Occurrence:—Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member), north of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Late Nabeyaman.

Reg. no. TGU. 1556.

Diplognathodus sp. B

Pl. 9, Figs. 17-20

Description:—Cup is smooth or with tiny one or two nodes. Blade is short, with moderately high anterior series of denticles. Posterior blade is denticulated and abruptly truncated posteriorly. In oral view, denticulated carina is straight at center of cup. Blade is short and less than half length of unit. Cup is irregularly expanded and generally smooth, but may be ornamented by one or two tiny node-like structures near posterior end of cup. In lateral view, cup is not appreciably arched. Anterior blade is high and gradually decreases posteriorly. Denticles are not differentiated into two types as in type species of this genus. These denticles are not confluent, but pointed and triangular in shape. Basal cavity occupies posterior half or more of unit. Posterior termination of denticles produces fan-like pattern. In aboral view, asymmetrical basal cavity is more expanded on outer side with deepest portion near the center of cavity and continues anteriorly as a groove along aboral surface of blade.

Remarks:—*Diplognathodus* sp. B resembles *Diplognathodus nodosus* Igo, n. sp. but it is distinguished from the latter by its shorter anterior free blade.

Occurrence:—Green bedded chert lens (Raidenyama Formation) at Tamanouchi near Itukaichi Town, Tokyo.

Geologic age:—Middle Sakamotozawan.

Reg. nos. TGU. 1557, 1558, 1559, 1560.

Diplognathodus sp. C

Pl. 9, Figs. 14, 15

Description:—In oral view, element consists of asymetrical cup with obsolete nodes and straight carina. Outer side of cup is semicircular and inner side is triangular in shape. In lateral view, slightly arched blade increases in height anteriorly, and anterior denticles of blade are discrete and roundly crested. Carina is straight and consists of a laterally compressed spatula-like ridge. In aboral view, basal cavity is asymmeterical and large. Its deepest portion is located at center.

Remarks:—This species closely resembles *Diplognathodus nodosus* Igo, n. sp. but it is distinguished from the latter by its highly asymmetrical cup and carina with spatula-like ridge. *Diplognathodus* sp. B is also similar to the present species, but *Diplognathodus* sp. C is larger than *Diplognathodus* sp. B and has less distinct nodes and characteristic carina with spatula-like ridge.

Occurrence:—Limestone lens of Nukui, Mugi Village, Mugi County, Gifu Prefecture.

Geologic age:—Early Akasakan.

Reg. nos. TGU. 1554, 1555.

Genus *Enantiognathus* Mosher and Clark, 1965

Enantiognathus tribulosus (Clark and Ethington), 1962

Pl. 12, Fig. 5

Spatognathus tribulosus Clark and Ethington, 1962, p. 107, pl. 1, figs. 3, 5, 13, 17.
Enantiognathus tribulosus (Clark and Ethington), Mosher and Clark, 1965, p. 559, pl. 65, fig. 6.

Ellisonia tribulosa (Clark and Ethington), Behnken, 1975, p. 303-306 pl. 2, figs. 1-4, 6.

Remarks:—Behnken proposed a multi-element species *Ellisonia tribulosa* which is composed of U-, LA2- and LC-elements. *Enantiognathus tribulosus* (Clark and Ethington) of a single element species identified as LA-2 and LC-elements of *Ellisonia tribulosa* (Clark and Ethington).

Occurrence:—Gujio Hachiman (Akuda Formation), Gifu Prefecture and Akiyama (Awano Group) north of Kuzuu Town, Tochigi Prefecture.

Geologic age:— Late Middle Sakamotazawan and Mitaian.

Reg. no. TGU. 1639.

Genus *Idiognathodus* Gunnell, 1933

Idiognathodus cfr. *ellisoni* Clark and Behnken

Pl. 7, Fig. 11

cfr. *Idiognathodus ellisoni* Clark and Behnken, 1971, pp. 435, 436, pl. 1, figs. 15-21; Clark, 1974, pl. 2, figs. 6, 7; Behnken, 1975, p. 306 (not figured).

Remarks:—The present material is fragmentary but with posterior platform. Accessory lobe is not well developed and transverse ridge is rather discontinuous in anterior part of platform as in the case of *Streptognathodus*. This specimen probably represents an immature stage.

Occurrence:—Shiraiwa Limestone (Kitaosoki Formation), western part of Ome City, Tokyo.

Geologic age:—Early Sakamotozawan.

Reg. no. TGU. 1521.

Genus *Lonchodina* Bassler, 1925

Lonchodina muelleri Tatge, 1956

Pl. 12, Fig. 16

Lonchodina muelleri Tatge, 1956, p. 133, pl. 5, fig. 15; Huckriede, 1958, pp. 151, 152, pl. 10, figs. 9, 16, 17, pl. 11, figs. 8, 9, pl. 12, figs. 28, 29, pl. 14, figs. 9, 33, 36; Hirschman, 1959, pp. 61-66, pl. 5, figs. 18-21; Bender and Stoppel, 1965, p. 347, pl. 15, figs. 12-14; Wang, 1978, p. 219, pl. 1, figs. 10, 11, 21.

Remarks:—The present material is poorly preserved. This species is known from the Triassic rocks in Europe and Japan, but Bender and Stoppel (1965) also recorded the occurrence of this species from the Permian of West Germany.

Occurrence:—Green bedded chert lens (Raidenyama Formation) at Tamanouchi near Itukaichi Town, Tokyo and Akasaka Limestone, Gifu Prefecture.

Geologic age:—Middle Sakamotozawan to Early Akasakan.

Reg. no. TGU. 1641.

Lonchodina sp. A

Pl. 12, Figs. 11, 12

Description:—Main cusp is long, sharply pointed and slightly bowed at posterior side. Element is triangular in posterior view. Two short lateral processes are provided with three to four short and sharply pointed denticles which are discrete in upper one-third of their length. Two denticles developed at both sides of main cusp are one-third length of main cusp. Basal cavity is located beneath main cusp and extends to both lateral processes as groove. Posterior margin of basal cavity flares upward.

Remarks:—This species resembles *Lonchodina* sp. E in having high and slightly long lateral processes, but the former carries shorter and lower lateral processes.

Occurrence:—Gujio Hachiman (Akuda Formation) and Yoro (lower subgroup of Yoro Group), Gifu Prefecture.

Geologic age:—Late Middle to Middle Late Sakamotozawan.

Reg. nos. TGU. 1616, 1619.

Lonchodina sp. B

Pl. 12, Fig. 17

Description:—Element is laterally compressed with denticulated posterior and anterior bars. Posterior process has five to seven denticles of irregular size. Upper one-third of denticles is discrete and sharply pointed. Main cusp is rather small and slightly longer than other denticles. Posterior process meets anterior one at a right angle. Denticles are fifteen to seventeen, laterally compressed and small. Basal cavity underside of main cusp is small and extends to posterior and anterior processes as a thin groove.

Remarks:—This unidentified species closely resembles the Genus *Xaniognathus* but it can be distinguished from the latter by long posterior process, numerous posterior denticles and bent posterior process.

Occurrence:—Ichinose (unnamed formation), Gifu Prefecture.

Geologic age:—Late Middle Sakamotozawan.

Reg. no. TGU. 1598.

Lonchodina sp. C

Pl. 12, Figs. 13, 14

Description:—Element is small, symmetrical, laterally compressed and slightly bowed posteriorly. Lateral processes respectively have two sharply pointed, slender and discrete denticles. Main cusp has laterally compressed fringe and sharp lateral edges in posterior part and is rhomboidal in cross section. Small basal pit is located beneath posteriorly inclined cusp.

Remarks:—This species resembles *Ellisonia tribulosa* (Clark and Ethington) LA-element (Behnken 1975, pl. 12, fig. 2) but it is distinguished from the latter by less numerous denticles and laterally compressed fringe of cusp.

Occurrence:—Gujio Hachiman (Akuda Formation) and Yoro (lower subgroup of Yoro Group), Gifu Prefecture, Samegai (Samegai Formation), Shiga Prefecture and green bedded chert lens (Raidenyama Formation) at Tamanouchi near Itukaichi Town, Tokyo.

Geologic age:—Middle Sakamotozawan.

Reg. nos. TGU. 1627, 1628.

Lonchodina sp. D

Pl. 11, Fig. 15

Description:—Element is laterally compressed and slightly bowed inside. Anterior process is short with two or three discrete, small, sharply pointed denticles. Posterior process is longer than anterior one. Denticles of posterior process are discrete, sharply pointed and larger than anterior ones. Lateral processes are strongly compressed laterally. Main cusp is high and sharply edged at both posterior and anterior margins. Inner side of main cusp has a remarkable rounded ridge. In lateral view, aboral margin is strongly arched and flared at the margin of basal cavity. Basal cavity is developed beneath main cusp and extended to lateral processes as a groove.

Remarks:—This species closely resembles *Lonchodina muelleri* Tatge, but the latter is characterized by long discrete denticles.

Occurrence:—Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member) of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Early Nabeyaman.

Reg. no. TGU. 1597.

Lonchodina sp. E

Pl. 12, Fig. 6

Description:—Element is slightly symmetrical. Lateral processes are high and laterally compressed and have coalescent and small denticles. Main cusp is large, sharply pointed, slightly inclined posteriorly with relatively large and conical basal cavity.

Remarks:—This species resembles *Lonchodina muelleri* Tatge, but it is distinguished from the latter by coalescent and short denticles.

Occurrence:—Green bedded chert lens (Raidenyama Formation) at Tamanouchi near Itukaichi Town, Tokyo.

Geologic age:—Middle Sakamotozawan.

Reg. no. TGU. 1638.

Genus *Neogondolella* Bender and Stoppel, 1965

Neogondolella asiatica Igo, n. sp.

Pl. 2, Figs. 1-13

Diagnosis:—In oral view, element is symmetrical, broad and inflated lanceolate in shape. Carina is composed of nine or more denticles; anterior three denticles are discrete and laterally compressed and others are very low and fused. Middle part of carina is the lowest. Relatively large cusp developed on posterior end of platform. Platform extends full length of unit and its margins are bowed gently upward. It is widest at a half length and tapers posteriorly abruptly and anteriorly gradually. Broad and shallow lateral furrow is present along the carina. In aboral view, lower surface bears broad keel. Basal groove extends entire length of keel and ends in small shallow basal cavity which locates at posterior one-fifth and is surrounded by a thin loop.

Comparison and remarks:—This new species resembles *Neogondolella carinata* (Clark), but the former is distinguished from the latter in having broader platform and keel.

Ontogenetic changes of morphology of this species are not so remarkable but some features do noticeably. While in early growth stage it has a large high cusp, discrete denticles on the carina, high and narrow keel and remarkable basal groove, it has thin broad and obscure keel and small basal cavity in mature stage.

Occurrence:—Gujio Hachiman (Akuda Formation), Gifu Prefecture.

Geologic age:—Late Middle Sakamotozawan.

Reg. nos. TGU. 1431 (Holotype), 1427, 1428, 1429, 1430, 1432, 1433, 1434, 1435, 1436, 1437, 1438, 1439.

Neogondolella bisselli (Clark and Behnken), 1971

Pl. 1, Figs. 1-10, 14, 17-19

Gondolella bisselli Clark and Behnken, 1971, p. 429, pl. 1, figs. 12-14.
Neogondolella bisselli (Clark and Behnken), Behnken, 1975, p. 306, pl.1, figs. 27, 31.
Neogondolella cfr. *bisselli* (Clark and Behnken), Malkowski and Szaniawski, 1976, p. 82, pl. 1, fig. 1.

Remarks:—The element has sharply pointed and fewer denticles in early growth stage than in the mature. Cusp is sharply pointed, and loop is high above basal cavity. Reticulate micro-ornamentation is observable on the oral surface of the platform. Characteristic deep troughs are developed along both sides of the carina, but they are rather shallow in mature individuals.

Occurrence:—Ichinose (unnamed formation), Yoro (lower subgroup of Yoro Group), Gifu Prefecture; Samegai (Samegai Formation), Shiga Prefecture; Green bedded chert lens (Raidenyama Formatian) at Tamanouchi near Itsukaichi Town, Tokyo.

