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PERMIAN DAVIDSONIACEA FROM
THE SOUTHERN KITAKAMI MOUNTAINS, JAPAN

by

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(with 7 text-figures and 9 plates)

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Contents

Introduction and Acknowledgements	361
Brief history of the previous studies of the Japanese Permian Davidsoniacea	362
Short remarks on terminology in taxonomy of the Davidsoniacea . . .	364
Materials	365
Affinities of the Davidsoniacean fauna of the Permian in the Kitakami Mountains	368
Classification of the Davidsoniacea	369
Systematic description	374
References	404

Introduction and acknowledgements

Davidsoniacea may be one of the representative groups among Japanese Permian brachiopods. As a matter of fact, a number of species belonging to this superfamily have been described from several districts in Japan prior to the present study; viz. from Maizuru, Akasaka, and Nabeyama in Central Honshu and the Abukuma and the Southern Kitakami Mountains, N. E. Honshu. Besides, the presence of certain species was listed from various localities in Japan although they have not been described yet.

In the present paper, previous studies for this group of fossils in Japan will be first outlined, classifications hitherto proposed by many specialists will be reviewed, and phylogeny newly compiled by the author will be briefly presented. Then, twenty-five species belonging to seven genera, all coming from the Permian of the Southern Kitakami Mountains will be described, which may be stratigraphically divided into three groups (namely Bp1, Bp2 and Bp3).

Before going further, the author wishes to express his sincere thanks in

particular to Prof. Dr. Masao MINATO of Hokkaido University, for his guidance through the course of the present study and critical reading of the typescript.

The present author is also grateful to Dr. Ichiro HAYASAKA, for the free use of his private library and encouragement given. He is also very much indebted to Dr. Makoto KATO of Hokkaido University for his kind assistance given in preparation of this paper.

Thanks are also due to Dr. A. GRIGORJEVA of the Palaeontological Institute of the U.S.S.R. Academy of Sciences, for her kindness in giving information of the stratigraphic position of *Magniderbyia magnifica* (LICHAREW) in the Northern Caucasus. Further, he wishes to extend his thanks to Dr. H. TAKEDA and Messrs. M. AKATSUKA, Y. KOZUCHI, T. MAEKAWA and M. HARADA for their kind disposal of the excellent collection for study. He is also very much obliged to Messrs. S. KUMANO and I. WATANABE for their aid in taking photographs used in this paper.

Brief history of the previous studies of the Japanese Permian Davidsoniacea

From the Southern Kitakami Mountains, twelve species belonging to the Permian Davidsoniacea have been hitherto described with illustrations by HAYASAKA (1925, 1953, 1960, 1963a, 1963b, 1966), HAYASAKA and MINATO (1956) and MINATO and NAKAMURA (1956). The formerly described species are listed below: *Derbyia hemisphaerica* WAAGEN, *D. magnifica* LICHAREW, *Geyerella arakii* HAYASAKA, *G. koizumii* HAYASAKA, *G. sp. indet.* MINATO and NAKAMURA, *Hamletella kitakamiensis* HAYASAKA, *Kiangsiella* cfr. *condoni* THOMAS, *Meekella gigantea* HAYASAKA, *M. striatocostata* (COX), *Orthotetes rugosa* FREDERICKS, *Orthotetina kayseri* (JÄKEL) and *Streptorhynchus pelargonatus* SCHLOTHEIM. All of them were collected from the lower part of the Kanokura series, ranging from the *Parafusulina* to possibly the *Neoschwagerina* zone. Further, a few other species have been listed by MINATO and others (1954) from the Lower Permian Sakamotosawa series (*Pseudoschwagerina* — *Pseudofusulina* zone) without description: *Derbyia* sp., *Streptorhynchus* sp. and *Meekella* sp.

In 1967 YANAGISAWA described two Davidsoniaceans, *Derbyia* cfr. *crassa* MEEK and HAYDEN and *Schuchertella?* sp. together with many brachiopod fossils collected from the Kashiwadaira formation in the Takakurayama — Yaguki area, southern part of the Abukuma Mountains.

The Nabeyama limestone developing in the Ashio Mountains, Central Honshu, has been well-known owing to its rich fusulinid and brachiopod remains. Among the brachiopods found from this limestone, HAYASAKA (1933)

described *Meekella gigantea* HAYASAKA, *Orthotetina planoconvexa* HAYASAKA and *O. eusarkos lata* HAYASAKA and MINATO (1949) later described *Streptorhynchus tubifera* MINATO.

From the Akasaka limestone, also in Central Japan, the presence of *Geyerella* sp. was noticed by HAYASAKA (1932).

SHIMIZU (1961a, 1961b) reported many brachiopod species from the Permian Maizuru group developing in the so-called Maizuru structural belt in Central Japan. According to him, fossils of the Maizuru group are faunistically further divisible into three units, namely Gujo, Kawahigashi and Takauchi faunules. These faunules are believed by SHIMIZU to be also roughly chronologically successive from the older Takauchi to the Gujo faunules.

The Takauchi faunule includes three Davidsoniacean species; *Kiangsiella? deltoidens* (WAAGEN), *Streptorhynchus semiplanus* (WAAGEN) and *S. kayseri* SCHELLWIEN (SHIMIZU, 1961a); the age of them may be, according to SHIMIZU, Middle to Upper Permian. Further, SHIMIZU estimated the age of the Kawahigashi faunule to be Late Permian, in which he found four septate Davidsoniaceans; *Derbyia altestiriata* WAAGEN, *D. cfr. altestiriata* WAAGEN, *D. cfr. grandis* WAAGEN and *D. hemisphaerica* var. *radiata* REED respectively.

The Gujo faunule is composed of many pelecypods and rather few brachiopods, and he correlated this faunule to the Uppermost Permian, from which he reported the presence of *Schellwienella ruber* (FRECH), *S. regularis* HUANG and *Orthotetina* sp., as the representative species of the Davidsoniacean brachiopods.

In addition to these records, the occurrence of certain Davidsoniaceans have also been known to exist from several other localities in Japan which will be listed below:

The Oashi formation developing in the Abukuma Mountains, Northeastern Japan; *Derbyia* sp. MINATO (1955).

The Oguradani formation developing in the Hida Mountains, Central Japan; Cfr. *Schellwienella regina* GRABAU, *Derbyia* sp. HAYASAKA and MATSUO (1951).

The Karita formation (Hiroshima Pref.); *Schellwienella* cfr. *ruber* (FRECH), *S. aff. acutangulata* Huang. IMAMURA (1957).

The Yamamba limestone (Kochi Pref.); *Meekella?* sp., *Streptorhynchus pseudopelargonatus* (BROILI). NONAKA (1946).

In the light of the recent progress of studies for the Davidsoniacean brachiopods, most of the former works in Japan, enumerated above, may need to be revised in many points.



Text-figure 1

Distribution of the Permian Davidsoniacea in Japan.

A — Southern Kitakami Mountains. B — Soma district, Abukuma Mountains. C — Takakurayama district, Abukuma Mountains. D — Ashio Mountains. E — Hida Mountains. F — Akasaka limestone plateau. G — Maizuru structural belt. H — Taishaku limestone plateau. I — Karita-mura, Hiroshima Prefecture. J — Yamamba limestone, Kochi Prefecture.

Short remarks on terminology of the Davidsoniacea

The author wishes to follow the terminology proposed by G. A. THOMAS in 1958 for description in the present paper, except for the term “cardinal area”, instead of “interarea” used by THOMAS. Further, he wishes to define certain terms more definitely in order to avoid confusions that might arise. Namely,

the median pseudo-septum must be a very rudimentary or faint septum in the pedicle valve as was named by I. THOMAS in 1910, while the peripheral ridge is a more or less strongly developed ridge encircling the muscular field.

Materials

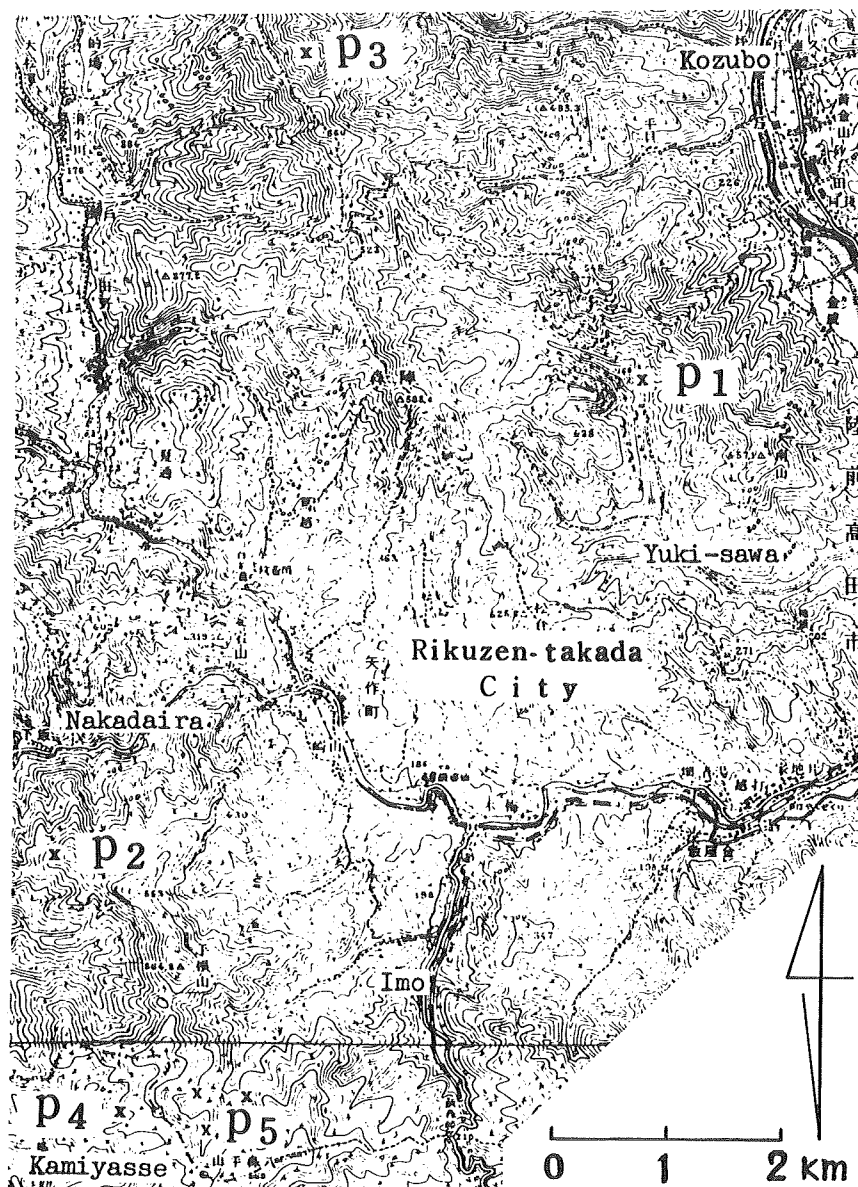
All of the species to be described in this paper are based on the specimens collected from the Southern Kitakami Mountains, Northeast Honshu, Japan. They may be divided into three groups through their stratigraphic occurrence which will be diagrammatically shown in the generalized stratigraphic column of the Permian deposits in the Southern Kitakami Mountains (text-figure 3).

The first group of them may be called Bp1, which is found from the Kawaguchi stage, the lower part of the Sakamotosawa series, corresponding to the *Pseudoschwagerina* zone. They are *Derbyia* sp. B, Cfr. *Orthotetes callytharrensensis* (THOMAS), *Magniderbyia* sp. and *Streptorhynchus* sp. Actually all the specimens of this group were collected only from the sandstone formation cropping out at Yukisawa, Rikuzentakada City.

The second group may be called Bp2, the stratigraphic position of which is situated at a certain horizon of the Kabayama stage, the upper part of the Sakamotosawa series, roughly corresponding to the *Pseudofusulina* zone. The specimens included in the second group were detected from the sandy slate formation developing at the Nakadaira district near Futamata, not far from the town of Rikuzentakada City. They are *Orthotetina* sp. B, *Meekella mexicana* Girty, *Derbyia* sp. C and *Schuchertella* sp. The locality and the stratigraphic distribution of these fossils will be given in the text-figures 2 and 3.

The third group designated as Bp3 includes plenty of representatives of the Davidsoniaceans which were also collected from various localities in the Southern Kitakami Mountains. The stratigraphic range of this group seems to be somewhat wider than in the former two groups. They may possibly range from the *Parafusulina* to *Neoschwagerina* zones, although detailed horizons for certain species have not been finally settled yet. Nevertheless, it may be almost certain that the third group of the Davidsoniaceans are found in association with a considerable number of *Leptodus* nearly everywhere in the Southern Kitakami Mountains. The representative localities where this group of brachiopods was obtained will be shown in the text-figure 2. Species known from this group will be listed as follows; *Orthotetina hayasakai* n. sp., *O. elongata* n. sp., *O. kayseri* (JÄKEL), *O. transversa* n. sp., *O. polita* FLIEGEL, *O.* sp. A, *Meekella* sp., *M.* cfr. *striatocostata* (COX), *M. garnieri* BAYAN, *M. rainatoi* n. sp., *M.* cfr. *eximia* (EICHWALD), *M. nodosa* n. sp., *Derbyia nipponica* n. sp., *D.* cfr. *acutiplicata* METZ, *D.* sp. A, *Schuchertella* sp., *S. frechi* HUANG and *Streptorhynchus pelargonatus* SCHLOTHEIM. Among them, *Schuchertella* sp. is

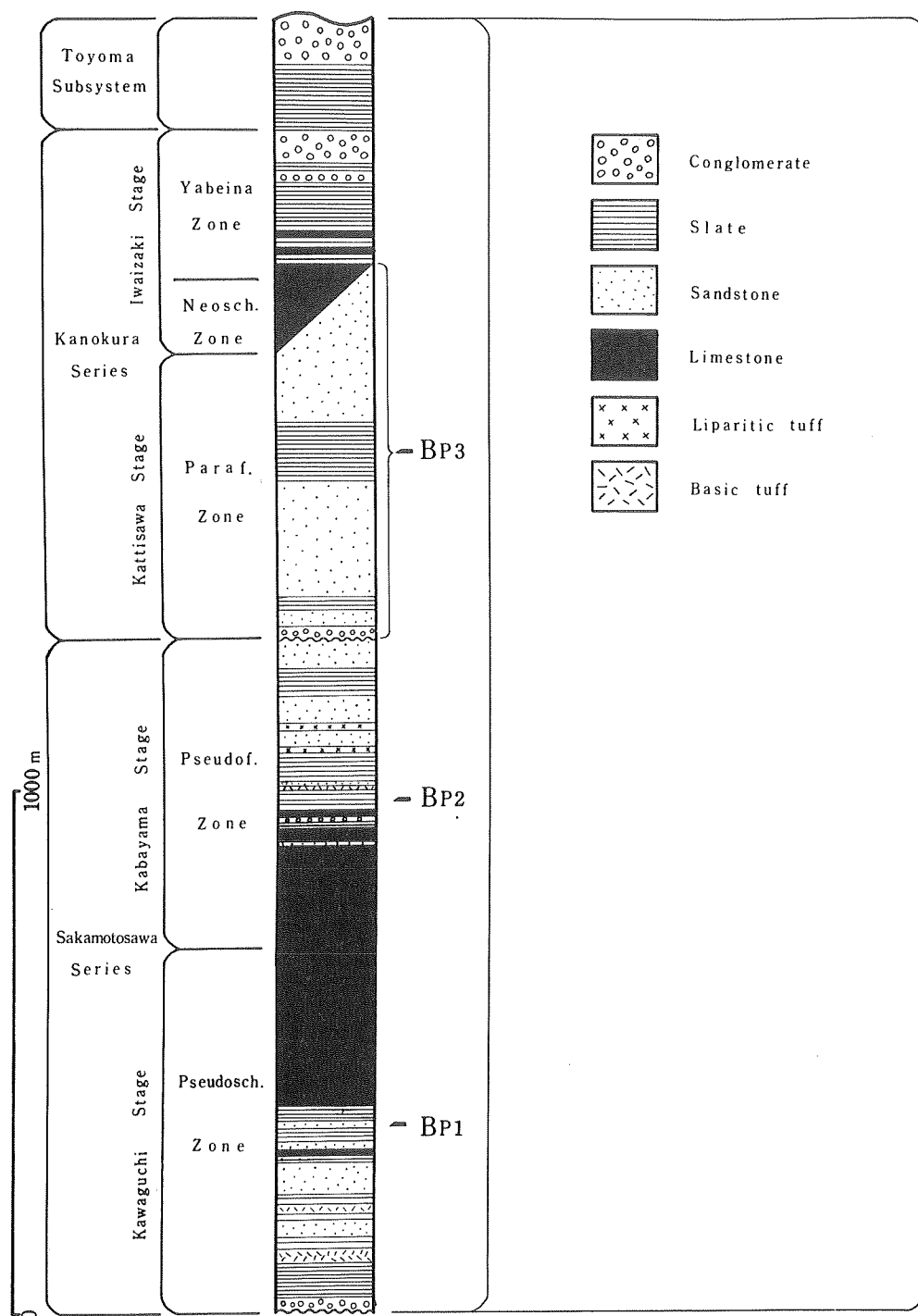
only a single common species between the Upper Sakamotosawa and the Lower Kanokura series.



