# Fusulinids from the Upper Permian Kuma Formation, Southern Kyushu, Japan : With Special Reference to the Fusulinid Zone in the Upper Permian of Japan

Kanmera, Kametoshi
Faculty of Sciences, Kyushu University

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# Fusulinids from the Upper Permian Kuma Formation, Southern Kyushu, Japan—With Special Reference to the Fusulinid Zone in the Upper Permian of Japan

By

**Kametoshi KANMERA**

ABSTRACT—The Kuma formation in the Kuma massif of southern Kyushu, about 900 m. thick, consists of remarkable conglomerates, sandstones, shales and subordinately intercalated limestone lenses at four horizons. Fusulinids herein described and illustrated are one new species of *Codonofusiella*, each one species of *Rauserella* and *Dunbarula* ?, one new and one previously described species of *Schwagerina*, one species of *Parafusulina* ?, one new subspecies and one unnamed new form of *Pseudodoliolina*, one species of *Verbeekina* ?, one new and two previously described species of *Yabeina* and two new species of *Lepidolina*. This fauna is characterized by the advanced types of *Yabeina* and *Lepidolina*, and is distinctly different from that of *Yabeina globosa* (=*Y. inouyei*) zone which has hitherto been regarded as the youngest fusulinid zone in Japan. The former is biologically more advanced than the latter. Based on this fusulinid fauna, the discussions on correlation with conglomerate-bearing late Permian formations in the Japanese Islands and with late Permian of British Columbia and Indochina are presented.

## Contents



## I. Introduction and Acknowledgements

It has been noticed by several authors that the late Permian strata of the Japanese Islands consist mostly of black shales (or slates), sandstones and conglomerates, with subordinately intercalated small lenses of limestone, and that the conglomerates contain in abundance boulders, cobbles and pebbles of granitic and various other igneous rocks. These strata have been found in a number of separated areas scattered extensively in the Japanese Islands, as shown in the text-figure 2. However, stratigraphy and rock facies of some of them have been reported only briefly and few of the fossils from them have been described. The correlation among them was based mainly on similarity in lithologic facies. Some of them do contain "*Yabeina*" *shiraiwensis* OZAWA and its allied species. However, many authors have included them simply in the zone of *Yabeina globosa*, which has hitherto been regarded as the youngest fusulinid zone in Japan.

In 1949, T. MATSUMOTO and K. KANMERA reported preliminarily on the conglo-glomerate-bearing Permian Kuma formation in the upper valley of the Hikawa in the Kuma massif, southern Kyushu. Very recently, I (1953) have published in Japanese with English résumé the details of its stratigraphy with some remarks on the contained rich fusulinids and discussions of the correlation, but without full paleontological description. In this memoir I describe the fusulinids obtained from the Kuma formation and discuss more precisely their stratigraphic significance.

I wish to express my sincere thanks to Professor T. MATSUMOTO of Kyushu University for his kind advices and for his kindness of reading the manuscript of this paper, and to Professor R. TORIYAMA of the same University for his continuous guidance in the study of the fusulinids. I am indebted to Mr. K. NAKAZAWA of Kyoto University and to Mr. K. KONISHI of Tokyo University for their friendship in offering at my disposal their collections of the fusulinids. I also express my gratitude for the grant provided by the Department of Education.

## II. A Concise Account of the Kuma Formation

The stratigraphy of the Kuma formation was already described in detail in my previous paper mentioned above. However the description in Japanese may not be easily accessible to the foreign geologists. In view of the importance of the Kuma formation, the very source of the fusulinids to be described in this paper, I will give here again a concise account of the Kuma formation itself.

The Kuma formation is best exposed in Kawamata-mura, Yatsushiro-gun, Kumamoto Prefecture, and is extended in NEE trend into Kuriki-mura and Kakisako-mura along the upper course of the Hikawa valley, forming a belt of two or three kilometers width. The strata of the formation are, at present, in contact with those of other formations of the Carboniferous and Permian on both the northern and southern sides and with those of the upper Triassic and late Mesozoic formations in the middle part. The contact is always a contorted zone of faulting.

The Kuma formation, about 900 meters thick, mainly consists of conglomerate, sandstone and shale, and subordinately contains small lenses of limestone. It is highly variable in detailed lithology horizontally and vertically and it does not show a regular arrangement of rocks in stratigraphic sequence so that a normal cycle of sedimentation is not recognized in it. Generally, in the lower part of the formation shale is predominant, finely banded and interbedded with thick sandstone and conglomerate at a few horizons; in the middle part conglomerate and sandstone occur frequently, accompanied by thin bedded alternation of shale and sandstone; and in the upper part again shale predominates, interbedded generally with sandstone and partly with conglomerate. However, there is a considerable change of rock facies horizontally from Kawamata-mura in the west to Kuriki-Kakisako-mura in the east. The difference between the two areas is due mainly to the degree of development of conglomerate. The conglomerate is developed typically in Kawamata-mura, occurr-

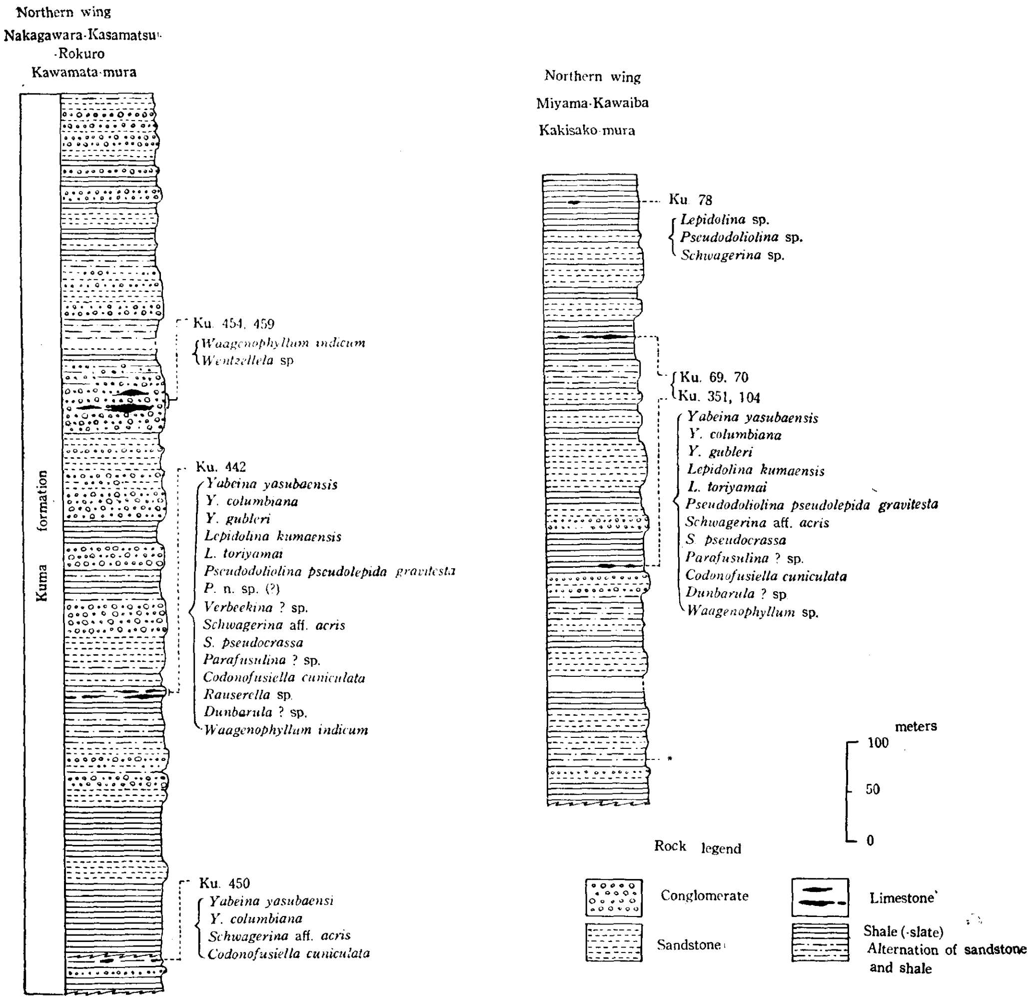


Fig. 1. Stratigraphical sections of the Kuma formation, showing the fusulinid faunas.
In the ribulets at Futae, about 3 km. west of Kawaiba, Kakisako-mura, limestones containing the same fusulinids as in Ku. 450 are exposed, which are the same horizon with that shown by asterisk (*)

ing at many horizons as thick beds, which contain abundant boulders, cobbles and pebbles. While, in Kakisako-Kuriki-mura it is rather poor in development, only forming thin beds which contain smaller cobbles and pebbles (see Fig. 1).

The conglomerate occurs sporadically at many horizons, is of fanglomeratic nature, sometimes thickened and sometimes thinned out, and passes rapidly to sandstone and shale. It is ill-sorted, consisting of well rounded boulders, cobbles, pebbles and granules. Its matrix is commonly muddy and sometimes sandy. Frequently the shale contains isolated pebbles and cobbles. The boulders, cobbles and pebbles are those of aplite, leucocratic granite, adamellite, biotite-trondhjemite, biotite-hornblende-granodiorite, tonalite, quartz-diorite, gabbro, diabase, metagabbro, serpentinite, quartz-porphyry, liparite and andesitic rock. In some case, sandstone, shale, marl and limestone occur abundantly as pebbles and rock-fragments which are probably a product of the contemporaneous erosion.

The limestone in the Kuma formation occurs as small bodies of lenticular or irregular form, passing laterally into calcareous shale, shale, sandstone and sometimes conglomerate within a short distance. The maximum thickness of the limestone-bodies is less than 15 m., commonly 3 to 1 m., and their lateral extension does not seem to exceed 25 m. They occur in certain definite horizons. They are composed mostly of organic remains, including fossil-debris, and other limy fragments of granule size, with matrix of usually argillaceous or arenaceous composition. Sometimes they contain rounded granules and pebbles of igneous and sedimentary rocks in small amount. The contained fossils are fusulinids, bryozoas, corals, sponges, calcareous algae and brachiopods, among which fusulinids are most abundant. However, these fossils are often destroyed or water-worn. Besides the fossils from the limestone, no fossils have yet been detected from the non-calcareous clastic rocks.

The accompanying columnar sections of the Kuma formation in Kawamata-mura and Kakisako-mura show the stratigraphic distribution of the fusulinids as well as the general lithology (see Fig. 1).

## III. Description of Species

### FAMILY FUSULINIDAE MÖLLER, 1878

### SUBFAMILY OZAWAINELLINAE THOMPSON & FOSTER, 1937

### GENUS *Rauserella* DUNBAR, 1944

#### *Rauserella* sp.

Plate 3, fig. 13

This form is represented by only one sagittal section which seems to be an immature specimen, so I am not able to determine all of the characters of this form.

Shell minute, 0.7 mm. in width in fourth volution. Height * of fourth volution about 170 microns. Inner 3 volutions planispiral and subdiscoidal in shape, having narrowly angular periphery, short axis of coiling and convex axial regions. Beyond third volution, axis of coiling rapidly changes position at almost normal to the previous volutions and the volutions rapidly expands. Length and width of first to third volution and their form ratios are as follows:

| Volution | Length | Width | Form ratio |
|---|---|---|---|
| 1 | 0.072 mm. | 0.129 mm. | 0.55 |
| 2 | 0.121 | 0.243 | 0.5 |
| 3 | 0.215 | 0.443 | 0.48 |

Proloculus minute, with outside diameter of about 50 microns. Heights of first to fourth volution 41, 65, 128 and 143 microns, respectively.

Spirotheca composed of tectum and less dense lower and upper tectoria in inner 3 volutions, and of tectum and somewhat dense dark lower tectorium in fourth volution. Thickness of spirotheca of second to fourth volution 10—14, 12—18 and 12—25 microns, respectively.

Septa unfluted, identical to spirotheca in structure. It counts 8 for fourth volution. Chomata not apparent even in inner volutions.

*Remarks:* As this form is represented by only one sagittal section, its generic affinity is not clearly understood. However, so far as the size and development of the shell and the spirothecal character are concerned, this form closely resembles the immature shell of the genus *Rauserella.* Although the irregularly coiled aberrant nature in the mature shell of *Rauserella* is not observed, this specimen is probably referable to the genus.

Unfortunately I have never had an opportunity to read the original description of *Rauserella erratica* DUNBAR. However, the present form is similar in some respects to the sagittal section of *Rauserella erratica* illustrated by THOMPSON (1948) as fig. 5 on his plate 3. However, the former differs from the latter in that the periphery is more sharply angular, the form ratios in the inner volutions are more smaller and the septal count seems to be less numerous.

*Occurrence:* This form has been found in the collections from the limestone lens (Loc. Ku. 499) of the upper coarse of the small tributary towards the northern side of the Kawamata valley, where it is associated with *Yabeina columbiana* (DAWSON), *Y. yasubaensis* TORIYAMA, *Y. gubleri*, n. sp., *Lepidolina toriyamai*, n. sp., *L. kumaensis*, n. sp.. *Pseudodoliolina pseudolepida gravitesta*, n. subsp., *Codonofusiella cuniculata*, n. sp. *Dunbarula ?* sp., *Schwagerina* aff. *acris* THOMPSON and WHEELER and *S. pseudocrassa* n. sp.

* Height of volution in this paper means the height from the upper surface of the tectum of the preceding volution to that of the next one.

## SUBFAMILY SCHUBERTELLINAE SKINNER, 1931

## GENUS *Codonofusiella* DUNBAR & SKINNER, 1937

### *Codonofusiella cuniculata*, n. sp.

Plate 3, figs. 12, 14–19

Shell minute, elongate subtriangular shape, with 4 1/2 to 4 3/4 volutions. First 1 to 2 volutions are coiled with short axis of coiling at angles as great as 90° to the axes of outer volutions, possessing narrowly rounded periphery. Third to fourth volution becomes fusiform with rather acutely pointed poles and simultaneously increases in height rapidly. The last 1/2 volution rapidly increases in length and height, forming a flaring lip and wing-like extremities polewards to the preceding volution and the midportion of the last volution becomes slightly concave.

Figured specimen (pl. 3, fig. 14) of 4 1/2 volutions about 2.0 mm. long and 0.62 mm. wide, with a form ratio of 3.2. Height of the last volution about 0.18 mm. In figure 15 of a sagittal section height of the last volution about 0.50 mm., and that of the other specimen of a somewhat oblique section about 0.80 mm.

Proloculus very minute, with outside diameter of 50 to 55 microns, averaging 52 microns for 4 specimens.

Spirotheca extremely thin, commonly composed of a tectum and a lower less dense layer, but in some portions of outer volutions composed of a single layer, the tectum. Thickness of spirotheca 4 to 8 microns in inner volutions, and does not exceed 20 microns even at the thickest portion of outer volutions.

Septa exceedingly thin, closely spaced. Septal counts of second to fourth volution in figure 15 of plate 3 are 11, 20 and 27, and that of the last half volution 24. Septal counts of first to fourth volution of other 3 specimens 8–11, 13–15, 18–22 and 25–28, respectively. Septa rather highly fluted in inner 2 volutions and narrowly and strongly fluted in outer volutions, forming chamberlets almost to the tops of chambers. Cuniculi well developed in at least outermost volution of mature specimens (see Pl. 3, fig. 19). Chomata indistinct.

*Remarks:* This new species resembles *Codonofusiella paradoxica* DUNBAR and SKINNER from the Carlsbad member of the Capitan limestone of Texas. However, the former has much more slender shell, more highly flaring extremities and has much more strongly and closely fluted septa so as to form distinct cuniculi at maturity.

*Occurrence;* This species occurs rather commonly in the limestones at the first horizon but rarely occurs in those of the second and third horizons. It is associated with the all species described in this paper.

## GENUS *Dunbarula* CIRY, 1948

### *Dunbarula* ? sp.

Pl. 3, figs. 8 (?), 9–11, 20.

Few specimens of a small fusulinid have been obtained from my collections. Most of them are crushed and incomplete, so that I am not able to determine all of the characters of this form. However, for the sake of completeness I illustrate some of the better oriented sections upon which the following description is based.

