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FUSULINE BIOSTRATIGRAPHY OF THE UPPER CARBONIFEROUS AND LOWER PERMIAN OF JAPAN, WITH SPECIAL REFERENCE TO THE CARBONIFEROUS-PERMIAN BOUNDARY

By

Kozo WATANABE

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Abstract

This paper deals with the fusuline biostratigraphy based on inflated schwagerinids of the upper Carboniferous and lower Permian in Japan.

More than 10,000 thin-sectioned specimens from a large number of systematically collected samples from the representative upper Carboniferous and lower Permian limestones have been examined for the purpose of defining stratigraphic and geographic distribution of inflated schwagerinids lineages. As the result, twelve standard fusuline zones, the *Obsoletes obsoletus, Montiparus matsumotoi inflatus, Schwagerina? satoi, "Pseudoschwagerina" morikawai, "Pseudoschwagerina" minatoi, Sphaeroschwagerina fusiformis, Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis, "Alpinoschwagerina" saigusai-Pseudoschwagerina* cf. *robusta, Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis, Paraschwagerina akiyoshiensis-Pseudofusulina firma, Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* and *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone, and ten Datum Levels have been established in the upper Carboniferous to the lower Permian sequences. It was also revealed that the Carboniferous-Permian boundary in Japan can be drawn between the "*Pseudoschwagerina*" *minatoi* Zone and the overlying *Sphaeroschwagerina fusiformis* Zone, which are correlated respectively with the Upper Gzhelian and Lower Asselian Stages of the strato-types of the upper Carboniferous and lower Permian in Russia.

As for the Japanese standard biostratigraphic divisions, the Upper Carboniferous Hikawan Stage and the Lower Sakamotozawan Stage are emended and the Nagatoan Stage is newly proposed for the lowest Permian of Japan.

FUSULINE BIOSTRATIGRAPHY OF THE UPPER CARBONIFEROUS AND LOWER PERMIAN OF JAPAN, WITH SPECIAL REFERENCE TO THE CARBONIFEROUS-PERMIAN BOUNDARY IN JAPAN

By

Kozo WATANABE

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I. Introduction

In 1902 the "*Schwagerina* Horizon" (C_3^3-Horizon) was differentiated by Tschernyschew on the basis of occurrence of "*Schwagerina*" *princeps* EHRENBERG from other part of the "Upper Carboniferous Limestone" of the Ural and Timan in Russia. Since then the stratigraphic divisions of the Carboniferous and Permian and the boundary between them have been controversial until the present time. Furthermore, the "*Schwagerina*" problem as to whether or not "*Schwagerina*" could be a zonal index to the lower Permian has been discussed by Dunbar and Skinner (1936), Rauser-Chernousova (1936, 1956), and Dunbar (1958). The type specimens of "*Schwagerina princeps*" Ehrenberg (1842) and "*Schwagerina princeps* var. *glomerosa*" Schwager (1883) were restudied by Dunbar and Skinner (1936) and Nogami (1965), respectively. While, Miklukho-Maklay (1956) proposed a new genus *Sphaeroschwagerina,* designating "*Schwagerina princeps*" by Schellwien (1898) as the type species. Thus the schwagerinids named "*princeps*" include four species that are now emended as follows:

a. *Borelis princeps* Ehrenberg (1842)
   = *Schwagerina princeps* (Ehrenberg) by Dunbar & Skinner (1936)
b. *Schwagerina princeps* by Moeller (1877)
   = "*Schwagerina*" *moelleri* Rauser-Chernousova, 1936
c. *Schwagerina princeps* var. *glomerosa* by Schwager (1883)
   = "*Schwagerina*" *glomerosa* (Schwager)
   = "*Pseudoschwagerina*" *glomerosa* (Schwager) by Nogami (1965)
d. *Schwagerina princeps* by Schellwien (1898)
   = *Sphaeroschwagerina sphaerica karnica* (Scherb.), 1949

Of these, the latter three "*princeps*" which have with *schubertella*-like juvenile volutions, are now referred to the genus *Sphaeroschwagerina* (see Figure 47-3a–3d).

At the 8th International Carboniferous Congress held at Moscow (1975), the base of the Permian System in the type area was determined to be defined by the first appearance of *Sphaeroschwagerina fusiformis* (Krotow) and *Sphaeroschwagerina vulgaris* (Scherbovich). Consequently the Carboniferous-Permian boundary should be discussed on the basis of the first appearance of species of the *Sphaeroschwagerina*-lineage. However, in Japan, China and North America, where *Sphaeroschwagerina* has been either unknown or only sporadically recorded,

the base of the Permian has been defined by the appearance of the genus *Pseudoschwagerina* Dunbar & Skinner. *Pseudoschwagerina* differs from *Sphaeroschwagerina* in its ontogeny, and in Russia it first appears in the Middle Asselian. According, if *Sphaeroschwagerina* faunas could be found in continuous limestone successions in Japan, their stratigraphic relationships to *Pseudoschwagerina* faunas and the Carboniferous-Permian boundary would be clearly defined.

The lower systemic boundary of the Permian in Japan has been placed at the base of the "*Pseudoschwagerina*" *morikawai* Zone by many previous workers. "*P.*" *morikawai* Igo that has *montiparus*-like juvenile volutions differs apparently from species of the *Sphaeroschwagerina*-lineage (see Figures 47 and 48).

The "*Pseudoschwagerina*" *morikawai* and "*P.*" *minatoi* faunas are known typically from the Yayamadake Limestone in southern Kyushu and the Ichinotani Formation in the Hida Massif, Central Japan. But these faunas, have not been found from the limestones of the Akiyoshi Terrane in the Inner Zone of Southwest Japan, such as the Akiyoshi and Atetsu Limestones, which are provided with the most complete fusuline successions in Japan. Because of the lack of these faunas these limestones are considered to have belonged to a different biogeographic province (Sada, 1965).

I have newly recognized the "*P.*"*morikawai* and *Sphaeroschwagerina* faunas from the Akiyoshi, Atetsu and Omi Limestone Groups of the Akiyoshi Terrane. I have also noticed that some species of the *Sphaeroschwagerina*-lineage has been described under the genus *Pseudoschwagerina* from the Akiyoshi Limestone (Ozawa, 1925; Toriyama, 1958; Hasegawa, 1958; Ota, 1977) and the Atetsu Limestone (Sada, 1965) can be referred to the genus *Sphaeroschwagerina*. In this connection, I have investigated the upper Carboniferous and lower Permian fusuline fossils in representative limestones, shown in Fig. 1, in the Inner Zone of Southwest Japan to know their stratigraphic distribution for a better understanding of the Carboniferous-Permian boundary in Japan. I have also studied Lower Sakamotozawa Formation in northeast Japan and its equivalent formations (Fig. 1) in some detail on the basis of robustoschwagerinids. As the result, precise fusuline zonation by inflated schwagerinids has been established in the Japanese upper Carboniferous and lower Permian.

Acknowledgments

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Particular thanks are due to Curators A. Sugimura and T. Haikawa of Akiyoshi-dai Science

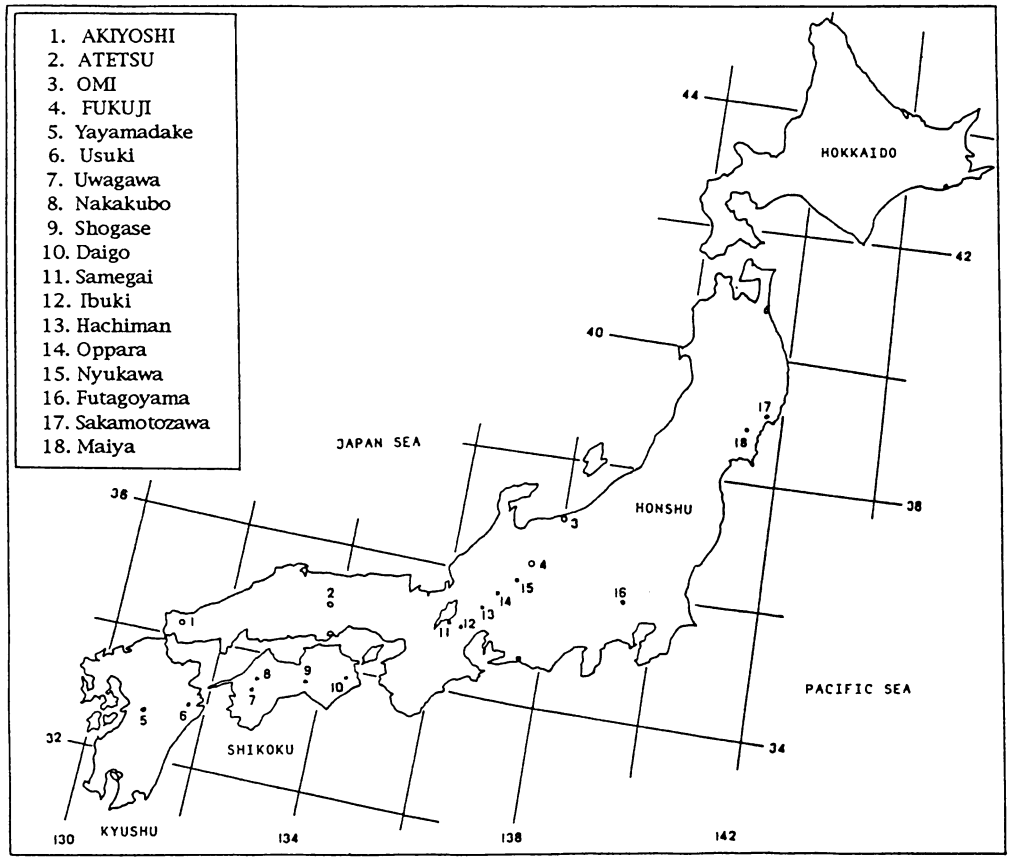


Fig. 1. Index map showing location of surveyed are (○) and fusuline collections-studied (●).

Museum for their cordial supports and convenience in course of my field survey.

II. Biostratigraphy of Upper Carboniferous and Lower Permian in Japan

1. Akiyoshi Limestone Group

1) Previous Work

Ozawa (1923, 1925) was the first to introduce fusuline zonation into the Akiyoshi Limestone Group, and within the upper Carboniferous and lower Permian he discriminated four zones and correlated them with Tschernyschew's divisions (1902) in the Russian Platform as follows:

P_1 ..... *Parafusulina japonica* Zone
CPg ..... *Parafusulina lutugini* Zone
C_3^2 ..... "*Pseudoschwagerina*" *glomerosa* or *Pseudofusulina vulgaris* Zone
C_3^1 ..... *Pseudoschwagerina muongthensis* Zone

The boundary between the Carboniferous and Permian in this sequence was placed at the base of the *Parafusulina lutugini* zone which is the Artinskian Stage in the present day divisions.

After World War II, the knowledge of the geology and paleontology of the Akiyoshi Limestone and adjacent areas has been greatly increased by many workers. Toriyama (1954, 1956,

1958), among others, systematically described fusulines from almost throughout the sequence of the limestone, and established the following zones in the upper Carboniferous and lower Permian rocks:

P1γ ..... *Pseudofusulina ambigua* subzone
P1β ..... *Pseudofusulina vulgaris* subzone
P1α ..... *Triticites simplex* subzone
Cmβ ..... *Fusulinella biconica* subzone

He found that the *Triticites simplex* subzone directly overlies either the *Fusulinella biconica* or the *Profusulinella beppensis* Zone. Hence stratigraphic break must be present under the base of the *Triticites simplex* subzone, although no distinct physical indication was recognized in the field. Laying stress on this stratigraphy, Toriyama placed the Carboniferous-Permian boundary at the base of the *Triticites simplex* subzone. The lower Permian comprises the *Triticites simplex, Pseudofusulina vulgaris,* and *Pseudofusulina ambigua* subzones in ascending order, of which the former two were correlated with the Sakmarian Stage and the latter one with the Artinskian in Russia. The *Triticites simplex* subzone was compared with Ozawa's *Pseudoschwagerina muongthensis* subzone.

Ota (1968–1977) refined and further extended the earlier works of Toriyama and others, and he supplemented some zones in the upper Carboniferous and lower Permian sections as follows:

B. Lower Permian Series
5. *Misellina claudiae* Zone (P1δ)
4. *Pseudofusulina ambigua* Zone (P1γ)
3. *Pseudofusulina vulgaris* Zone (P1β)
2. *Pseudoschwagerina muongthensis* Zone (P1α_2)
1. *Triticites simplex* Zone (P1α_1)
..... unconformity .....
A. Upper Carboniferous Series
Triticites matsumotoi Zone (Cuα)
..... unconformity .....

2) Present Investigation

(A) Measured Sections

As the Akiyoshi Limestone is unstratified throughout the sequence, measured sections have been taken so as to cross the general trend of the upper Carboniferous and lower Permian rocks in the areas where exposures are nearly continuous, and sampling has been made at unevenly spaced intervals to finding out fusuline-bearing rocks as throughly as possible along the sections. The measured sections and their locations are as follows (Fig. 2):

A: measured 100 m along the Akiyoshi-Dai Toll Road, east of Akiyoshi-Dai Science Museum
B: measured 200 m nearly parallel to and 50 m west of Section A.
C: measured about 100 m on the middle between Sections B and D.
D: measured 250 m along the Natural Investigate Road from the Museum to Wakatake-Yama
KII: measured about 200 m along the Akiyoshi-Dai Toll Road on the western flank of Kaerimizu Doline
KI: measured up about 100 m at a right angle to the Akiyoshi-Dai Toll Road.

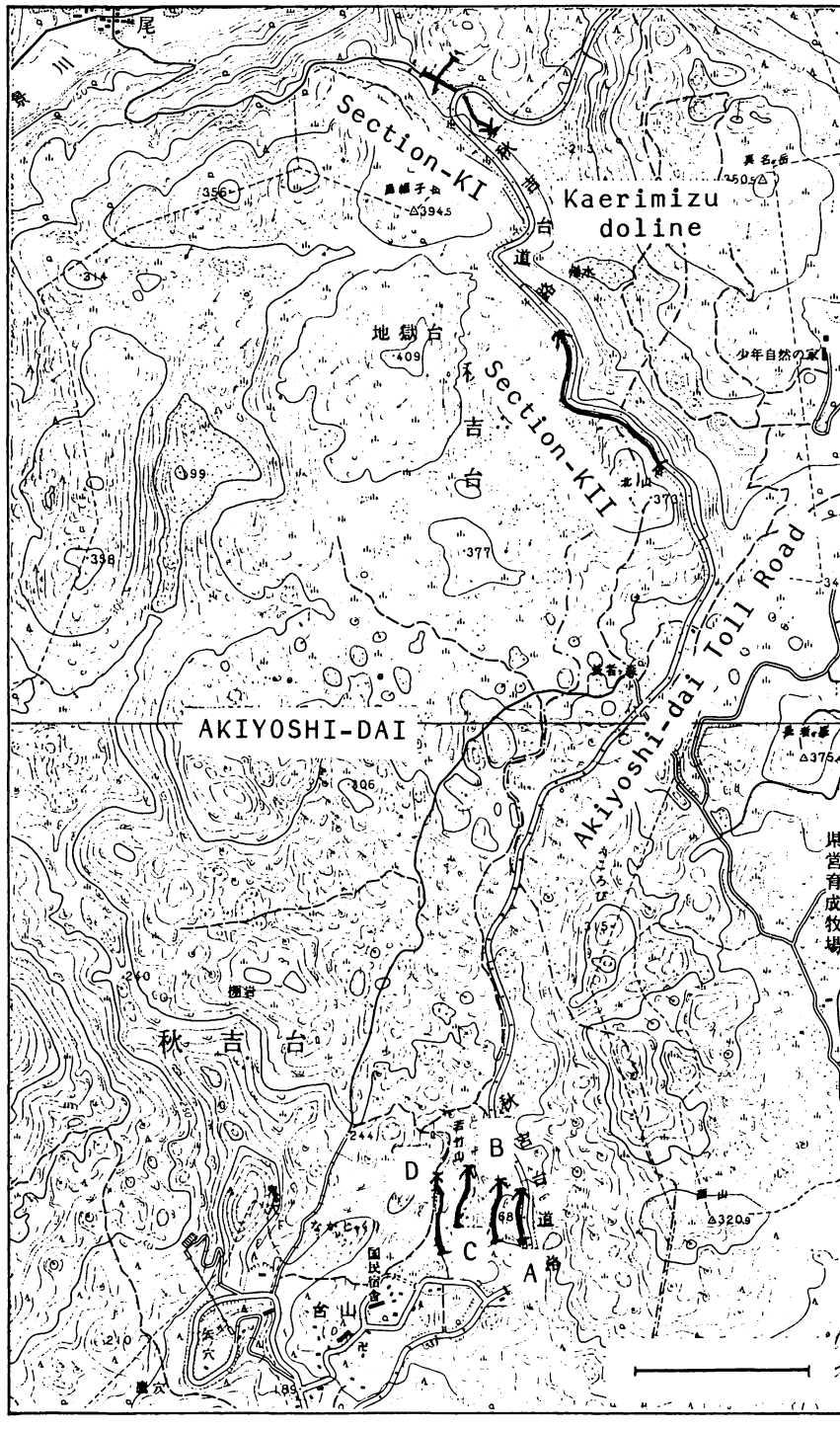


Fig. 2. Index map showing location of measured sections on the Akiyoshi Plateau. Section A to D in the sheet map "Akiyoshi-dai" (1:25,000) and sections KI and KII in the sheet map "Northern part of the Akiyoshi-dai" (1:25,000).

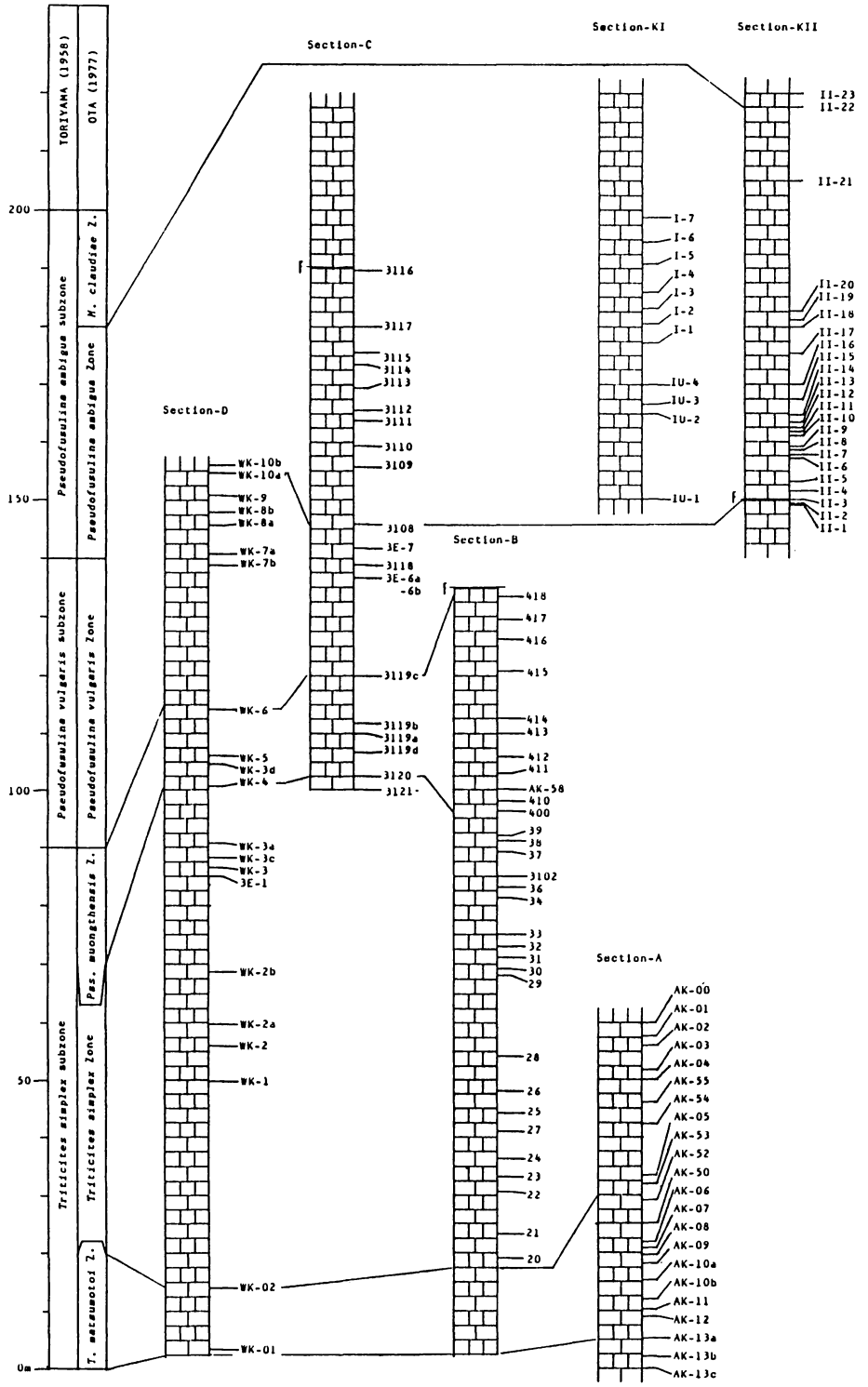
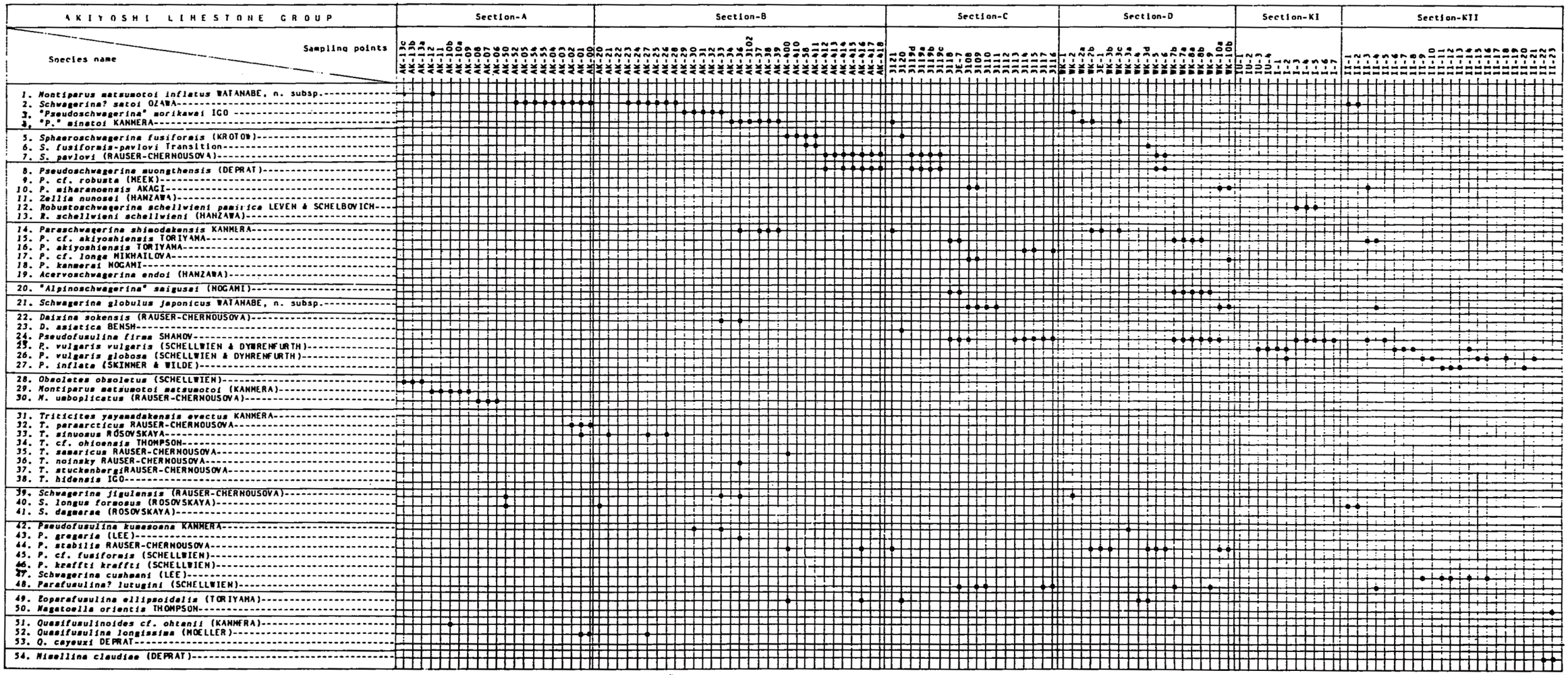


Fig. 3. Measured sections of the Akiyoshi Limestone Group, showing location of fusuline collections.