Geologic age:—Middle Sakamotozawan.

Reg. nos. TGU. 1409, 1410, 1411, 1412, 1413, 1414, 1415, 1416, 1417, 1418, 1419, 1423, 1426, 1427.

Neogondolella gujioensis Igo, n. sp.

Pl. 3, Figs. 1-19; Pl. 4, Figs. 1-6

Diagnosis:—In oral view, element is laterally subsymmetrical, lanceolate and highly arched. Carina is composed of anterior four or five discrete, laterally compressed denticles and a posterior nodose ridge. Posterior cusp exists at the posterior end, but it is not well developed in most adult specimens. Platform extends in full length of unit and its both sides are subparallel in central part. Anterior one-third of platform is subtriangular with rounded point. Margins of platform bow upward. Surface of platform is smooth to granular with shallow and broad lateral furrow. In aboral view, lower surface bears broad keel. Obscure groove is connected to small basal cavity, which is surrounded by loop.

Comparison:—Ontogenetic changes are not so distinct, but in early growth stage the element bears large posterior cusp extended beyond posterior end. Thin loop appears surrounding basal cavity and narrow basal groove is developed in early growth stage. In mature stage, conspicuous posterior cusp disappears. Obscure basal groove, low and broad obscure keel and small rounded cusp are characteristic in this stage. Lateral furrow in early growth stage is shallower than that of mature stage. This species resembles *Neogondolella bisselli* (Clark and Behnken), particularly in early growth stage, but the former is distinguishable from the latter in having relatively short and posteriorly broadened platform. This species resembles *Neogondolella idahoensis* (Youngquist, Hawley and Miller), but the former can be easily distinguished from the latter by the features of the lower surface, i. e. *Neogondolella gujioensis* Igo, n. sp. has broad keel, but *Neogondolella idahoensis* has narrow one. Furthermore, the latter has remarkable basal groove which is lacking or obscure in the former.

Occurrence:—Gujio Hachiman (Akuda Formation) and Ichinose (unnamed formation), Gifu Prefecture and Mt. Ibuki (Ibukiyama Limestone Group), Shiga Prefecture.

Geologic age:—Late Middle Sakamotozawan and Early Akasakan.

Reg. nos. TGU. 1454 (Holotype), 1440, 1441, 1442, 1443, 1444, 1445, 1446, 1447, 1448, 1449, 1450, 1451, 1452, 1453, 1455, 1456, 1457, 1458, 1459, 1460, 1461, 1462, 1463, 1464.

Neogondolella idahoensis (Youngquist, Hawley and Miller), 1951

Pl. 1, Figs. 11-13, 15, 16

Gondolella idahoensis Youngquist, Hawley and Miller, 1951, p. 361, pl. 54, figs. 1-3, 14, 15; Clark and Ethington, 1962, p. 108, pl. 2, figs. 15, 16; Clark and Mosher, 1966, p. 388, pl. 47, figs. 9-12; Clark and Behnken, 1971, p. 431, pl. 1, fig. 9.

Gondolella phosphoriensis Youngquist, Hawley and Miller, 1951, p. 362, pl. 54, figs. 10-12, 27, 28; Clark and Ethington 1962, p. 108, pl. 2, figs. 17, 18.

Neogondolella idahoensis (Youngquist, Hawley and Miller), Behnken, 1975, pp. 306, 307, pl. 1, figs. 28-30; Wang, 1978, pp. 220, 221, pl. 2, figs. 23-26; Szaniawski and Malkowski, 1979, pp. 246, 247, pl. 4, figs. 1-8, pl. 5, figs. 5a, b.

Remarks:—Behnken (1975) pointed out that this species is different from other Permian species of *Neogondolella* in the feature of platform without any ornamentation. Most of the Japanese Permian species of *Neogondolella* are *Neogondolella idahoensis*-type. However, *Neogondolella serrata serrata*-type with transverse ridge on platform is rarely yielded in chert.

Occurrence:—Gujio Hachiman (Shimadani Formation), Gifu Prefecture; Quarry of the Tokyo Lime Industry Co. Ltd. and Yamasuge (Yamasuge Limestone Member) of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Late Sakamotozawan to Early Nabeyaman.

Reg. nos. TGU. 1420, 1421, 1422, 1424, 1425.

Neogondolella intermedia Igo, n. sp.

Pl. 4, Figs. 7-11

Diagnosis:—In oral view, element is laterally subsymmetrical and composed of carina and platform. Carina is composed of discrete, laterally compressed anterior denticles of irregular size and node-like posterior ones. Cusp is small and roundly pointed. Lowest part of carina exists in center of platform. Discrete denticles appear throughout on carina in early growth stage. Platform extends in full length of element with the widest part at the middle, and its margins are subparallel to longitudinal axis of unit in posterior two-thirds. Anterior end of element is pointed and posterior end is roundly square. Relatively deep lateral furrows appear along both sides of carina. Surface of platform is granular. In aboral view, small basal cavity is situated beneath posterior cusp and surrounded by a relatively large, rounded to square loop. Aboral keel consists of relatively raised ridges in mature stage, but it is thin-walled and narrow in early growth stage.

Comparison:—This species resembles *Neogondolella bisselli* (Clark and Behnken) and *Neogondolella idahoensis* (Youngquist, Hawley and Miller). Characteristic morphology is recognized in these three species: i. e. *Neogondolella bisselli* has roundly pointed posterior end, discrete rounded denticles and roundly pointed small loop. *Neogondolella intermedia* has roundly square posterior end, fused high denticles in the anterior half, slightly small cusp and relatively large and rounded square loop. *Neogondolella idahoensis* has square posterior end, discrete high denticles in the anterior half, fused node-like denticles in the posterior half, large cusp, and large and square loop. Behnken (1975) pointed out that *Neogondolella bisselli* is the ancestral form of *Neogondolella idahoensis*. The author agrees with his opinion and considers that *Neogondolella intermedia* represents an evolutionary link between *Neogondolella bisselli* and *Neogondolella idahoensis*.

Occurrence:—Gujio Hachiman (Kuchibora Formation) and Ichinose (unnamed formation), Gifu Prefecture.

Geologic age:—Early Late Sakamotozawan.

Reg. nos. TGU. 1469 (Holotype), 1465, 1466, 1467, 1468.

Neogondolella sp. A, n. sp.

Pl. 4, Fig. 12

Description:—In oral view, element is laterally subsymmetrical, lanceolate with sharply pointed posterior end and widest near center. Platform is slightly bowed upward anteriorly and flat posteriorly. Surface of platform is minutely granulated. Shallow lateral furrows are present on both sides of anterior carina. Carina is composed of node-like denticles. Anterior end is unknown because of no complete specimens were obtained. In lateral view, element is arched slightly and carina projects over upper surface of platform. In aboral view, thin-walled and relatively wide keel with V-shaped cross section appears on aboral surface. Basal cavity is small and surrounded by small posteriorly pointed loop.

Remarks:—The specimen is imcomplete but is safely referred to *Neogondolella* by the above noted features. *Neogondolella bisselli* (Clark and Behnken) and this unidentified species are oldest *Neogondolella* in Permian. *Neogondolella* sp. A, n. sp. probably ancestor of *Neogondolella gujioensis* Igo, n. sp. and *Neogondolella asiatica* Igo, n. sp. These species have small, posteriorly pointed loop and laterally inflated keel.

Occurrence:—Minokuchi (Raidenyama Formation) near Itukaichi Town, Tokyo.

Geologic age:—Early Middle Sakamotozawan.

Reg. no. TGU. 1470.

Genus *Neospathodus* Mosher, 1968

Neospathodus cfr. *arcucristatus* Clark and Behnken, 1971

Pl. 12, Fig. 2

cfr. *Neospathodus arcucristatus* Clark and Behnken, 1971, p. 436, pl. 2, figs. 1, 2, 5; Behnken, 1975, p. 309, pl. 2, fig. 8.

Remarks:—The present specimens differ from the holotype described by Clark and Behnken in fewer number of the anterior denticles and smaller basal cavity. Identification is reserved for future because of poor preservation of the present material.

Occurrence:—Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member) of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Middle Nabeyaman.

Res. no. TGU. 1633.

Neospathodus divergens (Bender and Stoppel), 1965

Pl. 12, Figs. 18, 19

Spathognathodus divergens Bender and Stoppel, 1965, pp. 350, 352, pl. 16, figs. 1, 2, 21.

Neospathodus divergens (Bender and Stoppel), Clark and Behnken, 1971, pp. 436, 437, pl. 2, fig. 6; Behnken, 1975, p. 309, (not figured).

Remarks:—This species can be readily discriminated from *Neospathodus arcucristatus* by smaller number of denticles and absence of posterior denticles.

Occurrence:—Yoro (lower subgroup of Yoro Group), Gifu Prefecture and Samegai (Samegai Formation), Shiga Prefecture.

Geologic age:—Late Middle Sakamotozawan.

Reg. nos. TGU. 1600, 1601.

Genus *Neostreptognathodus* Clark, 1972

Neostreptognathodus exsculptus Igo, n. sp.

Pl. 5, Figs. 2, 3a, b, 4a, b

Diagnosis:—In oral view, the element is laterally subsymmetrical, elongate and sharply pointed posteriorly. Platform is provided with twelve to fifteen transverse ridges. Well developed deep, narrow median trough extends through platform. Transverse ridges are slightly inclined to median trough in posterior half of platform and take irregular attitude in anterior half. In lateral view, the element is slightly arched and free blade has laterally compressed, high and discrete denticles. Lower surface of blade slightly curved upward. In aboral view, basal cavity is elongate, large, deepest at center of platform and extends as a narrow groove into the free blade.

Comparison:—This new species resembles *Neostreptognathodus sulcoplicatus* (Youngquist, Hawley and Miller), but it is distinguished from the latter by its numerous transverse ridges. This species resembles *Neostreptognathodus foliatus* Igo, n. sp., but the former is easily distinguished from the latter by its narrow platform with deep, narrow median trough. All the specimens in hand are mature form, and therefore, ontogenetic development of this species is unknown.

Occurrence:—Yoro (lower subgroup of Yoro Group) and Ichinose (unnamed formation), Gifu Prefecture.

Geologic age:—Early Late Sakamotozawan.

Reg. nos. TGU. 1478 (Holotype), 1477, 1479.

Neostreptognathodus foliatus Igo, n. sp.

Pl. 5, Fig. 6

Diagnosis:—The element is elongate, laterally asymmetrical. Platform is high, sharply pointed posteriorly and provided with ninteen to twenty transverse to oblique, low and thin ridges. Those ridges are gently arched and more numerous than in any other *Neostreptognathodus*. Median trough is very shallow and narrow, but increases in width toward anterior end. Both lateral margins of posterior part of platform respectively form node-like, low and narrow ridge. Basal cavity is large, elongate, slightly flared and located beneath platform, extending to free blade as a narrow groove.

Comparison:—Only two specimens of this species were obtained. This new species resembles *Neostreptognathodus prayi* Behnken, but it is distinguished from the latter by its more numerous transverse ridges and longer platform. Ontogenetic development of this new species is unknown. However, the morphology of this element is characteristic enough to propose a new species.

Occurrence:—Gujio Hachiman (Akuda Formation), Gifu Prefecture.

Geologic age:—Late Middle Sakamotozawan.

Reg. no. TGU. 1481 (Holotype).

Neostreptognathodus pequopensis Behnken, 1975

Pl. 5, Figs. 8-11

Neostreptognathodus pequopensis Behnken, 1975, p. 310, pl. 1, figs. 19-22, 25.

Remarks:—The specimens in my collection show remarkable ontogenetic change. The morphology of the present specimens coincides with Behnken's description before gerontic stage. However, two rows of nodes become contact with each other and low carina appears along mid-line of platform in gerontic growth stage particularly in posterior part of platform. The gerontic features of this species resemble that of *Neostreptognathodus toriyamai* Igo, n. sp., and therefore gerontic specimens of these two species are hardly distinguishable. Behnken (1975) pointed out that *Sweetognathus whitei* (Rhodes) and this species are almost indistinguishable in early growth stage.