Text-figure 2

Geographical map of a part of the Kitakami Mountains, showing locations of the Permian Davidsoniacean fossils described in this article.

P1 — Yukisawa, Yahagi-cho, Rikuzentakada City. P2 — Nakadaira, Yahagi-cho, Rikuzentakada City. P3 — Kozubo-sawa, Yokota-cho, Rikuzentakada City. P4 — Kamiyasse, Niitsuki-cho, Kesennuma City. P5 — Imo, Yahagi-cho, Rikuzentakada City.



Text-figure 3

Standard columnar section of the Permian deposits of the Southern Kitakami Mountains

indicating stratigraphical occurrences of the species herein dealt with. The present section was compiled by M. MINATO et al. in 1954. Neosch: *Neoschwagerina*, Paraf: *Parafusulina*, Pseudof: *Pseudofusulina*, Pseudosch: *Pseudoschwagerina*.

Unfortunately available specimens in this study are mostly imperfect in preservation. They are too deformed by rock pressure in general to reconstruct their original convexities and outer configurations. In most cases, shells have been completely dissolved, so that only impressions of the inner and outer surfaces of the fossils are preserved as moulds. Accordingly, it is not always possible to estimate the exact height, width, thickness and so forth in the specimens concerned.

Affinities of the Davidsoniacean fauna of the Permian in the Kitakami Mountains

As stated in the preceding chapter, the Davidsoniaceans herein dealt with may be divided into three groups in their stratigraphic occurrences.

The Lower Sakamotosawa series contains the oldest Permian shells in the Kitakami Mountains. *Magniderbyia* sp. is much related to *M. magnifica* originally described by LICHAREW from the Upper Permian of the Northern Caucasus. So far as the writer is concerned, however, the latter has not been hitherto known outside the Northern Caucasus. One of the other shells in the Kitakami Mountains quite resembles *Orthotetes callytharrensensis* (THOMAS) found from the Callytharra formation (Earliest Artinskian or Late Sakmarian) of Western Australia. But, the specimen at hand unfortunately lacks a pedicle valve which is actually more important in generic and specific identification. *Derbyia* sp. B strongly recalls *Derbyia regularis* WAAGEN from the Middle *Productus* limestone of the Salt-Range Pakistan, the Upper Carboniferous of Russian Platform and the Lower Permian of the Ural Mountains.

Bp2 faunule contains four Davidsoniacean brachiopods: *Meekella mexicana* described by GIRTÝ from the Pennsylvanian of New Mexico and the Permian of Texas, U.S.A.; *Schuchertella* sp. resembled *S. cfr. semiplana* WAAGEN having been described by CHAO from the Chihshia limestone of South China, and *Schuchertella* sp. which, however, ranges from the Upper Sakamotosawa to the Lower Kanokura series in the Southern Kitakami Mountains.

A considerable number of species belonging to Bp3 group are found also in the Upper Permian Lopingian of South China, for instance, *Orthotetina kayseri* (JÄKEL), *Meekella nodosa* n. sp., *M. garnieri* BAYAN, *Schuchertella frechi* HUANG and *Streptorhynchus pelargonatus* SCHLOTHEIM. This Davidsoniacean faunule also shows some common aspect with those of the Salt-Range. *Derbyia*

hemisphaerica WAAGEN originally described by WAAGEN from the Upper *Productus* limestone of the Salt-Range was once found by HAYASAKA (1925) from the Lower Kanokura series of the Kitakami Mountains. Although being a rather cosmopolitan species, *Streptorhynchus pelargonatus* SCHLOTHEIM is known to occur from both Kitakami and the Salt-Range. *Orthotetina polita* has been reported by FLIEGEL (1901 — 2) from the Upper Permian of Central Sumatra, whereas *Meekella minatoi* n. sp. was recently found by Dr. K. ISHII and others from the Middle or Upper Permian of Gua Musang in Kelantan, Malaya, although it has not yet been described. In addition to these forms above stated, some other species may be further enumerated as the representatives indicating Middle to Upper Permian in age.

To summarize, the Upper Carboniferous and Lower Permian species are more or less predominant in the Davidsoniacean faunule belonging to each Bp1 and Bp2 group in the Kitakami Mountains. Among them any particular palaeobiogeographic indicator does not seem to be included. On the other hand, the Davidsoniaceans from the Lower Kanokura series shows strong affinity with the Lopingian in China and Mostly consist of the Middle to Upper Permian elements.

Classification of the Davidsoniacea

Very diverse views on classification or phylogeny of this group of brachiopods have been held by WAAGEN (1884), SCHELLWIEN (1900), DUNBAR and CONDRA (1932), LICHAREW (1939), MINATO (1953), WILLIAMS (1953, 1965), STEHLI (1954), CAMPBELL (1957), THOMAS (1958), SOKOLSKAJA (1960) and HAVLICEK (1967).

The superfamily name Orthotetacea was first proposed by WILLIAMS (1953) for the families including Orthotetidae MCEWAN, 1939, Gemmellaroiidae WILLIAMS, 1953, Scacchinellidae WILLIAMS, 1953 and Thecospiridae BITTNER, 1893; then the definition was given as "Strophomenoids without a functional pedicle; pedicle valve usually greatly modified and cemented by the umbo or a greater part of the shell surface to a foreign body, brachial valve convex throughout ontogeny; cardinal process bilobed often greatly extended into the pedicle valve, sometimes highly modified, lophophore probably spirolophous in all stocks, exceptionally impressed and supported by spirally coiled calcareous ribbons. Upper Ordovician to Triassic".

According to G. A. THOMAS (1958), STEHLI (1954) slightly modified the former definition on this superfamily proposed by WILLIAMS, 1953. Namely, STEHLI removed the family Scacchinellidae from the present superfamily and referred it to the Productoidea. In this regard he was later followed by

MUIR-WOOD and COOPER (1960), SARYTCHEVA, LICHAREW and SOKOLSKAJA (1960), and others. He seems to have been undecided as to whether or not the family Gemmellaroiidae may be included in the Orthotetacea. Further he revised and restricted the definition of the Orthotetidae of MCEWAN, 1939, and proposed a new family, Schuchertellidae, in which he grouped certain genera formerly included in the Orthotetidae by MCEWAN, 1939.

In 1960 SOKOLSKAJA, however, did not accept the validity of the Schuchertellidae proposed by STEHLI and she only placed two families, Orthotetidae WAAGEN, 1884 and Davidsoniidae KING, 1850 into the Orthotetacea. Besides these two families, she hesitatingly assigned Thecospiridae into this superfamily. The Gemmellaroiidae was removed from the present superfamily by her. Actually, MUIR-WOOD and COOPER (1960) placed the genera included in the Gemmellaroiidae into the Richthofenidae of the Productoidea.

Recently WILLIAMS (1965) revised his earlier classification and then proposed the suppression of the superfamily name Orthotetacea in favour of Davidsoniacea. Further, he included the following five families in the Davidsoniacea; Meekellidae STEHLI, 1954, Schuchertellidae WILLIAMS, 1953, Orthotetidae WAAGEN, 1884, Davidsoniidae KING, 1850 and Thecospiridae BITTNER, 1893. Among them, the former three families are closely related to each other from the morphological point of view. On the other hand, the latter two are quite distinct from the former three primarily in differences of internal structures of the brachial valve. Namely, the Davidsoniidae, in which three Devonian genera, *Davidsonia*, *Biconstrophia* and *Pro davidsonia* are included, possess a pair of spirally coiled brachia in the brachial valve. The family Thecospiridae, represented by Triassic genus *Thecospira*, is also different in having a pair of spirally coiled calcareous ribbons as brachia. Although the difference of form of brachia seems to be of fundamental importance, which may be more than family character, a more detailed research is necessary on this organ before this problem can be settled in the future.

As to the former three families, Meekellidae by WILLIAMS may be nothing else than the family Orthotetidae defined by STEHLI (1954) in every detail. Namely, WILLIAMS (1965) adopted Meekellidae instead of Orthotetidae as a family name for this group with true dental plates in the pedicle valve, because, *Orthotetes radiata* FISCHER de WALDHEIM, type species of *Orthotetes*, which is the type genus of the family Orthotetidae, apparently lacks true dental plates in the pedicle valve. Therefore, the genus should be excluded from this group of Davidsoniacea.

WILLIAMS (1965) divided the family Meekellidae into two subfamilies, younger Meekellinae and older Fardeniinae. The latter was then newly

proposed by him. When HAVLICEK (1967) published his study of the Silurian and Devonian brachiopods of Bohemia, he thought that the shape of dental plates may be valuable as a family character. Then he grouped the genera with short and divergent dental plates as Chilidiopsidae, which may be accordingly equal with the subfamily Fardeniinae of WILLIAMS (1965). Therefore, the Meekellidae s.s. may be defined to include the genera with long and almost parallel dental plates in the pedicle valve.

WILLIAMS (1965) referred the genera without true dental plates to either Schuchertellidae s.s. or Orthotetidae, on the basis that the latter is provided with a median septum in the pedicle valve, in contrast to the lack of such septum in the former.

Now, the apical structure of the pedicle valve has long been believed to be the most fundamental basis in classification of this group of brachiopods, to which the present author completely agrees. He believes, however, that presence or absence of a median septum in the pedicle valve is not of fundamental importance as a family character, but may be only applicable as a basis in distinction of subfamilies. In this regard, the author completely agrees with STEHLI's opinion.

According to HAVLICEK (1967), the shape of brachiophores was viewed to be of importance in the classification of subfamilies especially by STEHLI (1954) as well as G. A. THOMAS (1958). Actually STEHLI divided Schuchertellidae into Schuchertellinae with low and concave brachiophores and Streptorhynchinae having straight and divergent ones. HAVLICEK was of the opinion that STEHLI's subfamilies must rather correspond to families and the distinction between each family lies, according to HAVLICEK, in the shape of cardinal process. Cardinal process is free and not welded into one piece in Schuchertellidae, while in Streptorhynchidae they are high, parallel, coalesced, penetrating deep into the delthyrial cavity of the pedicle valve. In these regards, the present author would like to accept the HAVLICEK's opinion, since absence or development of a median septum in the pedicle valve or the shape of brachiophores is generally of less value than characters of cardinal process in this case. The family name schuchertellidae, however, has to be replaced by Orthotetidae, since the genus *Orthotetes* may be included in this subordinate group and the subfamily name Orthotetinae based on *Orthotetes* had been used considerably earlier than the subfamily name Schuchertellinae first proposed by WILLIAMS in 1953.

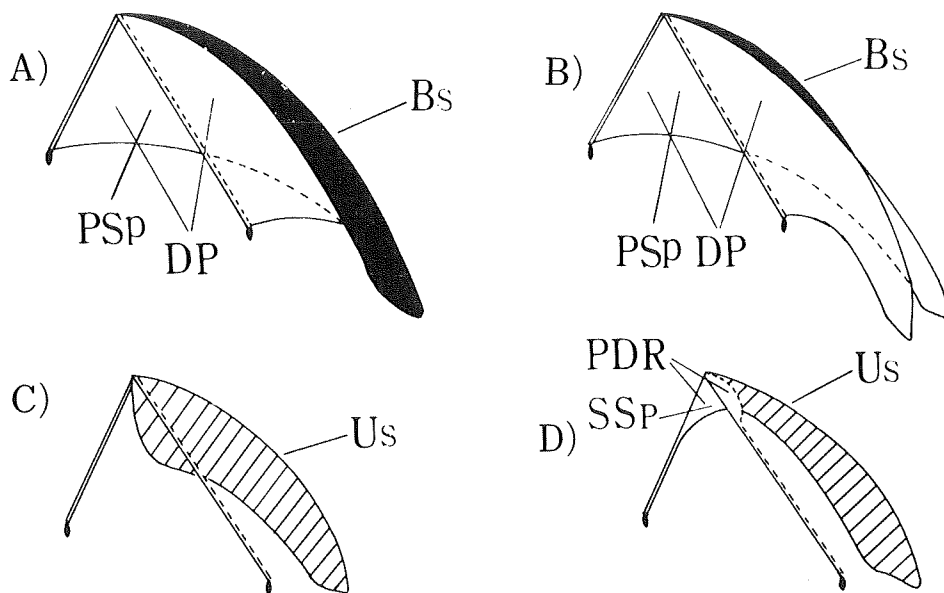
In reviewing the previously proposed classification of the Davidsoniacea, the following six families, viz. Davidsoniidae, Thecospiridae, Chilidiopsidae, Meekellidae, Orthotetidae and Streptorhynchidae seem, according to the author's view, to be valid families in the superfamily Davidsoniacea.

The Permian Davidsoniacea from the Kitakami Mountains to be described in the present paper all belong to the three families, Meekellidae, Orthotetidae and Streptorhynchidae. Each of these three families can be further divided into two subfamilies.

The Meekellidae may consist of two subfamilies which are Meekellinae STEHLI, 1954 and Omboniinae SOKOLSKAJA, 1960. The latter is distinct from the former in having a primary spondylium in the pedicle valve.

The subdivision of this family by means of presence or absence of plications on the shell surface was once employed by STEHLI in 1954. Although shell sculpture has been found to be of considerable importance as a generic or specific character, its value as a subfamily character seems to be less certain.

The name Omboniinae was proposed by SOKOLSKAJA in 1960 for a subfamily. Then, she described the subfamily to include all the Davidsoniacean genera with a spondylium at the apical interior of the pedicle valve. But, the grouping having been tried by her can not be largely acceptable to the present author. For instance, it may be obvious that the spondylium of the genus *Orthotetes* is not homologous with that of *Ombonia*. The former is formed by direct prolongation of the dental ridge and called a secondary spondylium, while the latter by union of dental plates and called a primary spondylium. As a matter of fact, the genus *Orthotetes* has been already removed from this group. Accordingly the Omboniinae must be reintroduced here as Meekellidae having a primary spondylium which is formed by union of dental plates before reaching floor of pedicle valve. Therefore, only one plate attaches to the floor of the valve in this case.



Text-figure 4

Diagrams schematically showing apical structure of pedicle valve in four Davidsoniacean genera.

A — *Ombonia*. B — *Perigeyerella*. C — *Derbyia* or *Derbyoides*. D — *Orthotetes*. Bs: Biseptum, PSp: Primary spondylium, Us: Uniseptum, SSp: Secondary spondylium, DP: Dental plates, PDR: Prolongation of dental ridges.

The Orthotetidae may contain two subfamilies, Orthotetinae WAAGEN, 1884 and Schuchertellinae WILLIAMS, 1953. The content of the Orthotetinae is quite similar to the Derbyoidinae defined by G. A. THOMAS in 1958. The Schuchertellinae may be distinguishable from the Orthotetinae in lacking a uniseptum in the pedicle valve. In certain species belonging to the Schuchertellinae, there is sometimes observable a small and tiny septum in the pedicle valve, apparently resembling a median uniseptum. However, this is in fact, not a true uniseptum but a median pseudo-septum designated by I. THOMAS in 1910.

The Streptorhynchidae may be divided into two subfamilies, Streptorhynchinae STEHLI, 1954 and Derbyiinae STEHLI, 1954. These two subfamilies may be distinct from each other by the absence or the development of a uniseptum in the pedicle valve, likewise in the division of the Orthotetidae. The Streptorhynchinae lacks a uniseptum, while such a septum surely exists in the Derbyiinae.