Table 1. Faunal association and distribution of fusuline species in the measured sections of the Akiyoshi Limestone Group.



The stratigraphic columns of these sections are shown in Fig. 3, and the faunal association and distribution of fusuline species are shown in Table 1.

(B) Stratigraphic Distribution of Fusulines

(1) Akiyoshi-Dai Science Museum Area

Obsoletes obsoletus (Schellwien) [Figure 20-1–5, 12, 17, 19, 20–22] occurs at AK-13c, AK-13b and AK-13a in Section A, and the rocks of this 5-m interval consist of white oosparitic limestone.

Dark-grey algal biosparite at AK-12 contains rare specimens of *Montiparus matsumotoi inflatus* Watanabe, n. subsp. [Figure 20-29].

Montiparus matsumotoi matsumotoi (Kanmera) [Figure 18-14) and *M. umboplicatus* (Rauser-Chernousova & Beljaev) [Figure 18-13] are obtained from many levels in a 40-m-thick sequence between AK-12 and AK-06 in Section A. The rocks in which these species occur are grey biosparite and biomicrite with some dark-brownish to dark-grey dolomitized limestones.

Quasifusulinoides cf. *ohtanii* (Kanmera) [Figure 20-26] occur in a level at AK-10b. This level is within the sequence of *M. matsumotoi matsumotoi* and is approximately the same as the zone of *Triticites matsumotoi* reported by Ota (1977).

Schwagerina longus formosus (Rosovskaya) [Figure 19-21–24] appears at AK-50 in Section A and AK-20 in Section B. The rocks of these points are white crinoidal biosparite.

Triticites sinuosus Rosovskaya [Figure 19-9–10] is common at AK-01 in Section A, and at AK-21, AK-26 and AK-27 in Section B.

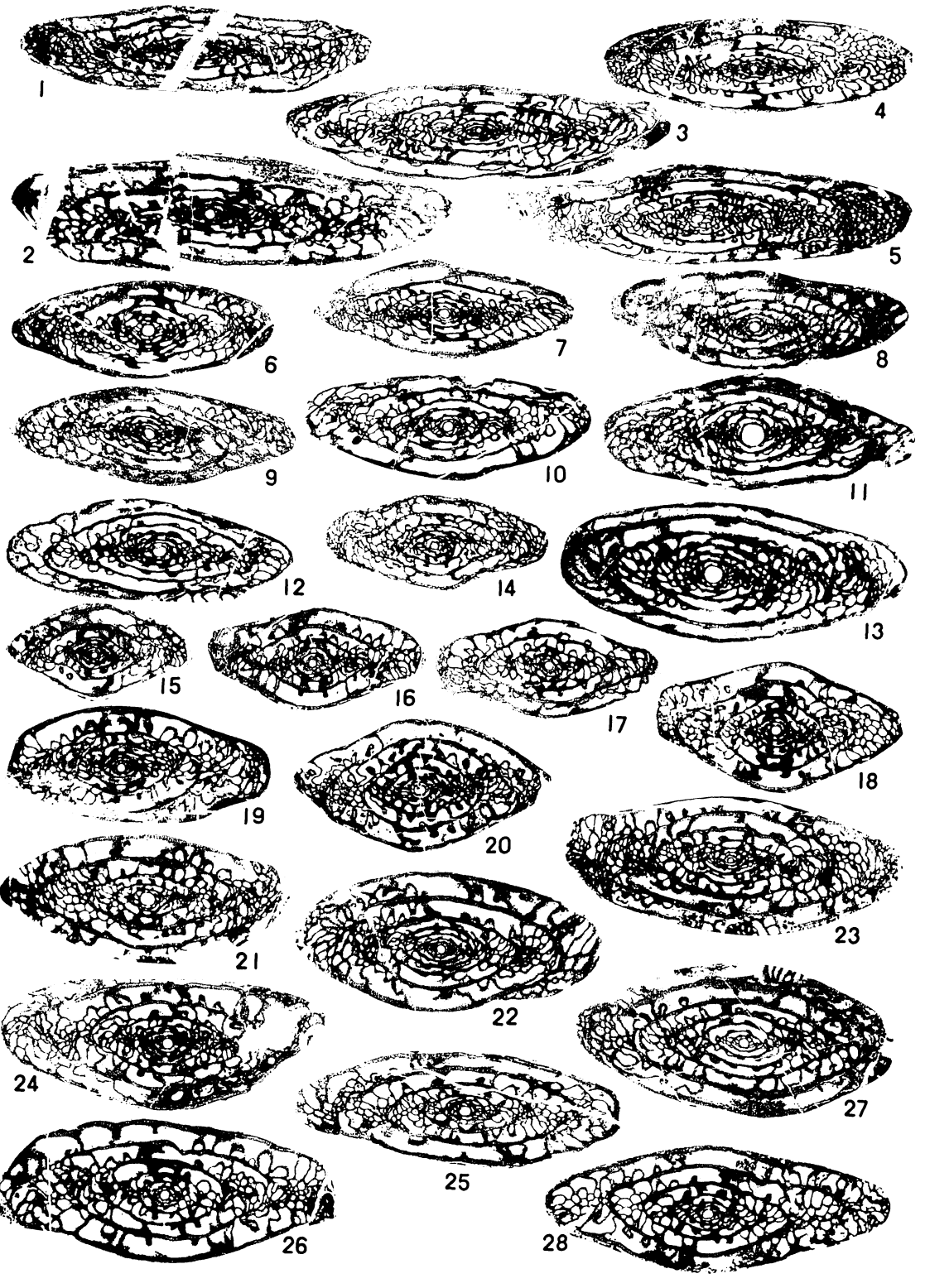
Schwagerina? satoi (Ozawa) [Figure 25-15–20] and *Quasifusulina longissima* (Moeller) are found from AK-00 and AK-01 in Section A and AK-27 in Section B. They occur in grey algal biomicritic limestones.

Conformably succeeding light-brownish biomicritic limestones from AK-29 to AK-33 yield abundant "*Pseudoschwagerina*" *morikawai* Igo [Figure 27-1–13]. This species is associated with *Schwagerina jigulensis* Rauser at WK-2 in Section D. "*Pseudoschwagerina*" *minatoi* Kanmera [Figure 30-1–11], *Paraschwagerina shimodakensis* Kanmera [Figure 42-1–7] and *Pseudofusulina stabilis* (Rauser-Chernousova) [Figure 5-19–28] are found at several levels from AK-34 to AK-39 in Section B, and 3121 in Section C, and WK-2a to WK-3E-1 in Section D. They occur in light-grey pelmicrite and pel-sparite limestone. *Paraschwagerina shimodakensis* is abundant in white crinoidal biosparite of AK-37 in Section B.

Succeeding grey homogeneous biomicrite limestone contains species of the *Sphaeroschwagerina*-lineage. The first occurrence of *Sphaeroschwagerina* is represented by *S. fusiformis* (Krotow) [Figure 32-1–11] from AK-400 to AK-411 in Section B, 3120 in Section C, and WK-3d in Section D. It is accompanied with *Pseudofusulina stabilis* (Rauser) and *Triticites samaricus* Rauser [Figure 4-6–13].

Sphaeroschwagerina pavlovi (Rauser-Chernousova) [Figure 35-1–17] and *Pseudoschwagerina muongthensis* (Deprat) [Figure 36-1–15] are common in dark-grey biomicrite from AK-412 to AK-418 in Section B and 3119d to 3119a in Section C, and WK-5 and WK-6 in Section D. They are associated with *Eoparafusulina ellipsoidalis* (Toriyama) [Figure 5-3–11].

Overlying white crinoidal biosparitic limestone yields "*Alpinoschwagerina*" cf. *saigusai*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(Nogami) [Figure 38-9–19] from 3118 and 3E-7 in Section C, and from WK-7b to WK-9 in Section D. The associated species are *Paraschwagerina* cf. *akiyoshiensis* Toriyama [Figure 42-9–18], *Pseudofusulina firma* Shamov [Figure 12-1–19], and *Parafusulina? lutugini* (Schellwien) [Figure 8-1–12].

Schwagerina globulus japonicus Watanabe, n. subsp. [Figure 41-1–13] and *Pseudoschwagerina miharanoensis* Akagi [Figure 39-1–14, 17] are obtained from white crinoidal biosparite at 3108 and 3109 in Section C, and at WK-10a and WK-10b in Section D. These species rarely occur with *Paraschwagerina* cf. *longa* Mikhailova [Figure 43-6–7] in pelsparitic limestone.

Paraschwagerina akiyoshiensis Toriyama [Figure 43-1–5] appears at AK-3114 and ranges up to 3116 in Section C, being associated with *Pseudofusulina firma* Shamov in algal biomicrite. The limestones containing this fauna are cut off by a fault, and the limestone yielding *Sphaeroschwagerina pavlovi, Pseudoschwagerina muongthensis* and *Schwagerina? satoi* is again exposed on the north.

As is understood from the above-mentioned stratigraphic distribution of fusulines, the measured limestone sections can be divided biostratigraphically into the following zones that are characterized by a diagnostic assemblage of species respectively.

(Akiyoshi-Dai Science Museum Area)
. . . . . fault . . . . . .
B. Lower Permian Series
10. *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone
9. *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone
8. "*Alpinoschwagerina*" cf. *saigusai* Zone
7. *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone
6. *Sphaeroschwagerina fusiformis* Zone
A. Upper Carboniferous Series
5. "*Pseudoschwagerina*" *minatoi* Zone
4. "*Pseudoschwagerina*" *morikawai* Zone
3. *Schwagerina? satoi* Zone
2. *Montiparus matsumotoi inflatus* Zone
1. *Obsoletes obsoletus* Zone

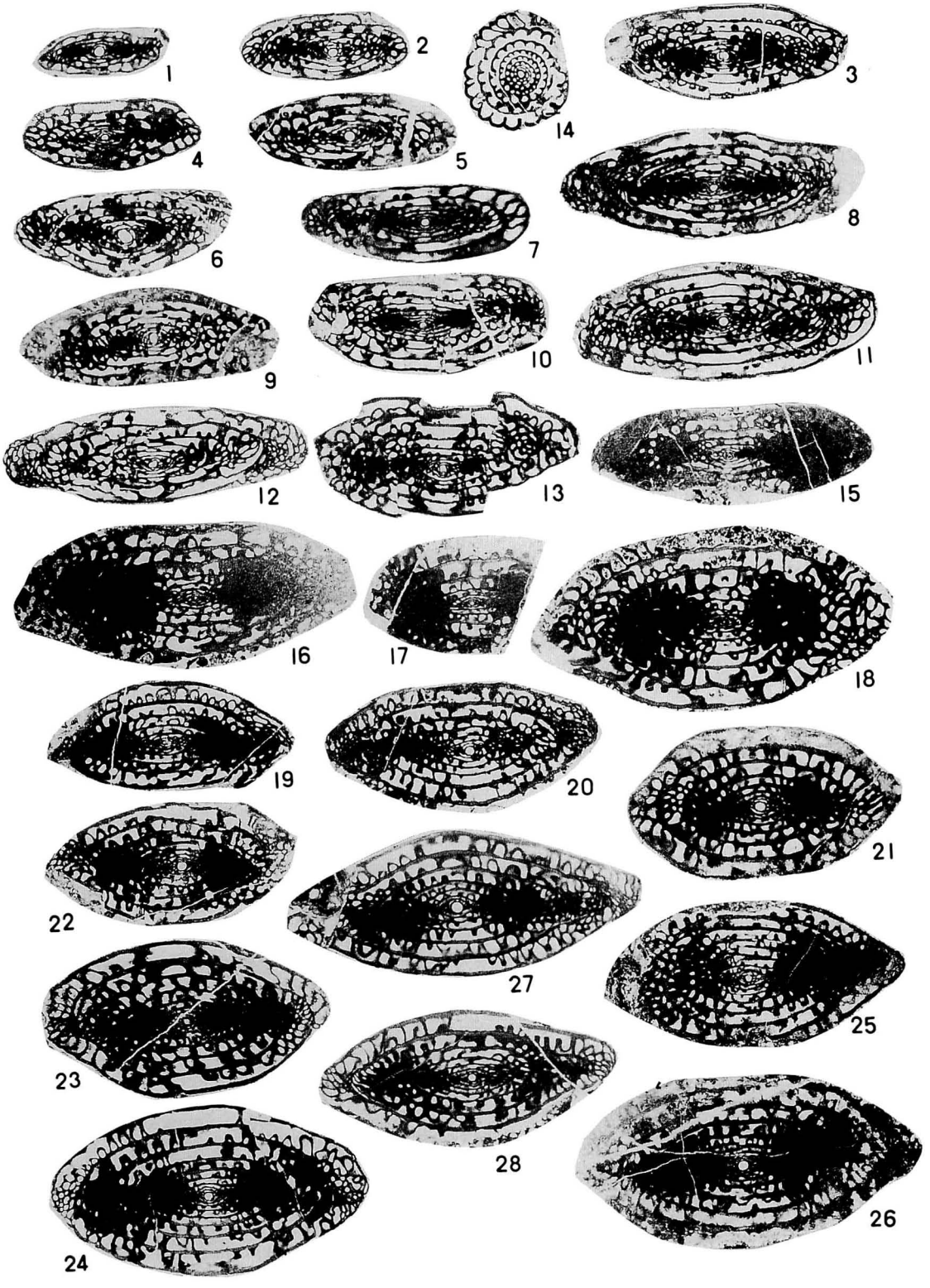
Throughout this sequence no stratigraphic break has been found.

(2) Kaerimizu Doline Area

Section KI and KII in the Kaerimizu doline area afford us the upper part of the lower Permian.

Schwagerina globulus japonicus Watanabe, n. subsp. and *Pseudoschwagerina miharanoensis* AKAGI occur in white crinoidal biosparite at II-4 of Section KII.

Fig. 4. All photographs ×10. **1–5: *Triticites* cf. *ohioensis* Thompson;** 1, 2: Atetsu Limestone Group; 3, 4: Mizuyagadani Formation; 5: Akiyoshi Limestone Group. The *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **6–13: *Triticites samaricus* Rauser-Chernousova;** Akiyoshi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Upper Carboniferous Series; **14–20: *Triticites hidensis* Igo;** Ichinotani Formation, Atetsu, Omi Limestone Groups, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **21–24, 27: *Triticites stuckenbergi* Rauser-Chernousova;** Akiyoshi and Atetsu Limestone Groups, the lower to middle part of the Nagatoan Stage, Lower Permian Series; **25, 26, 28: *Triticites noinsky* Rauser-Chernousova;** Akiyoshi and Omi Limestone Groups, the *Sphaeroschwagerina fusuformis* to *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, Lower to lower part of the Middle Nagatoan Stages, Lower Permian Series.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Paraschwagerina akiyoshiensis Toriyama and *Pseudofusulina firma* Shamov are obtained from II-3 to II-4 in Section KII.

Robustoschwagerina schellwieni pamirica Leven & Schelbovich [Figure 44-1–5] and *Schwagerina krotowi* (Schellwien) appear at I-3 and range up to I-4 in Section KI. These species occur in white biosparitic limestone.

Grey biomicritic limestone of IU-3 to I-2 in Section KI and II-6 to II-9 in Section KII yield a typical form of *Pseudofusulina vulgaris vulgaris* (Schellwien & Dyhrenfurth) and *P. vulgaris globosa* (Schellwien & Dhyrenfurth). These species are associated with many schwagerinids including *Paraschwagerina akiyoshiensis* Toriyama.

About 40 m above this level comes dark grey biomicritic limestone which yields abundant *Misellina claudiae* (Deprat).

Thus, in Section KI and KII the same zones as and the sequence of some higher levels than the upper part of the sequence of Section A to D are present, and the following zones can be discriminated:

(Kaerimizu Doline Area)
B. Lower Permian Series
5. *Misellina claudiae* Zone
4. *Pseudofusulina vulgaris vulgaris* Zone
3. *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone
2. *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone
. . . . . .fault? . . . . . .
1. *Schwagerina? satoi* Zone

2. Atetsu Limestone Group

1) Previous Work

Stratigraphical and paleontological knowledge of the Atetsu Limestone Group was remarkably promoted by Okimura (1958), Imamura (1959), Sada (1960, 1964, 1965), and Nogami (1961a, 1961b, 1962).

Nogami (1962) established the following litho- and fusuline biostratigraphic divisions in the Permian sequence of the Atetsu Limestone Group.

B. Permian System
3. Conglomeratic Limestone Formation
-Neoschwagerina douvillei-N. craticulifera Zone
2. Massive Limestone Formation
-Parafusulina kaerimizuensis-Pseudofusulina kraffti magma Zone
1. Oolitic Limestone Formation
-Pseudoschwagerina subsphaerica-Quasifusulina longissima ultima Zone
. . . . . fault? . . . . . .
A. Carboniferous System

Fig. 5. All photographs ×10. **1–14: *Eoparafusulina ellipsoidalis* (Toriyama);** Akiyoshi, Omi, Atetsu Limestone Groups, the *Sphaeroschwagerina fusiformis* to *S. pavlovi-Pseudoschwagerina muongthensis* Zone, Lower to lower part of the Middle Nagatoan Stage, Lower Permian Series; **15–18: *Pseudofusulina gregaria* (Lee);** Akiyoshi, Omi Limestone Groups, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series; **19–28: *Pseudofusulina stabilis* (Rauser-Chernousova);** Akiyoshi, Omi Limestone Groups, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series.

A few years later Sada (1964, 1965), using the same stratigraphic divisions and names as Imamura's (1959), made a detailed fusuline zonation as follows, and recognized stratigraphic hiatus between the Carboniferous and Permian rocks.

B. Lower Permian: Sabushi Group
  2. Shoyama Formation: *Pseudofusulina* Zone
    b. *Parafusulina kaerimizuensis* subzone
    a. *Pseudofusulina vulgaris* subzone
  1. Iwamoto Formation: *Pseudoschwagerina* Zone
    b. *Pseudoschwagerina kanmerai* subzone
    a. *Rugosofusulina arctica* subzone
. . . . . unconformity . . . . . .
A. Middle Carboniferous: Mitsudo Group
  2. Kodani Formation: *Fusulinella* Zone
    b. *Fusulinella imamurai* subzone

2) Present Investigation

I have examined the distribution of inflated schwagerinids in the upper Carboniferous and lower Permian sections in areas of Morikuni, Shimo-yukawa and Matsunagi (Fig. 6). The stratigraphic columns of these sections are shown in Fig. 7, and faunal association and distribution of fusuline species in the sections are shown in Table 2.

(A) Measured sections

Morikuni A and B: measured 70 m and about 100 m respectively on the western and eastern sides of a road from Shimoazai to Iwamoto in Morikuni, being apart about 150 m from each other.

Shimo-yukawa: measured about 100 m along a road from Yukawa to Uyama south of Shimo-yukawa.

Matsunagi: measured about 90 m eastward and northeastward from Matsunagi.

(B) Stratigraphic Distribution of Fusulines

Limestones at SYU-7b in Section Shimo-yukawa and at MT-1 in Section Matsunagi are conglomeratic, dolomitized and pigmented dark-brownish. These rocks contain abundant *Montiparus umboplicatus* (Rauser-Chernousova & Beljaev). *Triticites montiparus gravitestus* Nogami and *T. montiparus* (Ehrenberg) that can be specifically referred to *Schwagerina? satoi* (Ozawa) [Figure 24-1–18] and *Quasifusulina longissima* (Moeller) occur from SY-22 to SY-17a and SY-134a in Section Shimo-yukawa and MK-01 to MK-03 in Section Morikuni A.

"*Pseudoschwagerina*" *nakazawai* Nogami that is also specifically referred to "*Pseudoschwagerina*" *morikawai* Igo [Figure 26-1–14] is found from MK-04 to MK-05 in Section Morikuni A and SY-134a and SY-134d in Section Shimoyukawa.

White to dark-grey medium-bedded biomicritic limestones from MK-100 and MK-101 in Section Morikuni A, and from SY-136 in Section Shimo-yukawa yield abundant "*Pseudoschwagerina*" *minatoi* Kanmera [Figure 29-1–10, 13, 14].

Conformably succeeding dark-grey homogeneous biomicrite limestones contain species of the *Sphaeroschwagerina*-lineage. A pioneer species of this lineage, *Sphaeroschwagerina fusiformis* (Krotow) [Figure 34-1–6], is rarely recognized at MK-25 in Section B of Morikuni.