Occurrence :—Gujio Hachiman (Akuda and Kuchibora Formations) and Yoro (lower subgroup of Yoro Group), Gifu Prefecture, Samegai (Samegai Formation), Shiga Prefecture, and Akasaka Limestone (lower division), Gifu Prefecture.

Geologic age :—Late Sakamotozawan and Late Nabeyaman.

Reg. nos. TGU. 1484, 1485, 1486, 1487.

Neostreptognathodus aff. *prayi* Behnken, 1975

Pl. 5, Fig. 5

aff. *Neostreptognathodus prayi* Behnken, 1975, pp. 310, 311, pl. 2, figs. 14, 17-20.

Remarks :—The author obtained one specimen identical to this species from limestone of Ichinose, Kamiishizu Village, Yoro County, Gifu Prefecture. This species is associated with *Neogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes) in the limestone above mentioned. According to Behnken, *Neostreptognathodus prayi* occurs in The *Neostreptognathodus sulcoplicatus—Neostreptognathodus prayi* Assemblage Zone in the Bone Spring—Victorio Peak sequence; Arcturus Limestone and Kaibab Formation; Pequop Formation in North America (Behnken, 1975).

Occurrence :—Ichinose (unnamed formation), Gifu Prefecture.

Geologic age :—Middle Sakamotozawan.

Reg. no. TGU. 1480.

Neostreptognathodus sulcoplicatus (Youngquist, Hawley and Miller), 1951

Pl. 5, Fig. 12

Streptognathodus sulcoplicatus Youngquist, Hawley and Miller, 1951, p. 363, pl. 54, figs. 7-9, 16, 17, 22-24; Clark and Ethington, 1962, p. 111, pl. 1, figs. 8, 9, 18, pl. 2, figs. 3, 4, 7; Clark and Behnken, 1971, pl. 1, figs. 22, 23.

Neostreptognathodus sulcoplicatus (Youngquist, Hawley and Miller), Clark, 1972, p. 155; Behnken, 1975, pp. 311, 312, pl. 1, figs. 1-4, 23.

Remarks :—Anterior blade is missing but platform is complete. Oral surface is characterized by narrow, deep median trough and transverse ridges. The present specimens have more numerous transverse to oblique ridges than the holotype which has eight to ten ridges. This species occurs in the Upper Leonardian, Pequop Formation and the Middle to Upper Leonardian, Arcturus Limestone in North America (Behnken, 1975). The Japanese specimens occur in the Middle Sakamotozawan, which is stratigraphically equivalent to the Upper Wolfcampian, and are associated with *Neogondolella bisselli* (Clark and Behnken) and *Sweetognathus whitei* (Rhodes).

Occurrence :—Yoro (lower subgroup of Yoro Grop), Gifu Prefecture.

Geologic age :—Middle Sakamotozawan.

Reg. no. TGU. 1660.

Neostreptognathodus toriyamai Igo, n. sp.

Pl. 6, Figs. 1-16

Diagnosis:—Element is laterally symmetrical to asymmetrical, laterally bowed slightly or straight and sharply pointed posteriorly. Platform is ornamented by nodose transverse ridges. Large basal cavity occupies entire part of lower side of platform, and extends to free blade as a groove. Ornamentation of platform changes in the ontogenetic development and three growth stages are distinguished.

Juvenile:—Element is small, symmetrical and provided with a single row of five nodes on upper surface. Free blade is about one-half of the element in length, has four to five laterally compressed denticles and does not extend onto platform. Its denticles are discrete only in upper one-third of their height. In lateral view, upper surface of free blade is nearly straight. Basal cavity is deepest at center of platform and extends anteriorly to free blade as a narrow groove.

Adolescent:—Element is symmetrical to subsymmetrical, provided in the middle part with two rows of nodes which are indistinctly separated by shallow and narrow median depression. One or two anterior and posterior node-like projections are not differentiated into transverse ridges. Basal cavity is deep, flared and extends anteriorly to free blade as a thin groove. Free blade is low and its length is approximately one third of element. It has seven to nine denticles.

Mature:—Symmetrical or asymmetrical large element is slightly bowed and arched. Node-like transverse ridges on platform are laterally expanded and increased in number from eight to nine. Narrow median ridge appears from the second or third posterior transverse ridge and extends anteriorly to joint with free blade. Very shallow depression forms on both sides of median ridge with growth. Both sides of transverse ridge expand laterally and width of platform increases. Transverse ridges become gradually flat in posterior end of platform. Posterior end of platform gradually decreases its height and reaches posterior terminal. Free blade is provided with 7 to 6 laterally compressed denticles which are discrete in upper one-third of their height. Free blade joins with narrow median ridge at anterior end of platform. Generally basal cavity is of the same size as platform.

Comparison and remarks:—While this species resembles *Sweetognathus whitei* (Rhodes) in juvenile stage, it also resembles *Neostreptognathodus pequopensis* Behnken in adolescent stage. As already pointed out in earlier lines, *Neostreptognathodus toriyamai* is considered to be diverged from *Neostreptognathodus pequopensis* Behnken.

Occurrence:—Gujio Hachiman (Kuchibora Formation), Gifu Prefecture.

Geologic age:—Middle Nabeyaman.

Reg. nos. TGU. 1502 (Holotype), 1489, 1490, 1491, 1492, 1493, 1494, 1495, 1496, 1497, 1498, 1499, 1500, 1501, 1502, 1503, 1504.

Genus *Streptognathodus* Stuffer and Plummer, 1932

Streptognathodus elongatus Gunnell, 1933

Pl. 7, Figs. 10, 12-15

Streptognathodus elongatus Gunnell, 1933, p. 283, pl. 33, fig. 30; Ellison, 1941, p. 130, pl. 22, fig. 9; Rhodes, 1963, p. 405, pl. 47, figs. 5, 6, 16-24, 27-34.

Streptognathodus simplex Gunnell, 1933, p. 285, pl. 33, fig. 40.
Streptognathodus cfr. *elongatus* Rhodes, 1952, p. 894, pl. 127, figs. 3, 4, 8.

Remarks:—The material examined has slightly bent platform with deep and V-shaped median trough which extends to posterior end of platform.

Occurrence:—Shiraiwa Limestone (Kitaosoki Formation), western part of Ome City and Minokuchi (Raidenyama Formation) near Itukaichi Town, Tokyo.

Geologic age:—Early Sakamotozawan.

Reg. nos. TGU. 1520, 1522, 1523, 1524, 1483.

Genus *Sweetognathus* Clark, 1972

Sweetognathus whitei (Rhodes), 1963

Pl. 6, Figs. 17-22; Pl. 7, Figs. 1-9

Spathognathodus whitei Rhodes, 1963, p. 404, pl. 47, figs. 4, 9, 10, 25, 26; Clark and Behnken, 1971, pl. 1, figs. 2-6; Merrill, 1973, p. 310, pl. 3, figs. 1-9.
Sweetognathus whitei (Rhodes), Clark, 1972, p. 155; Clark 1974, pl. 2, figs. 12-18; Behnken, 1975, p. 312, pl. 1, fig. 26.
Sweetognathus behnkeni Kozur, 1975, pp. 3, 4.

Remarks:—This species was recovered from many localities of the Japanese Lower Permian. Juvenile specimens of this species may be confused with the juvenile forms of *Neostreptognathodus toriyamai* Igo, n. sp., because the above two species respectively have a single carina in the juvenile stage. In mature specimens of *Sweetognathus whitei*, nodes become larger and are expanded to lateral margin. Kozur (1975) proposed *Sweetognathus behnkeni* Kozur and he selected *Sweetognathus whitei* (Rhodes) of Clark and Behnken (1971, pl. 1, fig. 5) as its holotype. However, Kozur's new species is apparently gerontic form of *Sweetognathus whitei* and it is a junior-synonym of *Sweetognathus whitei*.

Occurrence:—Gujio Hachiman (Akuda Formation), Ichinose (unnamed formation) and Yoro (lower subgroup of Yoro Group), Gifu Prefecture. Samegai (Samegai Formation), Shiga Prefecture. Minokuchi (Raidenyama Formation) and green bedded chert lens (Raidenyama Formation) at Tamanouchi near Itukaichi Town, Tokyo.

Geologic age:—Middle Sakamotozawan.

Reg. nos. TGU. 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1519.

Genus *Xaniognathus* Sweet, 1970

Xaniognathus abstractus (Clark and Ethington), 1962

Pl. 11, Figs. 9, 10

Subbryantodus abstractus Clark and Ethington, 1962 (partim), p. 112, pl. 1, figs. 16, 20, pl. 2, fig.2 (non pl. 1, fig. 21), non Behnken, 1975, p. 313, pl. 1, fig. 15.

Remarks:—This species resembles *Xaniognathus sweeti* Igo, n. sp., but it is readily distinguished from the latter by discrete and long denticles and slightly slim main cusp. Also, it is easily distinguished from *Xaniognathus* sp. A by long denticles on the anterior process.

Occurrence:—Gujio Hachiman (Akuda Formation), Ichinose (unnamed formation) and Yoro (lower subgroup of Yoro Group), Gifu Prefecture. Samegai (Samegai Formation), Shiga Prefecture.

Geologic age:—Late Middle Sakamotozawan to Late Nabeyaman.

Reg. nos. TGU. 1585, 1586.

Xaniognathus deflectens Sweet, 1970

Pl. 11, Figs. 11-13

Xaniognathus deflectens Sweet, 1970, p. 266, pl. 3, fig. 20.

Remarks:—This element was described from the West Side of Chhidru Nala, Salt Range, Pakistan by Sweet. The present material is not well preserved, but general important features are similar to Sweet's specimens. Geologic age of this species is Early Triassic. The present specimens were discovered in the Upper Middle Sakamotozawan, therefore, this species has longer range than previously considered.

Occurrence:—Gujio Hachiman (Akuda Formation), Gifu Prefecture.

Geologic age:—Late Middle Sakamotozawan.

Reg. nos. TGU. 1588, 1589, 1590.

Xaniognathus sweeti Igo, n. sp.

Pl. 10, Figs. 13-15; Pl. 11, Figs. 1-6

Ozarkodina cfr. *delicatula* (Stuffer and Plummer), 1932, Rhodes, 1963 (partim), pl. 7, figs. 13, 15, (non figs. 11, 12, 14).

Diagnosis:—Blade is laterally compressed, straight and thickest near mid-lateral rib. Anterior and posterior processes meet at an angle of about 110 degrees. Anterior blade is longer than posterior one and has eight to seven denticles, of which posterior three to five denticles are coalesced and anterior four to five ones are discrete only in upper half of their height. Posterior blade had eight or seven almost equally high denticles, which are laterally compressed and somewhat smaller than those of anterior blade. Anterior two or three denticles of posterior blade are coalesced and form an angle of 70 to 80 degrees with base of blade. Main cusp is large, laterally compressed, sharply pointed and almost twice or more wider and longer than other denticles. Main cusp is extended from posterior process. In aboral view, basal cavity is large, deeply concave and is connected to both blades by a narrow groove.

Comparison:—This species closely resembles *Xaniognathus abstractus* (Clark and Ethington), but the former differs from the latter in having more numerous, coalescent and shorter denticles. Furthermore, the basal cavity of this species is larger than that of *Xaniognathus abstractus*.

Occurrence:—Gujio Hachiman (Kuchibora Formation) and Yoro (lower subgroup of Yoro Group), Gifu Prefecture. Quarry of the Tokyo Lime Industry Co. Ltd. (Yamasuge Limestone Member), Yamasuge (Yamasuge Limestone Member) near the

Tenjin bridge of Kuzuu Town, Quarry of the Miyata Lime Industry Co. Ltd. (Karasawa Limestone Member) north of Kuzuu Town, Tochigi Prefecture.

Geologic age:—Early to Late Nabeyaman.

Reg. nos. TGU. 1572 (Holotype), 1573, 1574, 1575, 1576, 1577, 1578, 1579, 1580.

Xaniognathus sp. A

Pl. 11, Figs. 7, 8

Xaniognathus toritilis (Tatge), 1956, Behnken, 1975, p. 313, pl. 2, fig. 13.
Xaniognathus abstractus (Clark and Ethington), Behnken, 1975 p. 313, pl. 1, fig. 15.