Shell minute, short, obese fusiform; with sharply pointed poles and rather steep and uniformly convex lateral slopes. One specimen of 5 volutions about 0.72 mm. long and 0.42 mm. wide, having form ratio of about 1.7.

Proloculus exceedingly minute, spherical in shape, having outside diameter of about 27 microns. Inner 3 1/3 volutions subdiscoidal in shape, with short axis ~~is~~ of coiling, umbilicated polar regions and broadly rounded periphery. Form ratios of inner 3 volutions 0.5 to 0.6. Beyond third volution axis of coiling rapidly changes position at normal to that of the previous volutions, and the poles become rapidly longer and gradually more sharply pointed. Heights of first to fifth volution of a typical specimen about 14, 31, 38, 64 and 102 microns, respectively.

Spirotheca thin. Its structure can not be determined with certainty. In inner volutions it consists of a exceedingly thin dense layer, the tectum, and less dense, rather lighter lower layer and rather darker upper layer, but in fourth volution a transparent layer is partly recognized between tectum and inner tectorium-like rather dark layer. Thicknesses of spirotheca of first to fifth volution measure 5–7, 7–10, 10, 10–15 and 13–18 microns, respectively.

Septa closely spaced. Septal counts of first to fifth volution 8, 13, 16, 17 and 18, respectively. They are apparently unfluted throughout length of the shell in inner volutions, but weakly fluted in the extreme polar regions of outer volutions. They are very thin in the inner volutions and composed of the downward deflection of the tectum, but beyond third volution they become more thicker and are composed of a tectum and anterior and posterior extensions of the tectoria. However, some of the septa in fourth volution have transparent layer in the posterior side of the tectum from the top to the lower margin.

Chomata are poorly developed, but the exact nature of them are not clearly understood in my specimens.

*Remarks:* As the specimens of this species are incomplete and probably immature individuals, its specific as well as generic affinities can not be determined with certainty. However, it does not seem to be referable to any previously described species. The general shape of the shell, the mode of coiling in the early volutions and the nature of the septal fluting of this form closely resemble those of the genus *Dunbarula*. It is impossible to determine with certainty the structure of spirotheca and septa of this form because of imperfect condition of preservation. So far as observed, however, the spirothecal and septal structures of this form seem to be more closely allied to those of *Dunbarula*, which has been shown by CIRY in his text-figure 1 and plate 1, figs. 1 and 2, than to those of any other genus. However, this form can be distinguished from *Danbarula mathieui* CIRY in having sharply pointed poles, more weakly fluted septa and more poorly developed chomata.

This form also closely resembles *Schubertella* sp. described and illustrated by GUBLER (1935) from Cambodge, in general structure and size of the shell and the thickness of spirotheca. But the former differs from the latter in having more highly vaulted shell and smaller form ratios for corresponding volutions.

Because of the insufficiency of the material and the poor state of preservation I hold even the generic identification as tentative.

*Occurrence:* This form occurs rarely in the limestones of the localities Ku. 442 and Ku. 351 of the second horizon of the Kuma formation, with the same association as given above for *Codonofusiella cuniculata*, n. sp.

## SUBFAMILY SCHWAGERININAE DUNBAR & HENBEST, 1930

## GENUS *Schwagerina* MÖLLER, 1877

### *Schwagerina* aff. *acris* THOMPSON and WHEELER

Plate 1, figs. 8-17, Plate 3, fig. 21

*Schwagerina pavilionensis* var. *acris* THOMPSON and WHEELER, 1942, Permian fusulinids from British Columbia, Washington, Oregon: Jour. Paleontology, vol. 16, no. 6, p. 707, pl. 105, figs. 1, 2.

*Schwagerina acris* THOMPSON and WHEELER, 1950, Middle and Upper Permian fusulinids of Washington and British Columbia: Contributions from the Cushman Foundation for Foraminiferal research, vol. 1, pts. 3 and 4, p. 56, pl. 8, figs. 11, 12.

Numerous incomplete specimens of this form have been obtained from my collections. Some outer volutions of all the specimens are so incomplete that most of the characters at maturity are not understood.

Shell elongate fusiform; with sharply pointed poles, low to nearly flat lateral slopes and straight to broadly curving axis. Number of volutions at maturity is at least more than 8 volutions. However, because outer several volutions are crushed, the exact length and width of full-grown shell can not be measured.

Specimens of 7 volutions more than 7.8 mm. long and 2.2 mm. wide, giving form ratios of about 3.4 to 2.7. Proloculus moderately large, and its outside diameter measures 214 to 292 microns, with an average outside diameter of 231 microns for 6 specimens. Inner 3 volutions tightly coiled, but beyond fourth volution shell expands rather rapidly. Average heights of first to seventh volution of 6 specimens 50, 79, 106, 141, 187, 256 and 290 microns, respectively.

Spirotheca relatively thick, composed of a tectum and a keriotheca with coarse alveoli. Average thicknesses of spirotheca in first to seventh volution of 6 specimens 25, 30, 38, 48, 63, 73 and 85 microns, respectively.

Tunnel low and narrow in inner volutions and gradually increases in breadth in outer volutions. Tunnel angle measures about 30 degrees in third volution and 35 degrees in the fifth. Low and narrow chomata occur in inner 4 volutions, but they are irregular and discontinuous. Axial areas broadly filled with the heavy deposits of dense calcite for about 6 volutions except for those of outer 2 or 3 volutions.

Septa relatively thin, narrowly and highly fluted throughout the shell, especially intensely in the polar regions of outer volutions. The fluting reaches tops of the chambers. Tangential sections do not display cuniculi. As there is no well-oriented sagittal section, it is not enough to give the septal count with certainty. However, in one specimen the septa are counted 8, 16, 16, 21, 19 and 25 for first to sixth volution, and those of the other specimen 9, 11, 19, 21 and 26 ?, respectively for first to fifth volution.

*Remarks:* This form is closely allied to *Schwagerina acris* THOMPSON and WHEELER from the Marble Canyon limestone of the Cache Creek series of Marble Canyon, British Columbia, in form ratios, shape, heights of volutions, thickness of spirotheca, development of chomata, degree of septal fluting and heaviness of axial fillings, but the former differs from the latter in having smaller septal count and somewhat tightly coiled inner volutions. Striking similarity between the specimens illustrated by THOMPSON and WHEELER as fig. 1 on their plate 105 and the present specimens illustrated here by figs. 8, 9 and 14 of plate 1 suggests that these two groups of specimens biologically are closely related. However, more sufficient and better specimens, especially of sagittal section, are needed to determine the exact specific characters.

The present form is similar in some respects to *Schwagerina chihsiaensis* (LEE) from the upper part of the Chihsia limestone of China, but the latter ha~~ve~~s larger shell, more numerous volutions and more thicker spirotheca.

*Occurrence:* This species occurs fairly abundantly in the limestones of the first to the third horizon of the Kuma formation. It is associated with the species given above for *Codonofusiella cuniculata*, n. sp.

## *Schwagerina pseudocrassa* n. sp.

Plate 1, figs. 6, 7.

*Pseudofusulina crassa* (DEPART) GUBLER, 1935, Les Fusulinides du Permien du ~~L~~'Indochine: Géol. Soc. France, Mém, Nouv. sér., Tome XI, fasc. 4, pp. 79-81, pl. 1, figs. 5, 6.

Many poorly oriented sections of this species were obtained from my collections, which are at a glance referable to the specimens described and illustrated by GUBLER as *Pseudofusulina crassa* (DEPRAT) from Cambodge. The following description is based entirely on the specimens from the Kuma formation.

Shell large, highly inflated in central area; with bluntly pointed poles, steep lateral slopes and straight axis of coiling. Outer few volutions of almost all of the specimens are missing or crushed and none of the present specimens is well-oriented axial section, so that the length and width of mature shell and the form ratio can not be measured exactly. However, specimens of 9 volutions are more than 8.6 mm. long and 4 mm. wide.

Proloculus small, its outside diameter in 3 specimens 160 to 234 microns. Inner 3–3$^1/_2$ volutions tightly coiled, following one increases in height rapidly and outer volutions highly inflated. In a figured specimen (pl. 1, fig. 6) heights of first to seventh volution 78, 70, 127, 273, 312, 332 and 332 microns, respectively. Spirotheca is relatively thin notwithstanding large size of the shell, and is composed of a thin tectum and a keriotheca with coarse alveoli. Thicknesses of spirotheca of first to eighth volution of 2 specimens 19–21, 24–28, 30–33, 35–38, 35–43, 43–53, 43–57 and 57–70 microns, respectively.

Septa narrowly and highly fluted throughout length of shell. Fluting reaches to tops of chambers but forms closed chamberlets only in lower two-thirds of chambers. Septal counts of first to seventh volution of ill-oriented section 12, 15, 17, 18, 23, 27 and 32, respectively.

Chomata probably absent. Dense deposits fill chambers in polar regions in inner 4 volutions. However, in outer volutions these deposits do not occur in polar regions but essentially tend to fill inside of chambers in areas on either side of median portion.

*Remarks:* Although the materials at my disposal are not sufficient and none of them is well-oriented section, the important characters observed in the present specimens quite agree with those of the specimens described and illustrated by GUBLER (1935) as *Pseudofusulina crassa* (DEPRAT) (pl. 1, figs. 5, 6) from Cambodge. However, the present specimens and GUBLER's ones are distinguishable from the original specimens of "*Fusulina*" *crassa* of DEPRAT (1913, Pl. IV, figs. 1–5) from Laos. That is, the former two have thinner spirotheca and less numerous septa for corresponding volutions, more tightly coiled inner volutions and larger heights of volutions in outer ones, and different mode of fillings of chambers. Therefore, I propose to give a new name *Schwagerina pseudocrassa* to the specimens from the Kuma formation. And as mentioned above, this species includes the specimens of Cambodge which were described by GUBLER under the name of "*Pseudofusulina crassa* (DEPRAT)."

This species somewhat resembles *Schwagerina douvillei* COLANI in general shape and mode of fillings of chambers. However, the former can be easily distinguished from the latter in having more tightly coiled inner volutions and thinner spirotheca.

*Occurrence:* Specimens of this species are common in limestone lenses of the second and third horizons of the Kuma formation; associated with *Lepidolina toriyamai*, n. sp., *L. kumaensis*,

n. sp., *Yabeina gubleri*, n. sp., Y. *columbiana* (DAWSON), *Y. yasubaensis* TORIYAMA, *Schwagerina* aff. *acris* THOMPSON and WHEELER, *Parafusulina* ? sp., *Codonofusiella cuniculata*, n. sp. *Rauserella* sp., *Dunbarula* ? sp., *Pseudodoliolina pseudolepida gravitesta*, n. subsp. and *P.* n. sp. (?)

## GENUS *Parafusulina* DUNBAR AND SKINNER, 1931

### *Parafusulina* ? sp.

Pl. 1, figs. 1–5.

Several elongate specimens of schwagerinid are found in my collections, which are not conspecific with any previously described species of *Schwagerina* and *Parafusulina.* However, I hesitate to propose a new specific name for them because my specimens are so incomplete. For the sake of completeness, I illustrate and describe some of my better specimens.

Shell large, elongate cylindrical to subcylindrical; with straight axis of coiling, straight to slightly convex lateral slopes and bluntly pointed to broadly rounded poles. Mature specimens consist at least of 9 volutions. The majority of thin sections ~~are~~ is so incomplete that the length, width and the form ratio of mature shell are not determined. Length and width of seventh volution in a specimen of 9 volutions about 11.21 mm. and 2.46 mm., respectively (both twice a half length and a half diameter), and gives form ratio of about 4.6. A partly preserved specimen (pl. 1, fig. 2) of almost half of shell suggests that mature specimen, if exist, are presumed to be about 15 mm. long and 32 mm. wide. Form ratios of first to sixth volution of the same specimen 2.3, 3.0, 3.5, 4.0, 4.4 and 4.6, respectively, and those of an immature specimen are nearly same values as given above.

Proloculus rather large, outside diameter in 2 specimens 273–295 microns. Heights of first to eighth volution of a specimen 67, 62, 113, 156, 195, 243, 254 and 312 microns, respectively. Thus shell expands uniformly.

Spirotheca composed of a tectum and a thick keriotheca with relatively fine alveoli. Thicknesses of spirotheca of first to seventh volution 29, 29, 33, 43, 52, 64 and 72 microns, respectively. Alveolar layer about 57 microns thick in seventh volutions.

Septa narrowly and regularly fluted throughout the shell and especially intensly in polar regions. Fluting reaches the tops of chambers and forms chamberlets closed about 4/5 the heights of the chambers. Septal counts of a specimen which seems to be referable to the same species 10, 19, 20, 25, 25 and 29, respectively, for first to sixth volution.

Tunnel low and narrow, and its path irregular. Tunnel angle about 43 degrees in third and fourth volutions in a specimen.

*Remarks:* This form does not resemble any previously described species of schwagerinid. Because well-oriented tangential section has not been obtained, the generic affinity of this species is not clearly understood. However, shape and development of the shell, thin spirotheca and intense and regular septal fluting of this species suggest that it seems to be more closely allied to the type species of *Parafusulina* than that of any other known genus.

*Occurrence:* The present species is rather rarely known from the limestones of the first to the third horizon. It is associated with all species described in this paper.

## SUBFAMILY VERBEEKININAE STAFF & WEDEKIND, 1910
## GENUS *Pseudodoliolina* YABE & HANZAWA, 1932

### *Pseudodoliolina pseudolepida gravitesta*, n. subsp.

Plate 2, figs. 1–6.

*Doliolina lepida* SCHWAGER, GUBLER, 1935, Société Géol. France, Mém., Nouv. Sér., Tome XI, fasc. 4, pp. 95-99, Pl. IV. figs. 4-7, Pl. V, figs. 14, 15.

Shell large, elongate ellipsoidal to subcylindrical, slightly inflated in midportion, having slightly convex lateral slopes and broadly rounded polar areas. Inner 3 or 4 volutions more rounded ellipsoidal, and beyond fourth volution shell becomes elongate elliøpsoidal.

Number of volutions more than 16. Size of full-grown shell can not be precisely measured because a few outer volutions of almost all of the specimens are missing. However, specimens of 15 volutions about 7.6–10.5 mm. long and 4.1 mm. wide, having form ratios of 2.0–2.1. Figured specimen (pl. 2, fig. 2) of 13 1/2 volutions 7.1 mm. long and 3.47 mm. and gives a form ratio of 2.1. Form ratio about 1.3 for first volution, 1.7 for third and 2.0–2.1 for fourth to thirteenth.

Proloculus large, spherical to ellipsoidal, and its outside diameter 186–276 microns, averaging 220 microns for 7 specimens. Shell expands slowly and uniformly. Heights of first to fourteenth volution (13 1/2) at midportion of shell of the figured specimen (pl. 2, fig. 2) 47, 49, 57, 70, 86, 100, 155, 122, 140, 160, 163, 172, 171 and 179 microns, respectively.

Spirotheca rather thick. In inner 2 volutions, it is composed of a tecum and a lower clear layer, the latter of which is very thin and somewhat less distinct in some portions. Beyond third volution it is clearly composed of a thin tectum, a rather thick clear central layer and a lower very thin dense layer. The upper surface of the tectum is coated with a more or less discontinuous layer of dense material which is continuous with parachomata. Extremely fine parallel dark lines are seen in the lighter central layer of spirotheca, which are normal to the surface of spirotheca. This fine alveolar structure is not so clear and thick as the alveoli of the type species of the genus *Misellina*.

Thickness of the primary layers of spirotheca in first to thirteenth volution 5, 6, 7, 10, 12, 14, 14, 16, 17, 19, 24, 24 and 24 microns, respectively, and thickness of the central layer in fifth to thirteenth volution about 6, 6, 7, 9, 10, 12, 18, 18 and 18 microns, respectively. The cetral layer becomes slightly thicker adjacent to the septa than in midportion between each septum.