The existing familial and subfamilial classification is, therefore:

Superfamily Davidsoniacea KING, 1850

Family Davidsoniidae KING, 1850

Family Chilidiopsidae BOUCOT, 1959

Family Meekellidae STEHLI, 1954

Subfamily Meekellinae STEHLI, 1954

Subfamily Omboniinae SOKOLSKAJA, 1960

Family Orthotetidae WAAGEN, 1884

Subfamily Orthotetinae WAAGEN, 1884

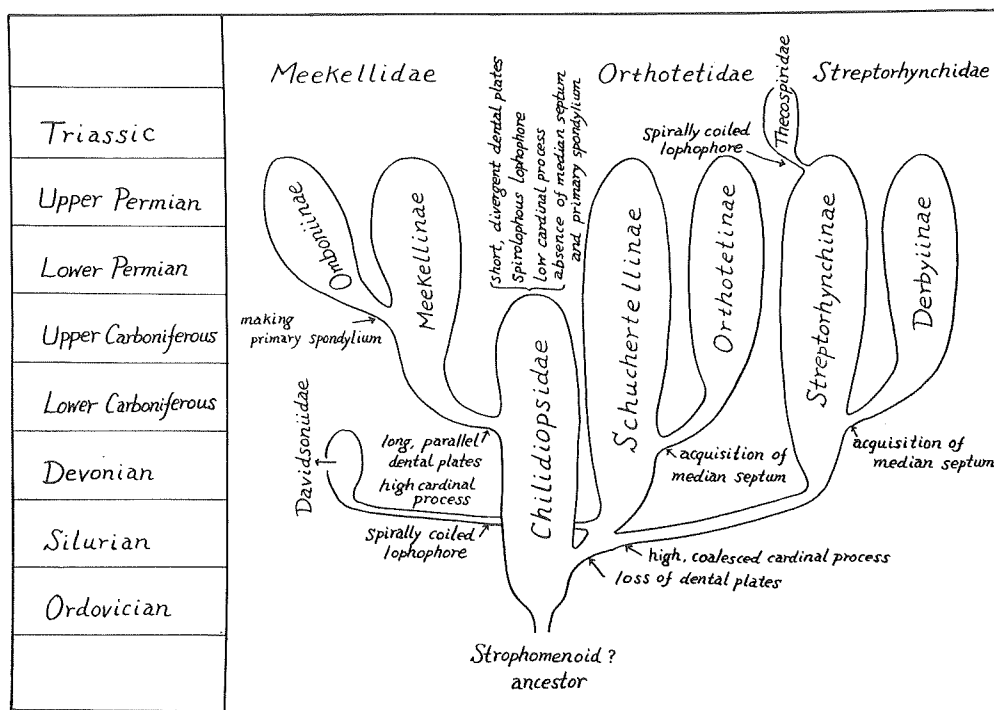
Subfamily Schuchertellinae WILLIAMS, 1953

Family Streptorhynchidae STEHLI, 1954

Subfamily Streptorhynchinae STEHLI, 1954

Subfamily Derbyiinae STEHLI, 1954

Family Thecospiridae BITTNER, 1893



Text-figure 5

Phylogeny of Davidsoniacea proposed by the author.

As to the lower rank of classification, generic or specific taxonomy for instance, the arrangement of the various kinds of plates developing in both valves, presence or absence of plications in the shell surface, the shape of socket plates and so forth must be brought into consideration.

Systematic description

Genus *Orthotetina* SCHELLWIEN, 1900

- 1900 *Orthotetina* SCHELLWIEN, p. 8.
- 1931 *Orthotetina* GRABAU, p. 250.
- 1932 *Orthotetina* DUNBAR and CONDRA, p. 132.
- 1953 *Hamletella* HAYASAKA, p. 92.
- 1960 *Orthotetina* SOKOLSKAJA, p. 218.
- 1965 *Orthotetina* WILLIAMS, p. H406.

Diagnosis: Almost moderate-sized meekellid with plications on the shell surface. Hinge-line much shorter than or nearly equal to the greatest width. Cardinal area considerably variable in height. Triangular delthyrium always entirely covered by an inflated pseudodeltidium. Pedicle valve interior with a pair of dental plates running in subparallel with each other. In the brachial valve a bifid cardinal process laterally united to divergent socket plates of moderate length. Surface of the valves covered by numerous costellae and a few concentric growth-lines at all growth-stages.

Remarks: The genus *Orthotetina* was erected by SCHELLWIEN in 1900 with *Orthotetina persica* as a type species. The genus most resembles *Meekella* WHITE and ST. JOHN in internal structures of both valves, but differs in lacking plications on the shell surface.

According to DUNBAR and CONDRA (1932), TSCHERNYSCHEW (1902) once considered that the presence or absence of plications is not a generic importance and then *Orthotetina* was regarded to be synonymous with *Meekella*. His conclusion was later followed by I. THOMAS (1910), LICHAREW (1930) and others. On the other hand, many palaeontologists, notably DUNBAR and CONDRA (1932), G. A. THOMAS (1958) and SOKOLSKAJA (1960), placed stress on the development of plications to separate generically *Orthotetina* from *Meekella*. However, there are such species showing transitional form between *Orthotetina* and *Meekella* in the development of plications as *Meekella minatoi* or *M. mexicana*. Nevertheless, the author still follows the opinion upheld by DUNBAR and CONDRA, G. A. THOMAS, SOKOLSKAJA and others as to the validity of the genus *Orthotetina*.

HAYASAKA established genus *Hamletella* in 1953, *Streptorhynchus altus* HAMLET from Timor as a type species. Then, he defined his genus as "Orthotetinae with high and usually distorted ventral beak, lacking median septum but developing a pair of parallel delthyrial supporting plates; surface ornamented with fine radial striae crossed by faint growth wrinkles". At the same time, he referred *Hamletella kitakamiensis* HAYASAKA from the Southern Kitakami Mountains to this new genus. Further, he doubtfully placed *Streptorhynchus altissimus* LICHAREW into the genus *Hamletella* as well, although the internal structure of that species was scarcely known. Judging from the diagnosis given by HAYASAKA, there seems to be no essential difference in the arrangement of dental plates between these two genera as G. A. THOMAS already noticed in 1958. Accordingly the genus *Hamletella* may be concluded to be merely distinguishable from *Orthotetina* in having shells with higher and more distorted cardinal area than that of the latter. In the author's collection of the meekellid shells now in concern there are however

recognizable certain species, such as *Orthotetina hayasakai* or *O. elongata*, both of which show rather transitional in feature regarding height and distortion of cardinal area between *Orthotetina* and *Hamletella*. As a matter of fact, the validity of the genus *Hamletella* has been already denied by WILLIAMS in 1965.

Seven species belonging to the genus *Orthotetina* to be described below may be separated into four groups by a difference in outer configuration as follows:

- 1) Elongate and rounded discoidal form. The hinge-line is slightly shorter than the greatest width of the shell: *O. hayasakai*, *O. elongata*, *O. kayseri*.
- 2) Triangular in form. The hinge-line is considerably shorter than the greatest width: *O. polita*.
- 3) Very transverse form. The hinge-line is nearly equal to the greatest width: *O. transversa*, *O. sp. A*.
- 4) Triangular form. The pedicle valve has a geniculation near the anterior margin: *O. sp. B*.

Orthotetina hayasakai n. sp.

Pl. 1, figs. 1 – 2

1925 *Orthotetes rugosa*, HAYASAKA (non FREDERICKS), p. 91, pl. 5, fig. 1.

Material: Two specimens obtained from the Lower Kanokura series at Imo, Yahagi-cho, Rikuzentakada City, Iwate Prefecture. One of them seems to be an immature individual, because of its smaller shell size. Reg. nos.: UHR 13572 (holotype), 13694.

Description: Shell in adult is of medium size, elongately ovate in outline. Hinge-line is nearly straight and a little shorter than the maximum width which lies at the portion of three fifths of the whole length measured from the apex.

Pedicle valve is much larger than the opposite valve and gently convex in either transverse or longitudinal profile. At the anterior part it becomes, however, nearly flat or slightly resupinate. Beak is not incurved but almost straight. Apical angle is about 75° . Median sulcus is never seen on this valve. In the opposite side, pretty high and twisted cardinal area which is slightly concave and elongately triangular in outline is observable. The height of the cardinal area is as long as one half of the whole length of the shell. Delthyrium is narrow and covered by a moderately inflated and medium-sized pseudo-deltidium. The internal structure of this valve is clearly traceable in

“Steinkern” specimens. The presence of dental plates running almost parallel with each other are represented by slits carved on the “Steinkern”, and they are rather long but do not reach as far as the hinge-line. The dental plates are closely placed on the floor with each other. Muscular scars are not discernible in the specimens at hand.

Brachial valve is much smaller than the pedicle one and moderately convex. The outline of the valve is subcircular with straight edge at the posterior portion. Neither sulcus nor fold is present on this valve, too. Internally, the presence of a pair of socket plates diverging antero-laterally at an angle varying between 90° – 110° and a lobated cardinal process is ascertained.

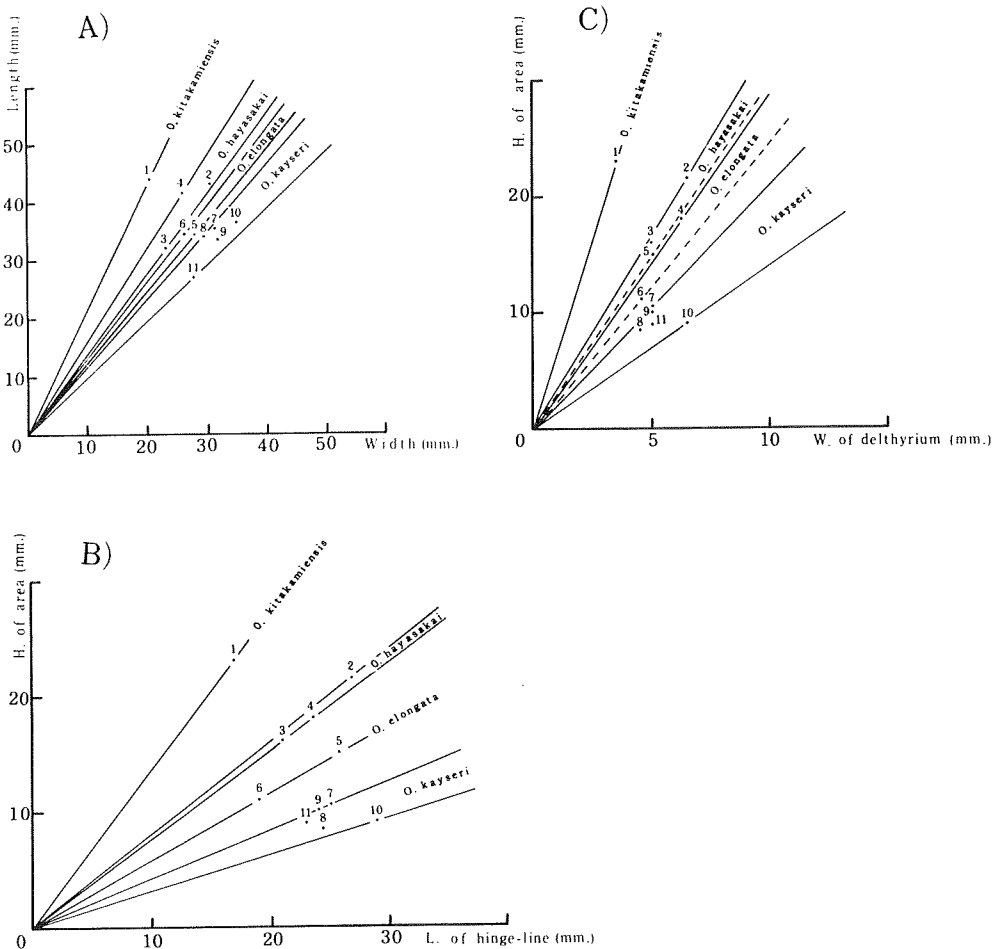
The surface of both valves is uniformly covered by fine radial costellae which may number as many as 23 in the space of 10 mm at the central region of the pedicle valve. These costellae gradually increase in number towards the anterior margin by intercalation. Concentric growth-lines are also observable on the surface of both valves, and they are especially conspicuous near the anterior margin of the pedicle valve.

Remarks: This species is easily distinguishable from *Orthotetina kitakamiensis* (HAYASAKA) by differences of outer configuration of shell, height of cardinal area and shape of delthyrium (see text-figure 6). Actually HAYASAKA's species has shells being much more elongated in form, with higher cardinal area, and longer and narrower delthyrium than those of the present species.

As a matter of fact, HAYASAKA (1925) first described the present species from the Lower Kanokura series of the Kitakami Mountains under the name of *Orthotetes rugosa* FREDERICKS. Because of the presence of a pair of dental plates in the pedicle valve, he later removed his specimen from the genus *Orthotetes* and placed it into *Orthotetina* in 1963. Furthermore, it was specifically identified with *Orthotetina kayseri* (JÄKEL) by him. HAYASAKA was of the opinion that *Orthotetina kayseri* is very variable in form, representing either elongate, ovate, rounded or discoidal shell. The author, however, now believes that three species may be actually distinguished among the forms described by HAYASAKA under the name of *Orthotetina kayseri*, which may be enumerated as follows: *hayasakai*, *elongata* and *kayseri* s.s. Differences in regard to shell form between these species listed above will be diagrammatically shown in the annexed text-figure 6.

HAYASAKA (1953) once stated that *Streptorhynchus altissimus* LICHAREW known from the Upper Permian of the Northern Caucasus seems to be possibly synonymous with his *Hamletella kitakamiensis*, if the Russian species had a pair of dental plates in the pedicle valve interior. In spite of this statement, the

author holds a different view in this regard. The Russian species now being considered may be nearly akin to the present species, *Orthotetina hayasakai*, instead of *kitakamiensis* in having similar outline of shell and shape of delthyrium, as shown in the text-figure 6.



Text-figure 6

Three diagrams giving key of specific distinction between four akin species, *Orthotetina kitakamiensis*, *O. hayasakai*, *O. elongata* and *O. kayseri*.

- A — Diagram showing relation between length and width of shell.
- B — Diagram showing relation between height of area and length of hinge-line.
- C — Diagram showing relation between height of area and width of delthyrium at its base.
- 1 — *Hamletella kitakamiensis* described by HAYASAKA(1953).
- 2 — *Orthotetina hayasakai* NAKAMURA(UHR 13572).
- 3 — *O. hayasakai* NAKAMURA(UHR 13694).
- 4 — *Streptorhynchus altissimus* described by LICHAREW(1932) — probably assignable into *Orthotetina hayasakai*.
- 5 — *Orthotetina elongata* NAKAMURA(UHR 13567).

- 6 — *O. kayseri* JÄKEL described as elongate type by HAYASAKA (1963)
- 7 — *O. kayseri* JÄKEL (UHR 13686).
- 8 — *O. kayseri* JÄKEL (UHR 13687).
- 9 — *O. kayseri* JÄKEL (UHR 13688).
- 10 — *O. kayseri* JÄKEL described as round type by HAYASAKA (1963).
- 11 — *O. kayseri* JÄKEL described by MINATO and NAKAMURA (1956).

Orthotetina elongata n. sp.

Pl. 1, figs. 3 — 6; Pl. 2, fig. 1

?1963b *Orthotetina kayseri*, HAYASAKA (non JÄKEL), p. 735, figs. 3a — b (non figs. 1, 2).

Material: Holotype (UHR 13567) is more or less completely preserved as external and internal moulds of both valves. Four more specimens (UHR 13689, 13690, 13691, 13692) are also available for study but are all worse in preservation. Horizon and locality are the same as in the preceding species.

Description: The general outline of the pedicle valve is longitudinally ovate. Although the original convexity is scarcely known owing to deformation of shells, the pedicle valve seems, in any case, to show weak convexity in both lateral and transverse profiles. Beak is neither twisted nor incurved but it is rather bluntly pointed. Beak ridges are not straight but angularly convex. Ears are hardly recognizable. A median sulcus faintly develops only at the anterior part and is very broad and shallow. Cardinal area is triangular in form and fairly high but lower than that of the preceding species. Internally a pair of dental plates measure about 16 — 20 mm in length. The interspace between dental plates gradually becomes wider towards anterior on the floor of the pedicle valve.