Description:—Blade is laterally compressed, high and slightly arched laterally. Mid-lateral rib is scarcely developed. Posterior denticles are three or four and anterior ones are seven or eight. All the denticles are of the same size, discrete and sharply pointed. Anterior denticles make an angle of about 30 to 40 degrees with anterior process. Posterior denticles meet at a right angle with posterior process. Main cusp is large, long, sharply pointed and laterally compressed. In aboral view, basal cavity is small and extended into both blades as a narrow groove. Aboral side of blade is sharply edged. The basal cavity beneath main cusp is weakly developed.

Remarks:—This species closely resembles *Xaniognathus toritilis* (Tatge), but the former differs from the latter in having higher blade and shorter denticles. The holotype of *Xaniognathus toritilis* (Tatge), (Tatge, 1956, pl. 5, fig. 11) has a denticulated long posterior process.

Occurrence:—Yoro (lower subgroup of Yoro Group), Gifu Prefecture; green bedded chert lens (Raidenyama Formation) Tamanouchi and Minokuchi (Raidenyama Formation) near Itukaichi Town, Tokyo.

Geologic age:—Late Middle Sakamotozawan.

Reg. nos. TGU. 1851, 1852.

Repository

All the specimens treated in this paper are preserved in the Department of Astronomy and Earth Sciences, Tokyo Gakugei University.

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Plate 1

Explanation of Plate 1

Neogondolella bisselli (Clark and Behnken) ....p. 37

Figs. 1-7, 10, 17, 18. Oral views, ×60, 1-7, 10, Loc. Ichinose, TGU. 1409, 1410, 1411, 1412, 1413, 1414, 1415, 1418; 17. Loc. Tamanouchi, TGU. 1426; 18. Loc. Minokuchi (Mn6), TGU. 1427.

Figs. 8, 19. Oblique lateral views, ×60, Loc. Ichinose, TGU. 1416, 1419.

Fig. 9. Oblique lateral view, ×60, Loc. Minokuchi (Mn6), TGU. 1417.

Fig. 14. Oral view of juvenile specimen, ×60, Loc. Tamanouchi, TGU. 1423.

Neogondolella idahoensis (Youngquist, Hawley and Miller) ....p. 38

Figs. 11, 12. Oral views, ×45, Loc. Kuzuu (Ya6), TGU. 1420, 1421.

Fig. 13. Lateral view of juvenile specimen, ×80, Loc. Kuzuu (To8), TGU. 1422.

Fig. 15. Aboral view of adolescent specimen, ×80, Loc. Kuzuu (To8), TGU. 1424.

Fig. 16. Lateral view of adolescent specimen, ×80, Loc. Kuzuu (To8), TGU. 1425.

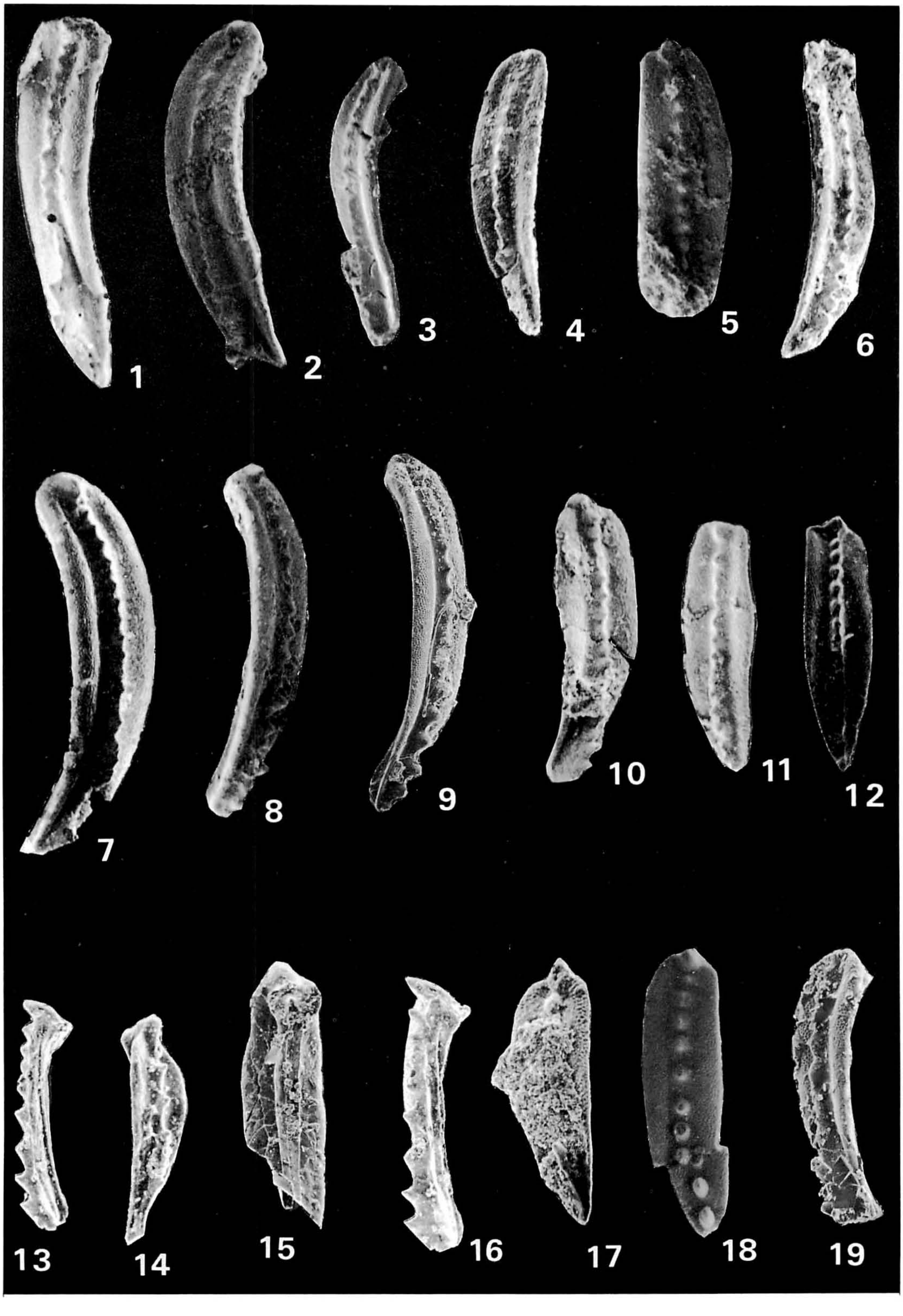
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Plate 2

Explanation of Plate 2

Neogondolella asiatica Igo, n. sp. .... p. 36

Fig. 5. Oral view of holotype, ×60, TGU. 1431.

Figs. 2-4, 6. Oral views of paratypes, ×60, TGU. 1428, 1429, 1430, 1432.

Figs. 1, 9-13. Oral views of paratypes, ×120, TGU. 1427, 1435, 1436, 1437, 1438, 1439.

Fig. 7. Aboral view of paratype, ×150, TGU. 1433.

Fig. 8. Aboral view of paratype, ×120, TGU. 1434.

All specimens from Gujio Hachiman (Ad5).

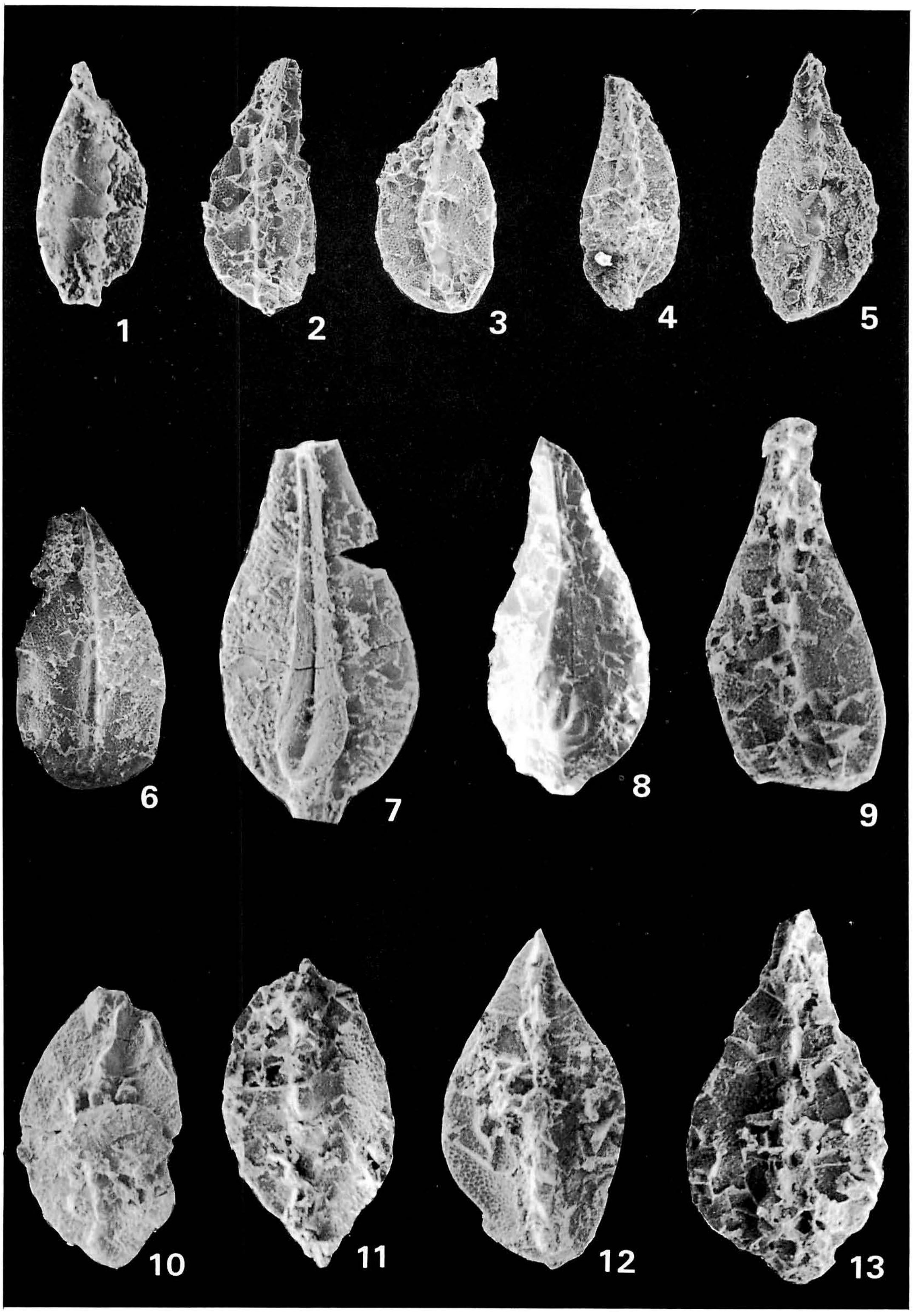
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Plate 3

Explanation of Plate 3

Neogondolella gujioensis Igo, n. sp. ....p. 37

Fig. 15. Oral view of holotype, ×54, TGU. 1454.

Fig. 1. Oral view of paratype, ×44, TGU. 1440.

Figs. 3–7. Oblique oral views of paratypes, ×60, TGU. 1442, 1443, 1444, 1445, 1446.

Fig. 9. Oblique oral view of paratype. ×45, TGU. 1448.

Fig. 10. Oral view of paratype, ×60, TGU. 1449.

Figs. 12, 13. Oblique oral views of paratypes, ×60. TGU. 1451, 1452.

Figs. 14, 17, 18. Oblique oral views of paratypes, ×54, TGU. 1453, 1456, 1457.

Fig. 16. Oral view of paratype, ×54, TGU. 1455.

Fig. 19. Oblique oral view of paratype, ×60, TGU. 1458.

Fig. 2, 8. Aboral views of paratypes, ×60, TGU. 1441, 1447.

Fig. 11. Aboral view of paratype, ×45, TGU. 1450.

All specimens from Gujio Hachiman (Ad5).


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Plate 4

Explanation of Plate 4

Neogondolella gujioensis Igo, n. sp. .... p. 37

Fig. 1, 6. Oblique oral views of paratypes, ×60, TGU. 1459, 1464.