Septa rather closely spaced, composed of a downward deflection of tectum and anterior and posterior downward extensions of keriotheca of spirotheca on the one-third of the distance. On the lower two-thirds of the distance they are coated on either side by deposits of the dense material which are apparently continuous with the parachomata. Average septal counts of first to eleventh volution in 4 specimens 7, 13, 16, 18, 20, 22, 24, 25, 27, 29 and 33, repectively. Septa unfluted throuthout length of shell.

Foramina small, essentially circular in cross section in inner volutions but elliptical in outer volutions. There are about 10, 12, 15, 15, 18, 20, 23, 25, 27, 31 and 34, respectively for second to eleventh volution. Parachomata well developed, and heights of them are slightly beyond a half of the heights of the chambers but they extend near the tops of the chambers adjacent to the septa.

*Remarks:* The present subspecies differs from the Yun-nan type by slightly larger shell, more thicker spirotheca and less massive parachomata. According to DEPRAT, the original specimens have a thickness of 10 microns for the tectum and alveolar layer. While the Kuma specimens have a thickness of 20 to 25 microns in outer volutions.

THOMPSON and FOSTER (1937) did not give the thickness of the spirotheca of their specimens from Shin K'ai Shi and Davies Bungalow, but their specimens seem to have a more thinner spirotheca than those of the Kuma specimens.

The specimens from the Kuma formation are probably conspecific with a part of the specimens, described and illustrated by GUBLER (1935) as *Doliolina lepida* from Cambodge (pl. IV, figs. 4–7, pl. V, figs. 14–15). GUBLER did not show the thickness of the spirotheca of his specimens, but from his good illustration his specimens seem to have nearly the same thickness of spirotheca as that of the Kuma specimens. The Cambodge specimens have a slightly more massive parachomata. However, this difference possibly is not a specific value. The GUBLER's specimens are also slightly larger than the original ones of *P. pseudolepida.*

As the above discussion indicates, the specimens from Kuma and Cambodge seem to have more thicker spirotheca and slightly larger shell than the original specimens from Yunnan and the specimens from Shin K'ai Shi and Bungalow. However, so far as the shape of shell, form ratio and size of proloculus are concerned, the formers can not be distinctly distinguishable from the ~~latter~~ latters.

The Cambodge and Kuma specimens occur in association with highly advanced forms of *Yabeina,* while the original specimens from Yunnan and the specimens from Shin K'ai Shi and Bungalow occur together with the fauna of the *Neoschwagerina-Verbeekina* zone. Probably the former specimens may be of highly developed of *P.*

*pseudolepida* (DEPRAT).

*Occurrence:* This subspecies is common in the limestones of the second and third horizons of the Kuma formation, and it is associated with the other all species described in this paper.

## *Pseudodoliolina* n. sp ?

Plate $\overset{2}{3}$, figs. 7, 8.

Associated with *P. pseudolepida gravitesta* n. subsp. in the collection from the limestone of the second horizon was found a sagittal and a tangential section of *Pseudodoliolina.* These two specimens, which are probably conspecific, seem to be not referable to any previously described species.

The specimen of a tangential section is very large and seems to be elongate fusiform, with rather highly inflated midportion, slightly concave lateral slopes and broadly rounded polar areas. This specimen is tangentially cut and outer few volutions are crushed, so that the size, shape and other important characters can not be determined exactly. However, the specimen is more than 9,75 mm. in length and 4,0 mm. in width. The form ratio may be more than 2.6. Heights of volutions in outer ones are about 160–190 microns. Spirotheca is rather thick for the genus, and apparently composed of a tectum and a lower clear layer. The clear layer does not show distinct alveolar structure. Thickness of spirotheca in outer volutions is about 16–19 microns. Surface of spirotheca is partly covered by dense materials which are continuous with the parachomata. Parachomata are rather low and narrow.

The sagittal section of 15 volutions is about 3.8 mm. wide. Proloculus is subspherical, with maximum outside diameter of 195 microns. Shell expands slowly and uniformly. Heights of first to thirteenth volution 50, 68, 74, 97, 98, 107, 118, 155, 160, 181, 205, 205 and 231 microns, respectively. Spirotheca rather thick for the genus, composed of a single dense layer in inner 3 volutions, but it is composed of a tectum and a lower clear layer in fourth to outer volutions. In the clear layer the alveoli are discernible distinctly. Total thickness of primary layers of spirotheca is 5–9 microns in first to sixth volution, 9–10 microns in seventh to eighth, 12–14 in nineth to tenth and 16–19 in eleventh to outer volutions. Septa rather thick, composed of a downward deflection of tectum and anterior and posterior downward extensions of a lower clear layer. But the lower edges of the septa are coated on either side with deposits of dense materials which are continuous with the parachomata. Septal counts of first to tenth volution are 13 (?), 16, 16, 13, 18, 19, 21, 22, 23 and 26, respectively.

*Remarks:* This form seems to be quite different from any previously described species of *Pseudodoliolina* in having larger size of the shell, concave lateral slopes and less massive parachomata. Probably this form is a new species. However, so little can be determined concerning the nature of this species that I hesitate to assign a new specific name to this form until more sufficient information becomes available.

*Occurrence:* This species was collected from the limestone of Loc. Ku 499; associated with *Yabeina yasubaensis* TORIYAMA, *Y. columbiana* (DAWSON), *Y. gubleri* n. sp., *Lepidolina kumaensis*, n. sp., *L. toriyamai*, n. sp., *Schwagerina* aff. *acris* THOMPSON and WHEELER, *S. pseudocrassa*, n. sp., *Parafusulina* ? sp., *Codonofusiella cuniculata*, n. sp., *Rauserella* sp., *Dunbarula* ? sp., and *Pseudodoliolina pseudolepida gravitesta*, n. subsp.

## GENUS *Verbeekina* STAFF, 1909

### *Verbeekina* ? n. sp.

Plate 2, figs. 9

Among my collections I have found only one specimen of this species which is represented by a diagonal section passing through the center of the proloculus. Although it is referable to the Subfamily *Verbeekininae* STAFF and WEDEKIND, its generic affinity is uncertain. I have not been able to determine many of significant specific characters from the specimen. However for the sake of completeness, I am illustrating the specimen.

Shell of about 17 volutions (the last volution missing), very large, probably ellipsoidal in shape and slightly inflated in midportion. Diameter of inner 16 volutions 4.68 mm. (twice a half width). Form ratio at least more than 1.4.

Proloculus small, spherical, with an outside diameter of 143 microns. Expansion of the shell uniform but inner volutions rather tightly coiled. Heights of first to fifteenth volution 39, 39, 44, 53, 92, 111, 90, 117, 125, 187, 203, 240, 228, 234 and 273 microns, respectively.

Spirotheca thin in inner three volutions and it appears to be composed of a dense layer, the tectum. Beyond fourth volution spirotheca composed of a very thin tectum, rather thick clear central layer and a lower very thin dense layer. Fine parallel dark lines are seen in the clear central layer of spirotheca. Upper snrface of spirotheca partly coated with a discontinuous layer of dense material which seems to be continuous with the parachomata. It gradually increases in thickness with the growth of shell. Thickness of spirotheca in first to fifteenth volution at the midportion of the shell 4-5, 6, 7, 8-9, 10-11, 10-11, 11-12, 13-14, 14-16, 16-18, 20-23, 23-28, 25-30, 30-32 and 33-37 microns, respectively. Alveoli about 27 microns thick in fifteenth volution.

As the present specimen is cut obliquely, the nature of parachomata is not clearly ascertained. However, low and narrow parachomata are well developed in sixth to outer volutions and they seem to be developed even in inner volutions. Septa not fluted throughout the shell, and they are coated by dense deposits to the tops of chambers.

*Remarks:* In thick spirotheca, rather less massive and low parachomata and attitude of septa this form is regarded as referable to the genus *Verbeekina*. But, it is not similar to the genus in that the expansion of shell in inner volutions is gradual and the proloculus is rather large. Moreover, although the true shape of the shell is not ascertained, its shape seems probably to be not so spherical to subspherical as in any described species of *Verbeekina*.

The gradual expansion of the shell, rather large size of the proloculus and rather somewhat ellipsoidal shape of the shell of this form suggest that it is more closely related to the genus *Pseudodoliolina* than to the genus *Verbeekina*, but its spirotheca is unusually thick and has distinct alveoli. I can not determine its definite generic affinity until better oriented sections are obtained. However, I am inclined to refer the specimen with question to the genus *Verbeekina*. This form is dissimilar to any other known species of *Pseudodoliolina* or *Verbeekina*. Whatever it is referred to the former or the latter, this species is probably a new spccies.

*Occurrence:* This form has been obtained from the limestone of the Loc. Ku. 449, with the same association as given above for *Pseudodoliolina* n. sp. ?

## SUBFAMILY NEOSCHWAGERININAE DUNBAR & CONDRA, 1928
## GENUS *Yabeina* DEPRAT, 1914

### *Yabeina columbiana* (DAWSON)

Plate 3, figs. 1-5, 6 (?), 7

*Loftusia columbiana* DAWSON, 1879, Quart. Jour. Geol. Soc. London, vol. 35, pp. 69-75, pl. 6, figs. 1-7.
*Yabeina columbiana* (DAWSON), THOMPSON and WHEELER 1942, Jour. Paleontology, vol. 16, no. 6, pp. 708-710, pl. 106, fig. 5; pl. 107, fig. 5; pl. 108, fig. 1; pl. 109, figs. 1-4
*Yabeina columbiana* (DAWSON), THOMPSON, WHEELER and DANNER, 1950, Contributions from the Cushman Foundation for Foraminiferal Research, vol. 1, pt. 3 & 4, p. 61, pl. 8, figs. 1-3.

Shell large, highly inflated fusiform, with straight axis of coiling, somewhat rounded to bluntly pointed poles. First 3 or 4 volutions subspherical in shape, and beyond fifth volution shell assumes its mature shape. Lateral slopes of mature shell uniformly straight to slightly convex.

The largest length and width of mature specimens cannot precisely be measured, because outer several volutions of mature shell are missing, having been crushed out in the time of deposition. However, mature specimens of 15–18 volutions measure 7.5–9.5 mm. in length and 4.5–6.0 mm. in width, giving form ratios of about 1.6–1.7. Figured specimen (pl. 3, fig. 3) of 15 volutions 7.8 mm. long and 4.9 mm. wide, with a form ratio of 1.6. The other one (pl. 3, fig. 2) of 17 volutions is 6.0 mm. wide. Average form ratios in 5 specimens are 1.0–1.2 for first to third volution, 1.4–1.5 for fourth to fifth and 1.6–1.7 for sixth to outer volutions. Mature shape of shell is first attained in about sixth volution.

Proloculus is small, spherical in shape, with outside diameter of 80–230 microns, averaging 205 microns for 7 typical specimens. Shell expands slowly and uniformly. Average heights of first to fifteenth volution of 6 specimens are 45, 59, 72, 89, 102, 117, 133, 144, 155, 167, 187, 198, 209, 226 and 236 microns, respectively. Heights of chambers are about the same thoughout the length of shell for all volutions.

Spirotheca is very thin, composed of a tectum and a keriotheca with very fine alveoli. Thickness of spirotheca is 9–14 microns in first to second volution, 9–11 microns in third to nineth and 14 microns in tenth to maturity. Throughout all volutions thickness of spirotheca does not exceed 15 microns.

In some well-preserved specimens, the spirotheca of outer several volutions consists only of a single layer, the tectum, from which the septula hang immediately. The spirotheca of such a specimen is more thinner for inner volutions than the values mentioned above. Septa somewhat irregularly and widely spaced. Because of a large number of septula and of ill-state of the preservation, it is difficult to count the septal number exactly. However, septal counts of first to thirteenth volution of a typical specimen are 8, 12, 14, 14, 14, 16, 17, 18, 18, 19, 19, 22 and 23 (?), respectively. The upper part of septa consists of a solid plate of the downward deflection of the tectum and transparent keriotheca on its both sides. But the lower part of them are solidified. Primary transverse septula occur throughout the shell and they count 8, 10, 13, 17, 19, 22, 25, 29, 35, 38, 42, 48 and 54 in second to thirteenth volutions, respectively. Secondary transverse septula first appear in fourth or fifth volution, and there are one septulum in most cases between adjacent primary transverse septula throughout the shell, but sometimes they occur 2 for outer volutions. Axial septula first appear in first or second volution and there are one septulum between adjacent septa in first to third volution, 2–4 in fourth to sixth, 3-6 in seventh to nineth and 4–7, sometimes 8, in outer volutions. They are generally long, and the last formed septula between the septa is commonly more longer than the others between the septa.

Foramina small, slightly elliptical in cross-section. There are 18–21 foramina in fifth volution, 39–41 in tenth and 53–56 in fourteenth.

*Remarks:* This species has many important features found in *Yabeina columbiana* (Dawson), described and illustrated by Thompson, Wheeler and Danner (1942, 1948) from the Marble Canyon limestone (Upper Permian) of British Columbia. However, it somewhat differs from the latter in that the proloculus is commonly large, the shell is slightly more inflated and the first appearance of the primary transverse septula is earlier than in *Y. columbiana*. The inside diameter of the proloculus of this form is 50 to 200 microns and usually 140 to 200 microns, while that of the Marble Canyon form is 94 to 140 microns. The primary transverse septula first appear in the fourth or fifth volution in this form, but apper in the seventh or eighth volution in the specimens of Marble Canyon. In other important characters, especially in the thickness of spirotheca, heights of volutions, septal counts and the number of foramina two forms are almost equal for the corresponding volution. Futhermore, the features of the development of axial septula closely resemble with each other. Therefore, it seems obvious that these two forms biologically are very closely related. Probably, few slight differences mentioned above between the present form and the type form from British Columbia seem to be within the limit of specific individual variation.

*Occurrence:* Abundant specimens of this form were obtained from the limestone lenses of the first to the third horizon of the Kuma formation; especially abundant at Loc. Ku. 442. It is associated with *Yabeina yasubaensis* TORIYAMA, *Y. gubleri*, n. sp., *Lepidolina kumaensis*, n. sp., *L. toriyamai*, n. sp., *Pseudodoliolina pseudolepida gravitesta* n. subsp., *Codonofusiella cuniculata*, n. sp., *Schwagerina pseudocrassa*, n. sp. and *S.* aff. *acris* THOMPSON and WHEELER.

## *Yabeina yasubaensis* TORIYAMA

Plate 2, figs. 10–13, Plate 5, figs. 14–19

*Yabeina yasubaensis* TORIYAMA, 1942, The fusulinids of the Yasuba conglomerate in the province of Tosa: Jap. Jour. Geol. Geogr., Vol. XVIII, no. 4, pp. 246-247, Pl. XXV, figs. 8-13

A number of specimens refered to *Y. yasubaensis* were obtained, but many of them are not well-oriented.

Shell large, highly vaulted fusiform with straight axis of coiling, nearly straight lateral slopes and bluntly rounded poles. First 2 or 3 volutions subspherical in shape, and beyond fourth volution shell assumes its mature shape.

The largest length and width of mature shell can not precisely be measured, because outer several volutions are missing or replaced by secondary dark materials. However, full-grown shells attain at least 13 volutions, and are about 6.5–7.5 mm long and 4.0–4.5 mm. wide, giving form ratios of 1.7–1.8. Form ratios are 1.2–1.4 for second to third volution, and 1.6–1.8 for fourth to outer volutions.

Proloculus large, with outside diameter of 390–546 microns, averaging 465 microns for 7 specimens. Heights of volutions of first to twelfth volutions are 70, 95, 105, 129, 125, 141, 156, 156, 169, 208, 208 and 213 microns, respectively. Heights of chambers are about the same throughout the length of shell for fourth to outer volutions.

Spirotheca is relatively thin, composed of a tectum and a very thin keriotheca with very fine alveoli. Thickness of spirotheca is difficult to measure exactly. So far as determined, however, thickness of spirotheca is 7–8 microns for first to seventh volution and 9–11 microns for eighth to outer volutions.