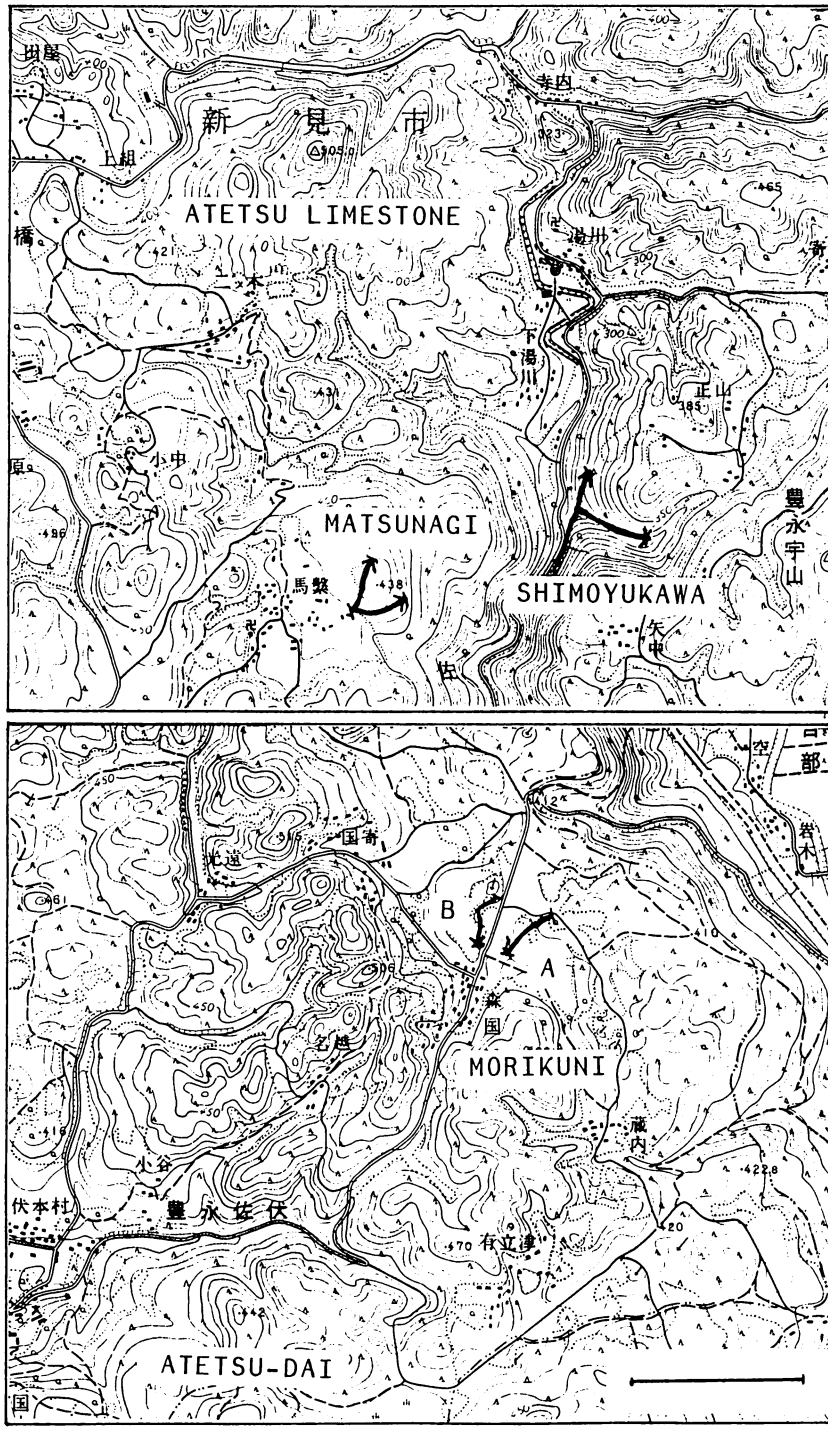


Fig. 6. Index map showing location of measured sections on the Atetsu Limestone Plateau. Sections A, B, Shimoyukawa, Matsunagi in the sheet map of "Ikura" (1:25,000).

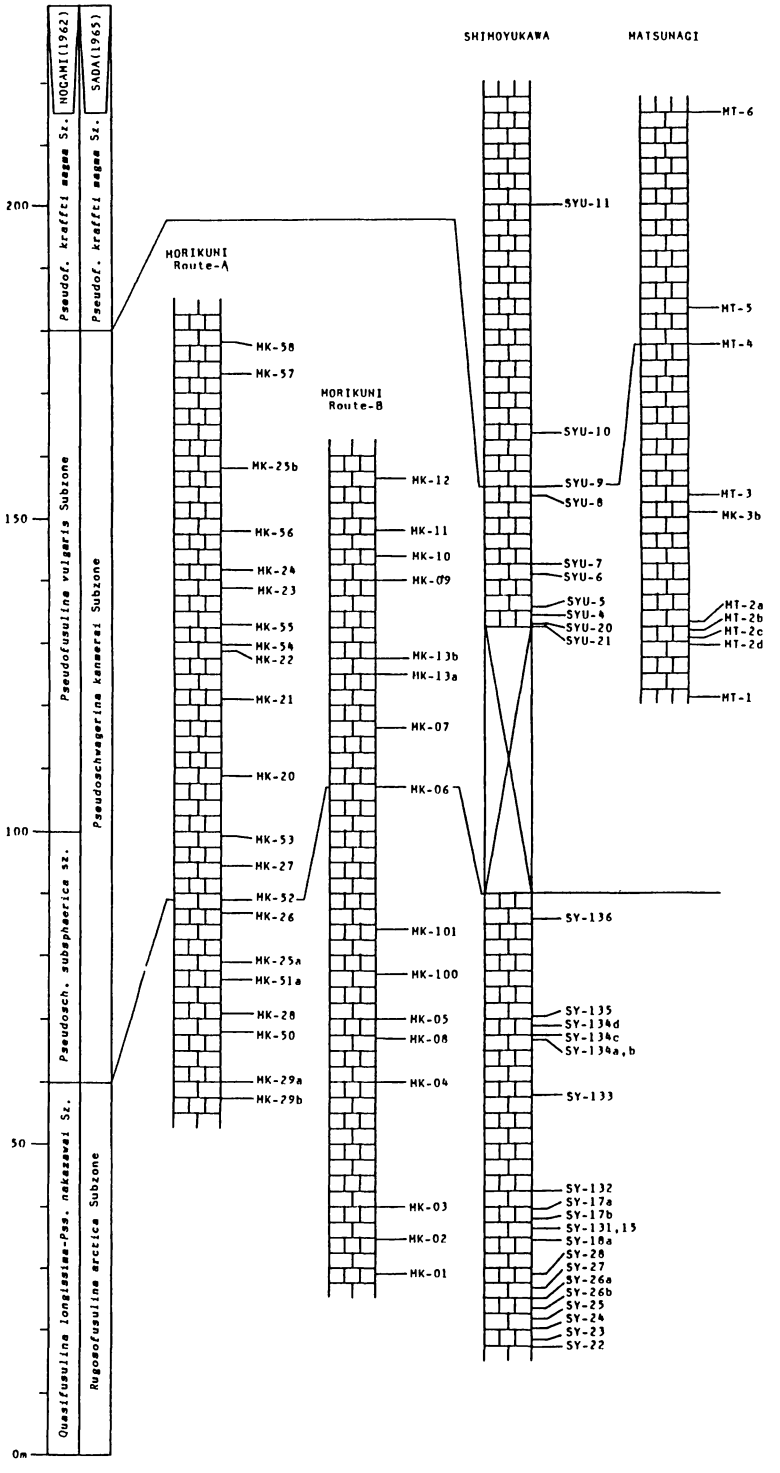


Fig. 7. Measured sections of the Atetsu Limestone Group, showing location of fusuline collections.

Table 2. Faunal association and distribution of fusuline species in the measured sections of the Atetsu Limestone Group.

ATETSU LIMESTONE GROUP

Species name / Sampling points

Species name	Morikuni Route-B	Morikuni Route-A	Shimoyukawa	Matsunagi
	MK-01 MK-02 MK-03 MK-04 MK-08 MK-05 MK-100 MK-101 MK-06 MK-07 MK-13a MK-13b MK-09 MK-10 MK-11 MK-12	MK-29b MK-29a MK-50 MK-28 MK-51a MK-25a MK-26 MK-52 MK-27 MK-53 MK-20 MK-21 MK-22 MK-54 MK-55 MK-23 MK-24 MK-56 MK-25b MK-57 MK-58	SY-22 SY-23 SY-24 SY-25 SY-26b SY-26a SY-27 SY-28 SY-18a SY-131 SY-17b SY-17a SY-132 SY-133 SY-134a SY-134c SY-134d SY-135 SY-136 SYU-21 SYU-20 SYU-4 SYU-4 SYU-5 SYU-6 SYU-7 SYU-8 SYU-9 SYU-10 SYU-11	MT-1 MT-2d MT-2c MT-2b MT-2a MT-3 MT-4 MT-5 MT-6
1. *Montiparus matsumotoi inflatus* WATANABE, n. subsp.				
2. *Schwagerina? satoi* OZAWA				
3. *"Pseudoschwagerina" morikawai* IGO				
4. *"P." minatoi* KANMERA				
5. *Sphaeroschwagerina fusiformis* (KROTOW)				
6. *S. fusiformis-pavlovi* Transition				
7. *S. pavlovi* (RAUSER-CHERNOUSOVA)				
8. *Pseudoschwagerina muongthensis* (DEPRAT)				
9. *P. cf. robusta* (MEEK)				
10. *P. miharanoensis* AKAGI				
11. *Zellia nunosei* (HANZAWA)				
12. *Robustoschwagerina schellwieni pamirica* LEVEN & SCHELBOVICH				
13. *R. schellwieni schellwieni* (HANZAWA)				
14. *Paraschwagerina shimodakensis* KANMERA				
15. *P. cf. akiyoshiensis* TORIYAMA				
16. *P. akiyoshiensis* TORIYAMA				
17. *P. cf. longa* MIKHAILOVA				
18. *P. kanmerai* NOGAMI				
19. *Acervoschwagerina endoi* (HANZAWA)				
20. *"Alpinoschwagerina" saigusai* (NOGAMI)				
21. *Schwagerina globulus japonicus* WATANABE, n. subsp.				
22. *Daixina sokensis* (RAUSER-CHERNOUSOVA)				
23. *D. asiatica* BENSH				
24. *Pseudofusulina firma* SHAMOV				
25. *P. vulgaris vulgaris* (SCHELLWIEN & DYHRENFURTH)				
26. *P. vulgaris globosa* (SCHELLWIEN & DYHRENFURTH)				
27. *P. inflata* (SKINNER & WILDE)				
28. *Obsoletes obsoletus* (SCHELLWIEN)				
29. *Montiparus matsumotoi matsumotoi* (KANMERA)				
30. *M. umboplicatus* (RAUSER-CHERNOUSOVA)				
31. *Triticites yayamadakensis evectus* KANMERA				
32. *T. paraarcticus* RAUSER-CHERNOUSOVA				
33. *T. sinuosus* ROSOVSKAYA				
34. *T. cf. ohioensis* THOMPSON				
35. *T. samaricus* RAUSER-CHERNOUSOVA				
36. *T. noinsky* RAUSER-CHERNOUSOVA				
37. *T. stuckenbergi* RAUSER-CHERNOUSOVA				
38. *T. hidensis* IGO				
39. *Schwagerina jigulensis* (RAUSER-CHERNOUSOVA)				
40. *S. longus formosus* (ROSOVSKAYA)				
41. *S. dagmarae* (ROSOVSKAYA)				
42. *Pseudofusulina kumasoana* KANMERA				
43. *P. gregaria* (LEE)				
44. *P. stabilis* RAUSER-CHERNOUSOVA				
45. *P. cf. fusiformis* (SCHELLWIEN)				
46. *P. kraffti kraffti* (SCHELLWIEN)				
47. *Schwagerina cushmani* (LEE)				
48. *Parafusulina? lutugini* (SCHELLWIEN)				
49. *Eoparafusulina ellipsoidalis* (TORIYAMA)				
50. *Nagatoella orientis* THOMPSON				
51. *Quasifusulinoides cf. ohtanii* (KANMERA)				
52. *Quasifusulina longissima* (MOELLER)				
53. *Q. cayeuxi* DEPRAT				
54. *Misellina claudiae* (DEPRAT)				

Sphaeroschwagerina fusiformis-pavlovi Transition [Figure 34-7–12] and *Pseudoschwagerina muongthensis* (Deprat) [Figure 37-1–13] are commonly found from MK-06 to MK-09 in Section Morikuni A and MK-27 to MK-22 in Section Morikuni B.

"*Alpinoschwagerina*" *saigusai* (Nogami) [Figure 38-1–5] is common in MK-10 and MK-11 in Section Morikuni A, and MK-54 to MK-56 in Section Morikuni B. *Pseudoschwagerina* cf. *robusta* (Meek) [Figure 38-6–8] is accompanied with this species at MK-12 in Section Morikuni A.

White crinoidal, medium-bedded biosparitic limestones at MK-25b in Section Morikuni B and MT-1 in Section Matsunagi yield *Schwagerina globulus japonicus* Watanabe n. subsp [Figure 41-14].

Paraschwagerina akiyoshiensis Toriyama occur in MK-57 and MK-58 of Section Morikuni B, and is associated with *Pseudofusulina firma* Shamov.

Robustoschwagerina subsphaerica (Nogami) that can be referred to *R. schellwieni pamirica* Leven & Schelbovich [Figure 44-6] is common in the matrix of a limestone conglomerate at SYU-7 in Section Shimo-yukawa and MT-3 [Figure 17-12] in Section Matsunagi, and occurs in association with *Paraschwagerina kanmerai* Nogami [Figure 43-8–13], *Pseudofusulina vulgaris globosa* (Schellwien & Dyhrenfurth) [Figure 17-8–11] and *Pseudofusulina* cf. *fusiformis* (Schellwien) [Figure 17-1–7].

In the measured upper Carboniferous and lower Permian sections of the Atetsu Limestone Group, the stratigraphic ranges of *Schwagerina? satoi,* "*Pseudoschwagerina*" *morikawai,* "*P.*" *minatoi, Sphaeroschwagerina pavlovi,* and *Schwagerina globulus japonicus* are well defined, but those of other species cannot be so clearly indicated as in the Akiyoshi Limestone Group. Nevertheless, based on the species assemblages the upper Carboniferous and lower Permian sections of the Atetsu Limestone can be divided into the following zones:

B. Lower Permian Series
  9. *Robustoschwagerina schellwieni pamirica* Zone
  8. *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone
  7. *Schwagerina globulus japonicus* Zone
  6. "*Alpinoschwagerina*" *saigusai-Pseudoschwagerina* cf. *robusta* Zone
  5. *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone
  4. *Sphaeroschwagerina fusiformis* Zone
A. Upper Carboniferous Series
  3. "*Pseudoschwagerina*" *minatoi* Zone
  2. "*Pseudoschwagerina*" *morikawai* Zone
  1. *Schwagerina? satoi* Zone

3. Omi Limestone Group

1) Previous Work

The Omi Limestone is located at the northern end of the Hida Marginal Belt in the western part of Niigata Prefecture, and is one of the limestones of the Akiyoshi Terrane. Hayasaka (1924) was the first to find out the Carboniferous rocks in Japan based on brachiopods, corals and fusulines in this limestone. Kawada (1954) and Fujita (1958) attempted to make fusuline zonation of this limestone in the Itagamine area of Omi-machi, and discriminated the *Triticites* and the *Pseudoschwagerina* Zone within the Carboniferous and lower Permian sequence. They thought that these two zones are conformable, although they recognized a limestone conglomerate between them. they listed many species, but did not describe the species.

Hasegawa and others (1969) divided the upper Carboniferous and lower Permian part of this limestone into the following fusuline zones:

B. Lower Permian Series
  2. *Pseudofusulina* Zone
    b. Pseudofusulina kraffti subzone
    a. *Pseudofusulina vulgaris* subzone
  1. *Pseudoschwagerina* Zone
    b. *Pseudoschwagerina* sp. subzone
    a. *Triticites simplex* subzone
    . . . . . unconformity . . . . . .
A. Middle Carboniferous Series
  2. *Fusulinella* Zone

They placed the Carboniferous-Permian boundary at the base of the *Triticites simplex* subzone, and correlated the *Fusulinella* Zone and *Pseudoschwagerina* Zones including the *T. simplex* subzone with the main part of the Moscovian and the Asselian, respectively. This correlation indicates that the upper Carboniferous rocks are lacking in this sequence. They recognized "a 10-m dark-brown sparry calcite layer" between the *Fusulinella* Zone and the *Triticites simplex* subzone, but no further investigation on this problem has been made.

2) Present Investigation

I have examined the distribution of inflated schwagerinids in the upper Carboniferous and lower Permian sections in the Itagamine area (Figs. 10, 11; Table 3).

(A) Measured Sections

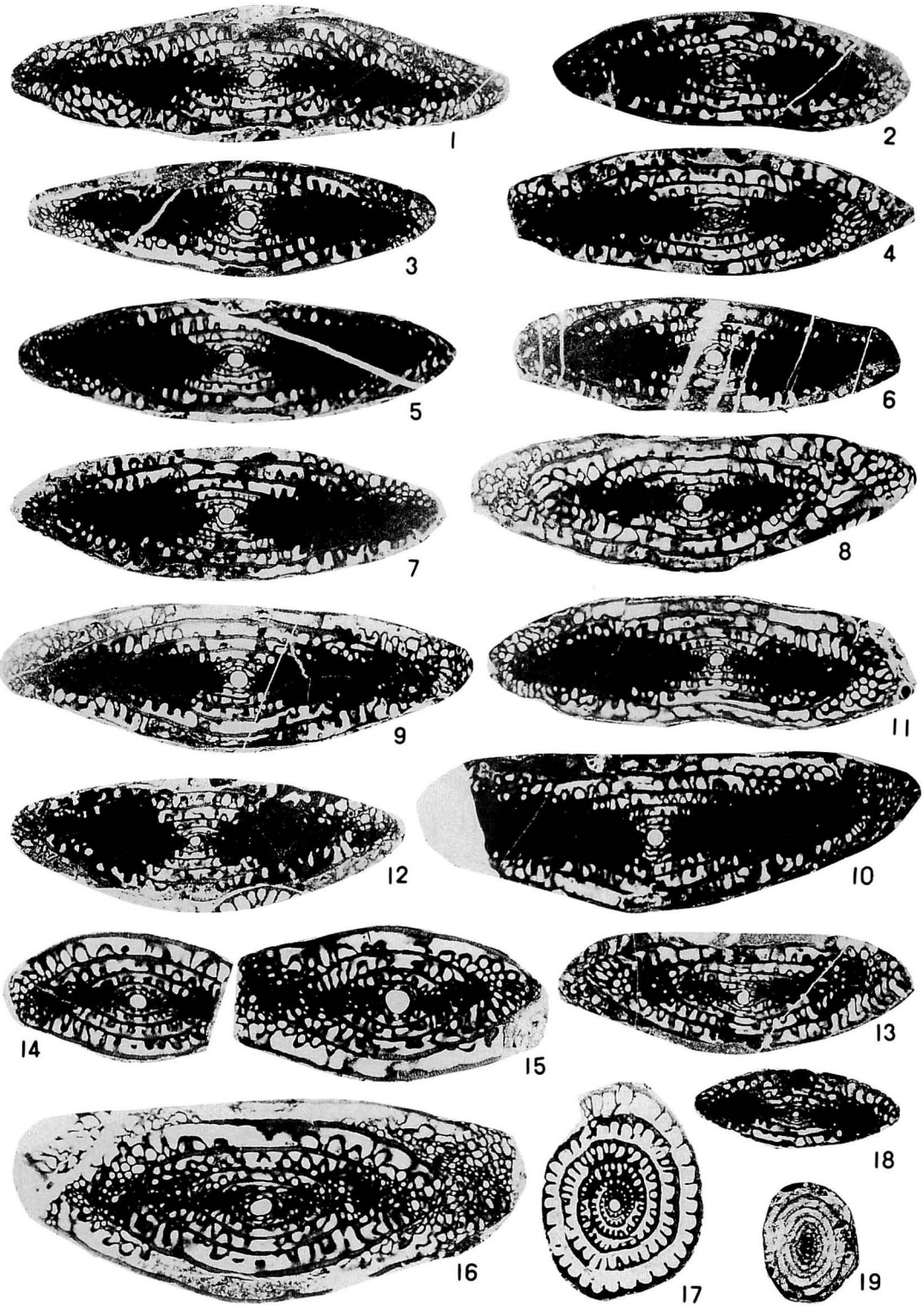
I hae measured five sections A to D and R-8 that transverse the upper Carboniferous and lower Permian limestones. Their locations are as follows:

A: measured 50 m on the eastern face of a abandoned glory hole of the Shinetsu Chemical Industry
B: measured 80 m on the western face of the same glory as the above
C: measured 100 m up the west slope of Gongen-yama
D: measured about 200 m on the northeastern flank of the Ryoun-zan
R-8: measured about 150 m along the National Road Route-8

(B) Stratigraphic Distribution of Fusulines

Obsoletes obsoletus (Schellwien) [Figure 20-6–11, 13–16,19,23] is found at C-4a and C-4c in Section C and D-56 in Section D. This species occurs in white oosparitic limestone that is estimated about 5 to 10 m thick.