Brachial valve is rounded, trapezoidal in outline and considerably smaller than the opposite valve. The convexity of this valve is as weak as that of the pedicle valve. The presence of a median sulcus being very broad and shallow is observable merely near the anterior portion. Cardinal process is short and a pair of normal socket plates diverge antero-laterally.

The surface ornamentation of both valves consists of fine radial costellae and concentric growth-lines. The radial costellae may number as many as 25 within the distance of 10 mm at the central part of the pedicle valve. They increase anteriorly in number by intercalation.

Remarks: HAYASAKA (1963) reported the occurrence of three Davidsoniacean species from the Lower Kanokura series of the Southern Kitakami Mountains. One of them was *Orthotetina kayseri* (JÄKEL) being represented by three specimens figured on his plate. The author, however, is of the opinion that these three specimens do not belong to a single species. The specimen illustrated in his figure 3 is elongate and ovate, while the others (figs. 1, 2) are rounded and discoidal in form. The latter two may in fact belong to *Orthotetina kayseri*, but the former may be specifically distinct from the latter. It seems to be rather conspecific with the species here newly proposed from outer configuration of shell. But, in HAYASAKA's specimen, the interspace between two dental plates is much closer, and the shape of brachial valve is more elongate.

Orthotetina kayseri (JÄKEL)

Pl. 2, figs. 2 – 5

- 1883 *Streptorhynchus crenistria* var. *senilis*, KAYSER (non PHILLIPS) p. 178, not figured.
1900 *Orthotetes (Orthotetina)* sp., SCHELLWIEN, p. 9, pl. 1, fig. 6.
1901 – 2 *Orthotetes (Orthotetina) kayseri*, FLIEGEL, p. 127, pl. 6, fig. 9.
1956 *Orthotetina kayseri*, MINATO and NAKAMURA, p. 152, pl. 24, fig. 4.
1963b *Orthotetina kayseri*, HAYASAKA, p. 753, figs. 1, 2 (non 3).

Material: Four specimens at hand are all well preserved as external and internal moulds of both valves. Reg. nos.: UHR 13686, 13687, 13688, 13693. Horizon and locality are the same as in the preceding species.

Remarks: MINATO and the author (1956) thoroughly described specific characters and nomenclatorial problems of this species. It was the first record of the occurrence of this species from the Japanese Permian.

HAYASAKA (1963) also lately reported this species from the same series developed near Kesennuma City. However, at least a part of the specimens considered by him may be better transferred into *Orthotetina elongata*, as it is discussed in the remarks on the preceding species.

Orthotetina polita FLIEGEL

Pl. 3, fig. 4; Pl. 4, figs. 1 – 2

1901 – 2 *Orthotetes (Orthotetina) politus*, FLIEGEL p. 97, pl. 6, fig. 8.

Material: Three specimens from the Lower Kanokura series of Imo. They are preserved as external and internal moulds of both valves. Reg. nos.: UHR 13663, 13664, 13668.

Description: Shell is medium in size, subtriangular in outline. Pedicle valve is nearly flat, while brachial valve more inflated. Hinge-line is much shorter than the greatest width of the shell.

Pedicle valve is rounded and fan-shaped. In the early growth-stage it is almost flat, whereas slightly inflated at the anterior half. Beak is somewhat reclined and rather pointed. Apical angle shows nearly 90° . Beak ridges are almost straight or slightly concave. Neither median sulcus nor fold is present in this valve, although the middle part of this valve becomes flattened. Cardinal area of isosceles triangle in form is high and slightly distorted. The outer surface of the cardinal area is covered by numerous fine horizontal striae. Delthyrium is narrow and covered by a strongly inflated pseudodeltidium. In the pedicle valve a pair of dental plates are slightly diverging towards the anterior.

Brachial valve is much smaller than the opposite one and transverse, ovate in form. The greatest width of the shell is measured at the midlength of the valve. A broad and deep sulcus is present in this valve. Socket plates are short and divergent. The presence of muscular scars are faintly traceable on the "Steinkern" specimen, although the details are not accessible.

The entire surface of both valves are uniformly ornamented with fine radial costellae numbering about 20 within the distance of 10 mm near the anterior margin of the pedicle valve. Further, faint concentric lines are developed and concentrated especially at the anterior part.

Remarks: The present species is characterized by having a broad and deep sulcus on the brachial valve and a somewhat reclined pedicle valve beak. Moreover, the hinge-line of the shell is considerably shorter than the greatest width. Specimens at hand is very similar to the holotype of this species described by FLIEGEL (1901 – 2) from Sumatra. The type specimen has sinuosus dental plates, whereas the specimens here examined possess flat and straight dental plates. But, the author considers that the sinuosus dental plates of the Sumatran specimen may result from deformation.

Orthotetina planoconvexa described by HAYASAKA (1933) from the Nabeyama limestone of the Ashio Mountains, Kwanto district seems to be also

somewhat akin to the present species, in having a plano-concave pedicle valve with pointed and reclined beak, as well as hinge-line being half as long as the maximum width. But, it is uncertain whether a sulcus is situated or not on the brachial valve of HAYASAKA'S specimen.

Orthotetina transversa n. sp.

Pl. 3, figs. 1 – 3

Material: Three specimens, two of which are nearly complete in preservation. All are obtained from the Lower Kanokura series of Imo. Reg. nos.: UHR 13573 (holotype), 13662, 19532.

Description: Shell is medium in size and transversely elongate, ovate in outline. Hinge-line is slightly shorter than the greatest width of the shell.

Pedicle valve is very transverse in form. The anterior margin of the pedicle valve is nearly straight or very weakly convex so as to run almost in parallel to the hinge-line. Beak is quite obtuse and beak ridges are nearly straight or slightly convex. Cardinal extremities are not acute but rounded. Median sulcus is unobserved on this valve. Cardinal area is moderately high, considerably wide and at the middle of that there may be found an extremely large, as well as broad delthyrium covered by a strongly inflated pseudodeltidium. Surface of the cardinal area is ornamented by fine horizontal striae.

Brachial valve may be only a little smaller than the opposite valve. It is moderately convex at the umbonal region, but becomes flat or rather concave at the anterior portion. Internally socket plates are short and widely divergent antero-laterally. A large cardinal process arises from the posterior terminal of the socket plates. Muscle scars are clearly traceable on the surface of the "Steinkern" specimen. They are semi-circular in shape and coarsely lobated. There are observable a pair of lateral ridges developing in subparallel with the hinge-line.

The entire surface of both valves is covered by rather fine radial costellae, which are counted as many as 9 within the space of 10 mm at the middle portion near the anterior margin of the pedicle valve. They increase in number only by intercalation in later growth-stage.

Remarks: The present species is very characteristic in having a shell much wider than its height, a broad and large delthyrium and lateral ridges in the brachial valve.

Orthotetina eusarkos lata described by HAYASAKA (1933) from the Nabeyama limestone of the Ashio Mountains may somewhat resemble the present species. But, the species now in concern is still distinguishable from HAYASAKA'S species in having a much smaller and more transverse shell.

It may be note-worthy that the presence of lateral ridges in the brachial valve of this new species is discernible. Its value as a generic character, however, seems to be less certain at present.

Orthotetina sp. A

Pl. 4, figs. 3 — 7

Material: Five incomplete pedicle valve from the Lower Kanokura series of Imo. Reg. nos.: UHR 12660, 13665, 13666, 13667, 17129.

Description: Shell is medium in size and transversely rectangular in outline. Hinge-line is slightly shorter than the greatest width of the shell.

Pedicle valve is transversely subovate or rectangular in outline and moderately convex in both transverse and longitudinal directions. Beak is not incurved and rather obtuse. Apical angle may be estimated no more than 150° . Cardinal area of moderate height is almost flat or slightly concave. Delthyrium is covered by a strongly vaulted pseudodeltidium. Dental plates are rather short and very closely arranged to each other.

The outer surface of the pedicle valve is ornamented with fine radial costellae and concentric wrinkle-like growth-lines. The distance of 10 mm at the middle of the frontal margin is occupied by 16 radial costellae.

Remarks: This species is characterized by its transverse outline. In this regard, the preceding species is similar to the present species. The former, however, is distinct from the latter in having a comparatively large delthyrium and horizontally projecting beak.

Orthotetina persica SCHELLWIEN resembles the present species in its outline and shape of cardinal area. The exact comparison between these two species is, however, quite impossible owing to the ill-preserved condition of the Kitakami specimens.

Orthotetina sp. B

Material: Three specimens represented by imperfectly preserved pedicle valve from the Upper Sakamotosawa series of Nakadaira. Reg. nos.: UHR 13067, 13068, 13069.

Description: Shell is small in size and subtriangular in outline. Hinge-line is considerably shorter than the greatest width.

Pedicle valve is only slightly convex or almost flat, except for the anterior portion where it is slightly geniculated. Beak is not incurved and moderately pointed. Neither sulcus nor fold is present in this valve. Internally dental plates are rather short and thin.

The surface of the pedicle valve is covered by numerous radial costellae and several concentric markings. The costellae number 6 to 8 within the distance of 5 mm just before geniculation, but suddenly increase in number by intercalation and become extremely finer beyond geniculation. The concentric markings are weakly developed, but comparatively concentrated near the frontal margin.

Remarks: This species is characteristic in having a rather flat pedicle valve with a sharp geniculation near the anterior margin and radial costellae which become considerably finer and increase in number just beyond the point of geniculation. In the first point, this species is closely related to *Meekella recta* IVANOV described and figured by SOKOLSKAJA (1954) from the Upper Carboniferous of the Russian Platform. The Russian species, however, may be distinguished from the Japanese one now in concern by having finer costellae at the posterior flat portion of the pedicle valve. Further, there are observable certain weak but definite radial plications developed near the frontal margin of the Russian species.

The present form may belong to a new species, although available specimens are unfortunately too incomplete to propose a new specific name for them.

Genus *Meekella* WHITE and ST. JOHN, 1867

1932 *Meekella* DUNBAR and CONDRA, p. 124.

1960 *Meekella* SOKOLSKAJA, p. 218.

1965 *Meekella* WILLIAMS, p. H405.

Diagnosis: Plicated Meekellinae with hinge-line always being considerably

shorter than the greatest width. Cardinal area of triangle shape moderately high and bisected by a delthyrium covered by a vaulted pseudodeltidium. Long and subparallel dental plates well observed in pedicle valve. Brachial valve interior with high and bilobed cardinal process and socket plates developing as strongly divergent septa. Both valves ornamented with many fine radial costellae and fewer plications, in addition to some concentric-lines.

Remarks: The genus *Meekella* was first established by WHITE and ST. JOHN in 1867 with *Plicatula striatocostata* COX, as a type species. As already mentioned in the remarks on the preceding genus, certain authors denied the validity of *Orthotetina* and designated *Meekella* to be the genus in which both plicated and non-plicated forms may be included. In the present day many specialists, including the author, hold the view that the presence or absence of plications is a generic character in this case and accordingly species with non-plicated shells have to be transferred from the genus *Meekella* (s.s.).

The species generically assigned into the genus *Meekella* herein described may be grouped into three types through the difference in surface ornamentation of shell.

- 1) Regular type. Plications are more or less well and regularly developed on the shell surface. *M. cfr. striatocostata*, *M. cfr. eximia*, *M. garnieri*.
- 2) Nodose type. Plications are crossed by some concentric folds to represent nodose surface on shells. *M. nodosa*.
- 3) Weakly plicated type. Plications are very weak and superficially resembles the ornamentation of *Orthotetina*. *M. minatoi*, *M. mexicana*, *M. sp.*

Meekella cfr. striatocostata (COX)

Pl. 5, figs. 1a – b

Compare with:

1932 *Meekella striatocostata*, DUNBAR and CONDRA, p. 125, pl. 16, figs. 1 (Cox's original specimen), 2, 5 and 9 only.

Material: Only a single pedicle valve represented by external and internal moulds was obtained from the Lower Kanokura series of Imo. Reg. no.: UHR 13574.

Remarks: Judging from COX's original specimen of *Plicatula striatocostata* illustrated by DUNBAR and CONDRA (1932), the type specimen of this species apparently shows a triangular outline and the lateral margins of the shell are

almost straight or slightly concave. Up to the present, not a few specimens of brachiopods have been specifically identified with *Meekella striatocostata*. But, the present author doubts somewhat whether the former identification of the species was always correct or not, because certain forms such as the specimen described by GIRTY (1909) under the name of *Meekella striatocostata* from the Manzano group have shells with convex lateral margins and transversely ovate outer configurations. In this regard, the specimen examined by the author is doubtlessly near to the type specimen, although the COX's original one may be more inflated than the specimen from the Kitakami Mountains. The author believes that the difference in strength of convexity between them may be due to deformation of the Japanese specimen. The surface ornamentation of the present material also closely resembles that of the original, especially in the number of plications and the coarseness of costellae. Plications of the Japanese specimen may be slightly lower and less angular than those of the type specimen, but this may have resulted from the deformation of the shell. In the Japanese specimen the shell is much depressed ventrally, and therefore the angularities of plications become less than in the original state.

In the meantime, *Meekella difcilis* described by GIRTY in 1909 may be also somewhat akin to the present species in the number of plications as well as in outline of shell. According to GIRTY however, his species is characterized by strongly angulated plications and the absence of fine radial costellae. The author now supposes that the apparently smooth surface of his shell has perhaps been caused by weathering. If it originally had fine radial costellae, the difference in angularity of plicae may become a problem. In this regard, the Japanese specimen may eventually be more akin to COX's species than to GIRTY's.

Meekella cfr. *eximia* (EICHWALD)

Pl. 6, figs. 5 – 6

Compare with:

1954 *Meekella eximia*, SOKOLSKAJA, p. 157, pl. 17, figs. 4 – 8.

Material: Two specimens (UHR 12576, 12646) from the Lower Kanokura series at Kamiyasse, Niitsuki-cho, Kesenuma City, Miyagi Prefecture. One specimen (UHR 12576) is more or less well preserved as "Steinkern" and external mould of both valves, while the other is only represented by an imperfect internal mould of brachial valve.

Description: Shell is moderate in size and rectangular with roundness in outline. Hinge-line is considerably short and exceeds no more than half the greatest width.

Pedicle valve is moderately convex at the posterior region and turn to be nearly flat at the anterior in longitudinal profil. Beak is somewhat pointed and slightly inclined backwards. Internally dental plates are rather short.

Brachial valve is a little smaller and more strongly inflated than the opposite valve. Median sulcus is very broad, shallow and originates with some distance from the beak.

The surfaces of both valves are uniformly covered by numerous fine radial costellae which always increase in number by intercalation and enumerated about 15 within the distance of 5 mm near the anterior margin of the pedicle valve. Some radial plications also observed on the external surface of the shell. They are not so angular and relatively few in number to be counted 12 near the frontal margin.

Remarks: Comparatively few radial plications, erect beak and transversely subovate outline of shell may be distinct characters of this species. The above enumerated features remind the present author of an European species, *Meekella eximia* (EICHWALD) ranging from Upper Carboniferous to Lower Permian in age.

Meekella garnieri BAYAN

Pl. 5, figs. 5 – 7

1964 *Meekella garnieri*, WANG et al., p. 200, pl. 28, figs. 19 – 20.

Material: Three specimens from the Lower Kanokura series at Imo, one of which is nearly complete, while the other two are preserved only as mould of pedicle valve. Reg. nos.: UHR 12577, 13576, 19533.

Description: Shell is medium-sized and subconical in outline. Hinge-line is straight and considerably shorter than the greatest width of the shell.

Pedicle valve is moderately convex both in longitudinal and transverse profiles. Beak is more or less prominent and moderately incurved. Cardinal area is average in height and fairly concave. Dental plates are moderate in length and somewhat varying in interstitial distance on the floor of the pedicle valve interior.

Brachial valve is nearly equal to those of the opposite valve in its size and curvature. A broad but shallow sulcus starts from the midlength of this valve.

Surface sculpture consists of numerous fine radial costellae developing uniformly throughout the whole shell surface, coarse radial plications being more or less angular and some concentric growth-lines.