Septa thin and rather loosely spaced. Because of the presence of numerous axial septula, it is difficult to determine the septal count exactly. However, average septal counts of first to eighth volution of 3 specimens are 7, 10, 11, 13, 15, 16, 16 and 18, respectively. Primary transverse septula very thin and present throughout shell. Secondary transverse septula first become distinct in second to third volution, and occur one between adjacent primary transverse septula in inner volutions, and commonly two in outer volutions. Axial septula present throughout shell. There are 3-5 axial septula in inner 5 to 6 volutions and 6-8 in outer volutions. Foramina small, circular in cross-section. There are 26-29 in fifth volution and about 41 in eighth volution.

*Remarks:* The present species are almost identical with the original specimens of TORIYAMA in every important characters.

As to the axial septula of the original specimens of *Y. yasubaensis* TORIYAMA stated that the axial septula generally absent in the early 3-4 volutions, but in the later volutions one to three septula are intercalated between each of the septa. Examining the original specimens owing to the kindness of Dr. TORIYAMA, however, the axial septula appear distinctly in the first volution and occur 3-5 in the inner volutions and much more in the outer volutions.

When TORIYAMA designated *Y. yasubaensis,* he considered that the species differs from *Y. shiraiwensis* OZAWA in having a more larger proloculus. He recognized, however, that two species biologically are closely related with each other.

Very recently, TORIYAMA and I examined the OZAWA's original specimen (OZAWA; section I-14, pl. X, fig. 2) and discovered that the proloculus of the type specimen of *Y. shiraiwensis* has a diameter of 410 microns and OZAWA's measurement on the determination of his species was incorrect. Therefore, so far as the size of proloculus is concerned, *Y. yasubaensis* can not be distinguished from *Y. shiraiwensis.* And also these two species closely resemble with each other in many important characters and the evolutionary development of both species is in almost the same degree. Accordingly, it is highly probable that these two species are conspecific. However, OZAWA's specimens are insufficient for a further discussion. Therefore, I here tentatively refer the specimens from the Kuma formation to *Y. yasubaensis* TORIYAMA.

*Occurrence:* The present species is common in the limestones of the first and second horizons of the Kuma formation, associated with *Yabeina columbiana* (DAWSON), *Y. gubleri* n. sp., *Lepidolina kumaensis,* n. sp., *L. toriyamai,* n. sp. and others.

### *Yabeina gubleri* n. sp.

Plate 4, figs. 1-10, 11 (?), 12, 13

Cfr: *Neoschwagerina megasphaerica* DEPRAT, GUBLER [part], 1935, Mém., Soc. Géol. France, Nouv. sér., Tome XI, fasc. 4, pp. 114-116, pl. VI, figs. 7, 11, pl. VII, fig. 3

Shell large, highly inflated fusiform; with straight to broadly curved axis of coiling and gently concave lateral slopes. Inner 2 volutions spherical to subspherical in shape, and third to fifth or sixth volution highly inflated fusiform, having steep and slightly convex lateral slopes and narrowly rounded poles. Beyond sixth or seventh volutions shell becomes elongate fusiform with inflated central portion, slightly concave lateral slopes and bluntly pointed poles. Number of volution, length and width of shell at maturity are not determined because outer few volutions of shell are missing, or replaced by secondary black materials. Mature specimens of 12 volutions measure 9.0–10 mm. in length and 3.8–4.5 mm. in width, giving form ratios of 2.0–2.3. Form ratios of first and second volutions about 1.1–1.3, that of fourth volution 1.5–1.7, and mature shape of shell is first attained in seventh or eighth volution where the form ratio is about 1.9–2.0.

Proloculus is very large, spherical to subspherical, with outside diameter of 470 micorns in minimum and 860 microns in maximum, and of about 600–750 microns in most specimens, averaging 670 microns for 15 specimens.

Expansion of shell is about uniform, but sometimes height of the preceding volution is higher than of the next one; for instance, the heights of the second and third volutions are frequently smaller than that of first one. Average heights of volutions of first to thirteenth volution of 12 specimens 99, 102, 111, 108, 122, 127, 147, 151, 165, 177, 190, 189 and 215 microns, respectively. Chambers increase in height slowly and uniformly poleward from median portion of shell.

Spirotheca very thin, composed of a tectum and a very thin keriotheca with very fine alveoli in inner 2 volutions. Thickness of spirotheca is 5–11 microns for first volution, 5 to 9 microns for second to third. However, beyond fourth volution spirotheca is composed, for the most part, of a thin single layer, and its thickness measures 5–7 microns and it never exceeds 9 microns for the thickest part.

Septa thin. Because of the presence of numerous axial septula, it is difficult to exactly determine the septal count. However, average septal counts of first to nineth volution of 7 specimens are 7, 11, 13, 15, 16, 17, 18, 18 and 20, respectively. Primary transverse spetula first appear in first volution in some specimens and become always distinct in second volution, and there are one septulum in most cases between adjacent septula throughout the shell but sometimes occur 2 septula in outer volutions. There are about 2–5 axial septula in first to fourth volution, 3-6 in fifth and sixth and 5–8 in outer volutions. Number of axial septula is somewhat variable in each chamber. Transverse secondary and axial septula are of generally bar-like shape and are very thin near their junctions with the spirotheca, and their lower parts are dilated by dark dense materials.

Foramina small, slightly elliptical, with the longest diameter of a cross-section parallel to the axis of shell. There are 18–20 foramina in second volution, 33–36 in fifth, 40–42 in seventh and 62–65 in tenth.

*Remarks:* In regard to the size of proloculus and general development of the shell, *Yabeina gubleri* n. sp. resembles closely *Yabeina hayasakai* OZAWA which has reported from Omi limestone of Japan (1922, 1925). However, *Y. gubleri* can be distinguished from *Y. hayasakai* by more longer shell, larger form ratio at maturity, smaller heights of corresponding volutions, and apparently more highly developed secondary transverse septula in the inner volutions. According to OZAWA, the secondary transverse septula of *Y. hayasakai* are not recognized in the inner one-third or more volutions of the mature shell (1922, p. 370); that is, the appearence of the secondary transverse septula in that species is apparently later than *Y. gubleri* n. sp. Restudying of OZAWA's specimens (OZAWA's collection No. $I_{10}$) shows that the spirotheca of *Y. hayasakai* is thicker than that of *Y. gubleri* for the corresponding volutions, especially in the inner ones.

In general development of the shell and the characters of the spirotheca and septula, *Y. gubleri* n. sp. resembles very closely "*Neoschwagerina megasphaerica*" (pl. VI, figs. 7, 11; VII, fig. 3) which was described and illustrated by GUBLER (1935) from Cambodge. *N. megasphaerica* was first reported by DEPRAT (1913) from Lang-Nac of Indochina. From the DEPRAT's description, text-figures (fig. 24, a–e, p. 57) and illustrations (pl. VII, fig. 26; pl. IX, figs. 4–8), his species seems to be somewhat highly evolved among species of *Neoschwagerina* in the structure of spirotheca and septula. It was found with *Neoschwagerina margaritae* DEPRAT and *Verbeekina verbeeki* (GEINITZ) and the stratigraphic horizon of the species is lower than that of most species of highly evolved forms of *Yabeina.*

OZAWA (1925) identified the same species from the Akiyoshi limestone of Japan, and his specimen (pl. XI, fig. 8) clearly belongs to *Neoschwagerina.* However, the GUBLER's and COLANI's specimens obviously show the characteristic features of the genus *Yabeina,* and they seem to be distinguished from the DEPRAT's original species in that these two forms have more highly evolved spirothecal structures and the better developed secondary transverse and axial septula. Although it is not advisable to attempt the specific correction without a detailed study of the specimens illustrated by the above workers, I consider that the GUBLER's and COLANI's specimens seem to be not identical with *Neoschwagerina megasphaerica* DEPRAT.

The present species under consideration very closely resembles GUBLER's form in all essential characters except only in having more elongate shell in the outer volutions and somewhat thinner spirotheca. Biologically speaking, these two forms are seemingly very closely related with each other. Therefore, I propose here the new specific name, *Y. gubleri* for the present form from the Kuma formation, based on the reasons mentioned above. This specific name is given in honor of Dr. J. GUBLER, who has greatly contributed to our knowledges of the Permian fusulinids of Indochina.

*Occurrence:* Yabeina *gubleri* n. sp. is fairly abundant in the limestones of the second and third horizons of the Kuma formation. It is associated with *Lepidolina toriyamai* n. sp., *Pseudodoliolina pseudolepida gravitesta,* n. subsp., *Codonofusiella cuniculata,* n. sp., *Schwagerina* aff. *acris* THOMPSON and WHEELER and *Schwagerina pseudocrassa,* n. sp.

## GENUS *Lepidolina* LEE, 1933

### *Lepidolina kumaensis*, n. sp.

Plate 5, figs. 1-13

Cfr: *Neoschwagerina douvillei* OZAWA, GUBLER [part], 1935, Mém. Soc. Géol. de France, Nouv. Sér., Tome XI, fasc. 4, pp. 111-113, pl. VII, figs. 7, 8 (?)

Shell moderately large, elongate subcylindrical fusiform in shape, with nearly straight to broadly curving axis of coiling. First 2 volutions spherical to subspherical, third to fourth or fifth volution highly inflated fusiform with slightly concave lateral slopes and bluntly pointed poles. Beyond fifth volution shell becomes elongate fusiform with somewhat bulged median portion, nearly flat lateral slopes and bluntly pointed poles.

Number of volutions seems to be 13 to 15 at maturity. Because some outer volutions of most specimens were eroded away in the time of deposition, the length and width of mature shell are not measured exactly. However, mature specimens of 13 volutions attain more than 8.3 mm in length and 3.0 to 3.2 mm in width, giving form ratios of 3.0 to 3.5. Form ratios of first to fifth vûlution 1.1, 1.3, 1.8, 2.4 and 2.8, respectively, but mature shape of shell is first attained in sixth volution where the form ratio is about 3.1. Form ratios in outer volutions seem to remain the nearly same value from eighth volution to maturity.

Proloculus large, spherical in shape, and its outside diameter 390 to 585 microns, averaging 472 microns for 20 specimens. Average heights of first to fourteenth volution of 12 specimens are 68, 66, 70, 75, 81, 91, 103, 112, 122, 124, 136, 148, 156 and 175 microns, respectively. Chambers increase in height slowly and uniformly poleward from median portion in outer volutions, but in inner 4 to 5 volutions they increase in height rather markedly near the poles.

Spirotheca is very thin. It is composed of a thin outer dense layer, the tectum, and thin inner layer with very fine alveoli in inner 2 or 3 volutions where the thickness is 6 to 10 microns. However, in fourth to outer volutions spirotheca is composed only of a single dense layer for the most part, and faint vestiges of alveoli remain partly only in the septula. Thickness of spirotheca in outer volutions 5 to 6 microns.

Septa thin, identical in structure to spirotheca. Average septal counts of first to eighth volution in 5 specimens 7, 10, 13, 14, 15, 17, 18 and 19, respectively. In outer volutions septal count is not determinable because of ill-state of preservation. In one specimen, however, 21, 22 and 24 septula are determined in nineth to eleventh volution respectively. They extend forward at a small angle and their lowermost margins bend forward at a sharp angle. Primary transverse septula occur throughout the shell; secondary transverse septula generally appear first in third volution, and 2 (sometimes 3) of them develop between adjacent primary transverse septula in sixth to outer volutions. Axial septula present throughout the shell; 1 to 3 occur between adjacent septa in first to third volution, 2 to 6 in fourth to sixth and 3 to 8 in outer volutions. Axial and transverse secondary septula are thin, rather irregular in shape and length, and more than a half of the length of both septula are dense and seemingly coated with secondary deposits. Their upper margins exceedingly thin, and alveoli almost absent in outer volutions. Foramina essentially elliptical in cross-section. There are about 18–20 in third volution, 33–36 in fifth, 45–47 in seventh and 58–60 in tenth volution.

*Remarks:* This species is one of the most elongate forms among species referred to *Yabeina* and *Lepidolina*, and is intermediate in phylogenetic development between these two genera. It may be referable to *Yabeina* in the characters of the spirotheca and septula of the inner few volutions. At present, however, I have at least placed it in the genus *Lepidolina*, because the keriotheca of the spirotheca in the fourth to the outer volutions of mature specimens is not visible, and the structure and arrangement of the septula are of highly evolved.

*Lepidolina kumaensis* n. sp. is somewhat closely allied to *Lepidolina* (?) *japonica* (HUZIMOTO) which was described and illustrated by HUZIMOTO from the Kwanto massif of Japan and has been referred originally to *Sumatrina*. However, in the spirothecal structure and characters of the septula the HUZIMOTO's species is considered to be much better to refer to *Lepidolina*. These two forms can be distinguished without difficulty in that the former has numerous volutions at maturity, more larger proloculus, highly vaulted shell in early volutions, slow rate of growth and its secondary transverse septula occur earlier in the inner volutions than those of the latter. It resembles *Lepidolina* ? sp. D. reported by TORIYAMA from the so-called *Yabeina*-limestone of the Kitakami massif of Northeast Honshu in general development of the shell, large proloculus and the arrangement of the septula, but it differs from the latter in having considerably smaller heights of volution for corresponding volutions. Because the species from Kitakami is represented by extremely insufficient and deformed materials, the true nature of that form is not understood adequately. Therefore, it is difficult to compare with certainty the present species with *Lepidolina* ? sp. D.

It is also very closely allied to some specimens of *Neoschwagerina douvillei* described by GUBLER (1935) from Cambodge in many respects. At a glance of his good illustrations, GUBLER's *N. douvillei* seemingly includes the forms of various types. For example, so far as the spirothecal structure and the characters of septula are concerned, it is difficult to determine with confidence if the form illustrated as pl. VI, fig. 2 is conspecific, or even congeneric with that of pl. VII, fig. 7. Although it is not advisable to attempt specific correction without a detailed study of the GUBLER's specimens, the specimens shown by pl. VII, fig. 7, 8 and pl. VIII, fig. 10. can easily be distinguished from the original form *Neoschwagerina douvillei* OZAWA in regard to the spirothecal structure, the presence of the secondary transverse septula even in the inner volutions and the characters of all the septula, and the heights of corresponding volutions. These specimens apparently are of more highly evolved than *Neoschwagerina douvillei* OZAWA in generic characters and are referable to *Yabeina* or *Lepidolina.*

The specimens described above as *Lepidolina kumaensis* n. sp. resemble the forms illustrated by GUBLER in his pl. VII, fig. 7 in all the essential characters more closely than any other species hitherto known, and probably both are conspecific with each other.

*Occurrence:* This species is abundant in the same limestones as given above for *Yabeina gubleri* n. sp. with the same association.

### *Lepidolina toriyamai* n. sp.

Plate 6, figs. 1–19

cfr. *Sumatrina annae* VOLZ, KONISHI, 1952, Transact. Paleont. Soc. Japan. New. Ser., No. 5, pp. 159-161, pl. 14, figs. 2-5, 7

*Sumatrina longissima* MÖLLER, KONISHI, 1952, Transact. Paleont. Soc. Japan, new Ser., No. 5, pp. 161-162, pl. 14, fig. 12

*Lepidolina* ? sp. C. TORIYAMA., 1952, Mem., Fac. Sci., Kyūshū Univ., ser. D., vol. III. no. 3, pp. 153-154, pl. VII, figs. 2-5

Shell large, highly elongate, cylindrical, tightly coiled; with a straight to broadly curving axis of coiling, flat to very low and gently concave lateral slopes and pointed to narrowly rounded poles. Mature specimens contain as many as 19 volutions, but it is difficult to obtain the size of full grown shells, because outer several volutions of mature shells of most specimens have been broken off or replaced by secondary dark materials. However, specimens of 16 volutions are 9–11 mm. long, 2.7–3.2 mm. wide, giving from ratios of 3.3–3.8. From ratio of full grown shell probably attains 4.0. In most specimens first volution is spherical in shape, second to third or fifth volution ellipsoidal and beyond fourth or fifth volution shell rapidly increases in length and becomes an elongate fusiform.