Fig. 8. All photographs ×10. **1–12: *Parafusulina? lutugini* (Schellwien)**; Akiyoshi and Omi Limestone Groups, the "*Alpinoschwagerina*" *saigusai* Zone to *Schwagerina globulus japonicus* Zone, upper part of the Middle Nagatoan to the lower part of the Sakamotozawan Stage, Lower Permian Series; **14–17: *Schwagerina jigulensis* (Rauser-Chernousova)**; Atetsu and Akiyoshi Limestone Groups, the "*Pseudoschwagerina*" *minatoi* Zone, lower part of the Upper Hikawan Stage, Upper Carboniferous Series; **13, 18: *Pseudofusulina gregaria* (Lee)**; Atetsu Limestone Group, the *Sphaeroschwagerina fusiformis* Zone, Lower Nagatoan Stage, Lower Permian Series; **19: *Staffella* sp.**; Akiyoshi Limestone Group, the *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone, upper part of the Upper Nagatoan Stage, Lower Permian Series.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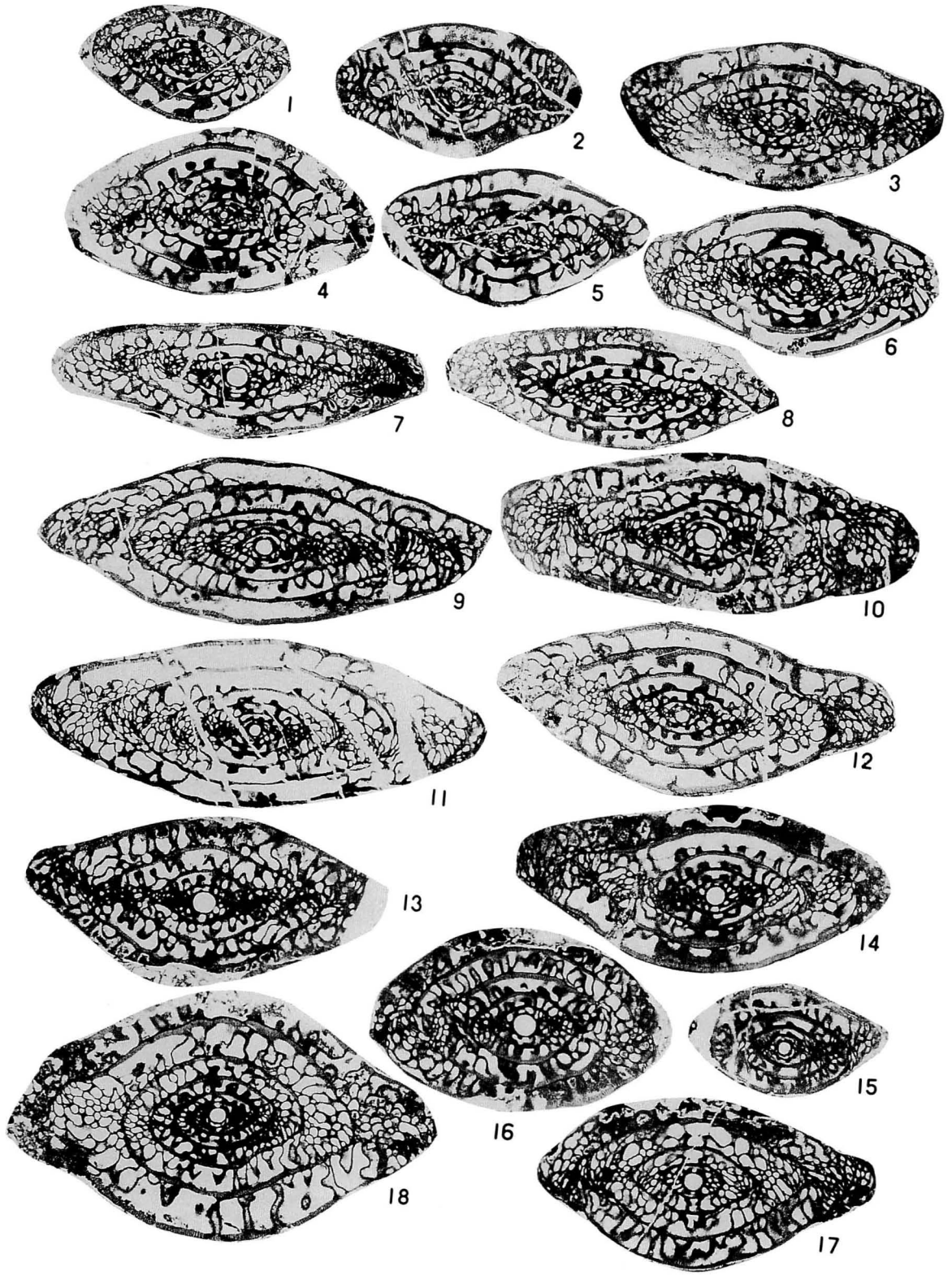
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Montiparus matsumotoi inflatus Watanabe n. subsp. [Figure 20-29–37], *M. matsumotoi matsumotoi* (Kanmera) [Figure 18-7–12], *M. umboplicatus* (Rauser-Chernousova & Beljaev) [Figure 18-13–19], and *Quasifusulinoides* cf. *ohtanii* (Kanmera) [Figure 20-24–25, 27, 28] are obtained from E-34a to E-29 in Section A, GW-11 to GW-8 in Section B, C-5a to C-30 in Section C, and D-56 to D-3 in Section D. These species occur in grey biosparite and biomicrite with partly dark-brown to dark-grey dolomitized limestone that reach about 50 m in the total thickness.

Schwagerina longus formosus (Rosovskaya) [Figure 19-19,20] and *S. magnus* (Rosovskaya) occur in white crinoidal biosparite or biomicritic limestone at E-26 in Section A, GW-1 in Section B, C-21 in Section C, and D-10 in Section D.

White algal biosparitic limestones at E-28b to E-26 in Section A, GW-6 to GW-1 in Section B, C-32 to C-21 in Section C, D-7a to D-7b in Section D, and R8-01 to R8-03 in Section R-8 contain *Schwagerina? satoi* (Ozawa) [Figure 25-1–14], *Quasifusulina longissima* (Moeller) and *Triticites yayamadakensis evectus* Kanmera [Figure 18-20–33].

Rare specimens of "*Pseudoschwagerina*" *minatoi* Kanmera [Figure 29-11,12] and *Paraschwagerina shimodakensis* Kanmera occur at W-00 and W-01 in Section B, D-3 in Section D, and R8-10 and R8-11 in Section R-8. These species occur in white biosparitic limestones, and is associated with *Pseudofusulina stabilis* (Rauser-Chernousova).

Succeeding homogeneous dark-grey biomicritic limestone at D-4 in Section D contains rare specimens of *Sphaeroschwagerina fusiformis* (Krotow).

Sphaeroschwagerina pavlovi (Rauser-Chernousova) [Figure 34-13–19] and *Pseudoschwagerina muongthensis* (Deprat) [Figure 37-14–20] are abundant in dark-grey biomicritic at W-20 to W-22 in Section B, D-2 in Section D, and R8-13 to R8-14 in Section R-8. These species are associated with *Eoparafusulina ellipsoidalis* (Toriyama) [Figure 5-1–14] and *T. samaricus* Rauser.

Rare specimens of *Pseudoschwagerina* cf. *robusta* (Meek) occur at W-24 and W-25 in Section B and R8-15 in Section R-8.

White crinoidal biosparitic limestones at B-100 and B-101 in Section B, D-100 and D-101 in Section D, and R8-16 in Section R-8 contain rare specimens of *Schwagerina globulus japonicus* Watanabe, n. subsp. [Figure 41-15,16] and *Pseudoschwagerina miharanoensis* Akagi.

Paraschwagerina akiyoshiensis Toriyama and *Pseudofusulina firma* Shamov occur at B-103 in Section B and D-102 to D-106 in Section D. Above this horizon come the limestones containing *Pseudofusulina vulgaris vulgaris, P. vulgaris globosa, P. kraffti* and *Misellina claudiae* successively.

The stratigraphic distribution of fusulines stated above allow us to divide the upper Carboniferous to the lower Permian sequence of the Omi Limestone in the Itagamine area into the following zones:

Fig. 9. All photographs ×10. **1–6: *Triticites stuckenbergi* Rauser-Chernousova;** Atetsu and Akiyoshi Limestone Groups, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series; **7–11: *Daixina asiatica* Bensh;** Atetsu and Omi Limestone Groups, the "*Pseudoschwagerina*" *minatoi* to *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, upper part of the Upper Hikawan Stage to lower part of the Middle Nagatoan Stage, Upper Carboniferous to Lower Permian Series; **12–18: *Schwagerina dagmarae* (Rosovskaya);** Atetsu Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series.

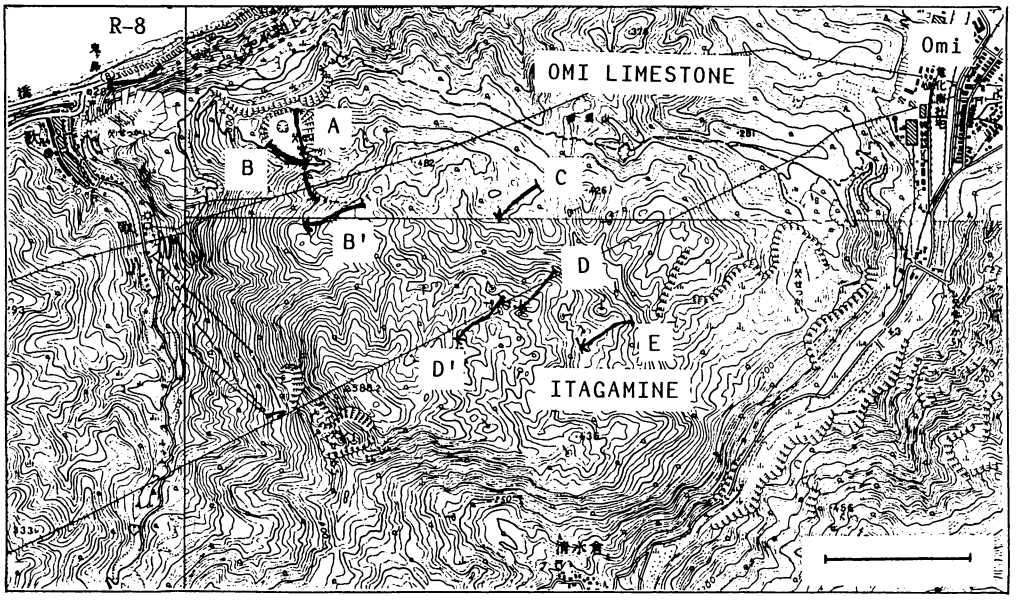


Fig. 10. Index map showing location of measured sections on the Omi Limestone. Section A to C in the sheet map "Itoigawa" (1:25,000), Section D and E in the sheet map "Kotaki" (1:25,000), and Section R-8 in the sheet map "Oyashirazu" (1:25000).

B. Lower Permian Series
  10. *Pseudofusulina vulgaris vulgaris* Zone
  9. *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone
  8. *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone
  7. *Pseudoschwagerina* cf. *robusta* Zone
  6. *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone
  5. *Sphaeroschwagerina fusiformis* Zone
A. Upper Carboniferous Series
  4. "*Pseudoschwagerina*" *minatoi* Zone
  3. *Schwagerina? satoi* Zone
  2. *Montiparus matsumotoi inflatus* Zone
  1. *Obsoletes obsoletus* Zone

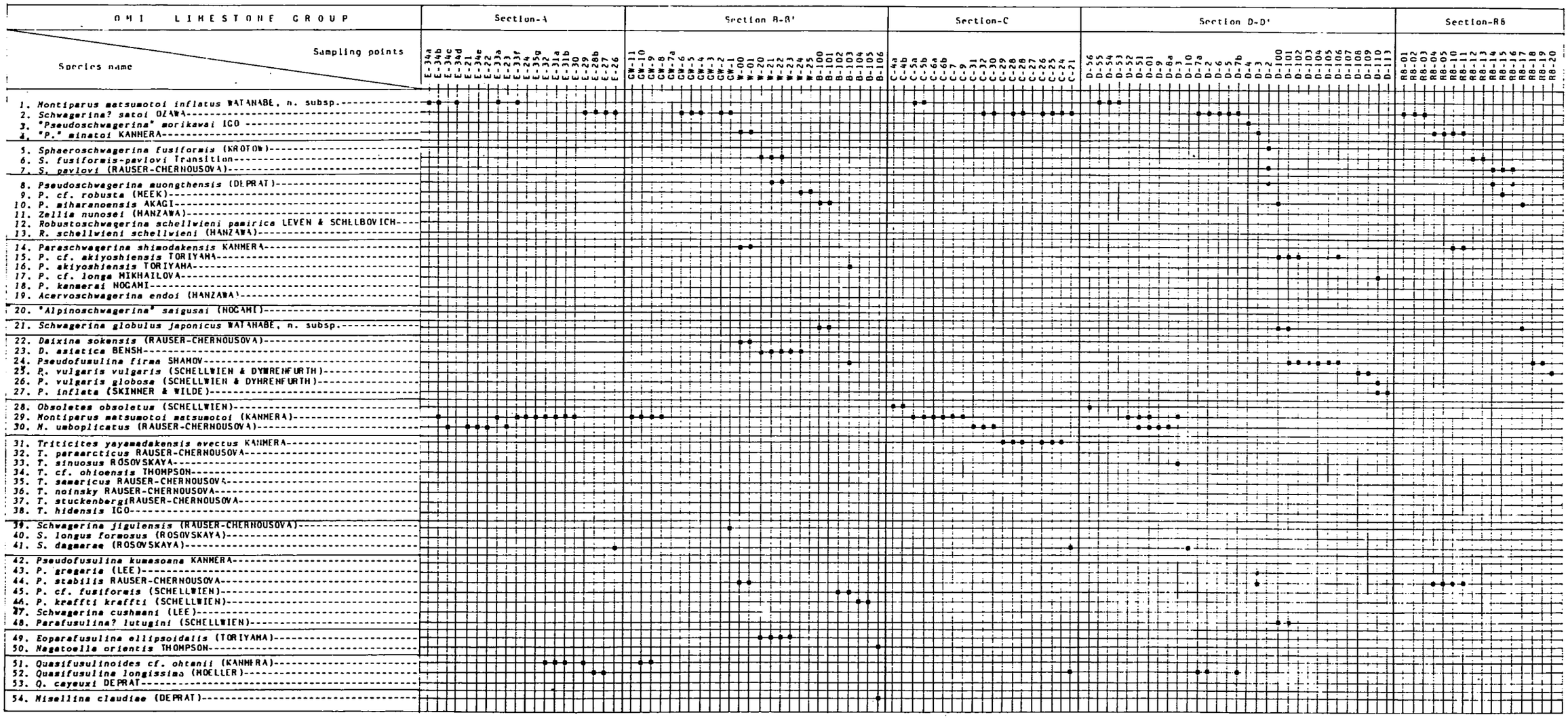
4. Ichinotani and Mizuyagadani Formations

1) Previous Work

A nearly complete sequence ranging from the lower to upper Carboniferous is represented by the Ichinotani and Mizuyagadani Formations in Fukuji, Yoshiki-gun, Gifu Prefecture, Central Japan. The Ichinotani Formation is characterized by grey to dark-grey, thin to thick-bedded limestones with interbeds of dark-grey shale and red shale, the latter of which is originated from residual soil (Igo, 1961). Igo described fusulines from these formations and established the following stratigraphy:

B. Lower Permian Series: Mizuyagadani Formation
  Pseudoschwagerina morikawai Zone
  . . . . . conformity . . . . . .

Table 3. Faunal association was distribution of fusuline species in the measured sections of the Omi Limestone Group.



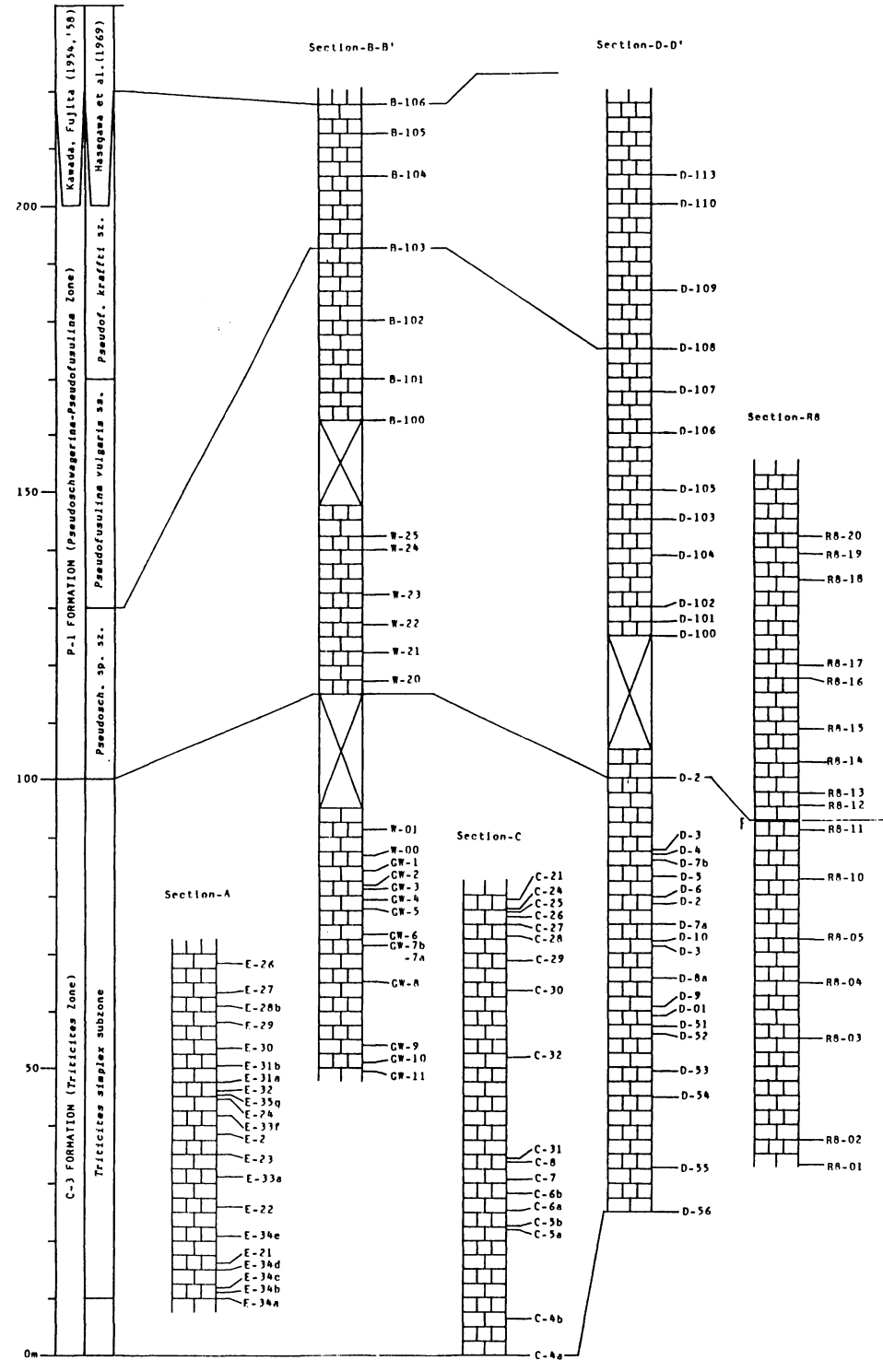
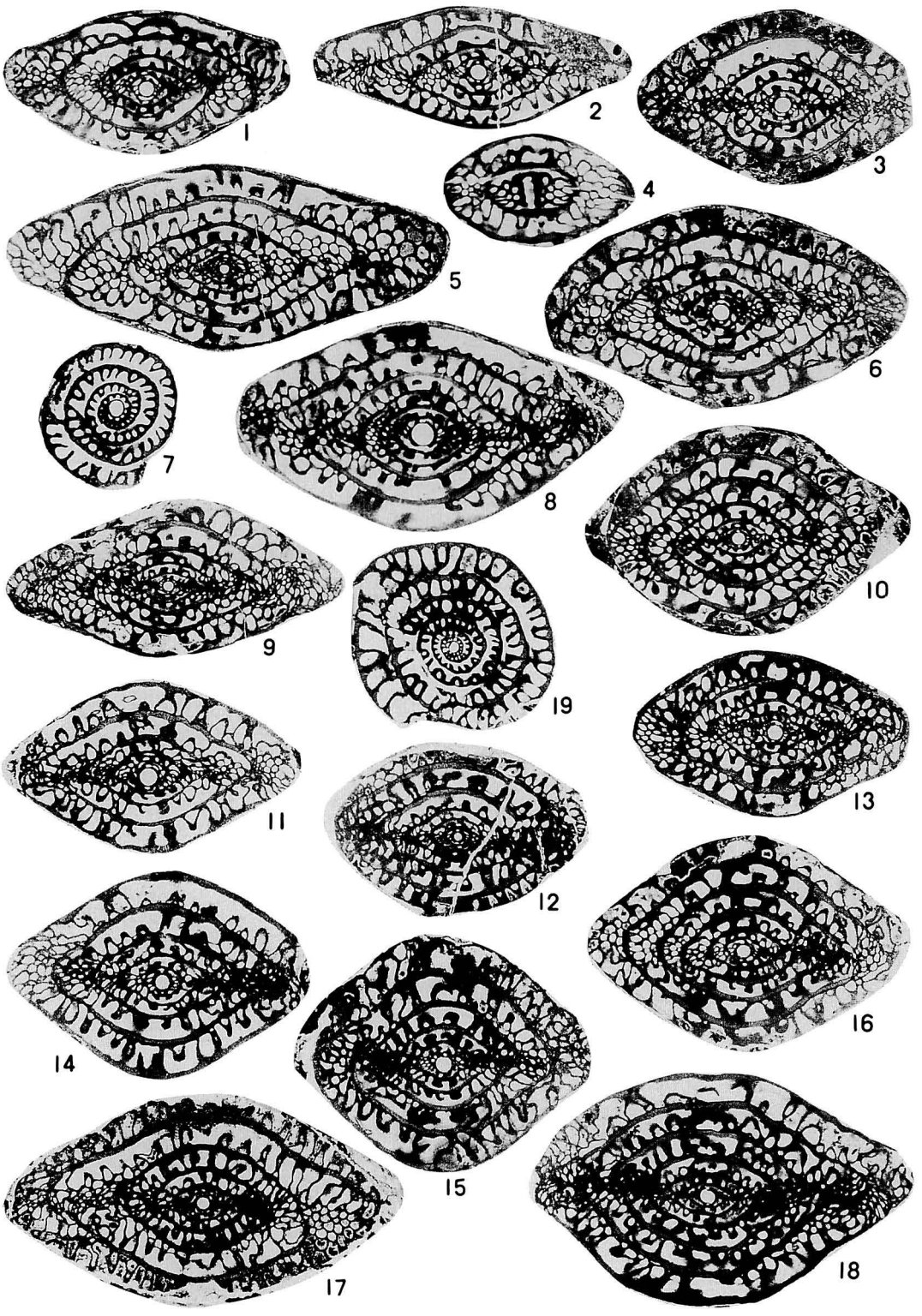


Fig. 11. Measured sections of the Omi Limestone Group, showing locations of fusuline collections.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A. Lower to Upper Carboniferous Series: Ichinotani F.
  c. *Triticites exculptus-T. hidensis* Zone
  b. *Fusulina lanceolata-F. ichinotaniensis* subzone
  a. *Fusulina fujimotoi* subzone

Igo (1978 and others) and Adachi (1980) restudied the Ichinotani Formation in detail on the basis of fusuline fossils, smaller foraminifers, corals and so on. Recently, Igo and Adachi (1984) subdivided this formation as follows:

Upper Member:
5. *Pseudoschwagerina morikawai* Zone
4. *Triticites exculptus* Zone
3. *Fusulinella soligalichi* Zone
2. *Beedeina ichinotaniensis* Zone
1. *Fusulinella bocki asiatica* Zone

They included the *Pseudoschwagerina morikawai* Zone in the Ichinotani Formation, and correlated this zone and the subjacent *T. exculptus* Zone with the Asselian and Kasimovian-Gzhelian Stages, respectively.