Figs. 2–5. Oblique oral views of paratypes, ×54, TGU. 1460, 1461, 1462, 1463.

All specimens from Gujio Hachiman (Ad5).

Neogondolella intermedia Igo, n. sp. .... p. 38

Figs. 7, 8. Oral views of paratypes, ×60, Loc. Ichinose, TGU. 1465, 1466.

Figs. 9, 10. Oblique oral views of paratypes, ×60, Loc. Gujio Hachiman (Ha67), TGU. 1467, 1468.

Fig. 11. Oblique oral view of holotype, ×60, Loc. Ichinose, TGU. 1469.

Neogondolella sp. A, n. sp. .... p. 39

Fig. 12. Oral view, ×100, Loc. Minokuchi (Mn6), TGU. 1470.

Neogondolella spp.

Fig. 13. Oral view of adolescent specimen, ×100, Loc. Yoro (Yo52), TGU. 1471.

Figs. 14, 15. Oblique oral views of juvenile specimens, ×100, Loc. Yoro (Yo2), (Yo52), TGU. 1472, 1473.

Fig. 16. Oblique oral view of adolescent specimen, ×100, Loc. Yoro (Yo52), TGU. 1574.

Fig. 17. Aboral view, ×100, Loc. Yoro (Yo52), TGU. 1475.

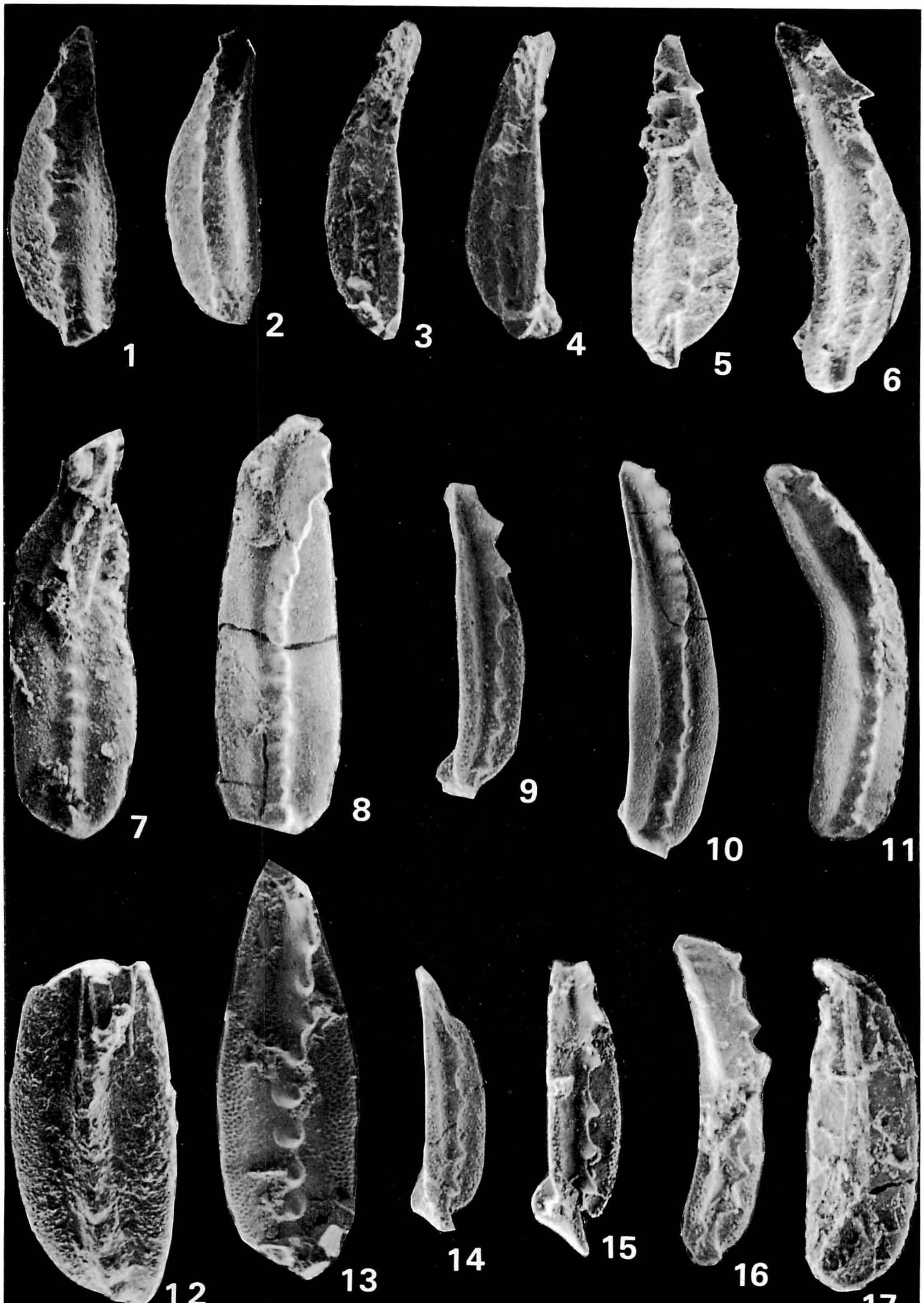
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Plate 5

Explanation of Plate 5

Neostreptognathodus sp.

Fig. 1. Oral view of broken specimen, ×110, Loc. Yoro (Yo27), TGU. 1476.

Fig. 7. Oral view of broken specimen, ×60, Loc. Yoro (Yo27), TGU. 1482.

Neostreptognathodus exsculptus Igo, n. sp. ....p. 40

Fig. 2. Oral view of broken specimen, ×110, Loc. Yoro (Yo27), TGU. 1477.

Figs. 3a, b. Oral views of the holotype, 3a, ×108, 3b, ×54, Loc. Yoro (Yo60), TGU. 1478.

Figs. 4a, b. Oral views of paratype, 4a, ×108, 4b, ×54, Loc. Yoro (Yo60), TGU. 1479.

Neostreptognathodus aff. *prayi* Behnken..p. 42

Fig. 5. Oral view, ×44, Loc. Ichinose, TGU. 1480.

Neostreptognathodus foliatus Igo, n. sp..p. 41

Fig. 6. Oral view of the holotype, ×36, Loc. Gujio Hachiman (Ha14), TGU. 1481.

Neostreptognathodus pequopensis Behnken..p. 41

Fig. 8. Lateral view, ×70, Loc. Gujio Hachiman (Ad5), TGU. 1484.

Fig. 9. Oral view, ×60, Loc. Yoro (Yo60), TGU. 1485.

Fig. 10. Oral view, ×70, Loc. Gujio Hachiman (Ad5), TGU. 1486.

Fig. 11. Oral view, ×54, Loc. Yoro (Yo60), TGU. 1487.

Neostreptognathodus sulcoplicatus (Youngquist, Hawley and Miller) ....p. 42

Fig. 12. Oblique oral view, ×100, Loc. Yoro (Yo27), TGU. 1660.

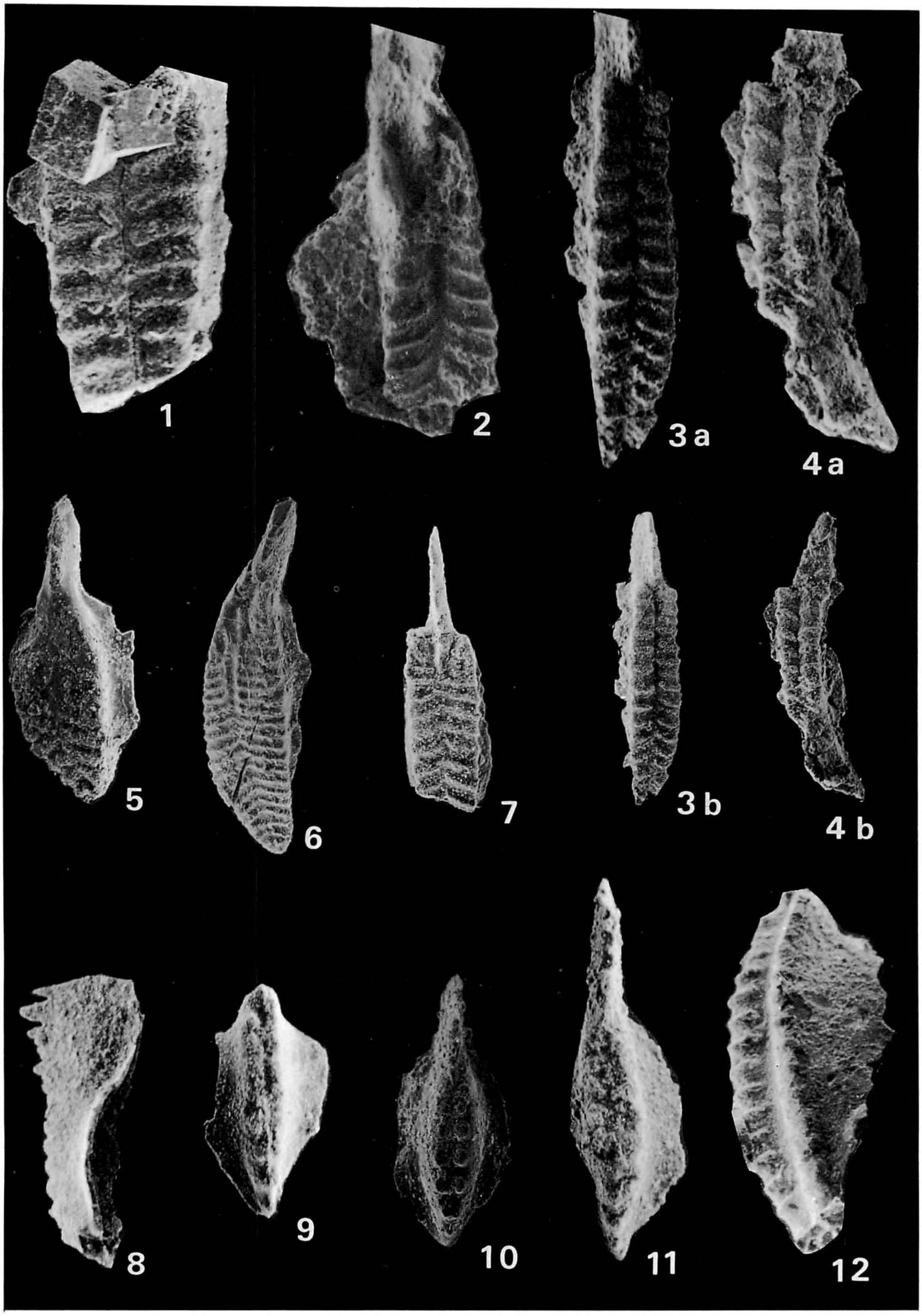
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Plate 6

Explanation of Plate 6

Neostreptognathodus toriyamai Igo, n. sp. ....p. 42

Figs. 1, 2. Oral views of paratypes, ×82, juvenile specimens, TGU. 1489, 1490.

Fig. 3. Oral view of paratype, ×60, juvenile specimen, TGU. 1491.

Figs. 4-8, 10-12. Oral views of paratypes, ×60, adolescent specimens, TGU. 1492, 1493, 1494, 1495, 1496, 6498, 1499, 1500.

Fig. 9. Lateral view of paratype, ×60, adolescent, TGU. 1497.

Fig. 13. Oral view of paratype, × 60, mature specimen, TGU. 1501.

Fig. 14. Oral view of holotype, ×60, gerontic specimen, TGU. 1502.

Fig. 15. Oral view of paratype ×82, gerontic specimen, TGU. 1503.

Fig. 16. Oral view of gerontic specimen, ×44, TGU. 1504.

All specimens from Gujio Hachiman (Ha115).

Sweetognathus whitei (Rhodes) ....p. 44

Fig. 17. Oral view of juvenile specimen, ×120, Loc. Yoro (Yo136), TGU. 1505.

Fig. 18. Oral view, ×60, Loc. Gujio Hachiman (Ad5), TGU. 1506.

Figs. 19, 20, 21. Oral views, × 100, Loc. Yoro (Yo136), TGU. 1507, 1508, 1509.