Proloculus large, spherical to subspherical, with inside diameter of 195 microns in minimum and 468 microns in maximum, averaging 370 microns for 22 specimens. In most specimens the inside diameter is 330–430 microns. The holotype specimen (pl. 6, fig. 1) has smaller proloculus below the average, but the section seemingly does not cut the center of proloculus. Expansion of shell in width is generally uniform and very slow but volutions considerably increase in length poleward. Average heights of first to fifteenth volution at median portion of 17 specimens 50, 54, 56, 59, 65, 68, 74, 84, 94, 100, 118, 120, 124, 132 and 142 microns, respectively. Chambers increase in height slightly poleward from median portion of shell.

Spirotheca very thin, mostly composed of only a thin single dense layer, the tectum, but in inner one to two volutions sometimes remains faint vestiges of keriotheca. Thickness of spirotheca 5–8 microns in inner 2 volutions and 4–6 microns in third to outer volutions. Septa thin and numerous. Due to the presence of numerous axial septula, it is difficult to determine precisely the septal count. However, average septal counts of first to tenth volution of 5 specimens 6, 9, 11, 13, 15, 16, 17, 18, 19 and 20, respectively. They extend anteriorly only slightly from the normal to spirotheca. One axial septulum first occurs between adjacent septa in first or second volution, 3–5 septula in third to fifth or sixth and commonly as many as 4–9 in outer volutions. However, development of axial spetula rather irregular and the number varies in each chamber. They are unequal in length, and their shape is commonly bar-like thickened dense lamellae and does not assume the appearance of club-shaped or pendant masses in cross-section.

Primary transverse septula thin and numerous, especially very thin at the junction with spirotheca, and they increase in thickness towards the base. Secondary transverse septula first appear in third volution and there is 1 septulum in inner volutions, but beyond nineth volution there are 2 for the most part or sometimes 3 septula. They are thin, generally bar and occasionally pendant club-shaped in cross-section, irregular in length, and not so regular in shape and length as in those of *Sumatrina*.

Foramina small, generally ellipsoidal in cross-section. There are about 16–18 foramina in third volution, 23–27 in fifth, 35–40 in seventh and 55–62 in tenth.

*Remarks:* *Lepidolina toriyamai* n. sp. has a more elongate shell than any of the species previously described by many workers in the group of *Yabeina* and *Lepidolina.* The form ratio of this species attains 3.5–4.0, and the shape of the shell is closely similar to that of *Sumatrina.* However, the characters of the axial and secondary transverse septula and the volution number of this species are quite distinct from those of *Sumatrina;* that is, the shape of the septula of the present species is mostly not pendant club-like shape but is almost lamellae and bar-like in cross-section, The length of the septula of this form is irregular and unequal, being generally longer than that of *Sumatrina;* and the number of the secondary transverse septula is less numerous for corresponding volutions. The mature shell of this species has as many as 17–19 volutions, but that of the species of *Sumatrina* has commonly 8–10 volutions. The spirotheca in the inner one to two volutions of this species sometimes remains faint vestiges of the keriotheca. Thus, from the several points stated above, it is beyond doubt that this species is not a representative of *Sumatrina* and is a descendant of the genus *Yabeina.*

This species is of most advanced form of the genus, and its keriotheca is hardly visible even in the inner volutions. Furthermore, the structure of the septula indicates that this form is of the highest evolved species. This species resembles closely the species reported by K. Konishi (1952) as *S. longissima* Deprat and *S.* cf.

*annae* VOLZ from the Dodo limestone-conglomerate of Okayama prefecture of Japan. Judging from the description and illustrations (pl. 14, figs. 2-5, 7 and 12) by KONISHI, these two species are probably conspecific and also identical with the present species under consideration.

*Lepidolina toriyamai* n. sp. well agrees with *Lepidolina* ? sp. C which was described by TORIYAMA from the Kitakami massif of Japan, in external shape, proloculus size, spirothecal structure and characters of septula. But there is a little difference between them, that is, the number of volutions of the present form is more numerous, and the heights of volutions are larger in the inner volutions and smaller in the outer volutions than those of corresponding volutions of the TORIYAMA's form. However, as far as the number of volutions and the heights of volutions are concerned, the measurements of the materials of Kitakami are far from the perfect because of the poor state of preservation and of the intense deformation. Therefore, it is highly probable that these two forms are conspecific, though more sufficient and better specimens are needed from Kitakami for the final determination.

This species is named in honor of Dr. R. TORIYAMA, who has given me varuable guidance on the study of fusulinids.

*Occurrence*: This species was collected abundantly from the limestone lenses of the second and third horizons of the Kuma formation, especially abundant in Loc. Ku. 499 and Ku. 165. Associated with *Yabeina yasubaensis* TORIYAMA, *Y. columbiana* (DAWSON), *Yabeina gubleri* n. sp., *Lepidolina kumaensis* n. sp.. *Pseudodoliolina pseudolepila gravitesta* n. subsp., *Condonofusiella cuniculata*, n. sp., *Rauserella* sp., *Schwagerina* aff. *acris* THOMPSON and WHEELER and *Schwagerina pseudocrassa* n. sp.

## IV. Stratigraphical Distribution of Fusulinids

In the Kuma formation limestones occur at four horizons from the lowest to the upper part, as indicated already in the columnar sections (Fig. 1). Followings are the summerized lists of fusulinids in ascending order, with a brief explanation on the mode of occurrence.

(1) The lowest limestones are situated at 20 m. above the exposed lower limit of the Kuma formation and are of very small lenses less than 50 cm. in thickness. They contain commonly specimens of the following species: (Loc. Ku. 511, 450, 55, 264)

*Yabeina yasubaensis* TORIYAMA.
*Y.* cf. *columbiana* (DAWSON)
*Codonofusiella cuniculata* KANMERA
*Schwagerina* aff. *acris* THOMPSON and WHEELER
*Schwagerina* sp.

(2) In the horizon about 240 m. above the lowest limestone there are highly fossiliferous limestones less than 2 m. thick. They contain specimens of the species of *Yabeina, Lepidolina* in abundance and those of other fusulinids. The specific names

are as follows: (Loc. Ku. 423, 442, 499, 138, 351, 104, 169)

*Yabeina yasubaensis* TORIYAMA
*Y. columbiana* (DAWSON)
*Y. gubleri* KANMERA
*Lepidolina kumaensis* KANMERA
*L. toriyamai* KANMERA
*Pseudodoliolina pseudolepida gravitesta* KANMERA
*Pseudodoliolina* n. sp. ?
*Verbeekina* ? sp.
*Schwagerina* aff. *acris* THOMPSON and WHEELER
*S. pseudocrassa* KANMERA
*Schwagerina* sp.
*Parafusulina* ? sp.
*Codonofusiella cuniculata* KANMERA
*Rauserella* sp.
*Dunbarula* ? sp.

(3) In the Kawamata-mura area there are limestones about 300 m. above the second horizon but fusulinids are rare in them. However, in the Kakisako-Kurikuma-mura area the limestones, which are regarded to lie at the same horizon as those in the Kawamata-mura area, contain abundantly the fusulinid remains. The species from this horizon are almost the same as those listed at the second horizon, but I have not yet identified *Pseudodoliolina* n. sp. ?, *Verbeekina* ? sp. and *Rauserella* sp. (Loc. Ku. 70, 165, 374, 370, 80)

(4) The heighest collection of the fusulinids is from the small shaly limestone lens (Loc. Ku. 78) in the Kakisako-mura area about 130 m. above the third horizon just mentioned. Because of poor preservation the specific determination is generally difficult. The identified species are *Lepidolina* sp., *Pseudodoliolina* sp. and *Schwagerina* sp.

Summarizing the above diagnostic elements are five species belonging to *Yabeina* and *Lepidolina*. Although no species of *Lepidolina* has been found at the lowest horizon, the two species of the same genus occur in abundance at the second and third horizons. Moreover, it is quite noteworthy that no species of *Neoschwagerina* has been found in the Kuma formation.

## V. Summary of the Paleontological Remarks

From what I remarked in the chapter of paleontological description I will here pick up the most significant points so that I shall be able to discuss clearly the problem of correlation as well as that of evolution.

(1) The species of *Yabeina* in the Kuma formation are of highly developed

forms of the genus. Namely *Yabeina yasubaensis* TORIYAMA, *Y. columbiana* (DAWSON) and *Y. gubleri* KANMERA belong to the subgroup which is more advanced than the type species of the genus, *Y. inouyei* (DEPRAT) [=*Y. globosa* (YABE)]. *Y. yasubaensis*, associating with *Y. shiraiwensis* OZAWA, was reported from the "limestone conglomerate" at Yasuba, Kochi prefecture. *Y. columbiana* is known from the Marble Canyon limestone, British Columbia, where *Y. minuta* THOMPSON and WHEELER, *Yabeina* ? n. sp. are associated with it. *Y. gubleri* KANMERA is one of the most advanced forms of *Yabeina*. It is closely allied to certain specimens in "*Neoschwagerina megasphaerica* DEPRAT" and "*N. multiseptata* DEPRAT" of GUBLER (1935, pl. VI. figs. 3, 7, 8, 11, pl. VII, fig. 3, only) from Cambodge. The above three species of *Yabeina* are more apdvanced in structure than *Y. katoi* OZAWA, *Y. kaizensis* HUZIMOTO and *Y. hayasakai* OZAWA. The latter three species are the elements of the zone of *Yabeina globosa* [=*Y. inouyei* (DEPRAT)] in Japan.

(2) *Lepidolina kumaensis* KANMERA is transitional between *Yabeina* and *Lepidolina*. It resembles closely certain specimens in "*Neoschwagerina douvillei* OZAWA" of GUBLER (1935, pl. VII. figs. 7, 8 ?) from Cambodge.

(3) *Lepidolina toriyamai* KANMERA is a derivative from *Yabeina* and one of the most specialized representatives of the fusulinids. It resembles "*Sumatrina longissima* DEPRAT" and "*S.* cfr. *annae* VOLZ" of K. KONISHI (1951) from a limestone conglomerate at Dodo, Okayama perfecture. The latter two are conspecific and should be assigned to *L. toriyamai* KANMERA.

(4) *Pseudodoliolina pseudolepida gravitesta* KANMERA seems to be the most advanced form of *Pseudodoliolina*. This subspecies includes, besides the type specimens from the Kuma formation, the specimens of Cambodge which were described by GUBLER under the name of "*P. lepida*."

(5) *Schwagerina pseudocrassa* KANMERA includes, besides the type specimens from the Kuma formation, the specimens of Cambodge which were described by GUBLER (1935) under the name of "*Pseudofusulina crassa* (DEPRAT)."

(6) *Schwagerina acris* THOMPSON and WHEELER is a typical form of the genus and belongs to the late Permian group. The specimen from the Kuma formation resembles the type specimen of *S. acris* from the Marble Canyon limestone in many respects, but it seems to be somewhat smaller than the latter.

(7) *Codonofusiella cuniculata* KANMERA seems to be more advanced than *C. paradoxica* in having larger shell and in forming cuniculi.

## VI. Correlation

As has been summarized in the preceding articles, the fusulinids of the Kuma formation constitute a rich fauna which is characterized by certain types of the *Neoschwagerininae* and *Verbeekininae*. The species and genera of the two subfamilies are generally regarded as the most reliable fossils for correlation and zoning of the main part of the Permian in the Japanese province and other related regions. Indeed our knowledge of stratigraphy and palaeontology is still insufficient in many areas for correlating precisely various formations with one another, but it seems possible to check the available data with the newly confirmed knowledge on the fusulinid fauna of the Kuma formation. In this article I will discuss the subject.

(1) *The Mizukoshi formation in central Kyushu:* T. MATSUMOTO and H. HUZIMOTO (1939) reported the Permian Mizukoshi formation in Kumamoto prefecture.

According to them it is a thick series (about 1000 m.) of slaty shale with intercalating members of conglomerate and sandstone, and contains small lenses of limestone. The conglomerate contains in abundance rounded pebbles, cobbles and boulders of granitic rocks and altered green andesites or porphyrites.

HUZIMOTO studied the fusulinids from the limestones and identified the following species: *Schwagerina bicornis* (CHEN), *Schwagerina* sp., *Pseudodoliolina ozawai* YABE and HANZAWA, *Neoschwagerina douvillei* OZAWA, *N. megasphaerica* DEPART, *N. margaritae* DEPART and *Yabeina* sp. The formation was referred to the Lower to the Middle Permian (Artinskian-Saxonian) in age.

Owing to kindness of the authors I have an opportunity of examining the specimens (now preserved in Kyushu University), with the result that HUZIMOTO's generic and specific determination are mostly disharmony with mine. Although the preservation of the specimens is not so good as to deserve of precise specific identification, all the forms which were referred to *Neoshwagerina* by HUZIMOTO doubtlessly belong to the advanced types of *Yabeina* (the group of *Y. shiraiwensis* OZAWA and *Y. gubleri* KANMERA) and some *Lepidolina*-like forms.* Moreover, the species referred to *Pseudodoliolina ozawai* has a larger shell and thicker spirotheca than the original form, being almost certainty of a group of *P. pseudolepida.* In conclusion, it is obvious that the fusulinid fauna of the Mizukoshi formation is characterized by the advanced forms of *Yabeina,* which are closely related to those of the Kuma formation, and does not contain the representatives of *Neoschwagerina* at all. Moreover, it is noteworthy that the formation is quite similar in lithological constituent to the Kuma formation.

(2) *The Shiraiwa formation in western Chugoku:* As one of strata that can be correlated to the Kuma formation there is the Tsunemori group (M. KATAYAMA, 1939), which is distributed in the western side of the Akiyoshi limestone plateau of Yamaguchi prefecture. It consists mainly of slaty shale and fine-grained sandstone, and contains lenticular limestones and conglomerates with cobbles and pebbles of granite and various other igneous rocks. The rock facies of this formation is quite similar to that of the Kuma formation. OZAWA described and illustrated one

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**Lepidolina ?* sp. B. TORIYAMA and *L. ?* sp. D. TORIYAMA (ref. R. TORIYAMA, Permian fusulinids from the Kitakami mountainland, Northeast Japan. Fac. Sci., Kyūshū Univ., Mem., Ser. D, Vol. III, No. 3, pp. 152-155, pl. VI, fig. 5, pl. VIII, figs. 1, 6)

species, *Yabeina shiraiwensis*,* from the limestone of the Tsunemori group at Shiraiwa. This species is a highly advanced form of *Yabeina* with its spirotheca of outer volutions composed of a single layer. In other places, as will be mentioned below, it is associated with *Y. gubleri* and *Lepidolina kumaensis*. Recently, R. TORIYAMA (1948) clarified that the conglomerate and limestone occur in the upper part of the Tsunemori group, and he proposed the name Shiraiwa formation for that part. The close similarity of the rock facies and fusulinid contents of the Shiraiwa formation to those of the Kuma formation suggests that these two formations are of the
same age.

In the northern part of Yamaguchi prefecture there is a formation consisting of slate, sandstone and remarkable conglomerate. We should examine its fusulinid fossils in detail, for "*Yabeina*" and "*Sumatrina*" were reported from it and its rock facies is similar to the Shiraiwa formation.

(3) *The so-called Yasuba type limestone conglomerate in Shikoku:* The fusulinids of "limestone-conglomerate" which is accustomed to be called the Yasuba type in Shikoku and Kwanto massifs were described by R. TORIYAMA (1942–1945). However, no details of the distribution, stratigraphy and rock facies have been published.

Through TORIYAMA's study two kinds of fusulinid faunules were distinguished, one containing pre-Permian and early (?) Permian fusulinids and the other containing late-Permian ones. The former was considered by him possibly Uralian or lowest Permian age and the formation which contains it was named Sakuradani conglomerate by T. KOBAYASHI (1951). Among the conglomerates which furnished the latter, those at three localities (Yasuba, Entrance of Wakamiya-onsen, and between Higashikawa and Wakamiya-onsen, all in Shinkai-mura, Nagaoka-gun) in Kochi prefecture contain *Yabeina* and other fusulinids in the matrix of the limestone conglomerate. TORIYAMA described and illustrated the following forms: *Yabeina shiraiwensis* OZAWA, *Y. yasubaensis* TORIYAMA, *Schwagerina* sp. A, *Schwagerina* sp. B, *Triticites truncatus* CHEN, *Triticites* sp. A, *Triticites* sp. B and *Fusulina shinkaiensis* TORIYAMA.