Fusuline fossils of the Ichinotani and Mizuyagadani Formations were also described by Niikawa (1978, 1980), and the following divisions were reported from the upper part of the Ichinotani Formation and the Mizuyagadani Formation:

B. Lower Permian Series: Mizuyagadani Group
  3. *Pseudofusulina* Zone . . . 4. P4-Formation / 3. P3-Formation
  . . . . . fault . . . . . .
  2. *Pseudoschwagerina* Zone . 2. P2-Formation / 1. P1-Formation
  . . . . . fault . . . . . .
A. Upper Carboniferous Series: Ichinotani Group
  1. *Triticites* Zone . . . . . b. Upper *Triticites* Zone / . . . . fault . . . . / a. Lower *Triticites Zone*
  . . . . . fault . . . . . .
  Upper *Fusulinella–Fusulina* Zone

Incidentally, Niikawa (1980) elevated the two formations to the rank of Group, and reported the presence of a fault at several levels as shown above. In this sequence, the *Triticites, Pseudoschwagerina* and *Pseudofusulina* Zones were correlated with the Uralian, Asselian and Sakmarian Stages, respectively. Thus in the previous work, the Carboniferous-Permian boundary was placed at the base of the *Pseudoschwagerina morikawai* Zone or the *Pseudoschwagerina* Zone.

2) Present Investigation

I have investigated the stratigraphic distribution of inflated schwagerinids along the Ichinotani and Mizuyagadani valleys, and the following species have been obtained (Figs. 13-15; Table 4):

Fusulinella rhomboidalis NIIKAWA is found at Ic-1 in the upstream of the Ichinotani valley. About 10 m above is dark-grey lenticular biosparitic limestone that is covered by a thin red shale.

Fig. 12. All photographs ×10. **1–19: *Pseudofusulina firma* Shamov;** Loc. 3118 in Section D, Akiyoshi Limestone Group, the "*Alpinoschwagerina*" *saigusai* Zone to *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone, upper part of the Middle Nagatoan to the Upper Nagatoan Stage, Lower Permian Series.

ICHINOTANI-MIZUYAGADANI FORMATIONS	Ichinotani										Mizuyaga-dani					
Species name \ Sampling points	Ic-1	Ic-2	Ic-3	Ic-4	Ic-5	Ic-6	Ic-7	Ic-8	R-A	R-B	R-C	Mz-2a	Mz-2b	Mz-3a	Mz-3b	Mz-4	Mz-5
1. *Fusulinella biconiformis* NIIKAWA	■																
2. *Protriticites variabilis* BENSH		■															
3. *Montiparus exculptus* (IGO)									■								
4. *Triticites hidensis* IGO										■							
5. *Triticites prisca* (SCHELLWIEN)											■						
6. *Triticites yayamadakensis evectus* KANMERA-				■													
7. *Schwagerina (?) satoi* (OZAWA)				■	■	■	■	■	■	■	■						
8. "*Pseudoschwagerina*" *morikawai* IGO											■						
9. "*P.*" *morikawai-minatoi* transition												■					
10. "*P.*" *minatoi* KANMERA														■	■		■
11. *Rugosofusulina alpina* (SCHELLWIEN)											■						
12. *Quasifusulina longissima* (MOELLER)					■	■	■	■	■		■			■	■	■	■

Table 4. Faunal association and distribution of fusuline species in the measured sections of the Ichinotani and Mizuyagadani Formations.

This limestone numbered Ic-2 contains *Protriticites valiabilis* Bensh.

Dark-grey bedded, argillaceous crinoidal limestone at Ic-4 to Ic-8 contains common specimens of *Schwagerina? satoi* (Ozawa) in association with *Quasifusulina longissima* (Moeller).

The type section of the *Triticites* and *Pseudoschwagerina* Zones designated by Igo (1957, 1978) and taken along an temporary path for timber transport on the eastern face of the mountain on the west side of Ichinotani valley (Igo & Adachi, 1981). As this mountainside is at present covered by thick vegetation, no exposures of limestones of these zones have been found. Incidentally, the fusulines of these two zones have been obtained from float boulders, some of which are dark-grey, argillaceous limestones and contain *Triticites exculptus* Igo and *Quasifusulina longissima* (Moeller), and *Schwagerina? satoi* (Ozawa) [Figure 24-26–27] of a smaller form.

From some other floats of a similar lithology, *Triticites hidensis* Igo [Figure 4-15,20] has been obtained along with *Quasifusulina longissima* (Moeller) and *Schwagerina? satoi* (Ozawa) [Figure 24-19–25,28–30] of a larger form.

Rare specimens of "*Pseudoschwagerina*" *morikawai* Igo [Figure 28-3–5] have been also detected from some other floats. This species is associated with *Quasifusulina longissima* (Moeller) and *Rugosofusulina prisca prisca* (Schellwien).

The upper part of the Ichinotani Formation is well exposed in the middle course of a NW-ascending tributary of the Mizuyagadani valley, although that part is segmented by NE— and NW-trending faults into several blocks.

Yellowish-brown taffaceous biomicritic limestone at Mz-2a contains a transitional form between "*Pseudoschwagerina*" *morikawai* and "*P.*" *minatoi* [Figure 28-1–2,6–16], and *Triticites prisca* (Schellwien).

"*Pseudoschwagerina*" *minatoi* Kanmera [Figure 31-1–5] has come from light to dark-grey biomicritic limestones at Mz-3a, Mz-3b and Mz-5. this species is accompanied by *Quasifusulina longissima* (Moeller) [Figure 31-6–11].

The measured upper Carboniferous and lower Permian sections of the Ichinotani and the Mizuyagadani Formation are not represented by a series of continuous exposures. Therefore,

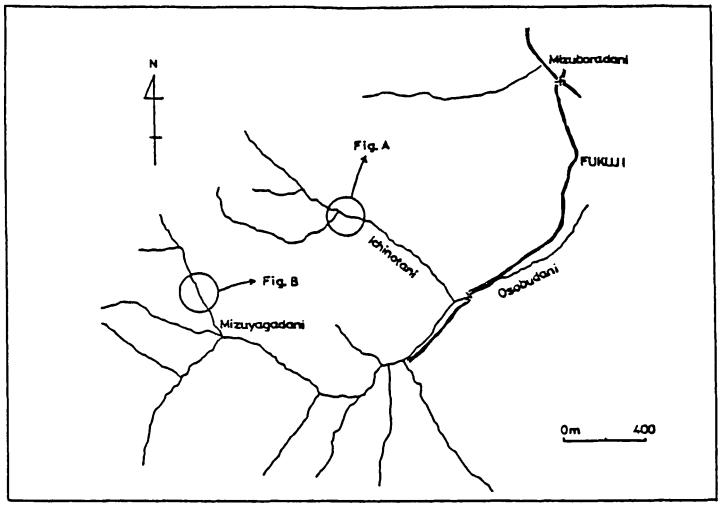


Fig. 13. Index map of the Fukiji area, showing location measured sections shown in Figure 14, 15.

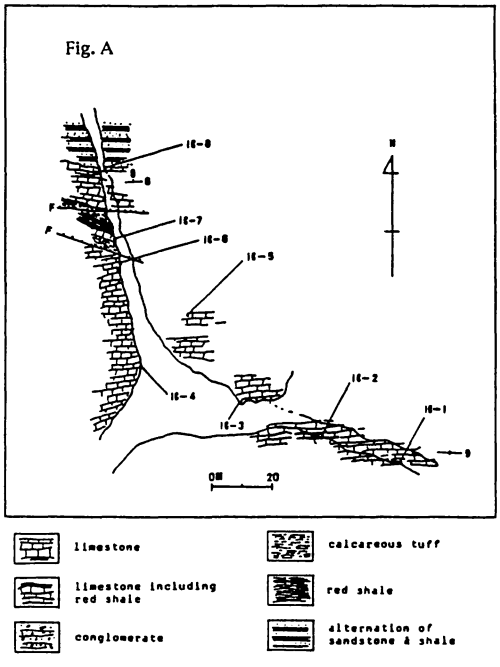


Fig. 14. Geologic route map along the Ichinotani Valley, showing location of fusuline collections.

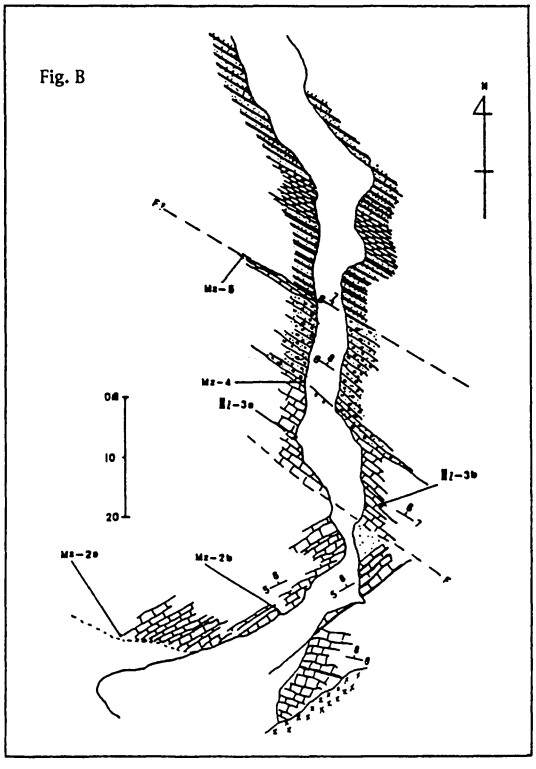


Fig. 15. Geologic route map along the Mizuyagadani Valley, showing location of fusuline collections.

the stratigraphic ranges of individual fusuline species have not always been ascertained definitely. However, available evidence, in addition to the hitherto known data, goes to show that the following zonation based on the inflated schwagerinids is possible:

Upper Carboniferous Series:
5. "*Pseudoschwagerina*" *minatoi* Zone
4. "*Pseudoschwagerina*" *morikawai* Zone
3. *Schwagerina? satoi* Zone
2. Barren Zone
1. *Protriticites variabilis* Zone

3) Faunal Affinities of the Ichinotani Fusulines

The upper Carboniferous fusuline fauna described by Igo (1957) and Niikawa (1978) comprises *Triticites exculptus* Igo, *T. exculptus naviforme* Igo, *T. hidensis* Igo, *T. saurini* Igo, *T. sakagamii* Igo, *Obsoletes obsoletus* (Schellwien), *T. paramontiparus* (Rosovskaya), *T. ichinotaniensis* Niikawa, *T. katoi* Niikawa, *Quasifusulina longissima* (Moeller), and *Q. pseudoelongata* M.-Maklay.

The species of *Triticites* and *Obsoletes* as well as the last two species listed above show striking affinities to those from the Russian Province.

Obsoletes obsoletus by Niikawa (1978, Pl. 2, Fig. 1 only) is closely similar to *O. grozdilovae* (M.-Maklay) from the *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone (Lower Kasimovian Stage) in Fergana.

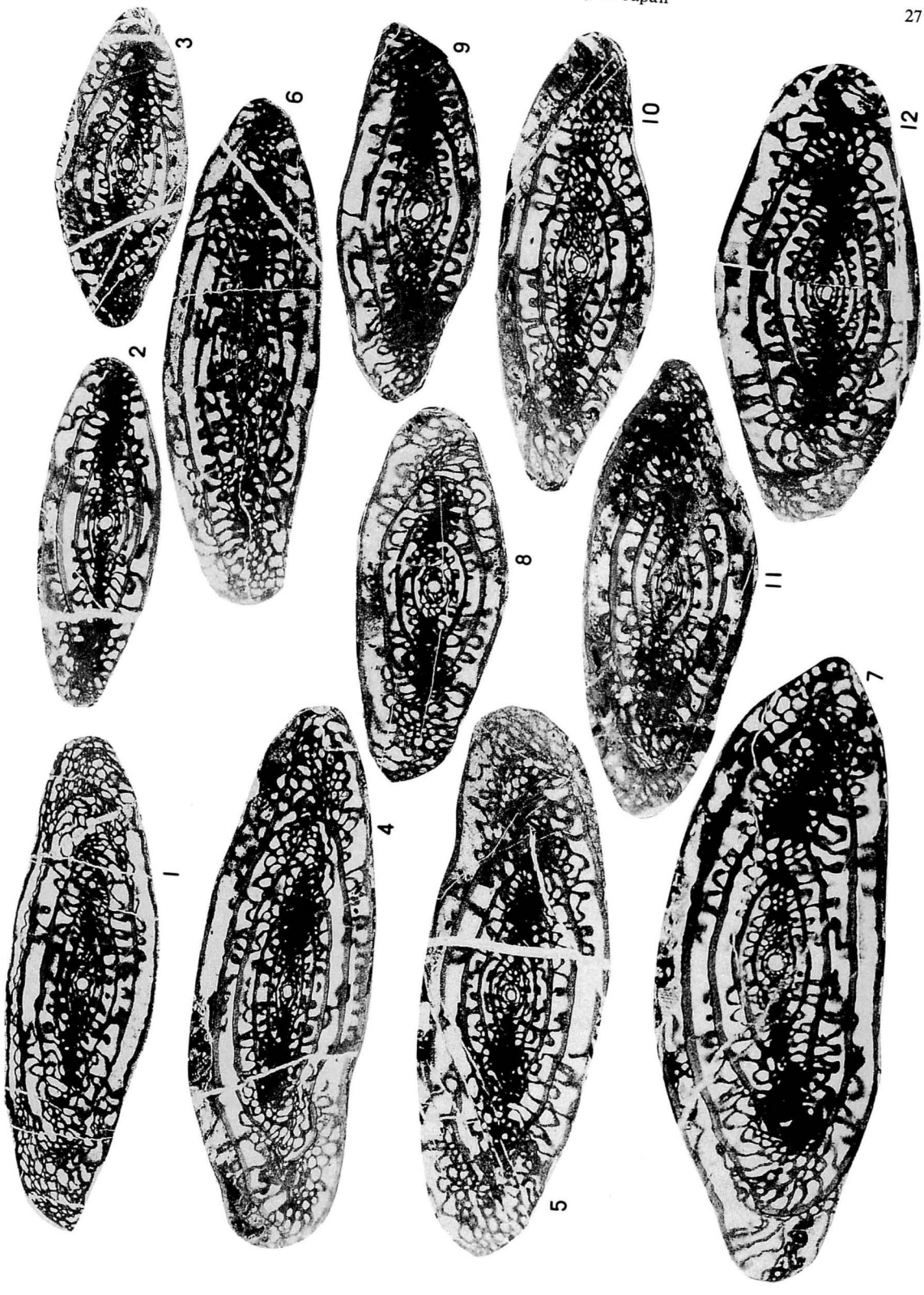
Triticites exculptus and *T. exculptus naviforme* are allied to *Montiparus umboplicatus* (Rauser-Chernousova & Beljaev) from the *Triticites arcticus-T. acutus* Zone (Bensh, 1972) of the Upper Kasimovian in Fergans.

Triticites saurini resembles *Montiparus sinuosus* Rosovskaya from the *Montiparus montiparus* Zone to the *Triticites arcticus-T. acutus* Zone of the Middle to Upper Kasimovian Stage in Ural and Fergana. This species is also allied to *T. pseudoarcticus* Rauser-Chernousova from the *Triticites arcticus-T. acutus* Zone in Pechora (Mikhailova, 1974).

Triticites ichinotaniensis, T. katoi and *T. paramontiparus* described by Niikawa (1978) can hardly be differentiated in general morphology from each other. They occur in association with *Triticites exculptus, T. hidensis* and *Quasifusulina longissima.* On the basis of my populational study of them obtained from one and the same rock sample, the differences among them are thought to be nothing but ontogenetical variations. Furthermore, examination of specimens of *Schwagerina? satoi* from the Ichinotani, Akiyoshi and Omi Limestones indicates that the *Schwagerina? satoi* population perfectly covers the variations of *Triticites ichinotaniensis, T. katoi* and *T. paramontiparus.* Therefore, these species are referable to *Schwagerina? satoi. Triticites expressus* Anosova, which has an inflated and globular form, from the *Montiparus montiparus* Zone to the *Triticites arcticus-T. acutus* Zone in Fergana shows a striking similarity to these species of Fukuji.

The *Pseudoschwagerina morikawai* Zone or the *Pseudoschwagerina* Zone of the Ichinotani Formation yields the following species: "*Pseudoschwagerina*" *morikawai* Igo, *Triticites saurini* Igo, *T. elongatus* Niikawa, *T.* cfr. *kagaharensis* Fujimoto, and *Rugosofusulina alpina* (Schellwien).

Fig. 16. All photographs × 10. **1–12: *Pseudofusulina kumasoana* Kanmera;** Shimoyukawa, Morikuni areas, Atetsu Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series.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Triticites elongatus Niikawa is much allied to *Jigulites longus formosus* Rosovskaya by Rosovskaya (1950) and *J. formosus turanicus* by Bensh (1972) from the *Triticites rossicus-Jigulites formosus turanicus* Zone (Middle Gzhelian Stage) in Fergana and its stratigraphic equivalents in the Russian Platform.

Rugosofusulina alpina by Igo (1957) is also closely similar to *R. prisca prisca* (Ehrenberg) from the *Triticites rossicus* Zone (Mikhailova, 1974) in Pechora and *R. prisca ovoidea* BENSH from the *T. arcticus-T. acutus* Zone (Bensh, 1972) in Fergana.

"*Pseudoschwagerina*" *morikawai* Igo is a Japanese endemic species. It is, however, shows a striking similarity to *Triticites gusanicus* Bensh from the *Triticites rossicus-J. formosus turanicus* Zone (Bensh, 1972) of Fergana.

The *Pseudofusulina* Zone (Niikawa, 1978) yields only *Pseudofusulina* sp. Niikawa. This species is somewhat similar to *Rugosofusulina dastarensis* Bensh from the *Pseudofusulina ferganensis* Zone (Bensh, 1972), Upper Gzhelian Stage in Fergana.

From the above-mentioned faunal comparisons, the *Obsoletes obsoletus* fauna can be assigned to the Lower Kasimovian, the *Triticites exculptus-T. hidensis* fauna to the Upper Kasimovian, the "*Pseudoschwagerina*" *morikawai* and *Pseudofusulina* fauna to the Lower to Upper Gzhelian Stage in Russia.

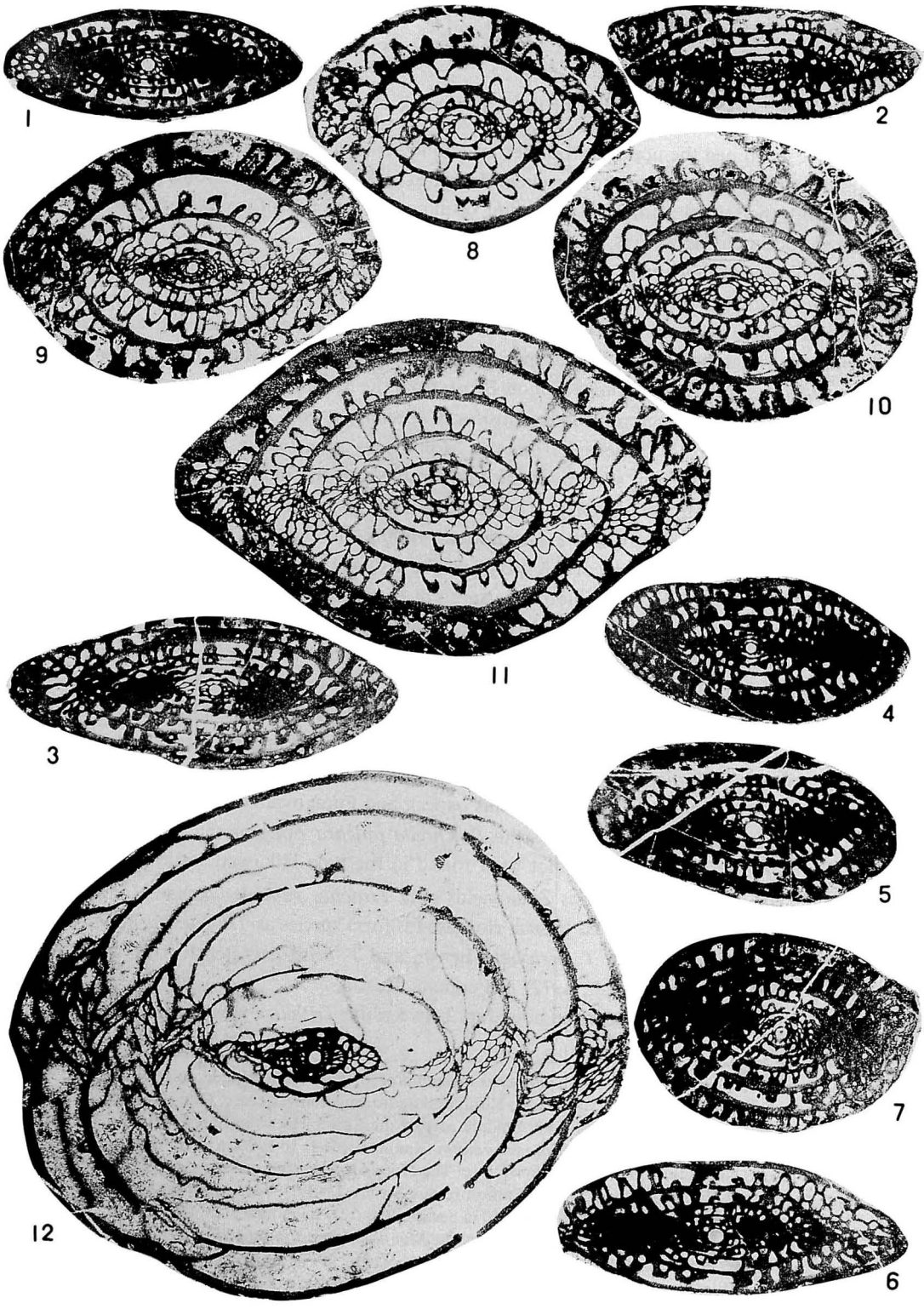
5. Yayamadake Limestone Subgroup

1) Previous Work

The Yayamadake Limestone represents the type sequence of the Middle Carboniferous Kurikian and the Upper Carboniferous Hikawan Stages in Japan. It is distributed in the environs of Mt. Yayamadake along the Hikawa valley in the Yatsushiro district, Kumamoto Prefecture, Southern Kyushu. Kanmera (1951, 1955, 1958) studied the fusuline biostratigraphy of this limestone in detail, and recognized the following six zones:

(Yayamadake Limestone Subgroup)
C. Sakamotozawan: Lower Permian Sereis
2. *Pseudoschwagerina minatoi* Zone
1. *Pseudoschwagerina morikawai* Zone
. . . . . disconformity . . . . . .
B. Hikawan: Upper Carboniferous Series
2. *Triticites yayamadakensis* Zone
1. *Triticites matsumotoi* Zone
. . . . . diastem . . . . . .
A. Kurikian: Middle Carboniferous Series
4. *Fusulina kurikiensis* Zone
3. *Fusulina ohtanii* Zone

Fig. 17. All photographs ×10. **1–7: *Pseudofusulina* cf. *fusiformis* (Schellwien & Dhyrenfurth);** Matsunagi-Section, Atetsu Limestone Group, the *Robustoschwagerina schellwieni pamirica* Zone, lower part of the Sakamotozawan Stage, Lower Permian Series; **8–11: *Pseudofusulina vulgaris globosa* (Schellwien & Dhyrenfurth);** Matsunagi-Section, Atetsu Limestone Group, the *Robustoschwagerina schellwieni pamirica* Zone, the lower part of the Sakamotozawan Stage, Lower Permian Series; **12: *Robustoschwagerina schellwieni pamirica* Leven & Schelbovich;** Matsunagi-Section, Atetsu Limestone Group, the *Robustoschwagerina schellwieni pamirica* Zone, lower part of the Sakamotozawan Stage, Lower Permian Series.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The base of the Hikawan is noted to being marked by a minor diastem and the top of the Hikawan by disconformity.