Remarks: In general outline and surface ornamentation, the present species bears superficial resemblance to *Geyerella tschernyschewi* LICHAREW from the Lower Permian of the Northern Caucasus as well as *Kiangsiella tingi* GRABAU et CHAO from the Lower Permian of South China. But, the latter two may be generically distinct from the former in revealing different feature of pedicle valve interior. *Meekella garnieri* was first described from the Upper Permian of South China by BAYAN in 1874.

Meekella nodosa n. sp.

Pl. 6, figs. 3 – 4

1933 *Meekella* sp., HUANG, p. 31, pl. 4, figs. 8, 9.

Material: Two specimens (UHR 12578 – holotype, 13674) are available for study. The holotype specimen is collected from the Lower Kanokura series at Kamiyasse and preserved as internal mould of pedicle valve. while the other from the same series at Imo is poorly preserved as fragments of external and internal moulds of pedicle valve.

Description: Shell is medium to large in size as a species belonging to this genus and slightly longer than wide. Hinge-line is relatively short and does not extend beyond seven tenths of the greatest width.

Pedicle valve is transversely oval or almost circular in outline and gently convex or almost flat except for the umbonal region at which it is considerably inflated. Cardinal area is low, broad and concave. No sinial depression is observed in this valve. Internally dental plates are moderate in length and measured as long as 20 mm on the internal surface of the valve in the holotype specimen.

Surface ornamentation is composed of numerous radial costellae and rounded, coarse plications in addition to several concentric wrinkles. Since the radial plications are crossed over with concentric wrinkles, the height and angulation of the plications are alternately and variously changed. Of this appearance, HUANG described as "Each plication is not of uniform height

throughout its length but is alternately weak and strong and thus appears nodose". The above-mentioned surface feature may be a distinct character of this species.

Remarks: Apart from its smaller shell size, the specimen described and figured as *Meekella* sp. by HUANG (1933) from South China quite resembles the present Japanese form. Disagreement of size, however, may not be worthy of specific distinction in this case. Although HUANG thought his specimen could not be identified with any other species which had been already reported before, he hesitated to describe the Chinese form as a new species. But, the species under consideration is specifically distinguishable from other meekellid shells in showing strongly nodose surface appearance. At the present moment, this species is found independently from two different localities, South China and Northeast Japan as well.

Meekella minatoi n. sp.

Pl. 6, figs. 1 – 2

Material: Two specimens from the Lower Kanokura series. One of them (UHR 12579 – holotype) was collected from Imo, while the other (UHR 13673) from a tributary of Kozubo-sawa, Yokota-cho, Rikuzentakada City, Iwate Prefecture. The former material is more or less well preserved; the latter is represented only by an internal mould of brachial valve.

Description: Shell is medium in size and elongately oval in outline. Although the original convexity of the shell cannot be exactly restored, it is almost certain that both valves are not very inflated. Hinge-line is as long as half the greatest width of the shell.

Pedicle valve is slightly vaulted and almost flat or rather warped ventrally near the frontal margin. Beak is large and obtuse with an apical angle of about 150° . Beak ridges are angulated. Cardinal area is moderate in height and almost pentagonal in outline. Delthyrium is completely covered by a strongly vaulted pseudodeltidium. Internally, a pair of dental plates are shorter than a third of the length of the valve and the interspace of the plates is narrow on the internal floor of the valve.

Brachial valve is elongate, ovate and moderately inflated. Socket plates are relatively long and slightly divergent antero-laterally.

Numerous fine radial costellae uniformly cover all the shell surface. Several

broad but very low plications and some concentric wrinkles are also observed especially on the posterior half of the valve.

Remarks: One of the characteristic features of this species lies on its unusual shell form with elongate oval outline. The presence of a cardinal area of pentagonal form and comparatively long socket plates also may be distinctive characteristics of this species. Considering from the viewpoint of surface ornamentation, the present species may be generically intermediate between *Orthotetina* and *Meekella*. The species is named in honor of Dr. Masao MINATO of Hokkaido University.

Meekella mexicana GIRTY

Pl. 5, figs. 3 – 4

1909 *Meekella mexicana*, GIRTY, p. 53, pl. 6, figs. 1 – 5.

1930 *Meekella mexicana*, KING, p. 55, pl. 7, figs. 1 – 5.

Material: Two specimens from the Upper Sakamotosawa series cropped out at Nakadaira. One of them (UHR 13670) is represented by an internal mould of the pedicle valve and the other (UHR 13671) by an internal mould of the brachial valve.

Remarks: The present species is characteristic in having a shell with a broad but shallow median sulcus in both valves. Moreover, plications developing on the pedicle valve are always low and rounded on the top. In this point of view, the species now under discussion seems to be a transitional form between *Meekella* and *Orthotetina*.

GIRTY first described *Meekella mexicana* from New Mexico in 1909. Then, KING (1930) reported a new occurrence of this species in the Glass Mountains of Texas. Several specimens upon which their specific description was based were variable especially in strength of plications. For instance, one of them (GIRTY's pl. 6, fig. 4) has almost a non-plicated shell, while some of the others (GIRTY's pl. 6, fig. 1; KING's pl. 7, fig. 2) have very faint plications on the pedicle valve. In this regard, they considered that the strength of plications was very variable within this species. The Kitakami specimens quite resemble externally the second type of this species (GIRTY's pl. 6, fig. 1; KING's pl. 7, fig. 2), although GIRTY's specimens from New Mexico has a more prominent beak.

Meekella sp.

Pl. 5, figs. 2a — b

Material: Only a single pedicle valve is obtained as both external and internal moulds from the Lower Kanokura series at Imo. Reg. no.: UHR 13669.

Remarks: Distinctive features of the present form are of its transversely ovate outline and presence of a low and small cardinal area. This species is also characterized by its rather low radial plications and slightly nodose surface ornamentation.

So far as the author is concerned, this species is closest to *Meekella abnormalis* described by HUANG (1933) from the Upper Permian of South China. Both quite agree with each other in having a comparatively low cardinal area and short dental plates. However, the hinge-line of the Japanese specimen is considerably shorter than that of the Chinese species. Further, the pedicle valve of the former is more inflated, although it is partially due to deformation.

Genus *Orthotetes* FISCHER, 1829

- 1957 *Werriea* CAMPBELL, p. 44.
- 1958 *Permorthotetes* G. A. THOMAS, p. 82.
- 1960 *Orthotetes* SOKOLSKAJA, p. 219.
- 1965 *Orthotetes* WILLIAMS, p. H409.

Diagnosis: Shell usually wider than long. Pedicle valve always less convex than dorsal. Hinge-line usually slightly shorter than the greatest width of the shell. Cardinal area in pedicle valve rather low or only moderately elevated.

In the pedicle valve a median septum joins with the prolongation of delthyrial ridges to form a small spondylium in umbonal region. In the brachial valve, socket plates recurved. In certain species there is a low and short septum in brachial valve. Surfaces of both valves bear numerous radial costellae and some fine concentric lines.

Remarks: According to DUNBAR and CONDRA (1932), *Orthotetes* was proposed by FISCHER in 1829, based upon a single pedicle valve derived from the Lower Carboniferous limestone of Kuluga, Russia. Then FISCHER had

neither described nor figured it. The figure of the valve was shown for the first time by himself the next year. In 1850 the same author revised the definition of the genus and then described two species *Orthotetes radiata* and *O. socialis*. The former species was later designated as a type species by GIRTY in 1908.

In 1884 WAAGEN first described genus *Derbyia* for orthotetid brachiopods with a septum in the pedicle valve and subdivided the genus into two types, septati and camerati. The latter was described to have a small spondylium in the apical part of the pedicle valve, whereas it lacks in septati. As a matter of fact, the camerati was later transferred to the genus *Orthotetes* by GIRTY in 1908.

According to G. A. THOMAS (1958), LICHAREW (1930) proposed the suppression of generic name *Orthotetes* in favour of *Ombonia* for loss of FISCHER's original specimen. *Ombonia* has been considered, as usual, to be almost synonymous with *Orthotetes* FISCHER, since the former was erected by CANEVA with *Ombonia dieneri* LICHAREW as a type species in 1906. As stated in the foregoing lines, however, *Ombonia* is obviously different from *Orthotetes* in having a primary spondylium made by union of two dental plates, instead of a secondary spondylium formed by direct prolongation of dental ridges in *Orthotetes*. Actually, each of these genera is now considered to belong to separate families.

In 1958, G. A. THOMAS held the view that *Orthotetes* closely resembled *Permorthotetes* having a small spondylium developed only in the young stage. As a matter of fact, *Permorthotetes* was placed in synonymy with *Orthotetes* by WILLIAMS (1965). In this concern, THOMAS (1969) briefly stated that *Permorthotetes* can be generically distinguished from the typical Moscovian *Orthotetes* through the difference of details of dorsal cardinalia. The present author, however, tentatively follows the interpretation held by WILLIAMS, until the distinction between these two forms will be fully described.

Cfr. *Orthotetes callytharrens* (THOMAS)

Pl. 9, fig. 1

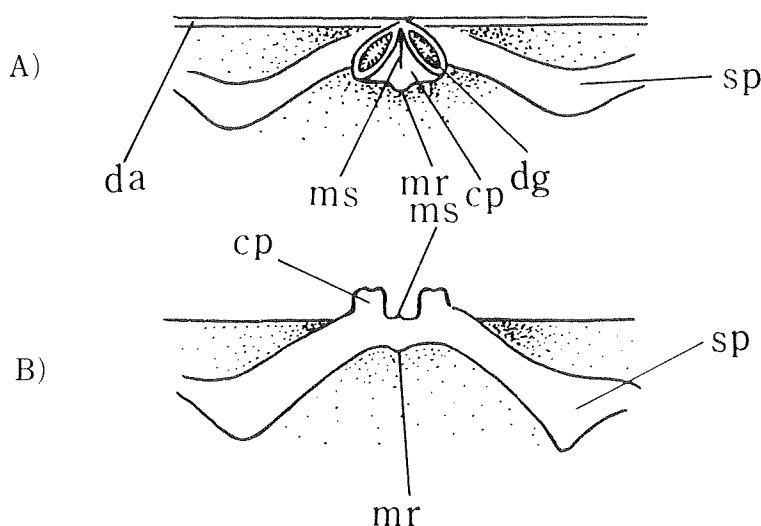
Compare with:

1958 *Permorthotetes callytharrens*, THOMAS, p. 84, pl. 4, figs. 1 – 8; Pl. 5, figs. 1 – 4; Pl. 6, fig. 6; Pl. 18, figs. 3 – 5; Pl. 20, figs. 1 – 2.

Material: Only a single brachial valve was obtained from the Lower Sakamotosawa series at Yukisawa. Reg. no.: UHR 13680.

Remarks: It is very difficult to determine to what genus the present form is assignable, because the specimen now at hand lacks the pedicle valve which is more valid for generic distinction. In spite of this, it may be safely concluded that the specimen generically belong to either *Orthotetes* or *Derbyoides*, judging from observation of apical features of the brachial valve interior.

A pair of socket plates are rather thick and recurved at the anterior end. From the posterior ends of the socket plates, a moderate-sized cardinal process arises into visceral cavity and is divided into two lobes at the top. Between those small lobes there is a shallow groove with a very faint median septum at the middle. The terminal of each lobe is slightly caved in and elongately oval in form. The details of the apical apparatus of the brachial valve will be shown in the text-figure 7.



Text-figure 7

Sketch of cardinal process of *Cfr. Orthotetes callytharrens* (THOMAS) described in this paper.

A — Posterior to ventral view. B — Anterior view.

cp: Cardinal process, da: Dorsal area, dg: Grooves for diductor muscles on posterior surface of cardinal process, mr: Median ridge on anterior surface of cardinal process, ms: Median septum between lobes of cardinal process, sp: Socket plates.

Among the previously known species included in *Orthotetes* or *Derbyoides*, *Orthotetes callytharrens* described by G. A. THOMAS (1958) from the Callytharra formation (Earliest Artinskian ?) of the Carnarvon basin in Western Australia most resembles the present form in having a fairly large shell with a shallow and narrow sulcus on the brachial valve. Further, judging from the outer configuration and convexity of the brachial valve as well as the nature of

cardinal apparatus, the Japanese form is probably conspecific with the Australian species. The absence of the pedicle valve in the Kitakami specimen, however, does not permit its correct assignment.

Genus *Schuchertella* GIRTY, 1904

- 1932 *Schuchertella* DUNBAR, and CONDRA, p. 117.
1960 *Schuchertella* SOKOLSKAJA, p. 218.
1965 *Schuchertella* WILLIAMS, p. H408.
1967 *Schuchertella* HAVLICEK, p. 201.

Diagnosis: Schuchertellinae with biconvex or plano-convex shell which is usually wider than long. Hinge-line nearly equal to the greatest width.

Cardinal area of pedicle valve always low and not distorted. Pedicle valve has neither median septum nor dental plates, but there is a median pseudo-septum in such certain species as *Schuchertella* sp. treated in this article. Cardinal process low and supported by recurved socket plates. Shell surface covered by fine radial costellae and some concentric growth-lines.

Remarks: The genus *Schuchertella* was introduced by GIRTY in 1904 with *Schuchertella lens* WHITE as a type species. Since then, the genus has been thought to have close relationship with *Streptorhynchus*. But, as stated before, this genus may be different from that in more than family rank.

Schuchertella frechi HUANG

Pl. 9, figs. 10a – d

- 1911 *Streptorhynchus semiplanus*, FRECH (non WAAGEN), p. 173, pl. 26, fig. 5.
1922 *Schuchertella* sp., HAYASAKA, p. 74, pl. 4, fig. 2.
1933 *Schuchertella frechi*, HUANG, p. 21, pl. 3, figs. 2 – 6.

Material: Fragmental external moulds of both valves and “Steinkern” specimen obtained from the Lower Kanokura series at Imo. Reg. no.: UHR 13661.

Description: Shell is medium-sized and rectangular in outline. Hinge-line is straight and considerably shorter than the greatest width.

Pedicle valve is, as a whole, slightly concave except for the umbonal region, where it is strongly elevated. Beak is pointed and projecting almost horizontally. Neither sulcus nor fold is seen on this valve. Cardinal area is rather low and no more than 5 mm high in the specimen measured.

Brachial valve is slightly convex and gradually tends to become flat towards the frontal margin. The area in this valve is very narrow and triangular. Internally a bilobed cardinal process and short socket plates are observed near the hinge margin. The socket plates with recurvature run almost parallel to the hinge-line.

Numerous fine radial costellae with various height and coarseness entirely cover the surface of both valves. They increase in number only by intercalation and are enumerated about 20 per 10 mm near the anterior margin of the pedicle valve. Concentric markings are hardly developed.

Remarks: According to HUANG (1933), the present species is characterized by having a concave pedicle valve with horizontally projecting beak in contrast with a moderately inflated brachial valve. Further, fine radial costellae with no uniformity both in strength and coarseness are thought to be distinct features of this species. In these respects, the Japanese specimen quite agrees with the Chinese one. The former has, however, a relatively shorter hinge-line and a cardinal area in brachial valve, whereas the latter was described as having a comparatively longer hinge-line and no cardinal area in the brachial valve.

The author considers that the slight difference in the length of the hinge-line is hardly of specific value in this case and the presence of a small dorsal area in the Chinese specimen might have escaped HUANG's attention, because of the poorly preserved material examined by him.

Schuchertella cfr. *beyrichi* (ROTHPLETZ)

Pl. 9, figs. 9a – b

Compare with:

1892 *Streptorhynchus Beyrichi*, ROTHPLETZ p. 78, pl. 5, fig. 13.

1911 *Derbyia schellwieni*, FRECH, p. 125, pl. 18, fig. 3.

1916 *Derbyia Beyrichi*, Broili, p. 7, pl. 115 (1) fig. 8.

Material: Only a single pedicle valve represented by its external and internal moulds from the Lower Kanokura series at Imo. Reg. no.: UHR 19536.

Remarks: The ornamentation of this species is noteworthy. The surface of the valve is ornamented with numerous radial costae or costellae of two orders. Four or five weaker costellae are placed alternately in each interspace between the stronger radials. In this regard, the Kitakami specimen may be specifically identified with *Schuchertella beyrichi* ROTHPLETZ, although the outer shape of the present form is a little more transverse than that of the specimen described by ROTHPLETZ from the Permian of Timor in 1892.