Dr. TORIYAMA kindly offered his materal at my disposal and I found that three species assigned to *Triticites* by him should be referred to the genus *Schwagerina*, and one of them, *T. trancatus*, is quite similar to *S.* aff. *acris* THOMPSON and WHEELER from the Kuma formation. Also, the species described as *Fusulina shinkaiensis* TORIYAMA is not referable to that genus but obviously belongs to *Pseudodoliolina*, probably to *P. pseudolepida gravitesta*, although the specimens are incomplete. Furthermore, besides the species reported by TORIYAMA, *Lepidolina kumaensis* KANMERA, *Y. gubleri* KANMERA, *Dunbarula* ? sp., and *Codonofusiella* sp. are identified in the same sections.** All these specimens are found in matrix of the conglomeratic limestones and ~~does~~ are not ~~be~~ contained in the breccia-like small limestone pieces. No remains

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* Ozawa stated in his postscript (1925, p. 86) that *Yabeina shiraiwensis* is identical with *Neoschwagerina multiseptata* DEPRAT em. COLANI. However, the type specimen of the latter species of DEPRAT (1914) is of much more highly advanced form than the latter in spirothecal structure and in development of septula.

** Fortunately, Dr. TORIYAMA now agrees with my opinion.

of *Neoschwagerina* have been found. All these facts indicate the close affinity of the two faunas under consideration and demonstrate that the Yasuba limestone "conglomerate" in Kochi prefecture are equivalent in age to the Kuma formation.

(4) *The limestone conglomerate at Dodo, Central Chugoku:* In 1952, K. KONISHI described and illustrated several species of *Sumatrina* and *Yabeina* from the so-called Yasuba type "limestone-conglomerate" at Dodo, Okayama prefecture.

According to him the limestone conglomerate occurs in wedge-form or as lens with 20 m. or less in thickness, and contains pebbles of various igneous rocks, slate, chert and "limestone." The matrix is argillaceous to arenaceous. In the conglomerate fusulinids occur not only in the matrix but also in the "limestone pebbles." They are composed of the following species: *Staffella* or *Nankinella* (?) sp., *Schwagerina pseudochihsiaensis* (CHEN), *Schwagerina* sp. indet., *Neoschwagerina craticulifera* (SCHWAGER), *N. minoensis* DEPRAT em. OZAWA, Cfr. *Sumatrina annae* VOLZ, *S. longissima* DEPRAT and *Yabeina* sp.

Fortunately, through the kindness of Mr. K. KONISHI, I had an opportunity to study his original material. From what I have discussed in the paleontological description of this paper (pp. 25, 26), "Cfr. *Sumatrina annae* VOLZ" (K. KONISHI, 1952, p. 159, pl. 14, figs. 2-5, 7) and "*Sumatrina longissima* DEPRAT" (p., 169, pl. 14, fig. 12) should be referred to *Lepidolina* ~~*kumaensis*~~ toriyamai KANMERA. Moreover, *Yabeina* sp. (p. 162, pl. 14, fig. 1) from Dodo is a highly advanced form of *Yabeina*. In KONISHI's collection there are a few specimens which were referred to *Neoschwagerina*, but they are too small to be precisely identified. In short, the fusulinid faunule of Dodo is characterized by *Lepidolina* and the highly advanced form of *Yabeina*, and contains the species common to or closely allied to those of the Kuma formation. Accordingly, these two formations are almost probably of the same age.

(5) *The Maizuru and Nukada formations near Kyoto:* The Upper Permian rocks were reported by K. NAKAZAWA and S. OKADA (1950–1951) in the northern part of Kyoto prefecture. They are called the Maizuru and Nukada formations respectively.

They are composed mainly of slaty shale and sandstone, containing lenticular beds of conglomerate and small lenses of sandy or conglomeratic impure limestone. NAKAZAWA reported the occurrence of numerous specimens of "*Yabeina megasphaerica* KANMERA" (= *Y. gubleri* KANMERA in this paper) and a moderate number of specimens of *Pseudodoliolina* cfr. *lepida* (SCHWAGER), *Neoschwagerina* sp. and *Schwagerina* sp. from the N~~a~~ukada formation.

Through the courtesy of Mr. K. NAKAZAWA of Kyoto University, I have been able to study thin sections of the fusulinids from the Nukada and Maizuru formations. They include abundantly specimens of *Yabeina yasubaensis* and *Y.* cf. *columbiana*, commonly those of *Yabeina* sp., *Lepidolina kumaensis*, *L.* cf. *toriyamai*, *Pseudodoliolina* cf. *pseudolepida gravitesta*, and *Schwagerina* cfr. *acris*, and rarely those of *Schwagerina* cf. *pseudocrassa*, *Codonofusiella* sp. and *Rauserella* ? sp., but no remain of *Neoschwagerina*. From these facts I have arrived at the conclusion that the fusulinid faunas of the two formations entirely agree with that of the Kuma formation. Therefore, the Nukada and Maizuru formations are without doubt correlated in age to the Kuma formation. Rocks which have similar lithology to that of the Nukada and Maizuru formations are distributed in separated areas of Hyogo, Okayama and Hiroshima prefectures, forming a belt of southwest trend. (See text-fig. 2). The limestone of Dodo area mentioned above is situated just in a fraction of this belt.

(6) *The Upper Permian of the Kitakami massif:* Permian sections in the Kitakami massif, northeastern Japan have hitherto been studied by a mumber of geologists.

In 1944, revising previous works, M. MINATO divided the Permian into three series, Sakamotozawa, Kanokura, and Toyoma in ascending order. The upper part of the Kanokura series is subdivided into two parts, the Iwaizaki stage (mainly limestone) in the lower and the Kohama stage (mainly shale with limestone) in the upper. From the Kohama stage MINATO listed *Yabeina shiraiwensis* OZAWA, *Verbeekina verbeeki* (GEINITZ) and *Parafusulina* sp. and from the Iwaizaki stage *Y. shiraiwensis*, *Y. hayasakai* OZAWA., *Yabeina* sp., *Verbeekina verbeeki*, *Neoschwagerina* sp., *Parafusulina* cfr. *japonica* (GUMBEL), *P. kraffti* (SCHELLWIEN) and *Parafusulina* sp.

Quite recently, R. TORIYAMA (1952) described and illustrated the following fusulinids from the so-called *Yabeina*-limestone of the Iwaizaki stage: *Millerella* ? sp., *Staffella yobarensis* OZAWA, *Schwagerina douvillei* (COLANI), *Schwagerina* ? sp. C, *Parafusulina* cf. *wanneri* (SCHUBERT), *Parafusulina* sp., *Pseudodoliolina* ? sp., *Lepidolina* ? sp. A, *L.* ? sp. B, *L.* ? sp. C and *L.* ? sp. D.

Although this assemblage of the fusulinids offers many questions before us, as TORIYAMA stated, the most characteristic elements are highly developed forms of *Yabeina* and undetermined species of *Lepidolina?*

The specimen from Kitakami are so ill-preserved and strongly deformed that the correct specific identification is rather difficult. However, *Lepidiolina* ? sp. C seems to be somewhat similar to *Lepidolina kumaensis*. The other species designated with question as *Lepidolina* are of without doubt highly evolved forms of the subfamily *Neoschwagerininae*.

While, in the Toyoma series no fusulinids have been reported and other fossils seem to be very scarce. According to MINATO, the upper part, the Tsuzuki stage, of the Toyoma series is mainly composed of clay slate and the lower half, the Okachi stage, is mostly composed of remarkable comglomerate containing boulders, cobbles and pebbles of granitic and various other igneous rocks. The conglomerate is called Usuginu conglomerate, about 500 meters in the thickest part. Although the main part of the Usuginu conglomerate is developed between the Tsuzuki stage above and the Kohama stage below, the lower part of the conglomerate is interbedded with the slate and limestone of the Kohama stage and *Yabeina*-limestone of the Iwaizaki stage.

Thus, from what described in literatures the Usuginu conglomerate seems to be a conglomerate facies of the lower part of the Toyoma series and the upper part of the Kanökura series, marginally interfingering with them. The conglomerate of the Kuma formation fairly resembles the Usuginu conglomerate not only in general rock facies but also in the constituents of the pebbles. No species of fusulinid which is clearly identical with species from the Kuma formation from the upper part of the Permian sections of the Kitakami massif. However, from the similarity in fossil contents and lithology, the Toyama series and the upper part of the Kanokura series seems to correspond to the Kuma formation in age.* However, there are still much to be done in the Permian sections of the Kitakami massif, where, unfortunately, I have had no opportunity to do field-works.

(7) *Other doubtful records in Japan:* Besides the formations mentioned above, the similar conglomerate-bearing strata are found in the northern part of the Abukuma massif, the Itsukaichi area in the Kwanto massif, Yuasa area in Wakayama prefecture, Kii massif, and the Naka-gawa valley, Tokushima prefecture, Shikoku. As their occurrences as well as stratigraphy have not yet been reported in detail, it should be examined more precisely in comparison with the Kuma formation.

In Japan, "*Lepidolina multiseptata* (Deprat)" was reported from Akasaka limestone in Gifu prefecture, Koyama limestone in Okayama prefecture and Taishaku limestone in Hiroshima prefecture. DEPRAT's report (1914) on the occurrence of that species from Akasaka was doubted by Y. OZAWA (1927) who studied in detail the fusulinid fauna. He stated "J. DEPRAT recorded *Neoschwagerina* (*Sumatrina*) *multiseptata* and *Neoschwagerina globosa* (=*Neoschwagerina douvillei* OZAWA) from the uppermost part of the Akasaka limestone, but their occurrence in the limestone seems to me to be very doubtful." Since the OZAWA's date, no one has reported the occurrence of that species from Akasaka.

HUZIMOTO (1939) reported "*Yabeina*" *multiseptata* (DEPRAT) from three localities of the Taishaku limestone but he did not describe the species. At one locality it was reported to occur from the limestone conglomerate together with the Carboniferous and Permian fusulinids. At the other two localities it is said to associate with *Staffella* sp., *Schwagerina* spp., *Sumatrina* cf. *annae* Volz, *Sumatrina* sp, and *Yabeina* sp. Lately, H. HUZIMOTO and K. HARA (1951) restudied the fusulinids of the Taishaku limestone, and reported that the upper part of the limestone is character~~acter~~ized by *Yabeina*, *Neoschwagerina* and *Sumatrina*. But they did not mention~~ed~~ on *Lepidolina multiseptata* (DEPRAT).

From the Koyama limestone that species was listed by R. CHO (in KOBAYASHI, 1950) together with *Yabeina*, *Sumatrina*, *Neoschwagerina* cf. *douvillei* OZAWA.

Thus all these occurrences of *Lepidolina multiseptata* (DEPRAT) are necessary to restudy in detail in the field, so that I will not touch them here for purpose of correlation.

(8) *Formations in the foreign countries:* Outside of the Japanese Islands there are several fusulinid faunas which are allied to the *Yabeina-Lepidolina* fauna of the Kuma formation. Those reported from the Upper Permian rocks of British Columbia, in North America and Cambodge and Yunnan in East Asia are the excellent examples.

THOMPSON and WHEELER (1942, 1950) described and illustrated nine species of fusulinids from the Marble Canyon limestone in Marble Canyon, near Lillooet, British Columbia and regarded the limestone to be Upper Permian in age. The fauna of the Marble Canyon limestone contains the following species, some of which are closely allied to those of the Kuma formation:

*Yabeina columbiana* (Dawson), *Y. minuta* THOMPSON and WHEELER, *Yabeina* ? n. sp., *Schwagerina pavillionensis* THOMPSON and WHEELER, *S. acris* THOMPSON and WHEELER, *S.* roy-*andersoni* ? THOMPSON and WHEELER, *Codonofusiella duffelli* THOMPSON and WHEELER, *Nankinella* ? sp. and *Staffella* ? sp.

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* In this connection it should be noted that no characteristic elements of the *Yabeina globosa* zone and *Neoschwagerina-Verbeekina* zone have been reported from the Iwaizaki limestone of the Kitakami massif.

As pointed out by THOMPSON, *Y. columbiana* is a more advanced form than *Y. inouyei* DEPRAT [=*Y. globosa* (Yabe)], the type species of *Yabeina*. *Y. columbiana* from the Kuma formation agrees with THOMPSON and WHEELER's form in many important characters and is probably referable to that species. *Y. minuta* THOMPSON and WHEELER is also a highly advanced type of *Yabeina*. That species and *Y. gubleri* KANMERA are almost the same in the degree of evolution of shell-structure. From the illustrated characters, *Yabeina* ? n. sp. of THOMPSON and WHEELER seems to be one of the most highly advanced forms of *Neoschwagerininae*, belonging probably to *Lepidolina*. As was already mentioned, *Schwagerina* aff. *acris* THOMPSON and WHEELER from the Kuma formation is closely allied to the original form, although my specimens are rather poor in preserved.

Thus, certain species of fusulinids from the Marble Canyon limestone are closely related to the species of the Kuma formation. The fact strongly suggests that the Marble Canyon limestone of the Cache Creek series is probably equivalent in age to the Kuma formation and that the two formations belong to the same faunal province.

GUBLER (1935) described at length the fusulinids from Battambang and its vicinity, Cambodge, Indochina. That fauna contains the elements closely related and common to those of the Kuma formation. He described several species of *Neoschwagerina* in his report. However, as pointed out by THOMPSON (1948), it is obvious that many of GUBLER's generic and specific references are not correct from the view point of modern classification and some of them must be separated to different species or even to different genera.

The specimens which were described by GUBLER under the name of "*Neoschwagerina douvillei* OZAWA" are apparently more highly evolved than the original form and is separable into at least two species. One [GUBLER, 1935, pl. VII, fig. 7 and 8 (?)] belongs centainly to *Lepidolina* and the other (Ibid., pl. VI, fig. 2 and pl. VIII, fig. 10) is referable to *Yabeina*. As was already discussed, the former is most probably assigned to *Lepidolina kumaensis* KANMERA. *Neoschwagerina megasphaerica* from Cambodge is undoubtedly referable to *Yabeina*, from the good illustration of GUBLER, and allied to *Y. gubleri* KANMERA in many respects. *N. megasphaerica* var. *giganitea* GUBLER, *N. elongata* GUBLER and most of the specimens of "*N. multiseptata* DEPRAT" are also of highly advanced group of *Yabeina*.

Some of the specimens of "*Pseudodoliolina lepida* (SCHWAGER)" in GUBLER (1935, pl. IV, figs. 5, 7 and pl. V, figs. 14, 15) should be transferred to *P. pseudolepida* (DEPRAT). Furthermore, "*Pseudofusulina crassa* DEPRAT" of GUBLER is hardly identified with the original form of DEPRAT, as was discussed in the description of *Schwagerina pseudocrassa* KANMERA. Moreover, *Dunbarula* ? sp. from Kuma is quite similar to the specimen of "*Schubertella* sp." from Cambodge.

In conclusion, the resemblance between the fusulinids from the Kuma formation and those from the Permian section of Cambodge demonstrates that the two formations under discussion are of the same age and that the faunal provinces are intimately related.

## VII. Conclusive Remarks

The zone of *Yabeina globosa* has hitherto been regarded as the youngest fusulinid zone in Japan. However, it is composed of rather primitive species of *Yabeina*, such as *Y. katoi* OZAWA, *Y. kaizensis* HUZIMOTO and *Y. hayasakai* OZAWA, and contains almost always certain species of *Neoschwagerina*, such as *N. minoensis* DEPRAT em. OZAWA, *N. douvillei* OZAWA and *N. margaritae* DEPRAT. While, as clarified in this paper, the fauna of the Kuma formation and the many formations correlated to the Kuma formation are characterized by *Lepidolina* and the advanced forms of *Yabeina* such as *Y. gubleri* KANMERA, *Y. shiraiwensis* OZAWA, *Y. yasubaensis* TORIYAMA and *Y. columbiana* (DAWSON). Moreover, associated with *Lepidolina* and *Yabeina* are larger form of *Pseudodoliolina* and specialized and aberrant forms including *Rauserella*, *Dunbarula* and *Codonofusiella*. Furthermore, neither species common to the *Yabeina globosa* zone nor distinct remains of *Neoschwagerina*, except for a doubtful occurrence from Dodo of Okayama, have been found from those formations. Thus in the fusulinids of the late Permian of Japan two entirely different faunas are clearly distinguished. One is composed of rather primitive species of *Yabeina*, together with certain representatives of *Neoschwagerina* and the other is composed of *Lepidolina* and advanced type of *Yabeina*, without any *Neoschwagerina*. Biologically the elements of the latter are more advanced than those of the former.