2) Faunal affinity of the Yayamadake fusulines and zonation

I have examined the upper Carboniferous and lower Permian sequence of the Yayamadake Limestone and the thin-sections of fusulines described by Kanmera (1955, 1958). In the following is dealt with the faunal affinity of important fusulines on the basis of my examination of newly collected specimens as well as Kanmera's collection.

The *Triticites matsumotoi* zone contains *Triticites matsumotoi* Kanmera, *Quasifusulina longissima* (Moeller) and *Staffella* sp.

Populational study indicates that *Triticites matsumotoi* has a wide variation in shell morphology. A globose form of this species from the lower part of this zone is closely similar to *Protriticites subschwagerinoides inflatus* Bensh from the *Montiparus montiparus* Zone (Bensh, 1972) in the Fergana region, Russia. Fusiform specimens with pointed poles are allied to *Montiparus montiparus* (Moeller) from the *Montiparus montiparus* Zone (Bensh, 1972) in Fergana. Elongate-fusiform specimens are comparable with the intermediate form between *T. matsumotoi* and *T. yayamadakensis*. This is also similar to *Montiparus umboplicatus* (Rauser-Chernousova & Beljaev) from the *Montiparus montiparus* Zone in the Russian Platform. Consequently, these three forms of this species can be assigned to *Montiparus matsumotoi inflatus* Watanabe, n. subsp., *M. matsumotoi matsumotoi* (Kanmera) and *M. umboplicatus* (Rauser-Chernousova & Beljaev), respectively. The strata containing these three species are designated as the *Montiparus matsumotoi inflatus* Zone, and are correlative with the *Montiparus montiparus* Zone of the Middle Kasimovian Stage in Russia. In the Tethys province, the *Obsoletes obsoletus* Zone is widely recognized in the lowest upper Carboniferous strata. Besides the Yayamadaka Limestone, this diagnostic species is also a good index to define the upper Carboniferous in Japan, for example, the *Obsoletes obsoletus* Zone established in the Omi Limestone (Watanabe, this paper), Akiyoshi Limestone (Watanabe, this paper), and Futagoyama Limestone (Morita, 1984 MS). This zone conformably overlies the *Pulchrella pulchra* Zone or the *Fusulinella gracilis-Fusulina ohtanii* Zone, but it has not been found in the type Hikawan section.

The *Triticites yayamadakensis* Zone yields only *Triticites yayamadakensis* Kanmera. This diagnostic species is closely related to such elongate-fusiform species as *Triticites fusiformis* BENSH and *T. parafusiformis* Bensh, *T. perlongus* Bensh, and *T. gissaricus* Bensh from the *Triticites arcticus-T. acutus* Zone (Bensh, 1972) in Fergana, Russia.

The limestone exposed near the boundary between the *Triticites yayamadakensis* Zone and

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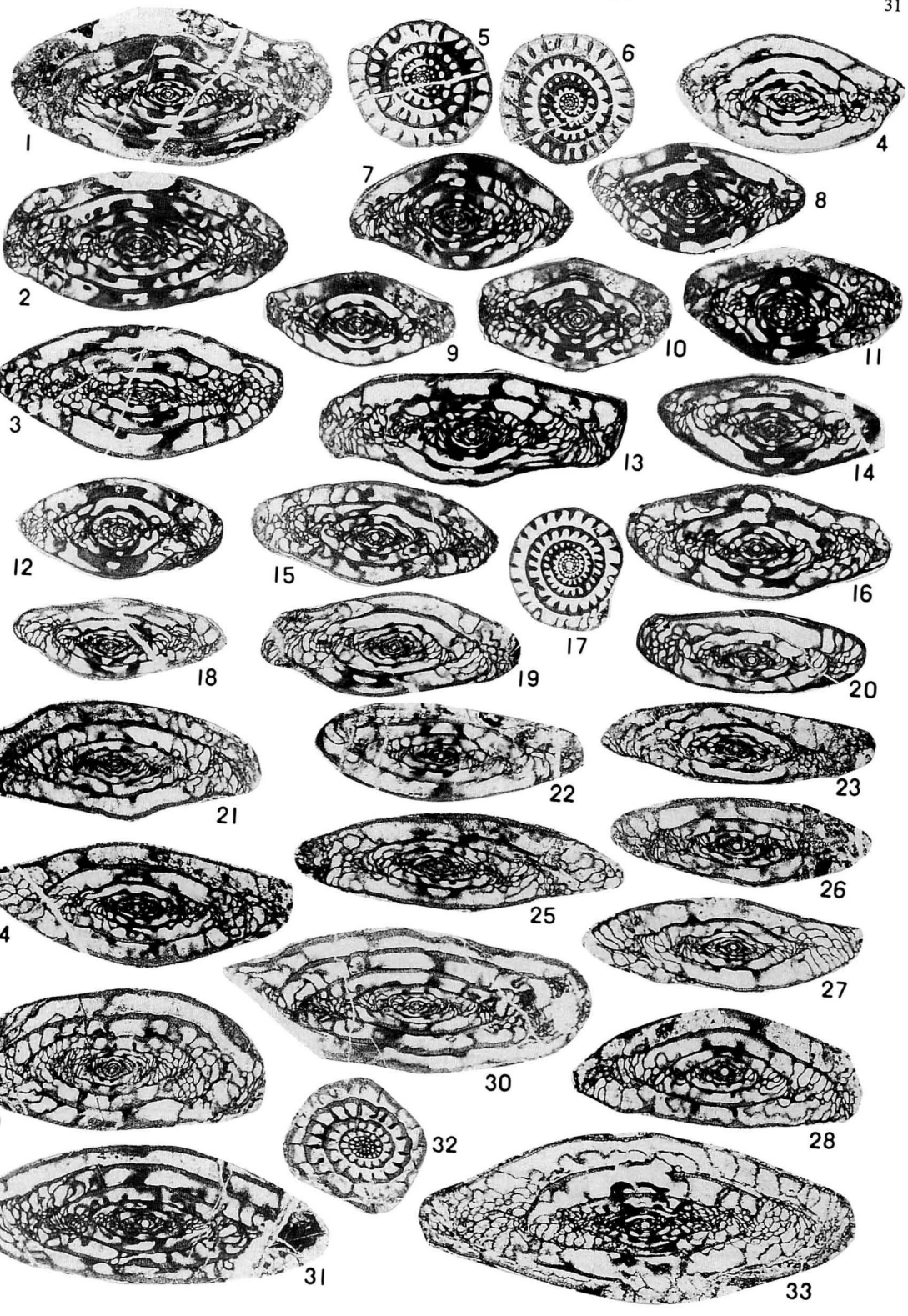
Fig. 18. All photographs × 10. **1–6: *Montiparus matsumotoi inflatus* Watanabe, n. subsp.**; Loc. D-1 to D-3 in Section D, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Montiparus matsumotoi inflatus* Zone, middle part of the Lower Hikawan Stage, Upper Carboniferous Series; **7–12: *Montiparus matsumotoi matsumotoi* (Kanmera)**; B-31 to B-28 in Section B, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. The *Montiparus matsumotoi inflatus* Zone, the middle part of the Lower Hikawan Stage, Upper Carboniferous Series; **13–19: *Montiparus umboplicatus* (Rauser-Chernousova & Beljaev)**; Loc. B-30 and D-10 in Section B and D, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Montiparus matsumotoi inflatus* Zone, the middle part of the Lower Hikawan Stage, Upper Carboniferous Series. **20–33: *Triticites yayamadakensis evectus* Kanmera**; Akiyoshi, Atetsu, Omi Limestone Groups, the *Schwagerina? satoi* Zone, the upper part of the Lower Hikawan Stage, Upper Carboniferous Series.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the overlying "*Pseudochwagerina*" *morikawai* Zone is highly dolomitized or silicified and partly interbedded with thin limestone conglomerate.

The "*Pseudoschwagerina*" *morikawai* Zone is a little obliquely disposed on the *Triticites yayamadakensis* Zone. Lying stress on this stratigraphic evidence, many previous workers placed the Carboniferous-Permian systemic boundary in Japan between these two zones.

The "*Pseudoschwagerina*" *morikawai* Zone is defined by the range of "*Pseudoschwagerina*" *morikawai* Igo and *Quasifusulina longissima ultima* Kanmera, and the association of *Triticites montiparus* (Moeller), *T. ozawai* Toriyama, *T.* aff. *haydeni* (Ozawa), *T. yayamadakensis evectus* Kanmera, and *Rugosofusulina prisca* (Moeller).

"*Pseudoschwagerina*" *morikawai* is thought to be endemic to Japan, but it is somewhat similar to *Triticites gusanicus* Bensh from the *Triticites rossicus-Jigulites formosus turanicus* Zone (Bensh, 1972) in Fergana.

Rugosofusulina prisca (Moeller is closely allied to *Triticites noinsky plicatus* Rosovskaya, *T. noinsky noinsky* Rauser-Chernousova, *Daixina prisca* Bensh and *D. asiatica* Bensh from the Upper Kasimovian and Middle Gzhelian Stages in Russia.

Triticites yayamadakensis evectus resembles *T. gissaricus* Bensh and *T. parafusiformis* Bensh from the *Triticites arcticus-T. acutus* Zone (Bensh, 1972) in the Fergana region, Russia.

Triticites aff. *T. haydeni* is allied to *Triticites kurshabensis* Bensh from the Upper Kasimovian in Fergana.

Triticites montiparus by Kanmera recorded from limestone conglomerate of the lower part of the "*Pseudoschwagerina*" *morikawai* Zone is referable to *Schwagerina? satoi* (Ozawa). *Schwagerina? satoi* is a diagnostic species of "*P.*" *morikawai* Zone in the Akiyoshi, Atetsu, Omi and Futagoyama Limestone Groups. Then, this species has probably been drived from the lower horizon.

Consequently, the "*Pseudoschwagerina*" *morikawai* Zone is correlative with the Lower Gzhelian Stage in Russia.

The uppermost fusuline zone of the Yayamadake limestone, the "*Pseudoschwagerina*" *minatoi* Zone (Kanmera, 1978), is defined by the range of "*P.*" *minatoi* Kanmera and *Triticites* aff. *T. pusillus* (Schellwien). *Paraschwagerina shimodakensis* Kanmera and *Schwagerina grandensis* Thompson appear in the lower part of this zone. *Pseudofusulina regularis* (Schellwien) and *P. santyuensis* Fujimoto occur in the upper part, *Schwagerina stabilis* Rauser-Chernousova and *Pseudofusulina kumasoana* Kanmera also in the upper part. *Triticites fornicatus* Kanmera and *T. samaricus* Rauser-Chernousova occur in the uppermost part of this zone. "*Pseudoschwagerina*" *minatoi* is a diagnostic species of this zone, and the distribution of this species and its allied ones is limited in the Japanese Islands and Inner Mongolia of China. Some Russian inflated *Triticites,* such as *Triticites globoides* Mikhailova and *T. expressus* Anosova from the *Montiparus montiparus* Zone (Mikhailova, 1974; Bensh, 1972) and the *Triticites arcticus-T. acutus* Zone (Bensh, 1972),

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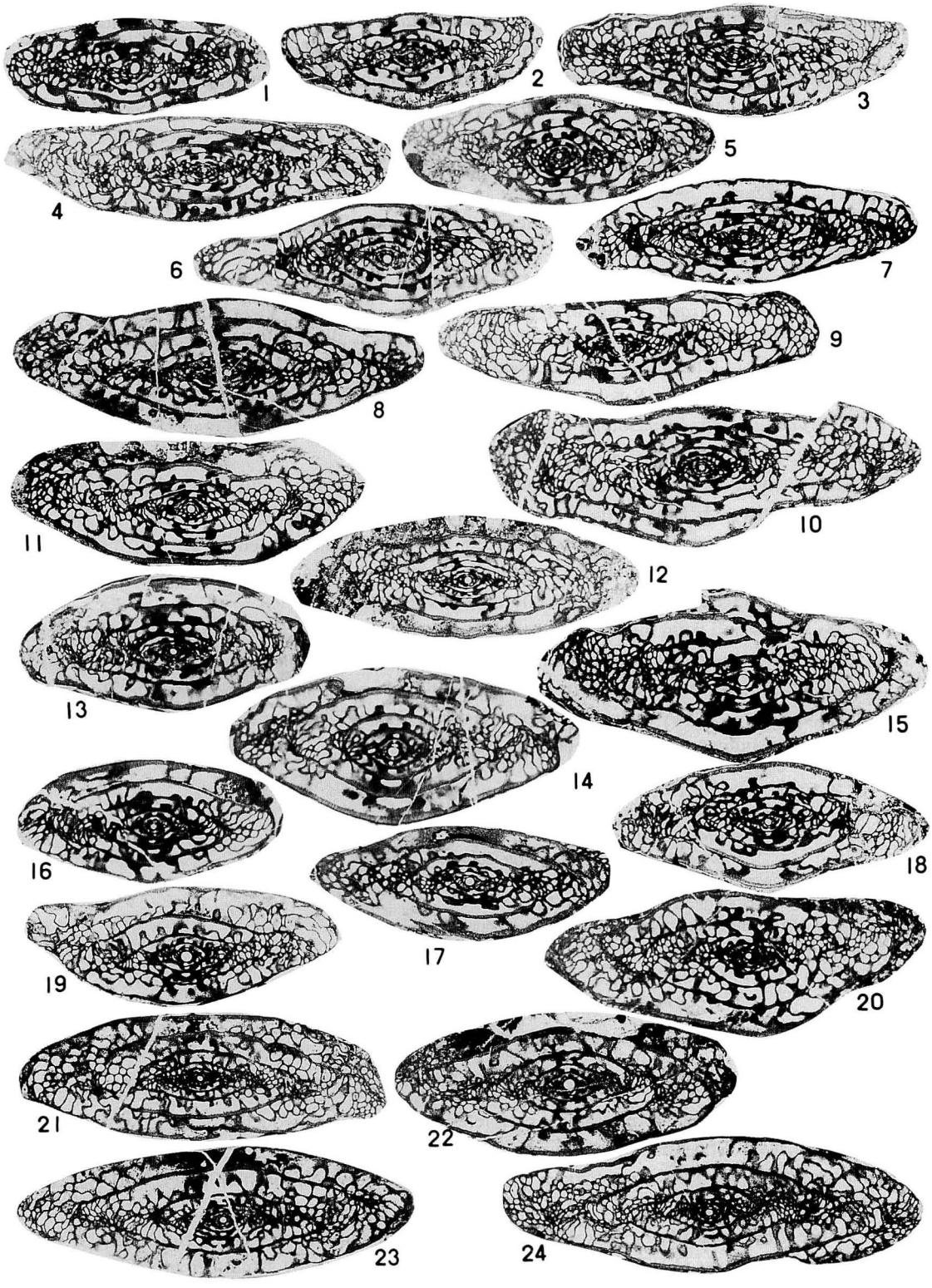
Fig. 19. All photographs ×10. **1–8: *Triticites paraarcticus* Rauser-Chernousova;** Atetsu and Akiyoshi Limestone Groups, the *Schwagerina? satoi* Zone, the upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **9, 10: *Triticites sinuosus* Rosovskaya;** Akiyoshi Limestone Group, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **11–18: *Triticites sinuosus* Rosovskaya;** 11, 18. Mizuyagadani valley, Fukuji; 12–17. Atetsu and Akiyoshi Limestone Groups, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **19–24: *Schwagerina longus formosus* (Rosovskaya);** 19, 20: Omi Limestone; 21–24. Akiyoshi Limestone Group, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series.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are somewhat allied to "*Pseudoschwagerina*" *minatoi*. They show the same evolutional stage as *Montiparus matsumotoi inflatus* and *Schwagerina? satoi* of Japan.

Paraschwagerina shimodakensis is the first appearance of paraschwagerinas in Japan, and is closely similar to *Paraschwagerina archaica* Leven & Schelbovich from the upper part of the *Jigulites jigulensis* Zone (Leven and Schelbovich, 1978) in the Darvus region, Russia. Also allied is *Alpinoschwagerina paranitida* Bensh from the *Occidentoschwagerina alpina* Zone (Bensh, 1972) in Fergana.

Some elongate schwagerinids species in this zone are allied to the Russian species from the Gzhelian Stage.

Schwagerina grandensis Thompson is referable to *Jigulites jigulensis formosus* Rosovskaya or *J. formosus turanicus* Bensh from the Lower to Middle Gzhelian Stage in Russia.

Pseudofusulina sokensis and *P. santyuensis* are much allied to the type species of *Daixina sokensis* (Rauser-Chernousova) and *Jigulites formosus* Rosovskaya, respectively, from the Upper Gzhelian Stage in Russia.

Pseudofusulina kumasoana resembles *Rugosofusulina praevia agregia* Shlykova from C_3C-C_3D zones in the Russian Platform.

Schwagerina stabilis is identical with the type species of *S. stabilis* and *Pseudofusulina gregaria* (LEE) from the C_3E zone in the Russian Platform.

Triticites fornicatus is described from the Lower to Middle Asselian Stage in the Darvus region, Russia. *Triticites uniensis* Grozdilova & Lebedeva from the Lower Asselian in Timan (Grozdilova and Lebedeva, 1961) is referable to this species.

As understood from the above mentioned evidence, the "*Pseudoschwagerina*" *minatoi* Zone of the type section is correlative with the Upper Gzhelian Stage in Russia. It should be noted here that no species of *Sphaeroschwagerina,* the lower Permian index, has been found from this zone. Then, the formerly designated Japanese upper Carboniferous and lower Permian standard stages and fusuline zonation can be amended as follows:

B. Upper Carboniferous Series
  2. Upper Hikawan Stage
    b. "*Pseudoschwagerina*" *minatoi* Zone
    a. "*Pseudoschwagerina*" *morikawai* Zone
  1. Lower Hikawan Stage
    b. *Triticites yayamadakensis* Zone
    a. *Montiparus matsumotoi inflatus* Zone
A. Middle Carboniferous Series
    Kurikian Stage

6. Sakamotozawa Formation

1) Previous Work

The Sakamotozawa Formation has been referred to as the type sequence of the Lower Permian Sakamotozawan Stage in Japan. This formation is distributed typically in the environs of Mt. Tashiroyama along the Sakamotozawa valley in the Kesen district, southern part of the Kitakami massif, Northeast Japan.

Since the name of the Sakamotozawa Formation and the Sakamotozawan Stage first introduced by Onuki (1937), the sequence has been investigated by a number of geologists and

paleontologists (Minato, 1942; Minato et al., 1954, 1964; Morikawa, 1953b; Murata, 1971; Onuki, 1956, 1980; Yamada, 1959; Kanmera and Mikami, 1965a, 1965b; Mikami, 1965).

Paleontological studies of fusuline fossils of the formation were undertaken by Hanzawa (1938, 1939), Toriyama (1952), Fujimoto (1956), Morikawa (1953b), Chisaka (1962), Igo (1964a) and Choi (1972, 1973). These works somewhat clarified the stratigraphy and paleontology of the formation, and the lower part of this formation was roughly regarded as the "*Pseudoschwagerina*" zone or the *Pseudoschwagerina-Pseudofusulina* Zone. Kanmera and Mikami (1965a, 1965b) and Mikami (1965) largely revised the stratigraphic sequence and divided this formation into five zones as follows:

B. Lower Permian Series
  c. Kanokura Formation
    . . . . . conformity or unconformity . . . . . .
  b. Sakamotozawa Formation: Sakamotozawan Stage
    2. Upper Subformation
      Member Sd . { 7. *Pseudofusulina ambigua* Zone
                  { 6. *Pseudofusulina fusiformis* Zone
      Member Sc . .5. *Pseudofusulina vulgaris* Zone
      . . . . . unconformity . . . . . .
    1. Lower Subformation
      Member Sb_3 . .4. Barren Zone
      Member Sb_2 . .3. *Nipponitella explicata-Monodiexodine langsonensis* Zone
      Member Sb_1 . .2. *Zellia nunosei* Zone
      Member Sa . . .1. Barren Zone
      . . . . . unconformity . . . . . .
A. Middle Carboniferous Series
  a. Nagaiwa Formation

2) Faunal affinity of the Sakamotozawa fusulines and Zonation

The Sakamotozawa Formation rests on the Lower Middle Carboniferous Nagaiwa Formation with distinct unconformity. The lowest Member Sa begins with a basal conglomerate and is succeeded by sandstone and black shale in the middle and upper parts. A silty sandstone bed of the middle part contains abundant fusuline casts. *Quasifusulina cayeuxi* (Deprat) and *Monodiexodina langsonensis* (Saurin) are recognized in this member. These species are also recognized in Members Sb_1 and Sb_2 of the Lower Subformation.

The *Zellia nunosei* zone occupies the main part of Member Sb_1 and is characterized by the occurrence of *Zellia nunosei* (Hanzawa), *Quasifusulina tenuissima* (Schellwien), *Nipponitella explicata* Hanzawa, *Monodiexodina langsonensis* (Saurin), *Rugosofusulina alpina* (Schellwien), *R.* sp., *Paraschwagerina* (*Acervoschwagerina*) sp. B, and *Paraschwagerina* sp. In addition, *Robustoschwagerina schellwieni pamirica* Leven & Schelbovich has been newly obtained from thin-bedded algae-rich limestone in the lowest part of this zone on my field investigation.

Zellia nunosei [Fig. 21-1–10] is stratigraphically restricted to Member Sb_1 and shows a wide morphological variation. This species is closely similar to the following species: *Zellia amedaei* Deprat) in Laos; *Z. heritschi colanii* (Kahler & Kahler) by Saurin in Vietnam; *Z. colanae* Kahler & Kahler by Chang in China; *Z. crassialveola* Chang by Leven and Scherbovich in Darvus, Russia; *Z. amedaei* (Deprat) by Leven in Afganistan; *Pseudoschwagerina galatea* Ciry and *P. necleolata* Ciry in Turkey; *P. nucleolata prisca* Kochansky-Devide in Yugoslavia. The strata containing these species are correlated with the Sakmarian Stage in Russia.