Fig. 22. Oblique oral view, ×100, Loc. Minokuchi (Mn6), TGU. 1510.

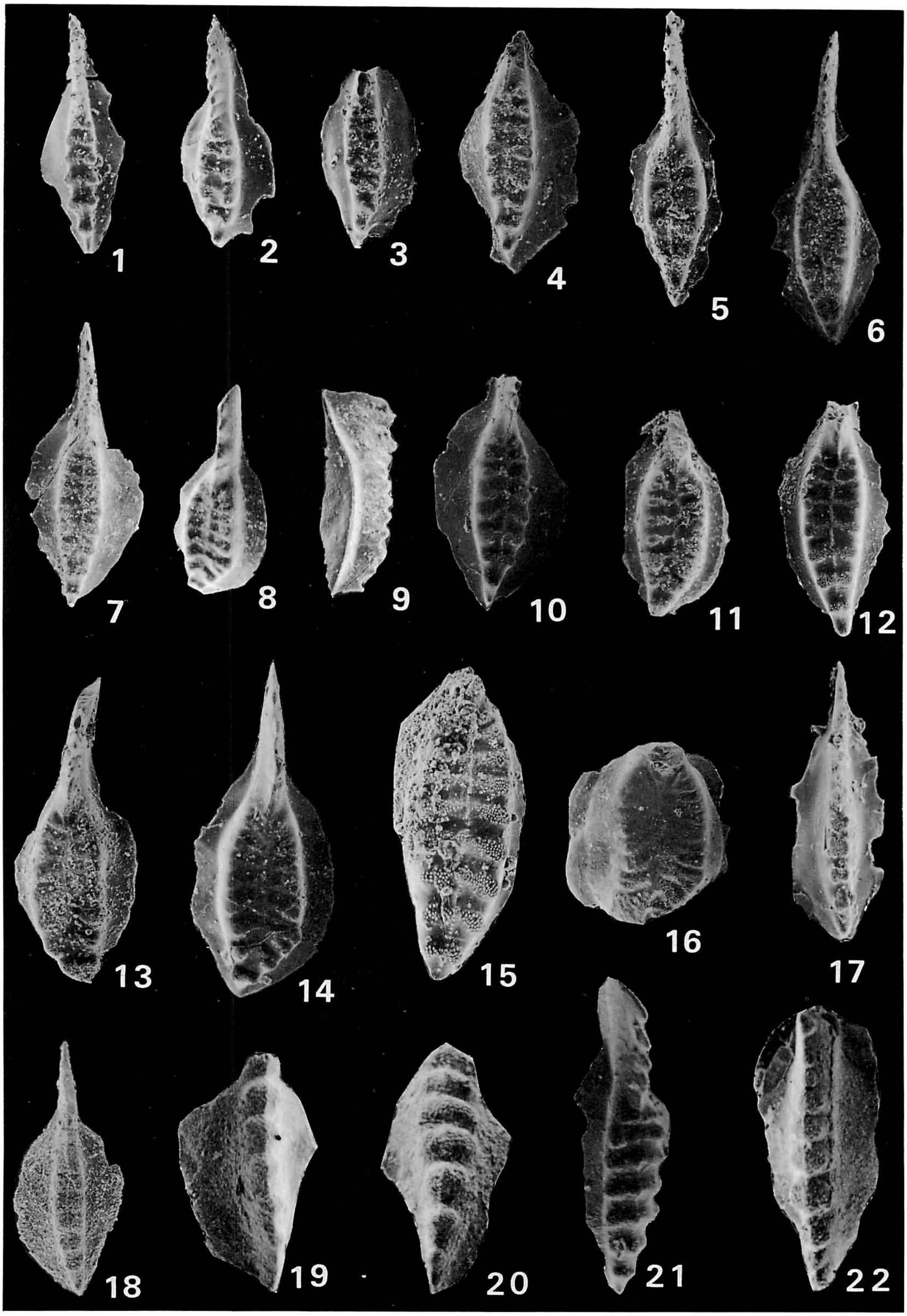
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Plate 7

Explanation of Plate 7

Sweetognathus whitei (Rhodes) .... p. 44
Figs. 1, 2. Oral views, ×100, Loc. Yoro (Yo136), (Yo66), TGU. 1511, 1512.
Fig. 3. Oral view, ×80, Loc. Samegai (Sa3), TGU. 1513.
Fig. 4. Oral view, ×100, Loc. Yoro (Yo66), TGU. 1514.
Fig. 5, 6. Oral views, Loc. Yoro (Yo136), ×100, TGU. 1515, 1516.
Fig. 7. Oral view, ×60, Loc. Gujio Hachiman (Ha68), TGU. 1517.
Fig. 8. Oral view, ×100, Loc. Yoro (Yo136), TGU. 1518.
Fig. 9. Lateral view, ×120, Loc. Yoro (Yo66), TGU. 1519.

Idiognathodus cfr. *ellisoni* Clark and Behnken .... p. 34
Fig. 11. Oral view, ×60, Loc. Shiraiwa Limestone, TGU. 1521.

Streptognathodus elongatus Gunnell .... p. 43
Fig. 10. Oral view, ×80, TGU. 1520.
Fig. 12. Lateral view, ×60, TGU. 1522.
Fig. 13. Oblique oral view, ×60. 1523.
Figs. 14, 15. Oral views. ×60, TGU. 1524, 1483.
All specimens from Minokuchi (Mn3).

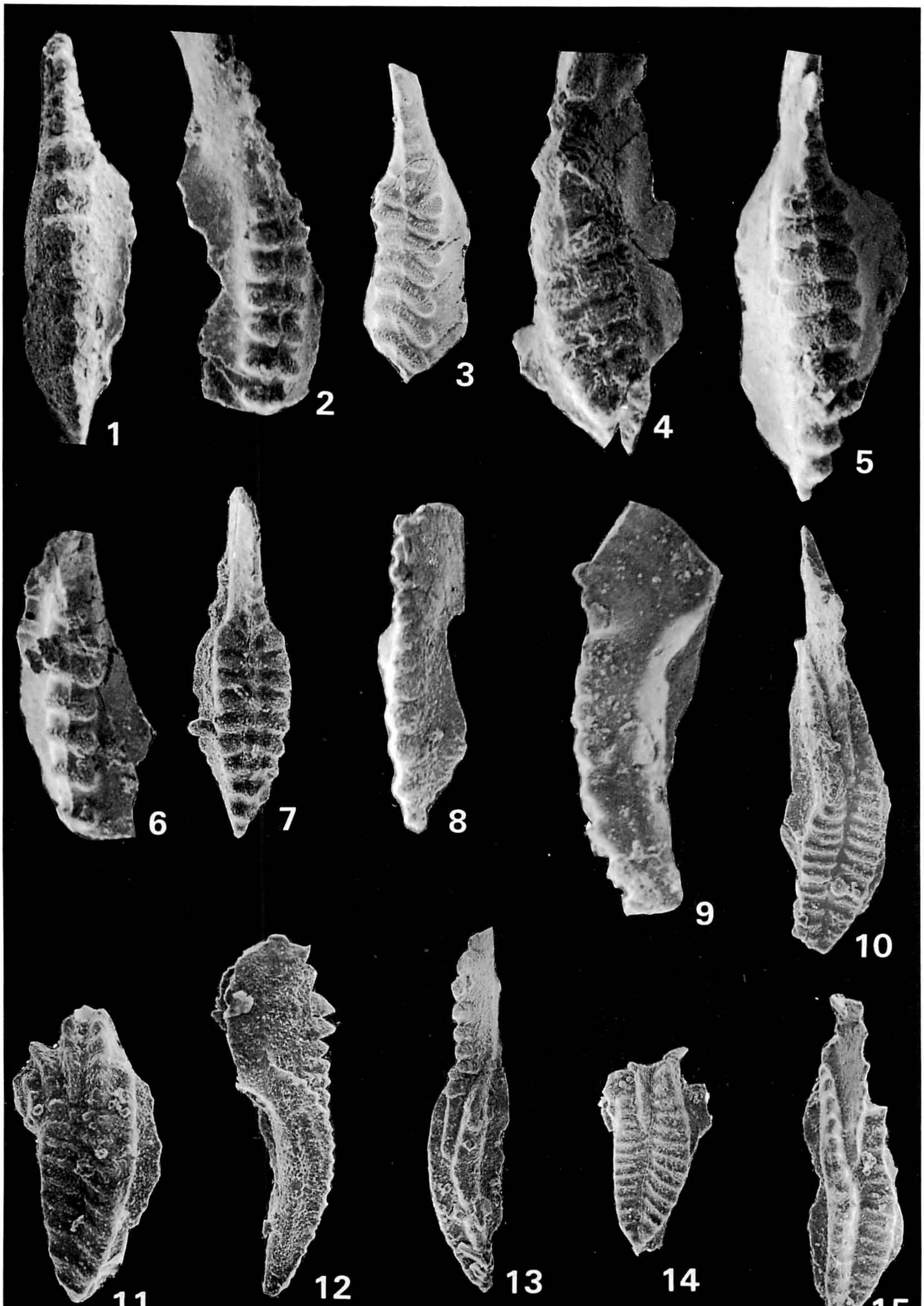
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Plate 8

Explanation of Plate 8

Diplognathodus augustus Igo, n. sp. .... p. 30

Figs. 1, 5, 7. Oblique oral views of paratypes, ×100, TGU. 1525, 1529, 1531.

Fig. 2. Oral view of holotype, ×100, TGU. 1526.

Figs. 3, 4, 8. Oral views of paratypes, ×100, TGU. 1527, 1528, 1532.

Fig. 6. Aboral view of paratype, ×100, TGU. 1530.

All specimens from Gujio Hachiman (Ha28).

Diplognathodus oertlii Kozur .... p. 32

Figs. 9, 10. Lateral views, ×100, Loc. Samegai (Sg3), Yoro (Yo62), TGU. 1533, 1534.

Fig. 11. Oblique oral view, ×200, Loc. Samegai (Sg3), TGU. 1535.

Fig. 12. Oral view, ×200, Loc. Samegai (Sg3), TGU. 1536.

Fig. 13-16. Oblique oral views, ×100, 13, Loc. Gujio Hachiman (Ad5), TGU. 1537, 14-16, Loc, Samegai (Sg3), TGU. 1538, 1539, 1540.