So far as our present knowledge is concerned, *Lepidolina* and the advanced forms of *Yabeina* have a very limited stratigraphic range in Japan, except the doubtful occurrence of the so-called *Lepidolina multiseptata* (DEPRAT) from a few localities mentioned above. The formations which contain them in abundance are always of the conglomerate-bearing peculiar facies which is characterized by black shale with a characteristic conglomerate and occupy the higher position in the Permian section. Strictly speaking, however, Japanese Permian rocks are structurally very complicated. Due to intense distortion, faulting, folding and igneous intrusions it is often difficult to determine their exact stratigraphic order. As a result, the actual stratigraphic distribution of the fusulinids in the field is often incompletely known. The stratigraphic relationship between the conglomerate-bearing formations with the fossil-assemblage of *Lepidolina* and advanced forms of *Yabeina* and the formations with that of the *Yabeina globosa* zone has nowhere been determined from purely stratigraphic field works. For example, in the Kuma massif the *Yabeina globosa* zone is exposed in a area somewhat separated from the area of the Kuma


Fig. 2. The map showing the distribution of the late Permian strata in the Japanese Islands.
× Upper Permian formations of the *Lepidolina* zone
• Upper Middle Permian formations of the *Yabeina globosa* zone

formation, and, accordingly, the stratigraphic relation is hardly determined in the field. Unfortunately, even in the Kitakami massif, the so-called standard area of the Japanese Palaeozoic, the relation is still ambiguous. However, in the Kitakami massif the Usuginu conglomerate, which is cerrelated to the Kuma formation, occurs in the lower part of the Toyoma series, which, in turn, lies disconformably under the Skytic Inai group and is without doubt the uppermost series of the Permian in the Japanese Islands.

As mentioned in the foregoing articles, the conglomerate-bearing peculiar Permian formations correlated to the Kuma formation are widely distributed in a number of separated areas in the Japanese Islands (see fig. 2). Throughout most of this wide geographic distribution this part of the stratigraphic section contains a characteristic fusulinid assemblage represented by the species of the genus *Lepidolina* and the advanced types of the genus *Yabeina*. On the basis of the available stratigraphic evidences and of the palaeontologic evidences, especially of the relative degree of evolutionary development, I am led to the conclusion that the fauna containing *Lepidolina* and advanced forms of *Yabeina* is stratigraphically younger than that of the *Yabeina globosa* zone and that the part of the section with the formers should be designated as the zone of *Lepidolina* (or the upper zone of *Yabeina*).

The faunas quite similar to that of the zone of *Lepidolina* are also found in the Marble Canyon limestone of British Columbia and the Upper Permian rocks of Cambodge. These rocks are possibly referable to the same faunal zone.

In Japan, the formations which are referred to the zone of *Lepidolina* show a similarity to one another in lithologic composition and rocks facies. They are composed mainly of slates of remarkable black colour, conglomerate of peculiar character and some sandstone, with subordinately contained small lenses of arenaceous or conglomeratic impure limestone, but do not include pyroclastic rocks and siliceous rocks usually called chert. While, the rocks of the zone of *Yabeina globosa* consist mostly of slate, chert and fine-grained sandstone, and frequently contains pyroclastric rocks which are accustomed to be called schalstein, but do not include conglomerate. In certain area this zone occupies a thick limestone, which has deposited uninterruptedly on the limestone of the zone of *Neoschwagerina-Verbeekina.* Thus a remarkable differences in lithology are recognized everywhere between the two zones under consideration.

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K. KANMERA

Fusulinids from the Upper Permian Kuma Formation, Southern Kyushu, Japan—With Special Reference to the Fusulinid Zone in the Upper Permian of Japan

# Explanation of Plates

## Explanation of Plate 1

All figures are ×10.

Figures 1–5. *Parafusulina* ? sp. ……………………………………………………………Page 11

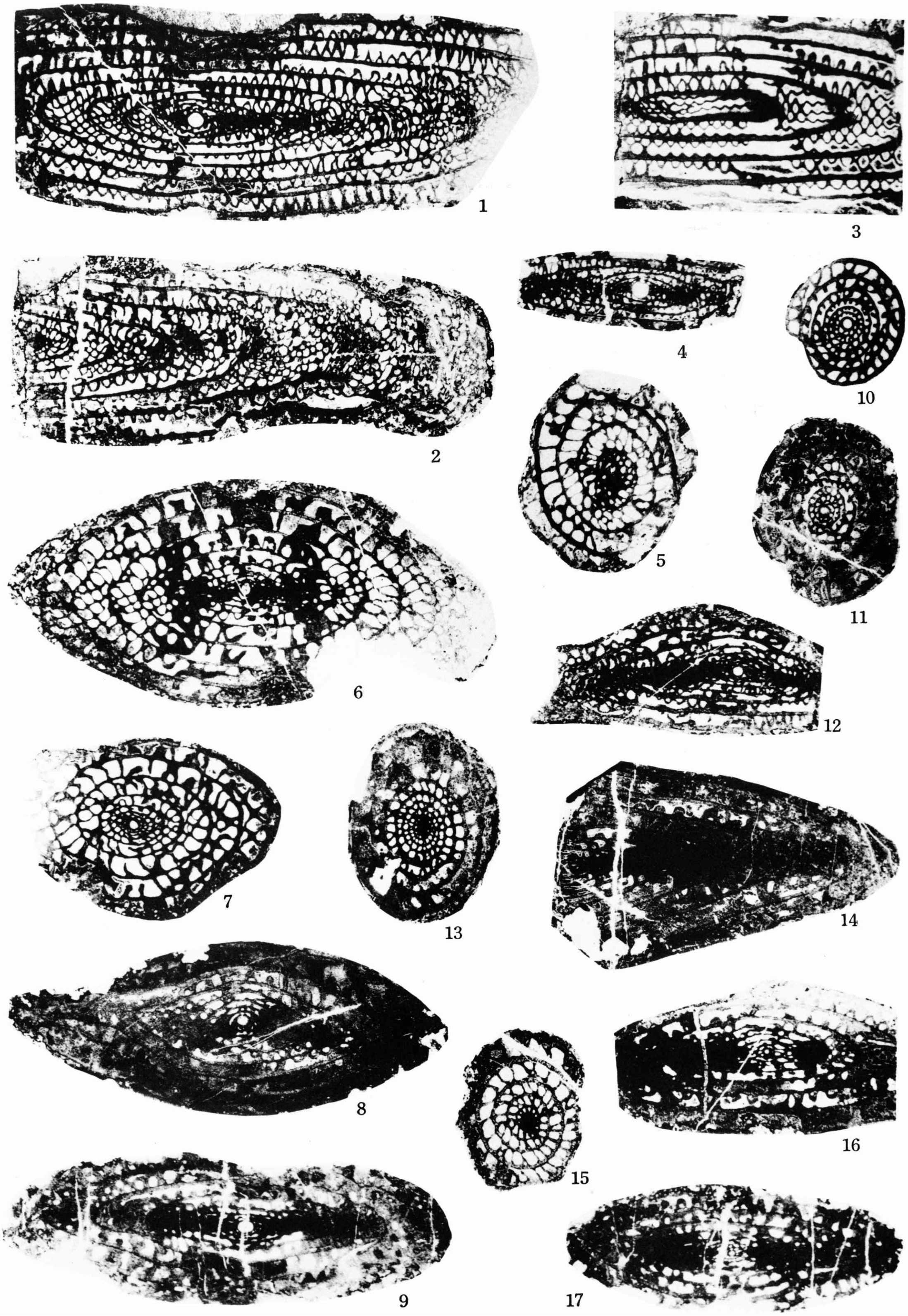
1, slightly oblique axial section; 2, axial section; 3, tangential section; 4, axial section of immature specimen; 5, parallel section; 1, 2, 4 and 5 are from Loc. Ku. 499; 3 is from Loc. Ku. 474.

Figs. 6, 7. *Schwagerina pseudocrassa* n. sp. ……………………………………………Page 9

6, slightly oblique axial section of the holotype; 7, centered oblique section of a paratype; All are from Loc. Ku. 499.

Figs. 8–17. *Schwagerina* aff. *acris* THOMPSON and WHEELER, 1942 ………………Page 8

8, 9, slightly oblique axial sections; 10, 11, sagittal sections; 12, axial section referred with question to this form; 13, near centered sagittal section; 14, near centered axial section; 15, parallel section; 16, 17, near centered oblique axial sections; 8, 9, 11–17 are from Loc. Ku. 442 and 10 is from Loc. Ku. 499.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## Explanation of Plate 2

All figures are ×10.

Figs. 1–6. *Pseudodoliolina pseudolepida gravitesta* n. subsp. ........................ Page 12

1, 2, axial sections; 3, 4 & 6, sagittal sections; 5, centered oblique section; All are from Loc. Ku. 499.

Figs. 7, 8. *Pseudodoliolina* n. sp. ? ........................................................ Page 14

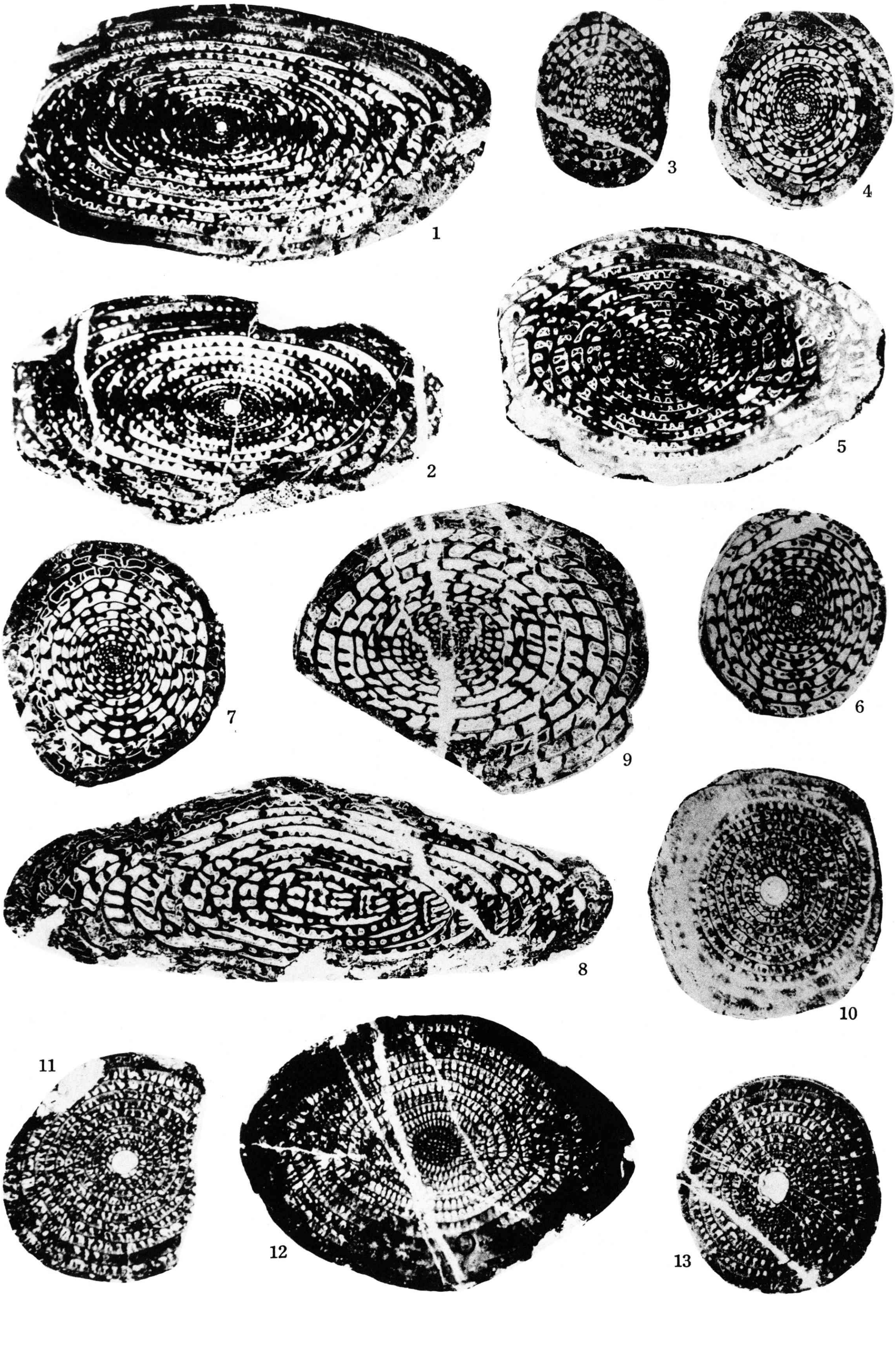
7, near centered sagittal section; 8, tangential section; Both are from Loc. Ku. 499.

Fig. 9. *Verbeekina* ? n. sp. ................................................................................ Page 15

Centered oblique section, Loc. Ku. 499.

Figs. 10–13. *Yabeina yasubaensis* TORIYAMA, 1942 ........................................ Page 18

10, 11, slightly oblique sagittal sections; 12, tangential section; 13, sagittal section; All are from Loc. Ku. 442.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## Explanation of Plate 3

Figs. 1-5, 6 (?), 7. *Yabeina columbiana* (DAWSON), 1879 ............................... Page 16

All figures ×10; 1, 3, axial sections; 2, near centered axial section; 5, 7, sagittal sections; 6, sagittal section referred with question to this species; 1-4, 6, 7 are from Loc. Ku. 442 and 5 is from Loc. Ku. 499.

Figs. 8 (?), 9-11, 20. *Dunbarula* ? sp. ............................................... Page 7

All figures ×10; 8, parallel section referred with question to this species; 9, 20, tangential sections; 10, near centered sagittal section; 11, axial section; 19, oblique section; 8, 9, 11 & 19 are from Loc. Ku. 499 and 9, 20 are from Loc. Ku. 442.