Robustoschwagerina schellwieni pamirica Leven & Schelbovich newly obtained from Sk-3 of Member Sb_1 is closely allied to the type specimen from the *Robustoschwagerina schellwieni* Zone (Leven and Schelbovich, 1978) in Darvus, Russia. This species is identical in morphological features with *R. schellwieni* (Hanzawa) from *Robustoschwagerina schellwieni* Zone (Kahler, 1974b) of the Trogkofel-Kalk in Carnic Alps. This zone was correlated by Kahler (1974) with the whole part of the Sakmarian Stage in Russia.

Schwagerina cushmani (Chen) newly obtained from this zone is closely similar to *S. cushmani* (Chen) from the *Schwagerina cushmani* Zone (Zhou, 1982) of the Chihsia Formation in southeastern Hunan, China. This species is also allied to *Schwagerina pamirica* (Leven) from the Sakmarian Horizon (Leven, 1967) in Pamir.

Quasifusulina tenuissima is thought on the basis of populational study to be referable to *Q. cayeuxi* (Deprat).

The *Monodiexodina langsonensis-Nipponitella explicata* Zone that occupies the uppermost part of Member Sb_1 and the large part of Member Sb_2 is characterized by the abundant occurrence of *Monodiexodina langsonensis* (Saurin), *Nipponitella explicata* (Hanzawa), *Rugosofusulina alpina* (Schellwien), and *R. rossica* (Schellwien).

Monodiexodina langsonensis resembles *Pseudofusulina? perplexa* Grozdilova and Lebedeva from the Tastubsky Horizon of the Lower Sakmarian Stage in the Timan region (Grozdilova and Levedeva, 1961) and is also closely similar to *Eoparafusulina thompsoni* Skinner and Wilde form the zone E of the MacCloud Limestone in California. The Timan species is associated with *Pseudofusulina indigaensis* Grozdilova & Levedeva and *P. paraverneuili* Vissarinova, which bear some resemblance to *Rugosofusulina alpina* (Schellwien) and *T. rossica* (Schellwien) from Member Sb_2. The Tastubsky Horizon in Timan was correlated with the *Pseudofusulina moelleri* Zone of the type Sakmarian in Ural, Russia.

Nipponitella explicata is an aberrant, uncoiled species. In Japan it is known only from the Kitakami Massif. Meanwhile, *Nipponitella explicata* was newly discovered together with *Zellia colaniae* from the upper part of the Amshan Formation in Inner Mongolia, China (Han & Guo, 1979). This species is somewhat similar to *Pseudofusulina? recondita* Grozdilova and Lebedeva from the Tastubsky Horizon in Timan, although the latter has no uncoiled volutions.

To summarize, the *Zellia nunosei* Zone is correlative with the Sakmarian Stage in Russia.

The *Pseudofusulina vulgaris* Zone in the lower part of the Upper Subformation (Member Sc) unconformably overlies by the Barren zone of Member Sb_3. This zone is characterized by *Pseudofusulina vulgaris* (Schellwien), *P. vulgaris globosa* (Schellwien), *P.* aff. *japonica* (Guembel), *Rugosofusulina* aff. *serrata* Rauser-Chernousova, *Schwagerina* aff. *compacta* (White), *Toriyamaia laxiseptata* Kanmera, and *Robustoschwagerina schellwieni* (Hanzawa).

Pseudofusulina vulgaris, a zonal diagnostic species, was studied in detail by Kanmera and Mikami (1965) and three forms were separated subspecifically as follows: *P. vulgaris vulgaris, P. vulgaris globosa,* and *P. vulgaris watanabei.* In the same year, Skinner and Wilde (1965b) proposed the new genera *Cuniculinella* and *Chalaroschwagerina* for the species group of *Pseudofusulina vulgaris* of the Tethys province.

Highly evolved forms with a large shell and cuniculi was first discussed by Morikawa (1952) and was referred to the genus *Parafusulina?*. The species named "*globosa*" by Deprat is a junior synonym of *P. vulgaris globosa* (Schellwien & Dyhrenfurth). For the time, I follow Kanmera and Mikami's opinion.

Pseudofusulina vulgaris vulgaris is a diagnostic species of the lower half of the Ulkian Stage that corresponds to the lower half of the type Artinskian Stage in Russia.

P. vulgaris globosa occurred from Members Sc and Sd has a wide morphological variation. A globose-form of this species is closely similar to *Chalaroschwagerina inflata* Skinner & Wilde from Zone G of the MacCloud Limestone in California.

Robustoschwagerina schellwieni schellwieni (Hanzawa) [Fig. 45-1–4] occurred in this zone is accompanied with *P. vulgaris globosa* and *P. vulgaris vulgaris*. I have recognized the same association at the type locality of the Nishikori Formation, Maiya district, Miyagi Prefecture. Here, the strara containing *R. schellwieni schellwieni* in this formation is correlative with Member Sc of the Sakamotozawa Formation. *R. hidensis* Igo from the Lower part of the Sote Formation of the Hida Mountains (Igo, 1964b) is included within a variation of this species, on the basis of my populational study. *R. tumida* (Likharev) from the Upper Artinskian Stage is closely similar to *R. schellwieni schellwieni* in Member Sc.

Pseudofusulina kraffti kraffti (Schellwien & Dyhrenfurth) from the upper part of this zone is also a diagnostic species of the Middle Ulkian Stage or the Middle Artinskian Stage in Russia.

Rugosofusulina sp. aff. *R. serrata* is closely allied to *Pseudofusulina lianyuanensis* (Zhou) and *P. wulungensis* Zhou from the *Schwagerina cushmani* Zone (Zhou, 1982) in the lowest part of the Chihsia Formation, southeastern Hunan, China. This species is also allied to *Pseudofusulina nalivkini* Leven from the Artinskian Stage in the Pamir region, Russia.

Schwaggerina sp. aff. *S. compacta* (White) is similar to *Pseudofusulina parviflucta* Zhou from the upper part of the *Schwagerina cushmani* Zone (Zhou, 1982) of the Chihsia Formation. This species is also allied to *P. nalivkini* Leven from the Artinskian Stage in Pamir, Russia.

To sum up, the *Pseudofusulina vulgaris* Zone is exactly correlative with the Lower Ulkian Stage or the Lower Artinskian Stage in Russia.

The *Pseudofusulina fusiformis* Zone is the lower part of Member Sd is characterized by the association of *Pseudofusulina fusiformis* (Schellwien), *Nagatoella minatoi* Kanmera and Mikami and *Toriyamaia laxiseptata* Kanmera.

Pseudofusulina fusiformis is a diagnostic species of the Upper Ulkian Stage or the *Misellina* Zone (Leven, 1967; Leven and Schelbovich, 1978) in the Darvus region, Russia.

Nagatoella minatoi is also a good index species of this zone and is similar to *Darvacites zulmartensis* Leven from the Upper Artinskian Stage, the *Misellina* Zone, in Darvus. This species is also allied to *Eoparafusulina nitida* Skinner and Wilde from Zone F of the MacCloud Limestone in California.

The *Pseudofusulina ambigua* Zone which occupies the upper part of Member Sd is characterized by *Pseudofusulina ambigua* (Deprat). This species is allied to *Pseudofusulina* ex gr. *kalmykovae* Leven of the Upper Ulkian Stage or the Upper Artinskian Stage in Russia.

To sum up, the two zones of Member Sd is exactly correlative with the Upper Ulkian or the Upper Artinskian Stage in Russia.

The Sakamotozawa Formation is conformably overlain by the Kanokura Formation in the type section (Kanmera and Mikami, 1965), but in Kesen district it is unconformably overlain by the Kanokura Formation (Tazawa, 1978; Minato and Kato, 1964).

No species of *Misellina* has been found in the type Sakamotozawa Formation, but Choi (1972, 1973) confirmed the existance of *Misellina* in his *Chalaroschwagerina vulgaria* Zone (Choi, 1973)

and a little higher horizon in the Setamai-Yahagi area. Incidentally *Misellina* is known as a marker of the Upper Ulkian Stage in the Darvus and Pamir regions.

Consequently, the Sakamotozawan Stage can be correlated with the Sakmarian and Artinskian Stages of the type sequence in Russia. The following zones based on inflated schwagerinids and recognized in the Sakamotozawa formation:

(Sakamotozawa Formation)
b. *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone
a. *Robustoschwagerina schellwieni pamirica-Zellia nunosei* Zone

III. Upper Carboniferous and Lower Permian Fusuline Faunas of Other Relevant Areas

1. Chichibu Terrane in Kyushu

Besides the Yayamadake Limestone Subgroup, the upper Carboniferous and lower Permian fusuline faunas were reported from the Tsukumi Limestone and described from the lowest part of the Kozaki Formation.

a. Usuki Area

The Furen Limestone Cave, one of the classical localities of pseudoschwagerinas lies at the western margin of the Tsukumi Limestone Belt in the southern part of Ohita Prefecture. The following species were described by Fujimoto (1937) from this cave area:

Pseudoschwagerina orientale Hujimoto
Triticites kawanoboriensis Hujimoto
Triticites satoi Hujimoto
Triticites parvulus (Schellwien)
Schwagerina douvillei (Colani)

The illustrated ill-preserved specimens of *Pseudoschwagerina orientale, T. satoi,* and *Schwagerina douvillei* are similar to "*P.*" *minatoi* Kanmera *Pseudofusulina santhyuensis* Fujimoto, and *Schwagerina stabilis* Rauser, respectively, from the "*Pseudoschwagerina*" *minatoi* Zone in the Yayamadake Limestone Subgroup. Therefore, this fauna is referable to as the "*Pseudoschwagerina*" *minatoi* Zone.

From the Inazumiyama Limestone Formation distributed in the environs of Mt. Inazumi-yama to the south of the Furen Limestone Cave, Nishida and others (1982) illustrated and listed up some lower Permian species. They are as follows:

Triticites sp. aff. *T. pusillus* (Schellwien)
Dunbarinella sp. cf. *D. cervicalis* (Lee)
Pseudoschwagerina sp. cf. *P. morikawai* (Igo)
Pseudofusulina sp. cf. *P. ambigua* (Deprat)
Brevaxina sp.
Misellina sp. cf. *M. claudiae* (Deprat)

The specimens illustrated by Nishida and others (1982, fig. 3) as *T.* sp. aff. *T. pusillus* are referable to *Triticites ellipsoidalis* Toriyama, which is known from the *Pseudoschwagerina muongthensis* Zone (Ota, 1977) of the Akiyoshi Limestone Group. *P.* sp. cf. *P. morikawai* is also referable to *Pseudoschwagerina muongthensis* (Deprat) from the same zone of the Akiyoshi Limestone Group. The other listed species are assigned to the elements of the Sakamotozawan Stage.

I have found *Sphaeroschwagerina* cf. *pavlovi* (Rauser-Chernousova) and *Pseudoschwagerina*

muongthensis (Deprat) from the Tsukumi Limestone at Hirabaru, Tsukumi-shi. This association apparently represents the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone.

b. Kozaki Formation

The Kozaki Formation (Kanmera, 1963) distributed in the western part of Kyushu contains the upper Sakamotozawan fauna. This fauna consists of *Misellina claudiae* (Deprat), *Minojapanella* sp., *Toriyamaia laxiseptata* Kanmera, *Nagotoella* sp. Kanmera, and *Parafusulina* (*Skinnerella*) gruperaensis Thomson and Miller. The *Misellina claudiae-Parafusulina* (*Skinnerella*) *gruperaensis* Association characterizes the Upper Artinskian Stage in Darvus region, Russia (Leven and Scherbovich, 1978; Kahler, 1974b).

Consequently, the lowest part of the Kozaki Formation can be correlated with the Upper Artinskian Stage in Russia or the Upper Sakamotozawan Stage in Japan.

2. Chichibu Terrane in Shikoku

The upper Carboniferous and lower Permian fusuline faunas are recognized in the following formations.

a. Miyanokuchi Formation

This formation (Katto and Suyari, 1956; Suyari, 1962) is distributed in the vicinity of Miyanokuchi, Kochi Prefecture. The following species are described by Suyari (1962) from this formation:

Quasifusulina longissima (Moeller)
Quasifusulina longissima compacta (Lee)
Quasifusulinoides hanzawai (Suyari)
Montiparus matsumotoi kattoi (Suyari)
M. matsumotoi suitaensis (Suyari)

This association is clearly of the *Montiparus matsumotoi inflatus* Zone, the middle part of the Lower Hikawan Stage.

b. Shogase Formation

This formation is distributed in the vicinity of Shogase, Kochi Prefecture. Suyari (1962) discriminated the following species from this formation:

Montiparus cf. *rhombiformis* (Rosovskaya)
Triticites yayamadakensis Kanmera

This assemblage is also of the *Montiparus matsumotoi inflatus* Zone to the *Schwagerina? satoi* Zone, the middle to the upper part of the Lower Hikawan Stage.

c. Daigo Formation

This formation (Suyari, 1954, 1961, 1962; raised up to a runk of Group by Ishida, 1977, 1979) is distributed in the northeastern part of Daigo, Tokushima Prefecture. *Triticites yayamadakensis* Kanmera is the only one species known from the upper Carboniferous section of this formation.

d. Kusune Formation

This formation (Hirayama *et al.*, 1956) is distributed to the east of Kusune, Tokushima Prefecture. Suyari (1962) discriminated the following species from this formation:

Quasifusulina longissima (Moeller)
Triticites kawanoboriensis (Fujimoto)
Triticites rossicus (Schellwien)

Schwagerina regularis (Schellwien)

Pseudoschwagerina aff. *geyeri* Kahler & Kahler

This fauna is of the *Schwagerina? satoi* Zone and the *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone of the upper part of the Lower Hikawan and the lower part of the Sakamotozawan Stage.

e. Uwagawa Formation

This formation (Kashima, 1969) is distributed around Mt. Gozaisho-yama at the prefectural boundary of Ehime and Kochi Prefectures. The following species are obtained from this formation:

Quasifusulina sp. Kashima

Paraschwagerina plicata (Lee)

Pseudofusulina regularis (Schellwien)

P. cf. *vulgaris* (Schellwien)

These species probably indicate that the lower part of this formation belongs to the *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone of the upper part of the Sakamotozawan Stage in Japan.

f. Kaifuku Formation

This formation (Ikebe, 1936; Kashima, 1969) is distributed in Nomura-cho, Ehime Prefecture. This formation contains *Triticites* ex gr. *yayamadakensis* KANMERA and *Quasifusulina* sp. This assemblage is of the *Schwagerina? satoi* Zone, the upper part of the Lower Hikawan Stage.

g. Nakakubo Formation

This formation (Kashima, 1969; raised up to a rank of Group by Yanagida and Hirata, 1969) is distributed in Yanagi-dani valley in Kamiuwa-gun, Ehime Prefecture. Yanagida and Hirata (1969) described many well-preserved brachiopods which are associated with the following fusuline fossils:

Pseudoschwagerina minatoi Kanmera

Schwagerina stabilis (Rauser-Chernousova)

Nankinella kawadai Igo

This fusuline fauna is apparently of the *Pseudoschwagerina minatoi* Zone, the upper part of the Upper Hikawan Stage. Kashima (1960) and Ishizaki (1962) also recognized the following species in this formation:

Pseudofusulina cf. *gregaria* Lee

P. tschernyschewi (Schellwien)

Pseudofusulina ambigua (Deprat)

Acervoschwagerina endoi (Hanzawa)

This fusuline fauna may be of the upper part of the *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone, the upper part of the Sakamotozawan Stage.

3. Hida Massif

The upper Carboniferous and lower Permian rocks in the Hida Massif are distributed in the Oppara and Nyukawa-Hirayu areas, Gifu Prefecture.

a. Oppara area

This area is situated in the southern part of the Hida Massif, and the geology and paleontology

of this area were studied by Kanuma (1951, 1958a, 1958b, 1959, 1960a, 1960b). He established the following fusuline biostratigraphy in descending order:

B. Lower Permian Series
  2. Okumyogata Formation or Akuda Formation
    b. *Pseudofusulina vulgaris* zonule
    a. *Pseudoschwagerina orientale-Triticites kawanoboriensis* zonule
A. Upper Carboniferous Series
  1. Oppara Formation
    b. *Triticites kiyomiensis* subzone
    a. *Triticites opparensis* subzone

The *Triticites opparensis* subzone in the lower part of the Oppara Formation is characterized by *Triticites opparensis* Kanuma, *T. opparensis longiformis* Kanuma, *T. nakatsugawensis* Morikawa, and *Quasifusulina* sp.

Based on my field investigation and populational study of collected fusulines, it is now known that *Triticites opparensis* is referable to *Obsoletes obsoletus* (Schellwien), and that *Triticites opparensis* to *Montiparus matsumotoi matsumotoi* (Kanmera) and *M. matsumotoi inflatus* Watanabe, n. subsp. Then, this fauna is of the *Obsoletes obsoletus* Zone and the *Montiparus matsumotoi inflatus* Zone in the Omi and Akiyoshi Limestone Groups.

The *Triticites kiyomiensis* subzone in the upper part of the Oppara Formation is characterized by *Triticites kiyomiensis* Kanuma, and *T. nakatsugawensis* Morikawa. Based on the illustrated specimens, these species are apparently referable to *Montiparus matsumotoi matsumotoi* (Kanmera). Then, this assemblage is of the *Montiparus matsumotoi inflatus* Zone.

The *Pseudoschwagerina orientale-Triticites kawanoboriensis* zonule in the lower part of the Okumyogata Formation includes, besides the named species, *Triticites onoensis* Kanuma, *T. subnathorsti* (Lee), *T.* cf. *plummeri* (Dunbar & Skinner). Based on my populational study, these species are referable to a variation of *Schwagerina? satoi* (Ozawa).

A specimen (Kanuma, 1958a, Pl. 3, Fig. 11) of *Triticites uddeni* Dunbar & Skinner is closely similar to *Jigulites longus formosus* (Rosovskya) from the Lower Gzhelian Stage in Russia. Also a specimen (Kanuma, 1958a, Pl. 3, Fig. 22) of *T. subnathorsti* is referable to "*Pseudoschwagerina*" *morikawai* Igo. For the time, *Pseudoschwagerina orientale* Hujimoto is referred to "*P.*" *minatoi* Kanmera. These three species belong to the *Schwagerina? satoi* Zone, "*Pseudoschwagerina*" *morikawai* Zone and "*Pseudoschwagerina*" *minatoi* Zone, respectively.

The *Pseudofusulina vulgaris* zonule in the upper part of the Okumyogata and Akuda Formations is characterized by the following species: *Pseudofusulina ambigua* (Deprat), *P. kraffti* (Schellwien), *P. vulgaris fusiformis* (Schellwien), *P.* cf. *crassiseptata* (Deprat), *p. vulgaris* (Schellwien), *P. vulgaris pseudowatanabei* Kanuma, in the lower part; *Pseudofusulina nelsoni* (Dunbar & Skinner), *P. gujyoensis* Kanuma, *Pseudoschwagerina uddeni* (Beede & Knicker), *Acervoschwagerina fujimotoi* Kanuma and *Minojapanella elongata* Fujimoto and Kanuma, etc. in the upper part.

The lower part of this zonule is correlative with the *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone rather than with the *Pseudofusulina vulgaria* Zone of the Sakamotozawa Formation. The upper part is apparently correlative with the *Robustoschwagerina schellwieni-Pseudofusulina vulgaris globosa* Zone, because *Pseudoschwagerina uddeni* is referable to *Robustoschwagerina schellwieni schellwieni* (Hanzawa).

Pseudofusulina nelsoni is closely allied to *Cuniculinella zulmartensis* (Leven) described by Igo and others (1979) from Johore, Malaysia.

To sum up, the following fusuline biostratigraphy is recognized in this area:

B. Lower Permian Series
  2. *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa*Zone
  1. *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone
A. Upper Carboniferous Series
  5. "*Pseudoschwagerina*" *minatoi* Zone
  4. "*Pseudoschwagerina*" *morikawai* Zone
  3. *Schwagerina? satoi* Zone
  2. *Montiparus matsumotoi inflatus* Zone
  1. *Obsoletes obsoletus* Zone

b. Nyukawa-Hirayu area

The Nyukawa Group (Isomi and Nozawa, 1957) is distributed in the Nyukawa and Hirayu areas, Gifu Prefecture, central Japan. Fusuline faunas were studied by Hanzawa (1939), Igo (1959, 1964, 1965) and Noda and others (1975). The Nyukawa Group, distributed in the Hatahoko area, is subdivided into the Urita, Sote, and Ikenomata Formations in ascending order. The lower Permian fusulines are known from the lower part of the Sote Formation.

Igo (1965) described the following species from three different horizons in this formation: *Schwagerina muraii* Morikawa, *S. ishiie* Igo, *S.* sp. A Igo, *Pseudofusulina isomie* Igo, *P. hexagonaria* Igo, *Parafusulina takanoe* Igo, *P. iwasensis* Igo, *Acervoschwagerina endoi* Hanzawa, *Misellina claudiae* (Deprat) in the upper horizon; *Pseudoschwagerina* (*Robustoschwagerina*) *hidensis* Igo, *Pseudofusulina kraffti* (Schellwien), *p. isomie* Igo, *P.* aff. *P. vulgaris* (Schellwien), *P. vulgaris globosa* (Schellwien) in the middle horizon; *P. duplitheca* Igo, *Misellina* sp.; *Toriyamaia* sp., *Schwagerina hawkinsiformis* Igo, *Pseudofusulina tschernyschewi* Schellwien), *P. kraffti* (Schellwien), *P. norikurensis* Igo, *Acervoschwagerina endoi* Hanzawa in the lower horizon.

Fusuline-bearing rocks in the lower part of the Sote Formation were grouped by Igo (1965) into the following two zones:

Lower Sote Formation-Lower Permian Series
  b. *Robustoschwagerina hidensis-Pseudofusulina kraffti magma* Zone
  a. *Acervoschwagerina endoi-Pseudofusulina isomiae* Zone

The Lower Sote Formation was thought to be equivalent with the Shiroi Formation in the Kute area. Igo (1965) recognized the following two zones in the Shiroi Formation:

Shiroi Formation-Lower Permian Series
  b. *Acervoschwagerina endoi-Pseudofusulina hexagonaria* Zone
  a. *Pseudofusulina tschernyschewi-Pseudofusulina kraffti* Zone

These two zones were correlated with the *Robustoschwagerina hidensis-Pseudofusulina kraffti* Zone and the *Acervoschwagerina endoi-Pseudofusulina isomiae* Zone, respectively, of the Sote Formation.

The populational study of *Robustoschwagerina schellwieni* (Hanzawa) from the Maiya Formation in southern Kitakami massif has ascertained that *Robustoschwagerina hidensis* Igo can be included within a variation of *R. schellwieni schellwieni* (Hanzawa). *Pseudofusulina* aff.