Schuchertella sp.

Pl. 9, figs. 5 – 8

Material: Three incomplete moulds of pedicle valve from the Upper Sakamotosawa series at Nakadaira. One poorly preserved internal mould of pedicle valve from the Lower Kanokura series at Imo is also studied. Reg. no.: UHR 13683 (Lower Kanokura series), UHR 13684, 13685, 12702 (Upper Sakamotosawa series).

Description: Shell is moderate in size and transverse, rectangular in outline. Hinge-line is straight and nearly equal to the greatest width. Although umbonal region is somewhat elevated, pedicle valve is, as a whole, slightly arched or almost flat in both longitudinal and transverse directions. Cardinal area is low and depressed triangular in shape. The surface of the pedicle valve is uniformly covered by numerous fine radial costae or costellae which always increase in number by intercalation. They number 14 – 15 per 5 mm at the middle near the frontal margin.

Remarks: The present form is comparable to *Schuchertella* cfr. *sempi plana* in external features described by CHAO from the Chihhsia limestone of South China in 1927, but nothing is known about the internal structure of the Chinese specimen. The Kitakami specimens possess a very low, short and tiny plate called median pseudo-septum by I. THOMAS in 1910 in the pedicle valve. If CHAO's specimen is provided with such a plate in the pedicle valve, both Chinese and Japanese forms may be almost conspecific.

Schuchertella semiplana originally described by WAAGEN (1884) from the Salt-Range of Pakistan is quite distinct from both Japanese and Chinese forms in having a more inflated and less transverse pedicle valve.

Genus *Streptorhynchus* KING, 1850

- 1932 *Streptorhynchus* DUNBAR and CONDRA, p. 121.
- 1958 *Streptorhynchus* G. A. THOMAS, p. 38.
- 1960 *Streptorhynchus* SOKOLSKAJA, p. 220.
- 1965 *Streptorhynchus* WILLIAMS, p. H409.

Diagnosis: Streptorhynchinae with non-plicated and subconical shell. Beak elevated and usually distorted. Hinge-line always shorter than the greatest width of shell. Pedicle valve has a high and triangular delthyrium covered by moderately convex pseudodeltidium. Internally, pedicle valve has any kind of apical plate, while brachial valve occasionally has a tiny septum in addition to constantly developing divergent socket plates. Cardinal process high and bifid. Surfaces of both valves costellate.

Streptorhynchus pelargonatus SCHLOTHEIM

Pl. 9, fig. 3

- 1856 *Streptorhynchus pelargonatus*, DAVIDSON, p. 32, pl. 2, figs. 32 – 36.
- 1880 *Streptorhynchus pelargonatus*, DAVIDSON, p. 32, pl. 30, fig. 3.
- 1884 *Streptorhynchus pelargonatus*, WAAGEN, p. 579, pl. 50, figs. 3 – 5, 7.
- 1911 *Streptorhynchus pelargonatus*, FRECH, p. 143, pl. 24, fig. 2.
- 1931 *Streptorhynchus pelargonatus*, GRABAU, p. 243, pl. 24, figs. 2a – e.
- 1932 *Streptorhynchus pelargonatus*, LICHAREW, p. 36, pl. 1, fig. 5; pl. 4, fig. 4.
- 1933 *Streptorhynchus pelargonatus*, HUANG, p. 17, pl. 2, fig. 13.
- 1956 *Streptorhynchus pelargonatus*, MINATO and NAKAMURA, p. 149, pl. 24, fig. 1.

Material: A single imperfect specimen collected from the Lower Kanokura series at Imo. Reg. no.: UHR 12367.

Remarks: *Streptorhynchus pelargonatus* is one of the most ubiquitous species in Permian brachiopod fauna. In Japan, the occurrence of this species was first recorded by MINATO and the author from the Southern Kitakami Mountains in 1956. Although the material lately collected is inferior to the formerly treated specimen in preservation, characteristic features of this species are recognized with certainty.

Streptorhynchus sp.

Pl. 9, figs. 4a – b

Material: A poorly preserved pedicle valve collected from the Lower Sakamotosawa series at Yukisawa. Reg. no.: UHR 13660.

Remarks: This species may be characterized by having a small-sized and depressed conical shell, and very coarse costae numbering about 5 to 6 within the distance of 5 mm near the anterior margin.

In these respects, *Schuchertella* ? sp. described by YANAGISAWA (1967) from the Permian Kashiwadaira formation of Takakurayama-Yaguki area, southern part of the Abukuma Mountains and *Streptorhynchus broillii* originally introduced by GRABAU (1931) from Mongolia resemble the present form. But, in any event, the poorly preserved specimen at hand does not seem to permit a precise comparison with previously known species.

Genus *Derbyia* WAAGEN, 1884

- 1908 *Derbyia* GIRTY, p. 181.
- 1932 *Derbyia* DUNBAR and CONDRA, p. 75.
- 1958 *Derbyia* G. A. THOMAS, p. 76.
- 1960 *Derbyia* SOKOLSKAJA, p. 219.
- 1965 *Derbyia* WILLIAMS, p. H411.

Diagnosis: *Derbyiinae* without plications. General outline, length of hinge-line and height of cardinal area all relatively variable. Internally, pedicle valve has a median septum united with pseudodeltidium near umbo, but not forming a spondylium. In certain species there is a small and short septum in addition to divergent socket plates in brachial valve. Cardinal process fairly high.

Remarks: Genus *Derbyia* was described by WAAGEN in 1884. As already stated in the remarks on the genus *Orthotetes*, he placed two types, viz. septati and camerati in the genus at that time.

GIRTY (1908) later revised and restricted the definition of the genus *Derbyia* and designated *Derbyia regularis* WAAGEN as the type species of this genus. As a matter of fact, only the septati was defined as true *Derbyia*, whereas the camerati was attributed to the genus *Orthotetes* also by him.

Derbyia nipponica n. sp.

Pl. 7, figs. 1, 4 – 9

1956 *Derbyia magnifica*, HAYASAKA and MINATO (non LICHAREW), p. 141, pl. 23, figs. 1a – c.

1960 *Derbyia magnifica*, HAYASAKA, p. 45, pl. 2, figs. 5, 6.

Material: Seven more specimens are added to the most complete specimen concerned by HAYASAKA and MINATO in 1956. Hor. and Loc.: Lower Kanokura series of Imo. Reg. nos.: UHR 17035, 16037, 11468, 12470, 13675, 19534, 19535.

Remarks: In 1956 HAYASAKA and MINATO specifically identified derbyiid brachiopods from the Lower Kanokura series of the Kitakami Mountains with *Derbyia magnifica* which had been originally described by LICHAREW (1932, 1939) from the Upper Permian of the Northern Caucasus. The Caucasian species was, however, excluded from the genus *Derbyia* by SOKOLSKAJA in 1960, because of the presence of conspicuously developing peripheral ridges in the pedicle valve. Thus, this species was chosen as a type species of the genus *Licharewiella* newly proposed by her. Afterwards, the generic name *Licharewiella* was, however, replaced by *Magniderbyia* by TING (1965) for the reason which will be stated on page 402.

Since the specimens having been treated by HAYASAKA and MINATO (1956) and figured herein by the author as well do not provide such a ridge marking the genus *Magniderbyia*, they may be neither congeneric nor conspecific with the Caucasian species.

As HAYASAKA and MINATO (1956) pointed out, *Derbyia cymbula* HALL and CLARK most reminds the author of this species. The distinction between them, however, was already clarified by them. *Derbyia grandis* first described by WAAGEN (1884) from the Salt-Range is also easily distinguishable from the present species in having much longer hinge in proportion to the greatest width.

Derbyia cfr. *acutiplicata* METZ

Pl. 7, figs. 2 – 3

Compare with:

1936 *Derbyia acutiplicata*, METZ, p. 163, pl. 5, fig. 4.

Material: Two internal moulds of pedicle valve are collected from the Lower Kanokura series at Imo. Reg. nos.: UHR 13578, 12652.

Description: Shell is small to medium in size and transverse, subovate or rectangular with roundness in outline. Hinge-line is straight and nearly equal to the greatest width of the shell. Pedicle valve is convex at an early stage, but upturned near the frontal margin. Umbonal region is much elevated. The surface of the shell is ornamented by numerous radial costellae with considerable diversity in thickness and a few concentric growth-lines.

Derbyia sp. A

Pl. 8, figs. 3a – c

1930 *Derbyia buchi*, KING (non d'ORBIGNY), p. 58, pl. 8, figs. 4 – 6.

Material: Only a single specimen represented by deformed external mould of both valves and "Steinkern" was derived from the Lower Kanokura series of Imo. Reg. no.: UHR 13580.

Remarks: The present form is quite similar to *Derbyia buchi* described by KING (1930) from the Upper Gym formation of the Glass Mountains, Texas, in having low cardinal area and not strongly inflated pedicle and brachial valves.

Orthotetes lindneri (described as *Permorthotetes lindneri*) first introduced by G. A. THOMAS (1958) from the Permian of western Australia is externally most related to the present specimen. The Australian species, however, has a secondary spondylium in pedicle valve and recurved socket plates in brachial valve, instead of nondevelopment of spondylium and the presence of socket plates without recurvation in this form.

The specimens described from Bolivia as *Derbyia buchi* by KOZŁOWSKI (1914), also have a secondary spondylium. In this regard, both Australian and Bolivian species quite agree with each other. D'ORBIGNY's article is at the moment inaccessible to the author. Therefore, it is not known whether KING's material is really congeneric and conspecific with d'ORBIGNY's original one. D'ORBIGNY's species might be a form of *Orthotetes*. Hence the specimen at hand is now only described as *Derbyia* sp. A.

Derbyia sp. B

Pl. 8, figs. 1, 7

Material: Two specimens from the Lower Sakamotosawa series at Yukisawa. Reg. nos.: UHR 13676, 13677.

Description: Shell is medium to large in size. Hinge-line is nearly equal to the greatest width.

Pedicle valve is semi-circular in outline. It is moderately convex at the posterior part, whereas almost flat or slightly concave around the anterior margin. Beak is obtuse with an apical angle being no more than 180° . Cardinal extremities are blunt and cardinal angle is nearly 90° . Neither distinct sulcus nor fold is pronounced in this valve. Cardinal area is low and triangular in form. Internally, median septum is moderate in length and extends up to one third of the whole length of the valve.

Brachial valve is also semi-circular in outline and moderately inflated in both longitudinal and transverse direction.

The surface ornamentations of both valves consist mainly of radial costellae, 16 of which occupy the space of 10 mm near the anterior margin. In addition to them, a few concentric growth-lines are observed.

Remarks: The present form is much allied to *Derbyia regularis* introduced by WAAGEN from the Middle *Productus* limestone of the Salt-Range in 1884, in its surface sculpture, general outline and shell convexity. The specimens described by SOKOLSKAJA (1954) from the Upper Carboniferous of the Russian Platform as *Derbyia regularis* also resemble the present form. Both Pakistani and Russian specimens, however, readily distinguishable from the present form having a shorter hinge-line in proportion to the greatest width. In this regard, *Derbyia robusta* HALL comes nearest to the specimens now in concern. But, the shell in the American species is more strongly inflated and the costellae seem to be much finer than those of the latter.

Derbyia sp. C

Pl. 8, figs. 2, 4 – 6

Material: Four specimens are obtained from the Upper Sakamotosawa series at Nakadaira. They are preserved as both external and internal moulds of

the pedicle valve. Reg. nos.: UHR 12573, 12653, 13678, 13679.

Description: Shell is moderate in size and subquadrate in outline. Hinge-line is nearly equal to or slightly shorter than the greatest width of the shell.

Pedicle valve is weakly convex or nearly flat except for the umbonal region, where it is moderately inflated. Near the frontal margin it is slightly concave. Beak is neither prominent nor erected. Although cardinal area is not well preserved, it may be rather low, depressed triangular in form and slightly concave. Pseudodeltidium is strongly vaulted and medium-sized. Median septum in the pedicle valve is thin but attains moderate length.

Pedicle valve is uniformly covered by fine radial costellae. They average 15 in 10 mm at the middle portion of the valve. Concentric wrinkles are more or less conspicuously developed.

Remarks: The present form is characterized by its subquadrate outer configuration and development of some conspicuous wrinkles, and *Derbyia crassa* MEEK and HAYDEN is most allied to the present form. The Kitakami specimens, however, are not well preserved for a precise specific comparison to be made.

Genus *Magniderbyia* TING, 1965

1960 *Licharewiella* SOKOLSKAJA, p. 219.

1965 *Licharewiella* WILLIAMS, p. H411.

Diagnosis: Shell large in size and having a fold in pedicle valve, while a sulcus in brachial valve. Hinge-line nearly equal to or only slightly shorter than the greatest width. Cardinal area variable in height but not strongly elevated. Internally, pedicle valve provides with peripheral ridges, in addition to a thick median septum. Surface of shell costellate but not plicated.

Remarks: In 1960 SOKOLSKAJA established the genus *Licharewiella* with *Derbyia magnifica* LICHAREW, 1939 (= *D. magna* LICHAREW, 1932) from the Upper Permian of Northern Caucasus as a type species. Then she emphasized the presence of peripheral ridges in the pedicle valve as a generic distinction between *Licharewiella* and *Derbyia*.

Afterwards, TING (1965) pointed out that the generic name of *Licharewiella* had been pre-occupied for a productoid by USTRITSKIY nine months before SOKOLSKAJA used this term as a generic name for the present type of

derbyid brachiopod. At the same time, he proposed to apply a new generic name of *Magniderbyia* in place of *Licharewiella* for these shells. As to distinctive characteristics of *Magniderbyia*, TING stated in Chinese as "Shell is gigantic in size. Hinge-line is equal or nearly equal to the greatest width of the shell. The shell with extending ears shows an alated feature as *Magniderbyia noinhoensis*, but in certain species as *M. semirecticulata*, such an appearance cannot be observed."

Contrary to SOKOLSKAJA'S view in which she emphasized the presence of peripheral ridges in the pedicle valve as a distinct characteristic, TING seems to have stressed the difference of superficial characteristics of the shell to separate these two genera. The present author maintains SOKOLSKAJA'S view in this regard, since distinct characters between *Magniderbyia* and *Derbyia* are considerably ambiguous in generic diagnosis given by TING.

Magniderbyia sp.

Pl. 9, figs. 2a — b

Material: External and internal moulds of a single pedicle valve are examined. They were collected from the Lower Sakamotosawa series exposed at Yukisawa. Reg. no.: UHR 13681.

Description: Shell is large in size and almost semi-circular in outline. Hinge-line is straight and nearly as long as the greatest width.

Pedicle valve is lengthwise elongated semi-circular in outline. It is weakly inflated at the posterior half, whereas it tends to be slightly resupinate at the anterior half. Beak is not pointed but rather obtuse. The presence of a broad but low median fold is indicated in the pedicle valve. Cardinal area of moderate height is almost flat. Delthyrium covered by a strongly vaulted pseudodeltidium is fairly large in size. The base of the delthyrium is as long as it is high. Median septum is not so long and extends approximately up to a third of the valve. It becomes considerably thicker near the posterior end. Muscular scars of cuspidate form is coarsely lobated and placed on both sides of the median septum. Muscular field is encircled antero-laterally with a high peripheral ridges which become gradually lower towards the posterior. The surface of the valve is covered by numerous fine, sharply elevated costae with broader interspaces. The costae increase in number mainly by intercalation and number 12 — 13 per 10 mm in the middle portion near the frontal margin.

Remarks: The present form resembles the type species of this genus described by LICHAREW (1932, 1939) from the Upper Permian of the Northern Caucasus in having a pretty large pedicle valve with a fold, a low but broad delthyrium and long hinge-line being equivalent in length to the greatest width.

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(All figures are in natural size)

Figs. 1, 2. *Orthotetina hayasakai* n. sp.