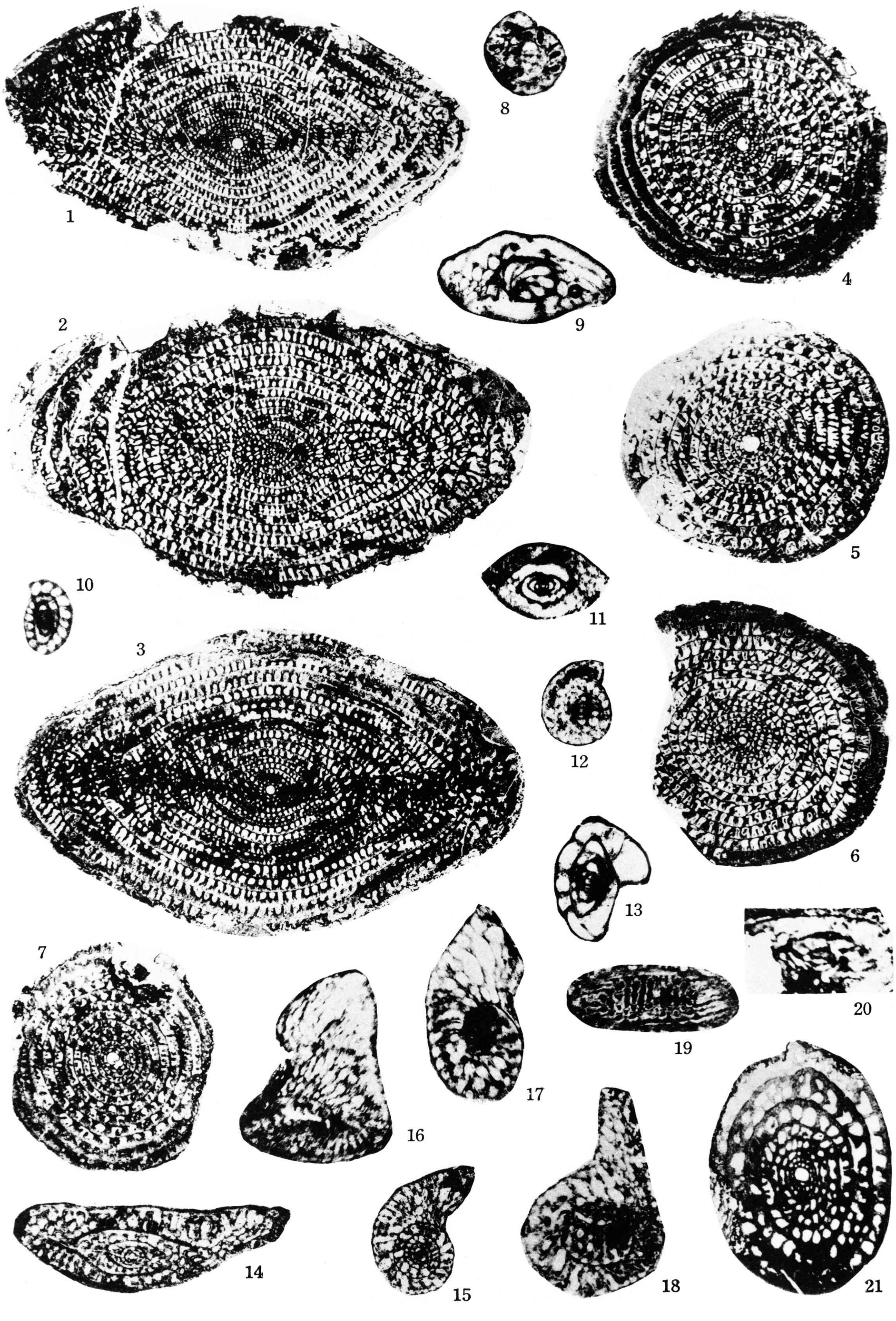
Figs. 12, 14-19. *Codonofusiella cuniculata* n. sp. ........................................ Page 6

12, sagittal section; 14, axial section; 15, near centered sagittal section; 16-18, parallel sections; 19, tangential section, showing the development of cuniculi; 12-15, 19 are ×22, 16-18 are ×30; 12 is from Loc. Ku. 442 and 14-19 are from Loc. Ku. 499.

Fig. 21. Oblique sagittal section referred with question to *Schwagerina acris* THOMPSON and WHEELER; ×10; Loc. Ku. 499.

Fig. 13. *Rauserella* sp. ............................................................................ Page 4

Tangential section of immature specimen; ×22, Loc. Ku. 499.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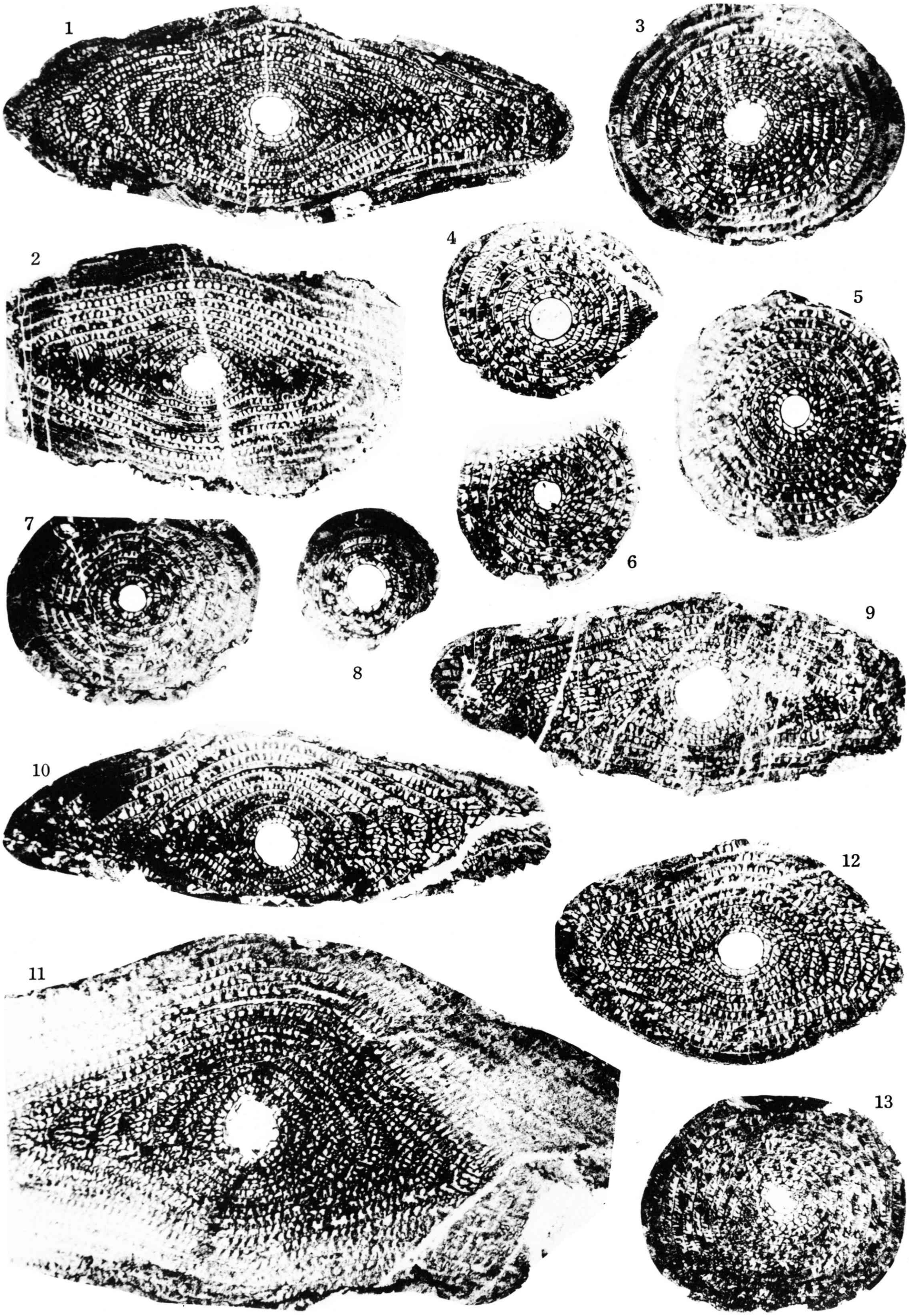
## Explanation of Plate 4

All figures are ×10.

Figs. 1–10, 11 (?), 12, 13. *Yabeina gubleri*, n. sp. ......................................... Page 19

1, axial section of the holotype; 2, axial section of a paratype; 3, slightly oblique axial section of a paratype; 4–8, sagittal sections of paratypes; 9, 10, slightly oblique axial sections of paratypes; 11, oblique axial section referred with question to this species; 12, oblique section of a paratype; 13, sagittal section of a paratype; 1, 2, 4–6, 8, 10, 12 and 13 are from Loc. Ku. 499, 3, 9 are from Loc. Ku. 442 and 11 is from Loc. Ku. 70.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## Explanation of Plate 5

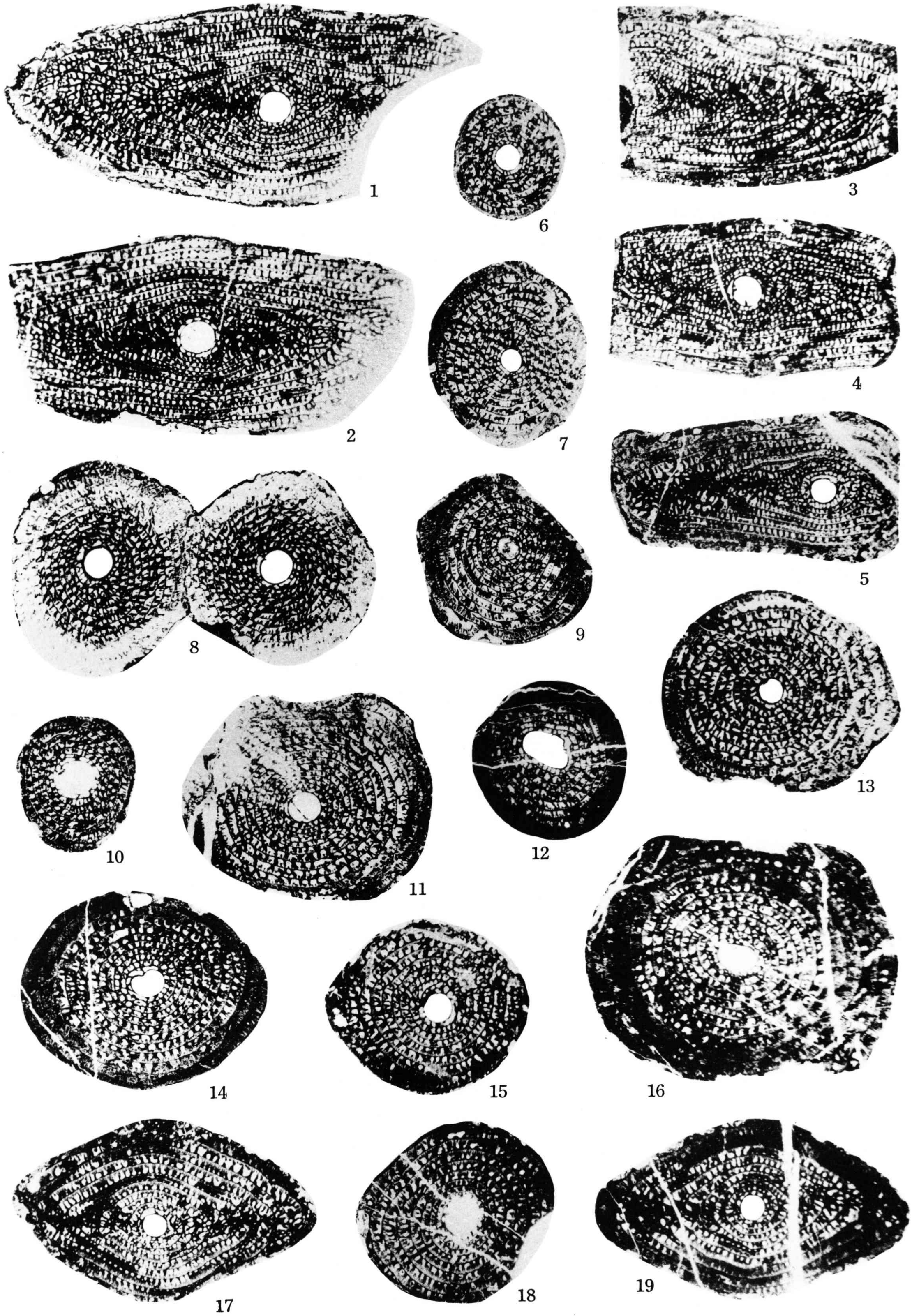
All figures are ×10.

Figs. 1–13. *Lepidolina kumaensis*, n. sp. ........................................................Page 22

1, axial section of the holotype; 2, slightly oblique axial section of a paratype; 3–5, axial sections of paratypes; 6, sagittal section of a paratype; 7, slightly oblique sagittal section of a paratype; 8–10, 12, sagittal sections of paratypes; 11 13, slightly oblique sagittal sections of paratypes; 1–7, 9–13 are from Loc. Ku. 499 and 8 is from Loc. Ku. 104.

Figs. 14–19. *Yabeina yasubaensis* Toriyama, 1942..........................................Page 18

14–16, 18, slightly oblique sagittal sections; 17, 19, axial sections; All are Loc. Ku. 442.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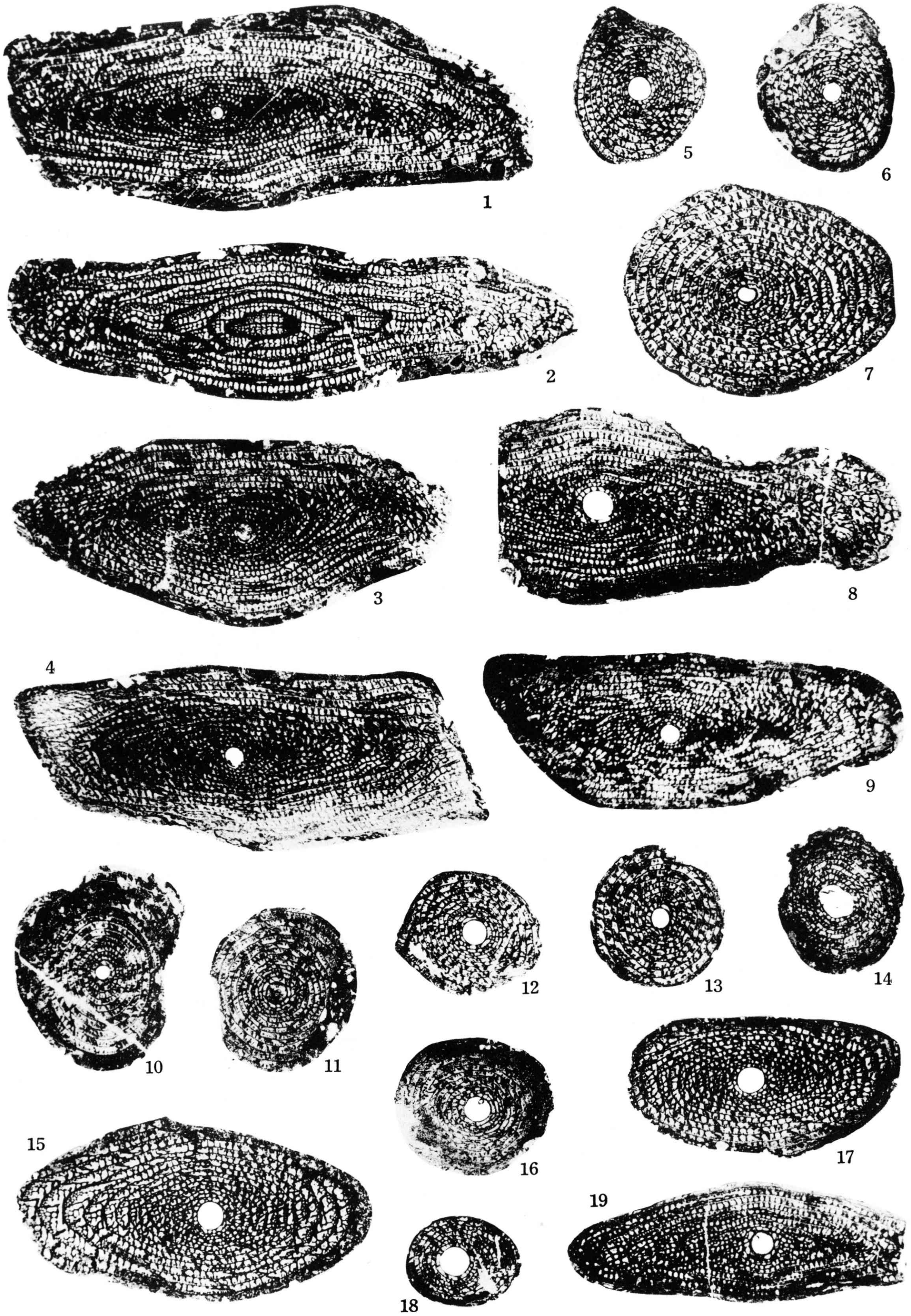
## Explanation of Plate 6

All figures are $\times 10$.

Figs. 1–19. ***Lepidolina toriyamai***, n. sp. ........................................................ Page 24

1, axial section of the holotype; 2, tangential section of a paratype; 3, 4, 8 & 9, axial sections of paratypes; 5, 6, sagittal sections of paratypes; 7, centered oblique section of a paratype; 10–14, 16 & 18, sagittal sections of paratypes; 19, slightly oblique axial section of a paratype; 1, 2, 5–19 are Loc. Ku. 499, 3 is from Loc. Ku. 165 and 4 is from Loc. Ku. 104.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