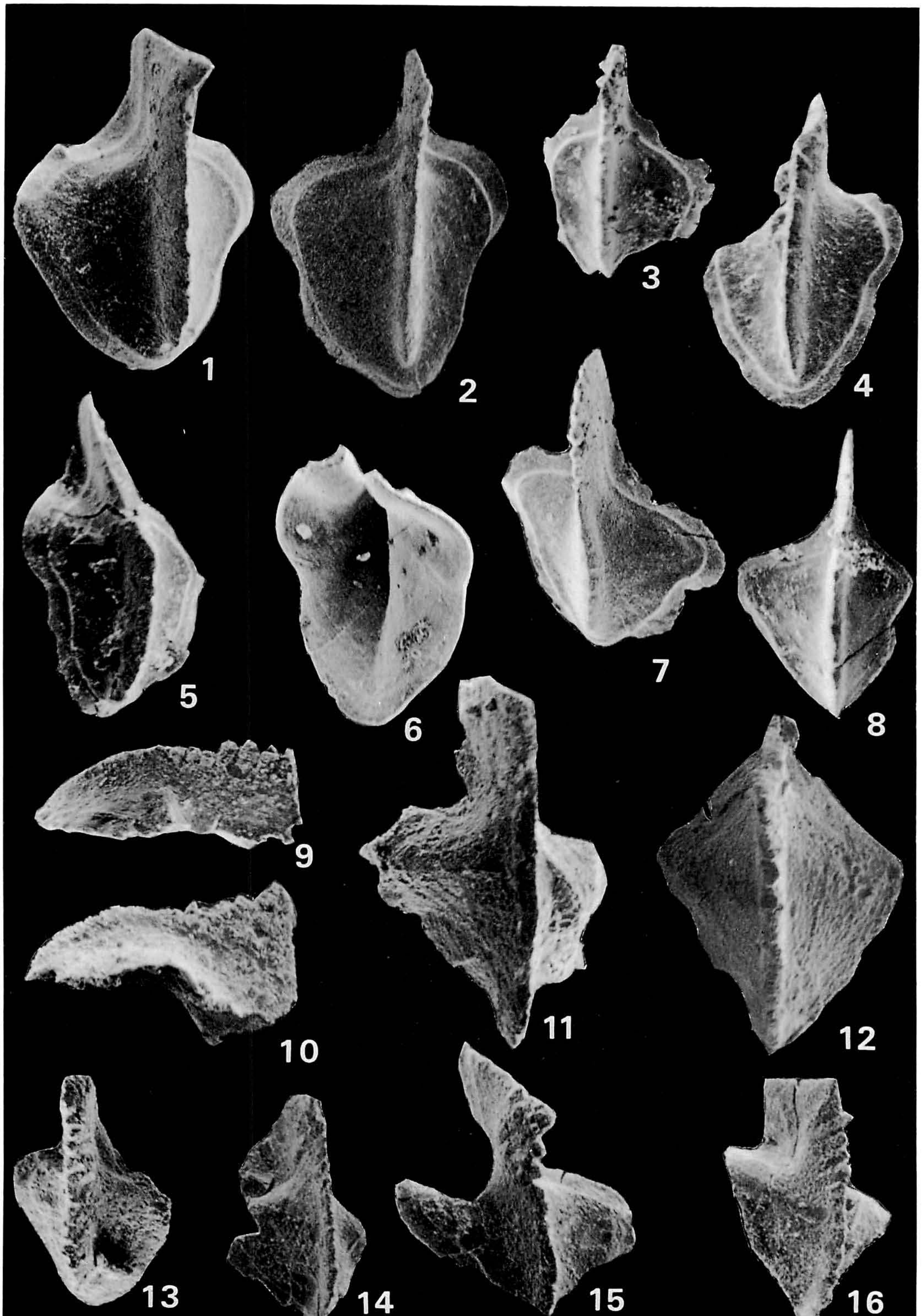
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Plate 9

Explanation of Plate 9

Diplognathodus lanceolatus Igo, n. sp. ....p. 30

Fig. 1. Oral view of holotype, ×120, Loc. Kuzuu (To4), TGU. 1541.

Figs. 2-5. Oral views of paratypes, ×60, Loc. 2, Kuzuu (To4), 3, 4, Kuzuu (To5), 5, Kuzuu (4024), TGU. 1542, 1543, 1544, 1545.

Figs. 7, 8, 13. Lateral views of paratypes, 7, ×120, Loc. Yoro (Yo87), TGU. 1546, 8, ×60, Loc. Kuzuu (4024), TGU. 1548, 13, ×60, Loc. Kuzuu (To5), TGU. 1553.

Diplognathodus nodosus Igo, n. sp. ....p. 31

Fig. 6. Oral view of holotype, ×60, Loc. Kuzuu (4054), TGU. 1547.

Fig. 9. Oral view of paratype, ×60, Loc. Kuzuu (4036), TGU. 1549.

Fig, 10. Oral view of paratype, ×60, Loc. Kuzuu (4035), TGU. 1550.

Fig. 11. Oblique oral view of paratype, ×80, Loc. Kuzuu (4033), TGU. 1551.

Fig. 12. Lateral view of paratype, ×60, Loc. Kuzuu (4054), TGU. 1552.

Diplognathodus sp. C...p. 33

Figs. 14, 15. Oral views, ×80, TGU. 1554, 1555.

All specimens from Nukui, Mugi County, Gifu Prefecture.

Diplognathodus? sp. A, n. sp...p. 32

Fig. 16. Oral view, ×100, Loc. Kuzuu (4035), TGU. 1556.

Diplognathodus sp. B ....p. 32

Fig. 17. Oral view, ×60, TGU. 1557.

Fig. 18. Oral view, ×70, TGU. 1558.

Fig. 19. Lateral view, ×60, TGU. 1559.

Fig. 20. Lateral view, ×70, TGU. 1560.

All specimens from Tamanouchi, north of Itukaichi Town, Tokyo.

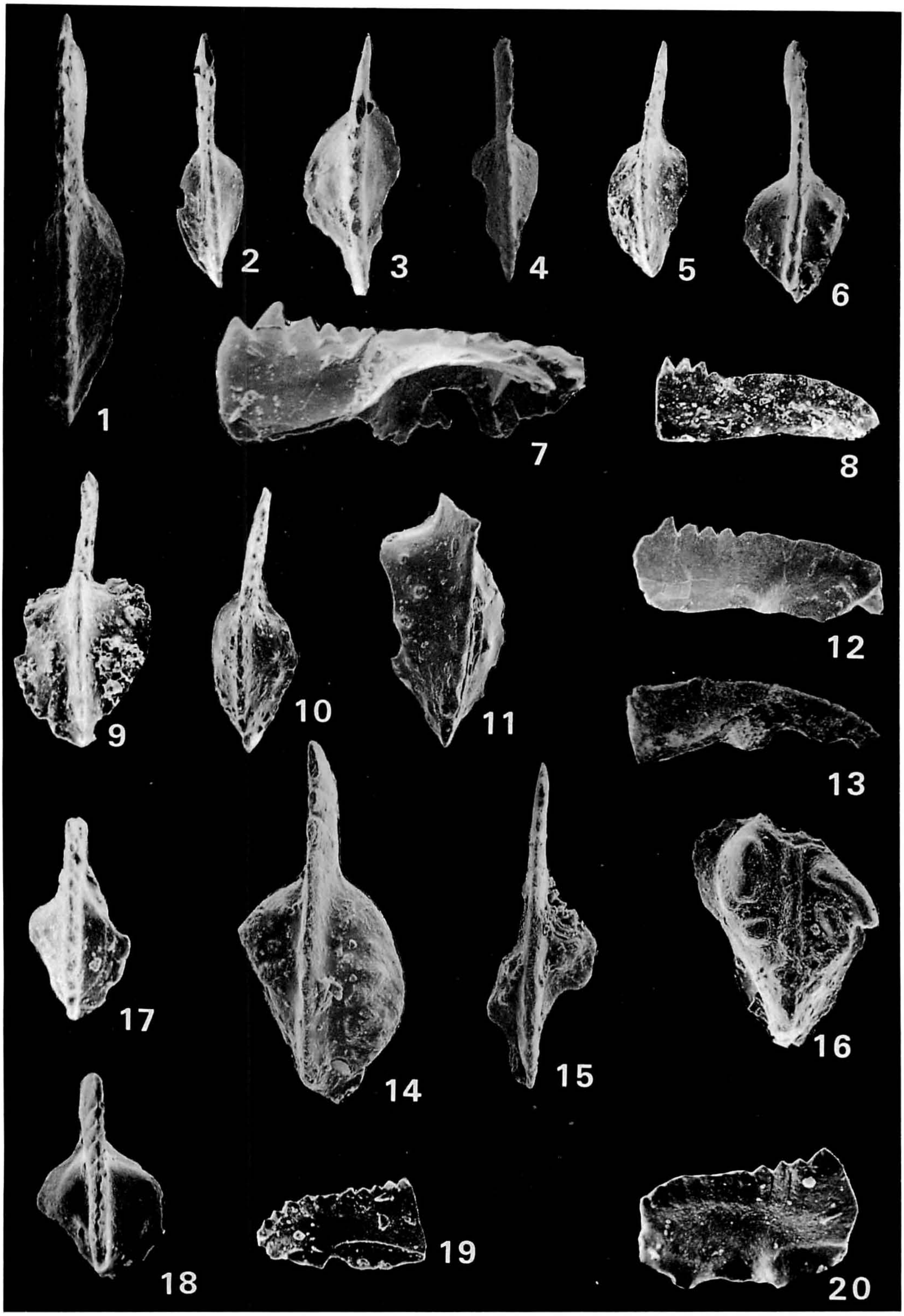
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Plate 10

Explanation of Plate 10

Anchignathodus minutus permicus Igo, n. subsp. ....p. 26

Fig. 1. Lateral view of paratype, ×100, Loc. Kuzuu (4054), TGU. 1561.

Fig. 2. Lateral view of holotype, ×100, Loc. Kuzuu (4033), TGU. 1562.

Figs. 3, 4. Lateral views of paratypes, ×100, Loc. Kuzuu (4033), (To7), TGU. 1563, 1564.

Anchignathodus minutus minutus (Ellison) ....p. 26

Fig. 5. Lateral view, ×100, Loc. Kuzuu (4055), TGU. 1565.

Fig. 8. Lateral view, ×100, Loc. Yoro (Yo27), TGU. 1568.

Fig. 11. Lateral view, ×100, Loc. Yoro (Yo52), TGU. 1570.

Anchignathodus typicalis Sweet...p. 27

Figs. 6, 9. Lateral views, Loc. Akiyama (3352), 6, ×100; 9, ×120, TGU. 1566, 1569.

Figs. 7, 12. Lateral views, Loc. Kuzuu (4024). 7. ×100; 12, ×200, TGU. 1567, 1571.

Xaniognathus sweeti Igo, n. sp...p. 45

Fig. 13. Lateral view of the holotype, ×130, TGU. 1572.

Figs. 14, 15. Lateral views of paratypes, ×130, TGU. 1580, 1573.

All specimens from Kuzuu (To4).

Anchignathodus sp. A ....p. 27

Fig. 10. Lateral view, ×130, Loc. Gujio Hachiman (Ad5), TGU. 1658.

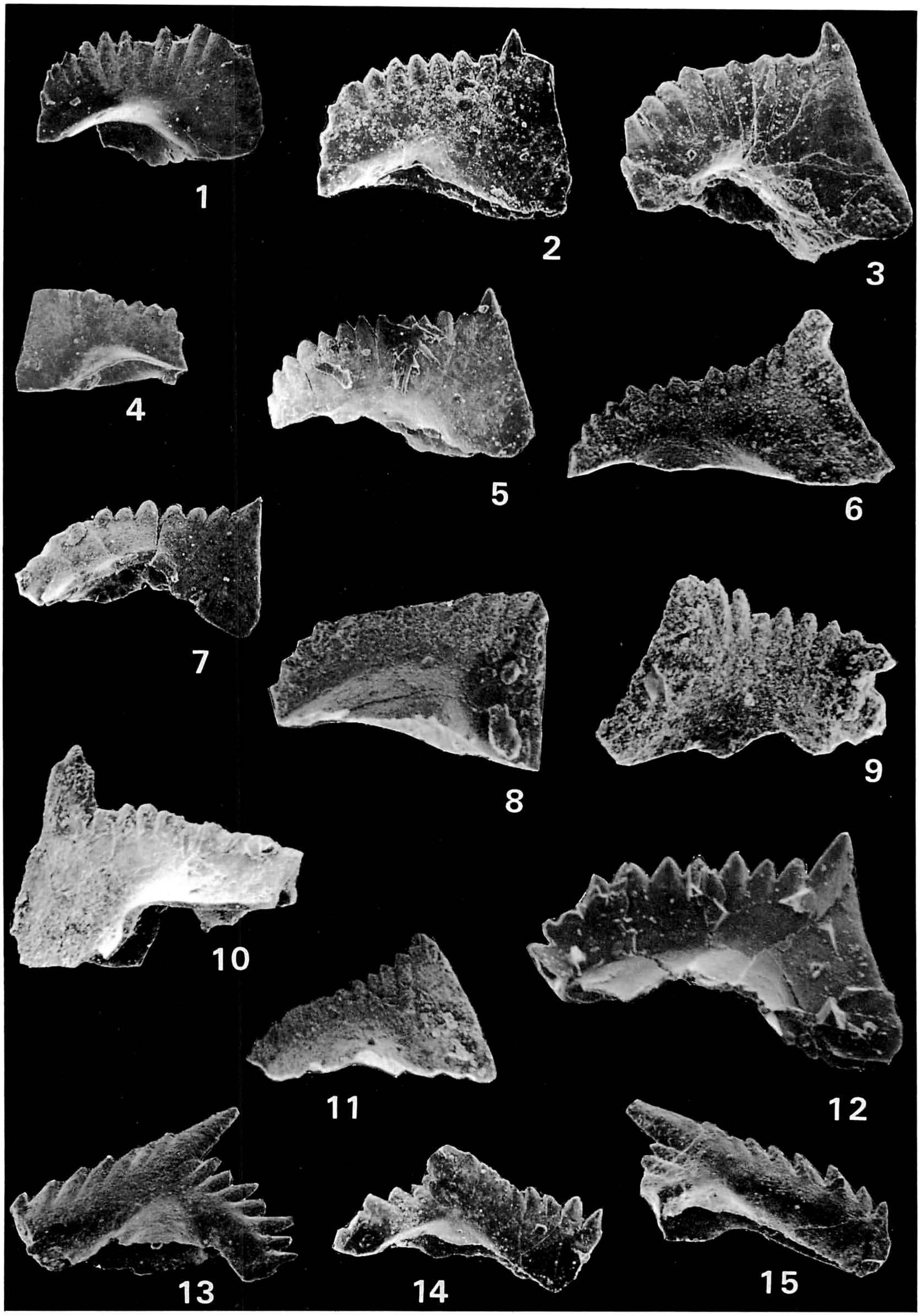
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Plate 11

Explanation of Plate 11

Xaniognathus sweeti Igo, n. sp. .... p. 45

Figs. 1-4. Lateral views of paratypes, ×130, 1, 4. Loc. Kuzuu (4033), 2, 3. Kuzuu (To7), TGU. 1574, 1575, 1576, 1577.