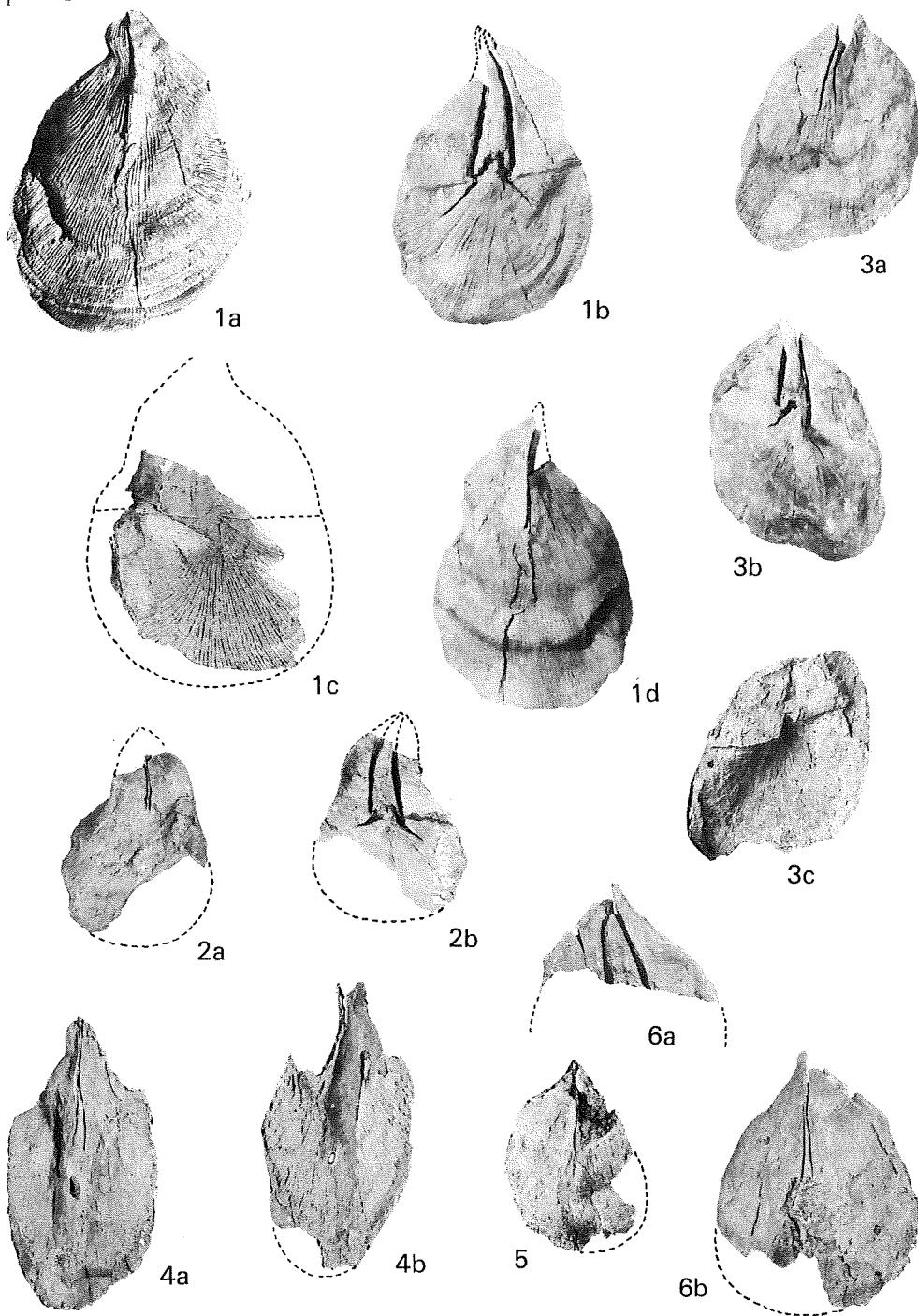
1. The holotype (UHR 13572), a — external mould of pedicle valve, b, d — dorsal and ventral views of “Steinkern”, c — incomplete external mould of brachial valve together with a part of mould of cardinal area.
2. Juvenile specimen (UHR 13694), a, b — ventral and dorsal views of “Steinkern”.

Figs. 3 — 6. *Orthotetina elongata* n. sp.

3. The holotype (UHR 13567), a, b — ventral and dorsal views of “Steinkern”, c — external mould of brachial valve with mould of cardinal area.
4. Deformed pedicle valve (UHR 13692), a, b — internal and external mould of pedicle valve.
5. Internal mould of pedicle valve (UHR 13689).
6. Pedicle valve (UHR 13690), a — internal mould of cardinal area, b — internal mould.

All specimens from the Lower Kanokura series at Imo.

plate I



Explanation of plate 2

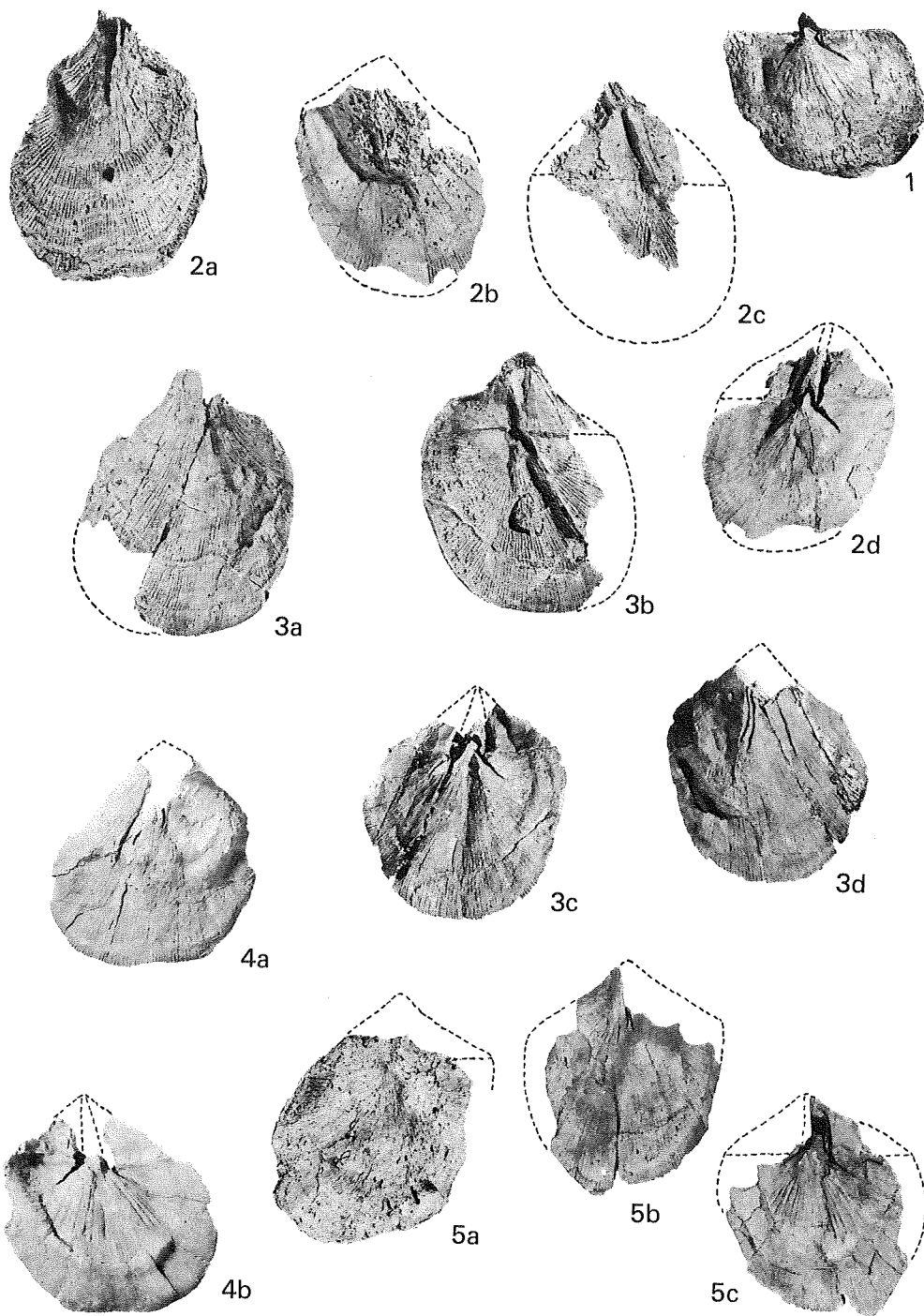
(All figures are in natural size)

Fig. 1. *Orthotetina elongata* n. sp.
(UHR 13691), internal mould of brachial valve.

Figs. 2 – 5. *Orthotetina kayseri* (JÄKEL)

2. (UHR 13693), a – external mould of pedicle valve, b, d – ventral and dorsal views of “Steinkern”, c – incomplete external mould of brachial valve with mould of cardinal area.
3. (UHR 13686), a – external mould of pedicle valve, b – external mould of brachial valve with mould of cardinal area, c, d – dorsal and ventral views of “Steinkern”.
4. (UHR 13688), a, b – ventral and dorsal views of “Steinkern”.
5. (UHR 13687), a – external mould of brachial valve with a part of mould of cardinal area, b, c – ventral and dorsal views of “Steinkern”.

All specimens from the Lower Kanokura series at Imo.



Explanation of plate 3

(All figures are in natural size)

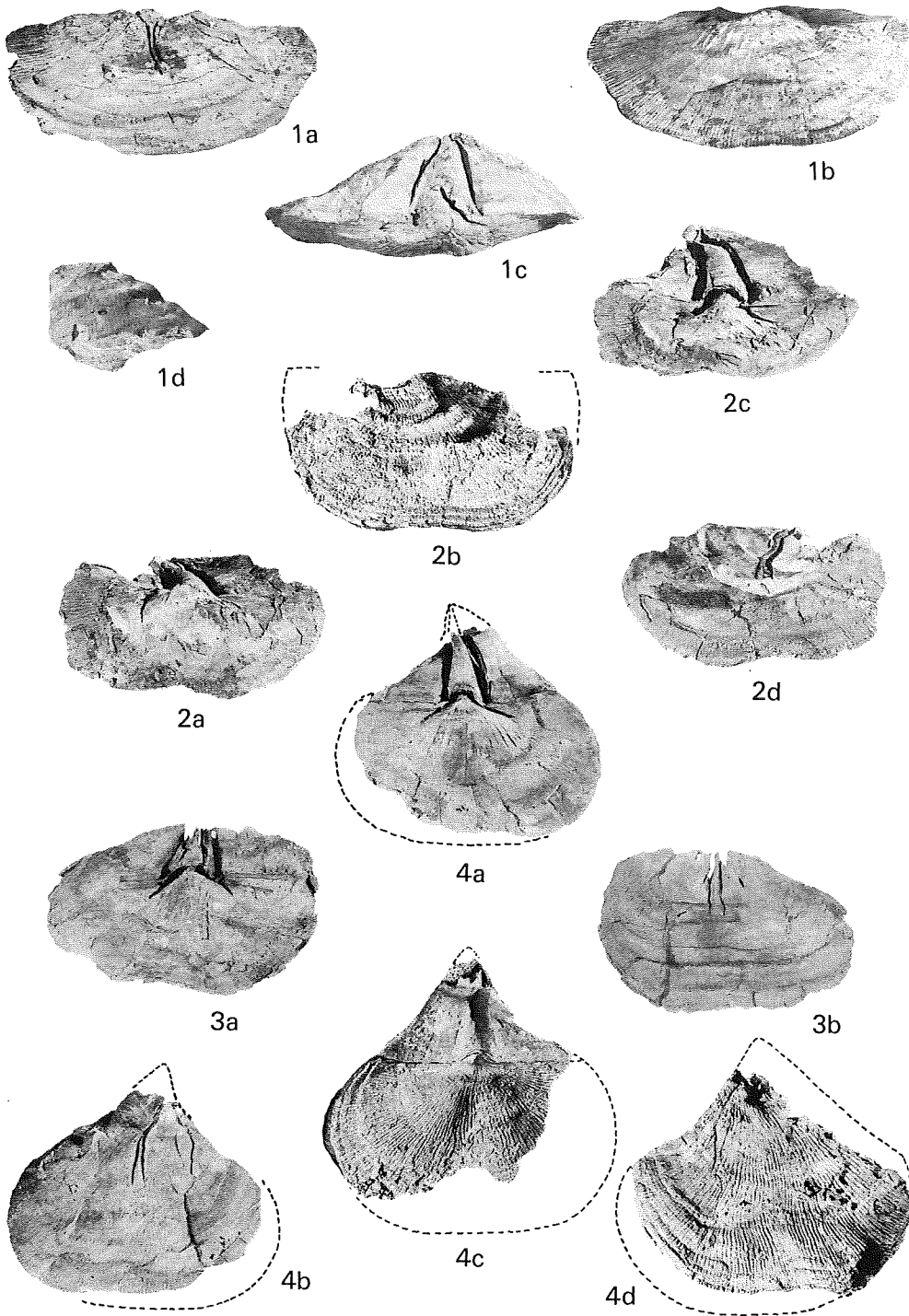
Figs. 1 – 3. *Orthotetina transversa* n. sp.

1. The holotype (UHR 13573), a, b, c, d – ventral, dorsal, cardinal and lateral views of “Steinkern”.
2. The paratype (UHR 13662), a, c, d – dorsal, dorso-cardinal and ventral views of “Steinkern”, b – incomplete external mould of pedicle valve.
3. (UHR 19532), a, b – dorsal and ventral views of “Steinkern”.

Fig. 4. *Orthotetina polita* FLIEGEL

(UHR 13663), a, b – dorsal and ventral views of “Steinkern”, c – incomplete external mould of brachial valve with mould of cardinal area, d – external mould of pedicle valve.

All specimens from the Lower Kanokura series at Imo.



Explanation of plate 4
(All figures are in natural size)

Figs. 1, 2. *Orthotetina polita* FLIEGEL

1. Incomplete specimen (UHR13664), a, b – ventral and dorsal views of “Steinkern”.
2. Considerably deformed specimen (UHR 13668), internal mould of pedicle valve.

Hor. and Loc.: Lower Kanokura series at Imo.

Figs. 3 – 7. *Orthotetina* sp. A

3. (UHR 13666), a, b – internal and external moulds of pedicle valve.
4. (UHR 13667), a – internal mould of cardinal area, b – internal mould of pedicle valve.
5. (UHR 17129), incomplete internal mould of pedicle valve.
6. (UHR 12660), deformed internal mould of pedicle valve.
7. (UHR 13665), a – internal mould of cardinal area, b – internal mould of pedicle valve.

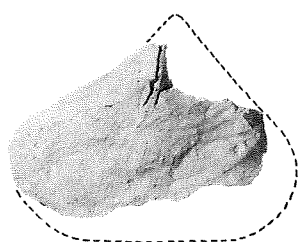
Hor.: Lower Kanokura series.

Loc.: figs. 3, 4, 7 – Imo, figs. 5, 6 – Matsukawa.

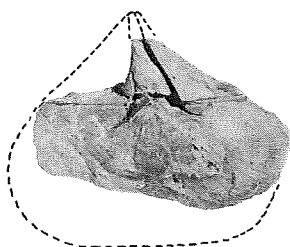
Figs. 8 – 10. *Orthotetina* sp. B

8. (UHR 13069), a, b – incomplete internal and external moulds of pedicle valve.
9. (UHR 13068), a, b – lateral and ventral views of “Steinkern” showing a sharp geniculation, c – external mould of pedicle valve.
10. (UHR 13067), a, b – external and internal moulds of pedicle valve.

Hor. and Loc.: Upper Sakamotosawa series at Nakadaira.



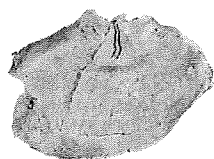
1a



1b



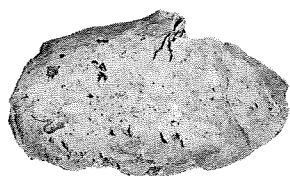
4a



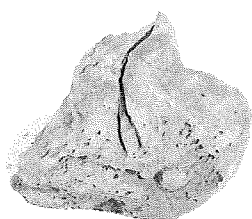
4b



7a



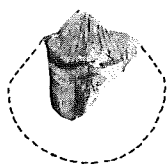
7b



2



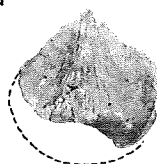
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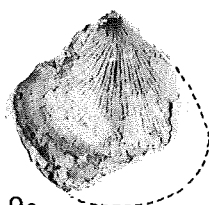
8a



9a



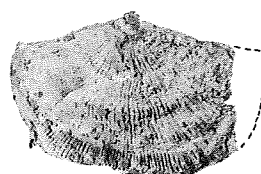
9b



9c



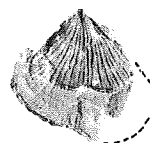
3a



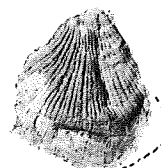
3b



6



8b



10a



10b

Explanation of plate 5

(All figures are in natural size)

Fig. 1. *Meekella* cfr. *striatocostata* (COX)

(UHR 13574), a, b – internal and external moulds of pedicle valve.
Hor. and Loc.: Lower Kanokura series at Imo.