Figs. 5, 6. Lateral views of paratypes, ×100, Loc. Kuzuu (To9), TGU. 1578, 1579.

Xaniognathus sp. A .... p. 46

Figs. 7, 8. Lateral views, ×150, Loc. Tamanouchi TGU. 1851, 1852.

Xaniognathus abstractus (Clark and Ethington) .... p. 44

Fig. 9. Lateral view, Loc. Yoro (Yo60), TGU. 1585.

Fig. 10. Lateral view, Loc. Yoro (Yo52), TGU. 1586.

All figures ×200.

Xaniognathus deflectens Sweet .... p. 45

Figs. 11-13. Lateral views, ×200, Loc. Gujio Hachiman (Ad5), TGU. 1588, 1589, 1590.

Cypridodella sp. D .... p. 29

Fig. 14. Lateral view, ×200, Loc. Gujio Hachiman (Ha67), TGU. 1596.

Lonchodina sp. D .... p. 36

Fig. 15. Posterior view, ×250, Loc. Kuzuu (To8), TGU. 1597.

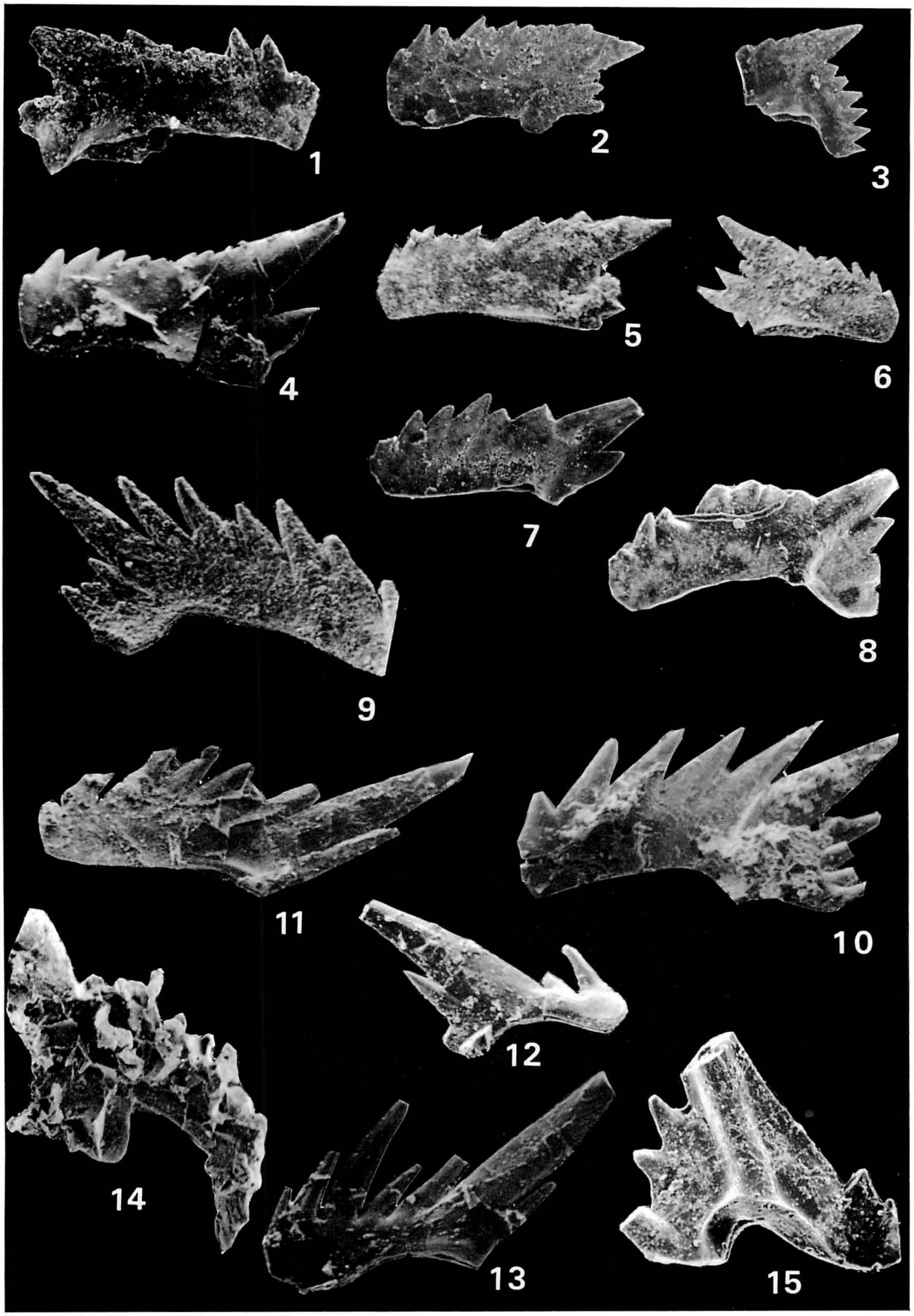
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Plate 12

Explanation of Plate 12

Diplododella sp. ....p. 29

Figs. 1, 7. Lateral views, ×100, Loc. Kuzuu (To8), TGU. 1630, 1631.

Neospathodus cfr. *arcucristatus* Clark and Behnken ....p. 40

Fig. 2. Lateral view, ×80, Loc. Kuzuu (To5), TGU. 1633.

Cypridodella sp. B ....p. 28

Figs. 3, 4. Lateral views, ×150, Loc. 3, Kuzuu (4033), TGU. 1610, 4, Kuzuu (To8), TGU. 1611.

Enantiognathus turibulosus (Clark and Ethington) ....p. 33

Fig. 5. Lateral view, ×120, Loc. Gujio Hachiman (Ha67), TGU. 1639.

Lonchodina sp. E ....p. 36

Fig. 6. Lateral view, ×100, Loc. Tamanouchi, TGU. 1638.

Cypridodella sp. A ....p. 28

Figs. 8, 9, 10. Lateral views, ×130, Loc. Gujio Hachiman (Ad11), TGU. 1604, 1605, 1607.

Lonchodina sp. A ....p. 34

Figs. 11, 12. Posterior views, TGU. 1616, 1619.
All specimens from Yoro (Yo52), ×150.

Lonchodina sp. C ....p. 35

Fig. 13. Posterior view, ×130, Loc. Tamanouchi, TGU. 1628.
Fig. 14. Posterior view, ×200, Loc. Gujio Hachiman, (Ha67), TGU. 1627.

Cypridodella sp. C ....p. 29

Fig. 15. Lateral view, ×200, Yoro (Yo52), TGU. 1621.

Lonchodina muelleri Tatge ....p. 34

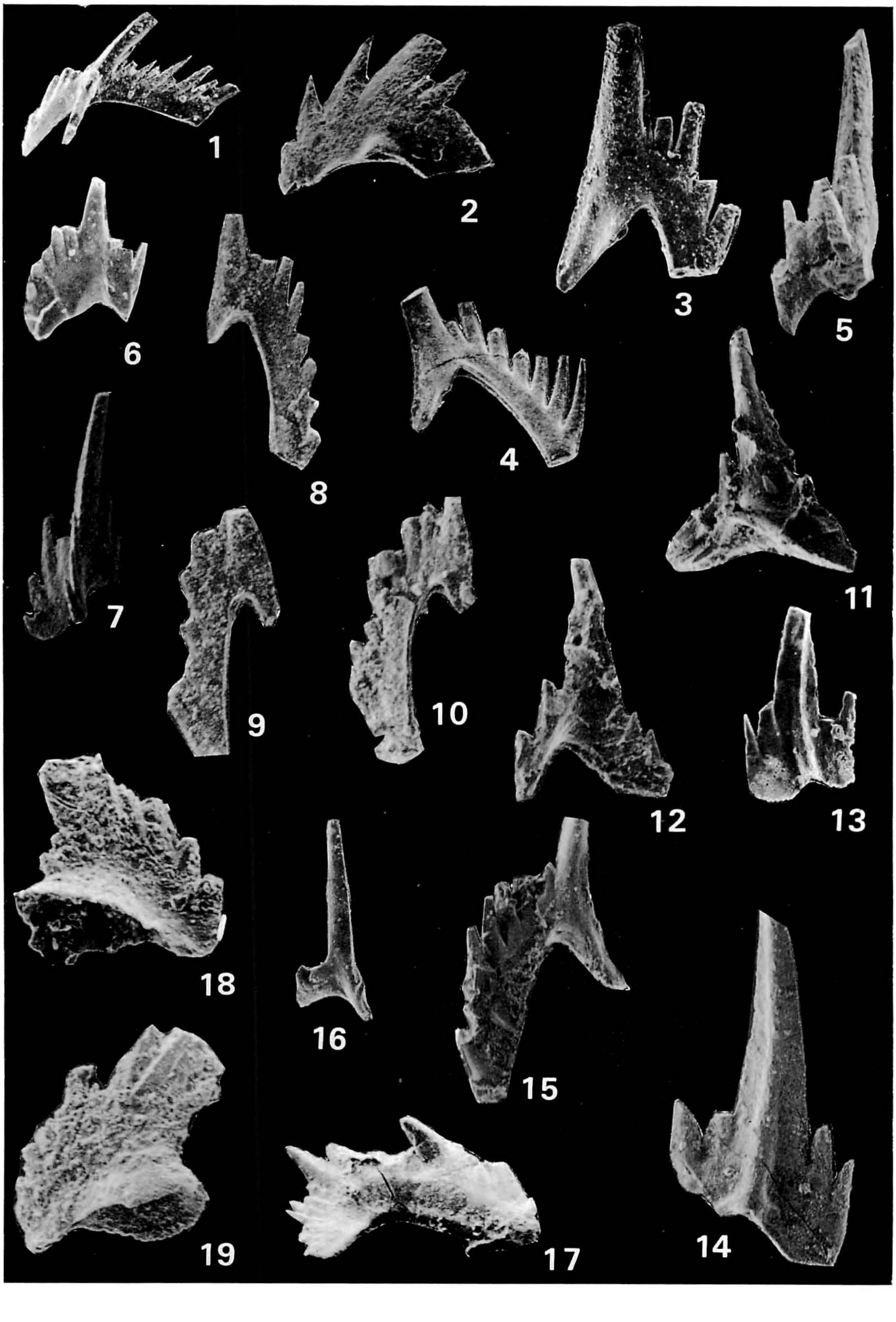
Fig. 16. Lateral view, ×100, Loc. Akasaka Limestone (Ak2), TGU. 1641.

Lonchodina sp. B ....p. 35

Fig. 17. Lateral view, ×100, Loc. Yoro (Yo27), TGU. 1598.

Neospathodus divergens (Bender and Stoppel) ....p. 40

Figs. 18, 19. Lateral views, ×200, Loc. 18, Samegai (Sg3), TGU. 1600, 19, Yoro (Yo60), TGU. 1601.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