Fig. 2. *Meekella* sp.

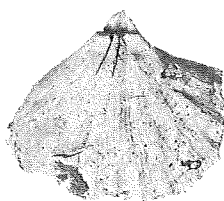
(UHR 13669), a, b – internal and external moulds of pedicle valve.
Hor. and Loc.: Lower Kanokura series at Imo.

Figs. 3, 4. *Meekella mexicana* GIRTY

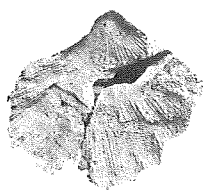
3. (UHR 13670), internal mould of pedicle valve.
4. (UHR 13671), internal mould of brachial valve.
Hor. and Loc.: Upper Sakamotosawa series at Nakadaira.

Figs. 5 – 7. *Meekella garnieri* BAYAN

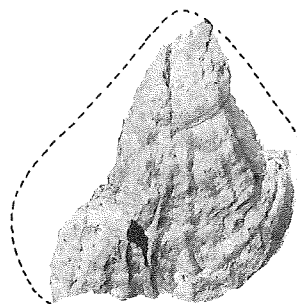
5. (UHR 12577), a, b – external and internal moulds of pedicle valve.
6. (UHR 19533), a, b, c, d – cardinal, ventral, lateral and dorsal views of “Steinkern”.
7. Apical region of internal mould of pedicle valve (UHR 13576).
Hor. and Loc.: Lower Kanokura series at Imo.



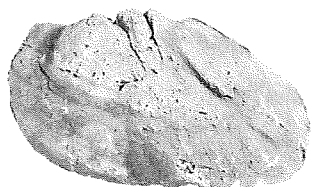
1a



1b



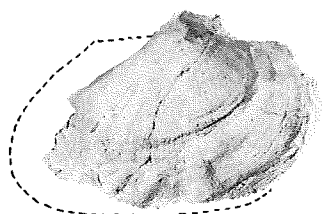
5a



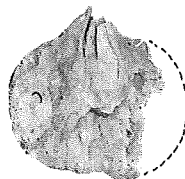
2a



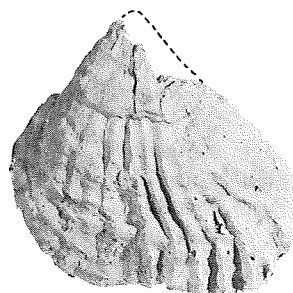
5c



2b



3



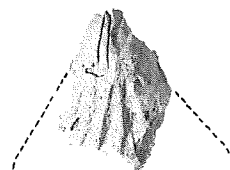
5b



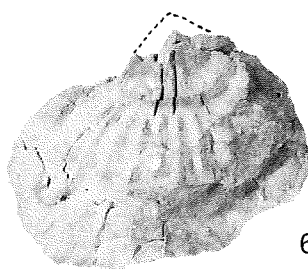
6a



4



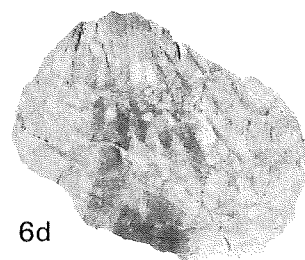
7



6b



6c



6d

Explanation of plate 6

(All figures are in natural size)

Figs. 1, 2. *Meekella minatoi* n. sp.

1. The holotype (UHR 12579), a, c — dorsal and ventral views of “Steinkern”, b — external mould of brachial valve with mould of cardinal area.
2. Incomplete internal mould of brachial valve (UHR 13673).

Hor.: Lower Kanokura series.

Loc.: fig. 1 — Imo, fig. 2 — Kozubo-sawa.

Figs. 3, 4. *Meekella nodosa* n. sp.

3. Fragmental internal mould (UHR 13674).
4. The holotype (UHR 12578), a — internal mould of cardinal area, b — internal mould of pedicle valve.

Hor.: Lower Kanokura series.

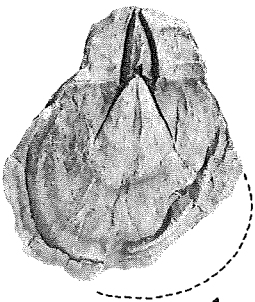
Loc.: fig. 3 — Imo, fig. 4 — Kamiyasse.

Figs. 5, 6. *Meekella* cfr. *eximia* (EICHWALD)

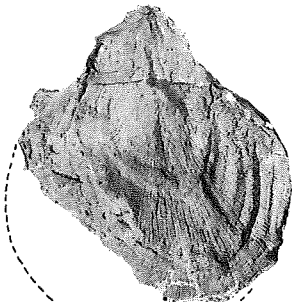
5. (UHR 12576), a, b — ventral and dorsal views of “Steinkern”, c — external mould of brachial valve.
6. Internal mould of brachial valve (UHR 12646).

Hor.: Lower Kanokura series.

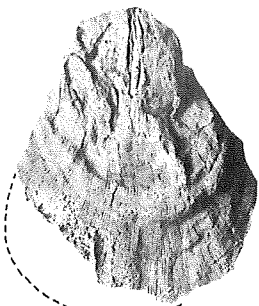
Loc.: fig. 5 — Kamiyasse, fig. 6 — Imo.



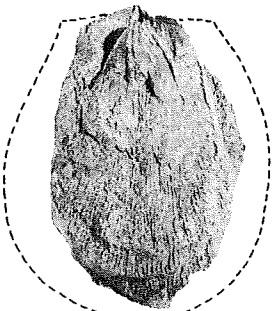
1a



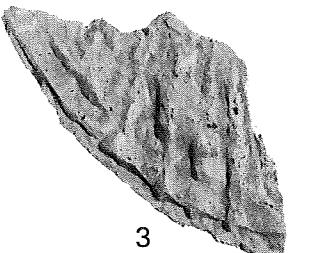
1b



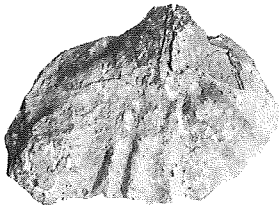
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2



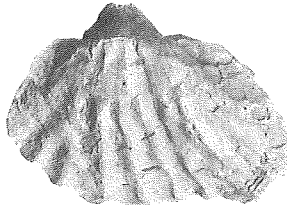
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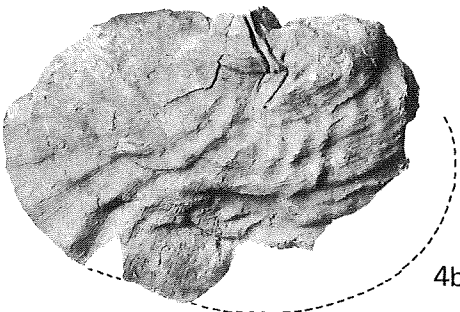
5a



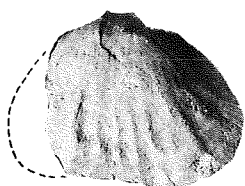
4a



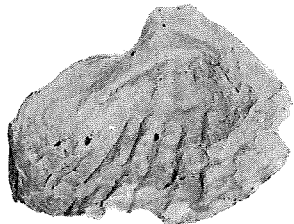
5b



4b



6



5c

Explanation of plate 7

(All figures are in natural size)

Figs. 1, 4 – 9. *Derbyia nipponica* n. sp.

1. Strongly deformed specimen (UHR 19534), a, b, c – ventral, dorsal and cardinal views of “Steinkern”.
4. (UHR 11468), a, b – ventral and cardinal views of internal mould of pedicle valve.
5. (UHR 12470), a, b – internal and external moulds of pedicle valve.
6. Depressed internal mould of pedicle valve (UHR 16037).
- 7, 8 9. (UHR 13675, 17035, 19535), all internal mould of pedicle valve.

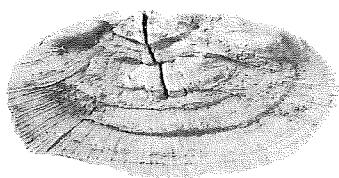
Hor.: Lower Kanokura series.

Loc.: figs. 1, 5, 6, 7, 8, 9 – Imo, fig. 4 – Iwaizaki.

Figs. 2, 3. *Derbyia* cfr. *acutiplicata* METZ

2. Young specimen (UHR 12652), internal mould of pedicle valve.
3. Internal mould of pedicle valve (UHR 13578).

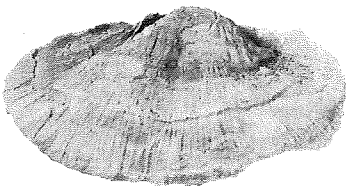
Hor. and Loc.: Lower Kanokura series at Imo.



1a



4a



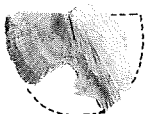
1b



4b



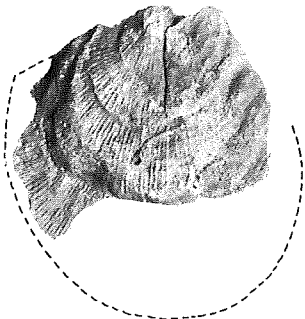
1c



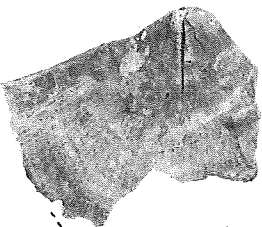
2



3



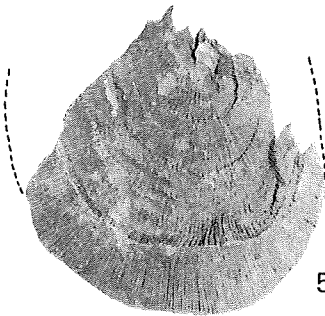
5a



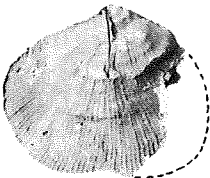
6



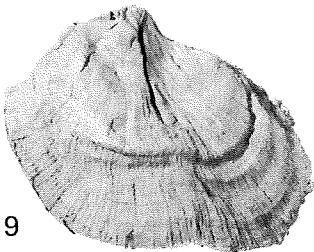
7



5b



8



9

Explanation of plate 8

(All figures are in natural size)

Figs. 1, 7. *Derbyia* sp. B.

1. (UHR 13676), a, b – internal and external moulds of pedicle valve.
 7. (UHR 13677), a, b – external and internal moulds of brachial valve.
- Hor. and Loc.: Lower Sakamotosawa series at Yukisawa.

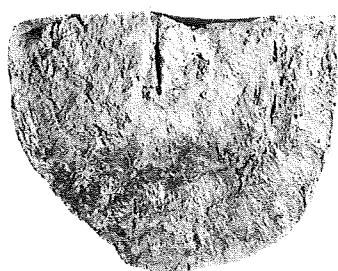
Figs. 2, 4 – 6. *Derbyia* sp. C

2. Internal mould of pedicle valve (UHR 12573).
 4. (UHR13678), a, b – internal and external moulds of pedicle valve.
 5. Internal mould of pedicle valve (UHR 12653).
 6. (UHR 13679), a, b – external and internal moulds of pedicle valve.
- Hor. and Loc.: Upper Sakamotosawa series at Nakadaira.

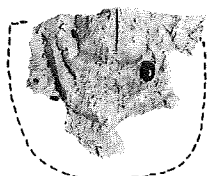
Fig. 3. *Derbyia* sp. A

(UHR 13580), a, c – dorsal and ventral views of depressed “Steinkern”, b – external mould of brachial valve with mould of cardinal area.

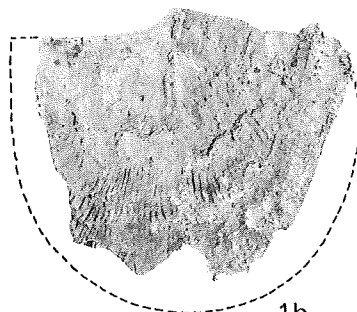
Hor. and Loc.: Lower Kanokura series at Imo.



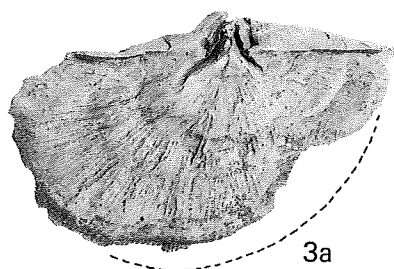
1a



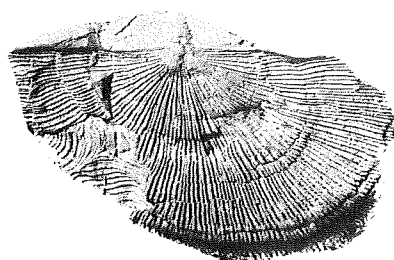
2



1b



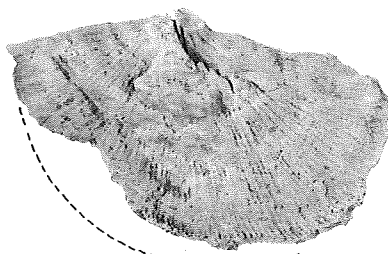
3a



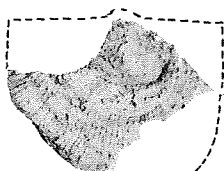
3b



4a



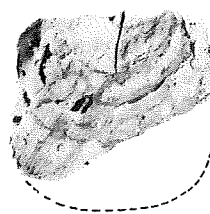
3c



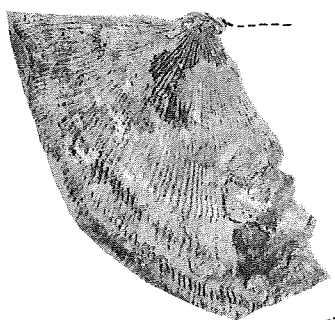
4b



6a



5



7a



6b



7b

Explanation of plate 9

(All figures are in natural size)

Fig. 1. Cfr. *Orthotetes callytharrens* (THOMAS)

(UHR 13680), internal mould of brachial valve.

Hor. and Loc.: Lower Sakamotosawa series at Yukisawa.

Fig. 2. *Magniderbyia* sp.

(UHR 13681), a, b — incomplete internal and external moulds of pedicle valve.

Hor. and Loc.: Same as in preceding species.

Fig. 3. *Streptorhynchus pelargonatus* SCHLOTHEIM

(UHR 12367), internal mould of brachial valve with mould of cardinal area.

Hor. and Loc.: Lower Kanokura series at Imo.

Fig. 4. *Streptorhynchus* sp.

(UHR 13660), a — internal mould of pedicle valve, b — ratex cast of pedicle valve.

Hor. and Loc.: Lower Sakamotosawa series at Yukisawa.

Figs. 5 — 8. *Schuchertella* sp.

5. (UHR 13683), internal mould of pedicle valve.

6. (UHR 13684), internal mould of pedicle valve.

7. (UHR 13685), a, b — internal and external moulds of pedicle valve.

8. (UHR 12702), a — ratex cast of pedicle valve, b — internal mould of the same valve.

Hor. and Loc.: fig. 5 — Lower Kanokura series at Imo, figs. 6 — 8 — Upper Sakamotosawa series at Nakadaira.

Fig. 9. *Schuchertella* cfr. *beyrichi* (ROTHPLETZ)

(UHR 19536), a — internal mould of pedicle valve, b — ratex cast of the same valve.

Hor. and Loc.: Lower Kanokura series at Imo.

Fig. 10. *Schuchertella frechi* HUANG

(UHR 13661), a, b, c, d — cardinal, lateral, dorsal and ventral views of “Steinkern”.

Hor. and Loc.: Same as in preceding species.