P. vulgaris (Schellwien) from the *R. hidensis-P. kraffti* Zone is a typical form of *Pseudofusulina vulgaris vulgaris* (Schellwien). *Misellina* sp. and *M. claudiae* (Deprat) are obtained from the lower part of the Sote Formation. These two species are known to characterize the Upper Sakamotozawan Stage.

Therefore, the fauna of the Lower Sote Formation is equivalent in constituents with that of the *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone in the Upper Sakamotozawan Stage and the Upper Artinskian Stage in Russia.

4. Futagoyama Limestone Group in Kanto Massif

The Futagoyama Limestone Formation or Group, one of the classical objects of fusulinacean studies in Japan, is distributed in Ogano-machi, Saitama Prefecture, Kanto Massif. After Fujimoto's study (1936), Takaoka (1966) established the following zones in this limestone:

B. Permian System
  2. *Neoschwagerina* Zone
  1. *Pseudoschwagerina* Zone
A. Carboniferous System
  2. *Triticites* Zone
  1. *Fusulinella-Fusulina* Zone

Recently, Morita (1984, MS) studied this limestone group and established the following zonation, in descending order:

C. Lower Permian Series
  3. *Pseudofusulina vulgaris globosa-Robustoschwagerina* sp. Zone
  2. *Sphaeroschwagerina* sp. Zone
  1. *Sphaeroschwagerina moelleri-Pseudoschwagerina muongthensis* Zone
B. Upper Carboniferous Series
  5. "*Pseudoschwagerina*" *minatoi* Zone
  4. "*Pseudoschwagerina*" *morikawai* Zone
  3. *Schwagerina? satoi* Zone
  2. Barren Zone
  1. *Obsoletes obsoletus* Zone
A. Middle Carboniferous Series
  3. *Fusulinella prolifica-Quasifusulinoides ohtanii* Zone

The lower three zones in the Upper Carboniferous Series are of the Lower Hikawan Stage. The barren Zone is composed of dark brownish dolomitized limestone which is lithologically closely similar to that of the *Montiparus matsumotoi inflatus* Zone in the Omi and Akiyoshi Limestone Groups. The upper two zones of the upper Carboniferous are of the Upper Hikawan Stage.

The *Sphaeroschwagerina moelleri-Pseudoschwagerina muongthensis* Zone in the lowest Permian of this limestone is in fault contact with the "*Pseudoschwagerina*" *minatoi* Zone of the upper Carboniferous. Therefore, the Carboniferous-Permian boundary in this limestone can not be determined.

The lower two zones in the lower Permian are assigned to the Nagatoan Stage, and are apparently correlated with the Middle and Upper Asselian Stage in Russia. The *Pseudofusulina vulgaris globosa-Robustoschwagerina* sp. Zone is of the Lower Sakamotozawan Stage.

Although many faults are recognized in this limestone, the Futagoyama Limestone is richly fossiliferous, and many interesting fusulinids of the Moscovian through the Sakmarian have been distinguished.

IV. The Standard Fusuline Zonation of the Upper Carboniferous and the Lower Permian in Japan

Geographic and stratigraphic distributions and morphological variations of fusuline species have been recently clarified on the basis of populational concept. Fusuline faunas in Japan are known to belong to the Tethyan faunal realm, and the late Carboniferous and early Permian fusuline faunas are also closely related with the faunas of Central Asia and Russian Platform. They include, however, some endemic species, such as "*Pseudoschwagerina*" *morikawai* Igo, "*P.*" *minatoi* Kanmera, and *Nipponitella explicata* Hanzawa. Thereby, Leven and Schellbovich (1978) and many other Russian students found great difficulties in correlating the Russian faunas with the Japanese faunas.

In the preceding chapter, I have presented the distributions of the Pseudoschwagerinae in representative upper Carboniferous and lower Permian sections including the type section in Japan. Here, I present a biostratigraphic zonation based on fusuline faunas, which could be most complete for the Carboniferous-Permian successions in Japan. This scheme would relieve the difficulties in the correlation between the stratigraphic divisions or units of Japan and other relevant provinces including those proposed by Rotai (1979) and F. Kahler (1974).

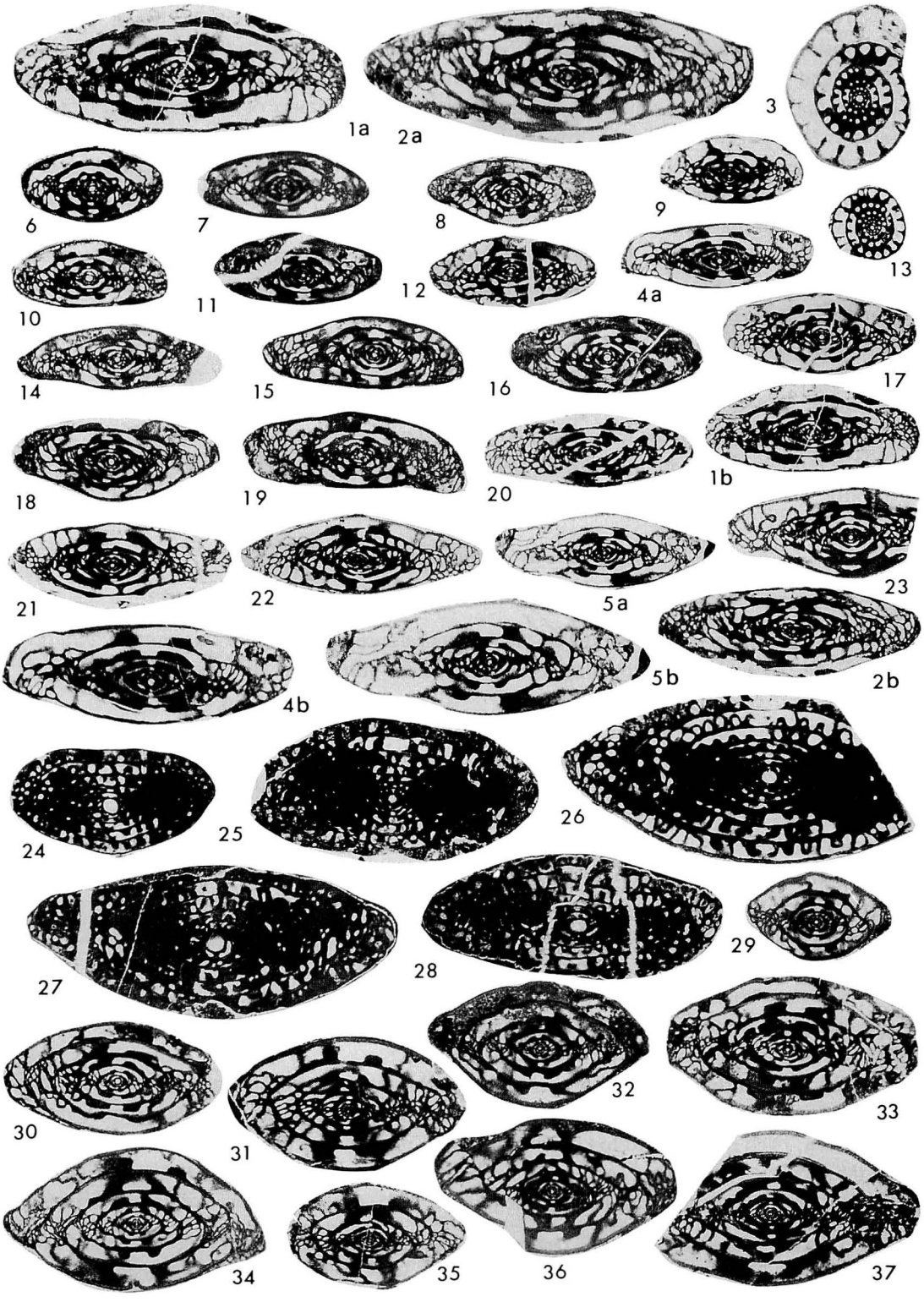
The following twelve fusuline zones can be recognized in the upper Carboniferous and lower Permian sediments in Japan, in descending order:

12. *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone
11. *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone
10. *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone
9. *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone
8. "*Alpinoschwagerina*" *saigusai-Pseudoschwagerina* cf. *robusta* Zone
7. *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone
6. *Sphaeroschwagerina fusiformis* Zone
5. "*Pseudoschwagerina*" *minatoi* Zone
4. "*Pseudoschwagerina*" *morikawai* Zone
3. *Schwagerina? satoi* Zone
2. *Montiparus matsumotoi inflatus* Zone
1. *Obsoletes obsoletus* Zone

1) *Obsoletes obsoletus* Zone

Figures 20, 22

Fig. 20. All photographs ×10. **1–23:** ***Obsoletes obsoletus*** **(Schellwien); 1–5, 12, 17, 19, 20–22:** Loc. AK-13b in Section A, northern part of the Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Obsoletes obsoletus* Zone, lower part of the Lower Hikawan Stage, Upper Carboniferous Series; **6–11, 13–16, 19, 23:** Loc. C-4 in Section C, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Obsoletes obsoletus* Zone, lower part of the Lower Hikawan Stage, Upper Carboniferous Series; **24–28:** ***Quasifusulinoides*** **cf.** ***ohtanii*** **(Kanmera); 24, 25, 27, 28:** Loc. B-33 in Section B, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Montiparus matsumotoi inflatus* Zone, middle part of the Lower Hikawan Stage, Upper Carboniferous Series; **26:** Loc. AK-10 in Section A, northern part of the Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone group, the *Montiparus matsumotoi inflatus* Zone, middle part of the Lower Hikawan Stage, Upper Carboniferous Series; **29–37:** ***Montiparus matsumotoi inflatus*** **Watanabe n. subsp.; 29–37:** Loc. B-36 in Section B and Loc. D-5 in Section D, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Montiparus matsumotoi inflatus* Zone, middle part of the Lower Hikawan Stage, Upper Carboniferous Series.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This zone is defined by the appearance of the zonal-index species above the top of the zone comprising *Pulchrella pulchra* (Rauser-Beljaev) and *Kanmeraia prolifica* (Kanmera) (Solovjeva, 1984), and contains the nominated species, *Quasifusulinoides ohtanii* (Kanmera) and *Staffella* sp. The upper limit of this zone is drawn just below the first appearance of *Montiparus matsumotoi inflatus* Watanabe, n. subsp.

This zone is typically represented in Section A along the Akiyoshi-dai Toll Road on the Akiyoshi Limestone Plateau (see Fig. 2), where this zone is 5 meters thick and is composed of white bio-oosparite.

This zone occupies the lowest part of the Lower Hikawan Stage in Japan and is exactly correlated with the *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone of the Carboniferous standard fusuline zones proposed by Rotai (1979), the Lower Kasimovian Stage in Russia.

This zone can be found in part of the following units previously reported: *Triticites matsumotoi* Zone (Ota, 1977) of the Akiyoshi Limestone Group; *Triticites opparensis* subzone (Kanuma, 1958) of the Oppara Formation; *Protriticites variabilis* Zone (Igo, 1978) and *Triticites* Zone (Niikawa, 1978) of the Ichinotani Formation; *Triticites* Zone (Kawada, 1954; Fujita, 1958) of the Omi Limestone Group; *Triticites* Zone (Takaoka, 1966) and *Protriticites obsoletus* Zone (Morita, 1984 MS) of the Futagoyama Limestone.

2) *Montiparus matsumotoi inflatus* Zone

Figures 18, 20, 22

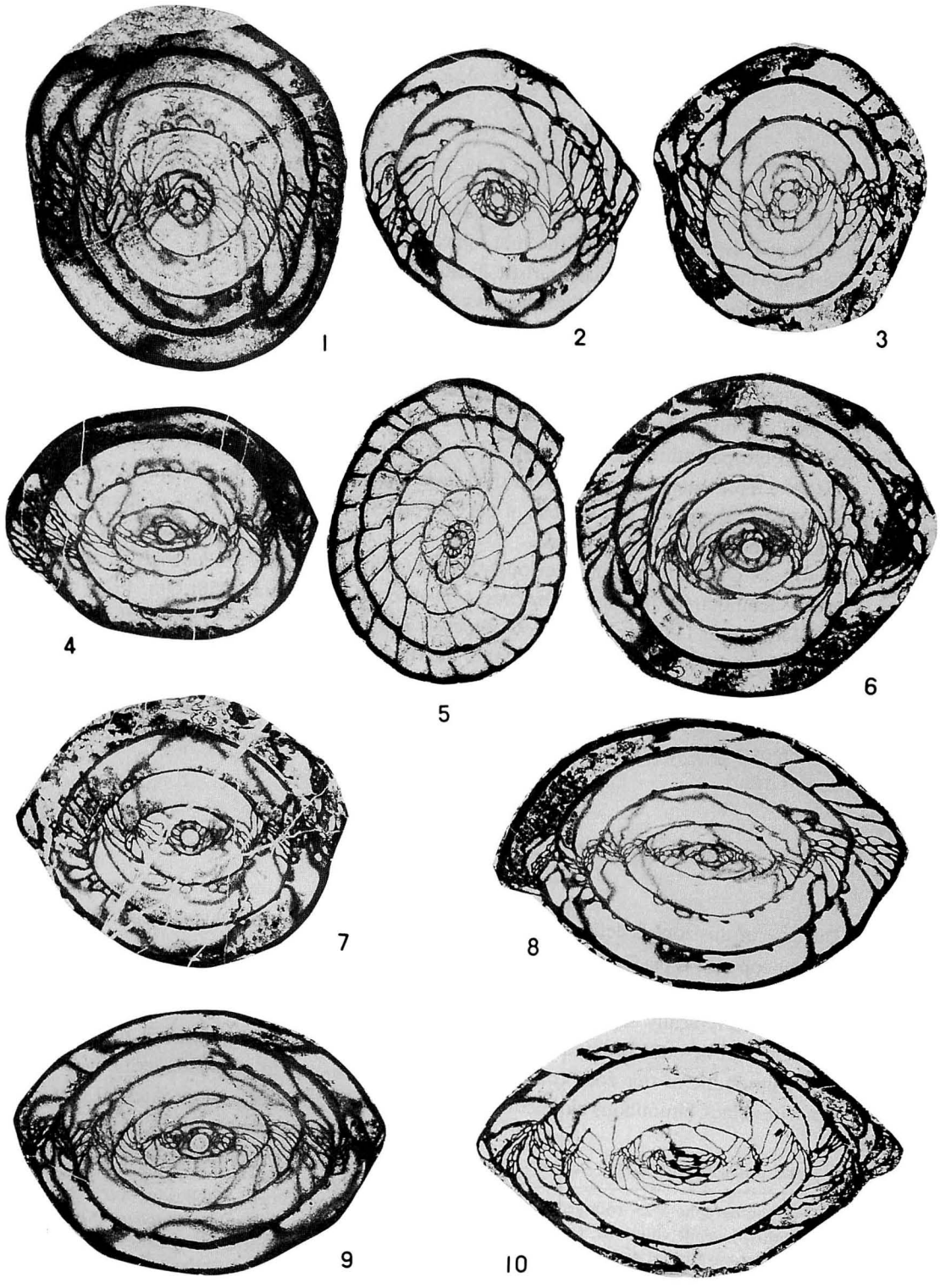
The base of this zone is marked by the first appearance of *Montiparus matsumotoi inflatus* Watanabe, n. subsp. The top of this zone is placed just below the lowest occurrence of *Schwagerina? satoi* (Ozawa).

The most complete section of this zone is exposed in Section B on the Akiyoshi Limestone Plateau (see Fig. 2) and the comparable sequences are seen in the Hiate-section noted by Kanmera (1952) and Section A of the Omi Limestone (Fig. 10). In the first and third sections, this zone is 30–70 meters thick and is composed of grey biosparite with dark-brownish to dark-grey dolomitized limestone in the lower part, and siliceous, dolomitized biomicrite in the upper part. *Montiparus matsumotoi inflatus* n. subsp. occurs abundantly in the lower part but less common in the upper part. *Montiparus matsumotoi* (Kanmera) is common in the middle part, and *Montiparus umboplicatus* (Rauser & Beljaev) and related *Montiparus exculptus* (Igo) are abundant in the upper part.

This zone holds the middle part of the Lower Hikawan Stage in Japan and is accurately correlated with the *Triticites montiparus* Zone of the Carboniferous standard divisions of Rotai (1979), the Middle Kashimovian Stage in Russia.

This zone includes the main part of the following units formerly proposed: *Triticites matsumotoi* Zone (Kanmera, 1955) of the Yayamadake Limestone Subgroup; *Triticites matsumotoi* Zone (Ota, 1977) of the Akiyoshi Limestone Group; *Triticites opparensis* subzone (Kanuma, 1958) of the Oppara Formation; *Triticites* Zone (Suyari, 1961) of the Miyanokuchi and Shogase Formations; *Protriticites matsumotoi* Zone (Ozawa, 1975) of the Kitaosogi Formation; *Triticites*

Fig. 21. All photographs ×10. **1–10: *Zellia nunosei* (Hanzawa)**; Loc. a float sample along Shiratori-zawa valley, west of Tashiroyama, Sakamoto, Ohfunato-shi, Iwate Prefecture. Sakamotozawa Formation, the *Robustoschwagerina schellwieni pamirica* Zone, lower part of the Sakamotozawan Stage, Lower Permian Series.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Zone (Kawada, 1954; Fujita, 1958) and the *Triticites* (*Montiparus*) *montiparus* Zone (Watanabe, 1973) of the Omi Limestone Group.

3) *Schwagerina? satoi* Zone

Figures 4, 19, 22, 24–25

The base of this zone is demarcated by the first appearance of *Schwagerina? satoi* (Ozawa) and the top of it is well defined by the first appearance of "*Pseudoschwagerina*" *morikawai* Igo. The following species are characteristic in this zone: *Triticites yayamadakensis* Kanmera, *Montiparus exculptus* (Igo), *Triticites subacutus* Mikhailova, *Triticites* cf. *stuckenbergi* Rauser, and *Quasifusulina longissima* (Moeller).

The representative faunal sequence of this zone is seen in Section B on the Akiyoshi Limestone plateau, Section A on the Omi Limestone and Shimo-yukawa Section on the Atetsu Limestone. In these sections, this zone attains a thickness of 20–30 meters, and consists of white-grey algal biomicrite to biosparrudite.

This zone represents the upper part of the Lower Hikawan Stage in Japan and is correlative with the *Triticites arcticus-T. acutus* Zone of the Carboniferous standard divisions of Rotai (1979), the Upper Kasimovian Stage in Russia.

The following units and fauna previously belong to this zone: *Triticites hidensis* Fauna (Igo, 1957) of the Ichinotani Formation; *Triticites simplex* Zone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group; *Triticites kiyomiensis* subzone (Kanuma, 1958) of the Oppara Formation; *Triticites* Zone (Morikawa, 1953a) of the Ishifune Formation; *Quasifusulina longissima ultima*-"*Pseudoschwagerina*" *nakazawai* subzone (Nogami, 1961a) of the Atetsu Limestone Group; *Triticites* Zone (Takaoka, 1966) and the *Schwagerina? satoi* Zone (Morita, 1984 MS) of the Futagoyama Limestone; *Schwagerina? satoi* Zone (Watanabe, this paper) of the Omi Limestone Group.

4) "*Pseudoschwagerina*" *morikawai* Zone

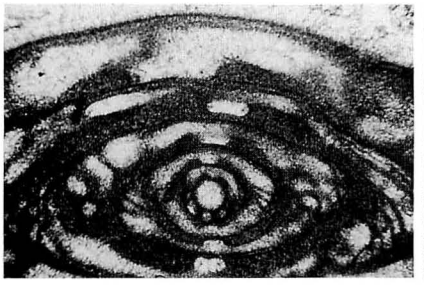
Figures 26–28, 46

The base of this zone is defined by the first appearance of "*Pseudoschwagerina*" *morikawai* Igo, and the top of it is placed just below the lowest occurrence of "*Pseudoschwagerina*" *minatoi* Kanmera.

This zone is typically exposed along Section B of the Akiyoshi Limestone (see Fig. 2) and the Hiate Section of the Yayamadake Limestone (Kanmera, 1952). This zone is 10–50 meters thick. The limestone of this zone consists of light brownish-grey to grey biomicrite in general, but comprises black bituminous biomicrite in the Ichinotani Formation and the Atetsu Limestone Group.

Faunal constituents differ between the black bituminous and grey limestones. The former

Fig. 22. All photographs ×25. enlarged figures of a part of the same specimens as following species, showing proloculus, juvenile volutions, wall thickness, and wall structure. **1–3: *Obsoletes obsoletus* (Schellwien)**; Omi Limestone Group; **4–7: *Montiparus matsumotoi matsumotoi* (Kanmera)**; Omi Limestone Group; **8, 9: *Triticites yayamadakensis* Kanmera**; Omi Limestone Group; **10, 11: *Schwagerina? satoi* (Ozawa)**; Omi Limestone Group; **12, 13: *Montiparus matsumotoi inflatus* Watanabe, n. subsp.**; Omi Limestone Group.



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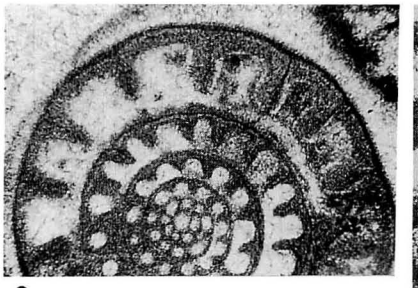

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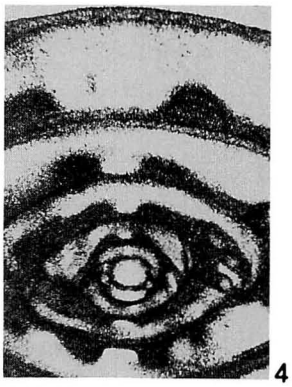

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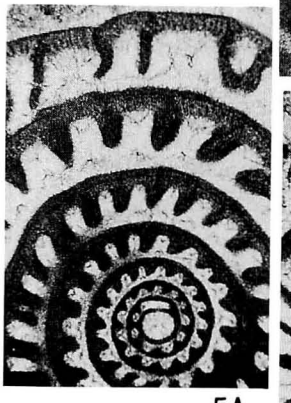

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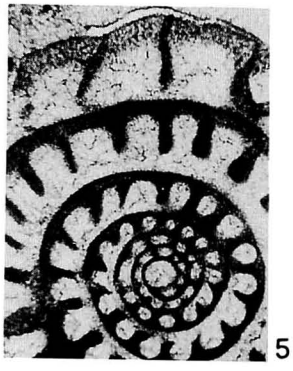

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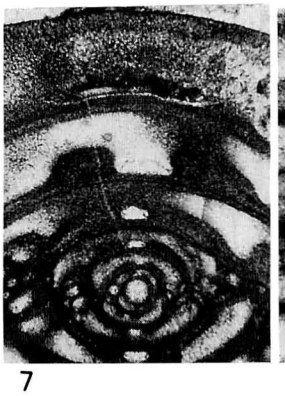

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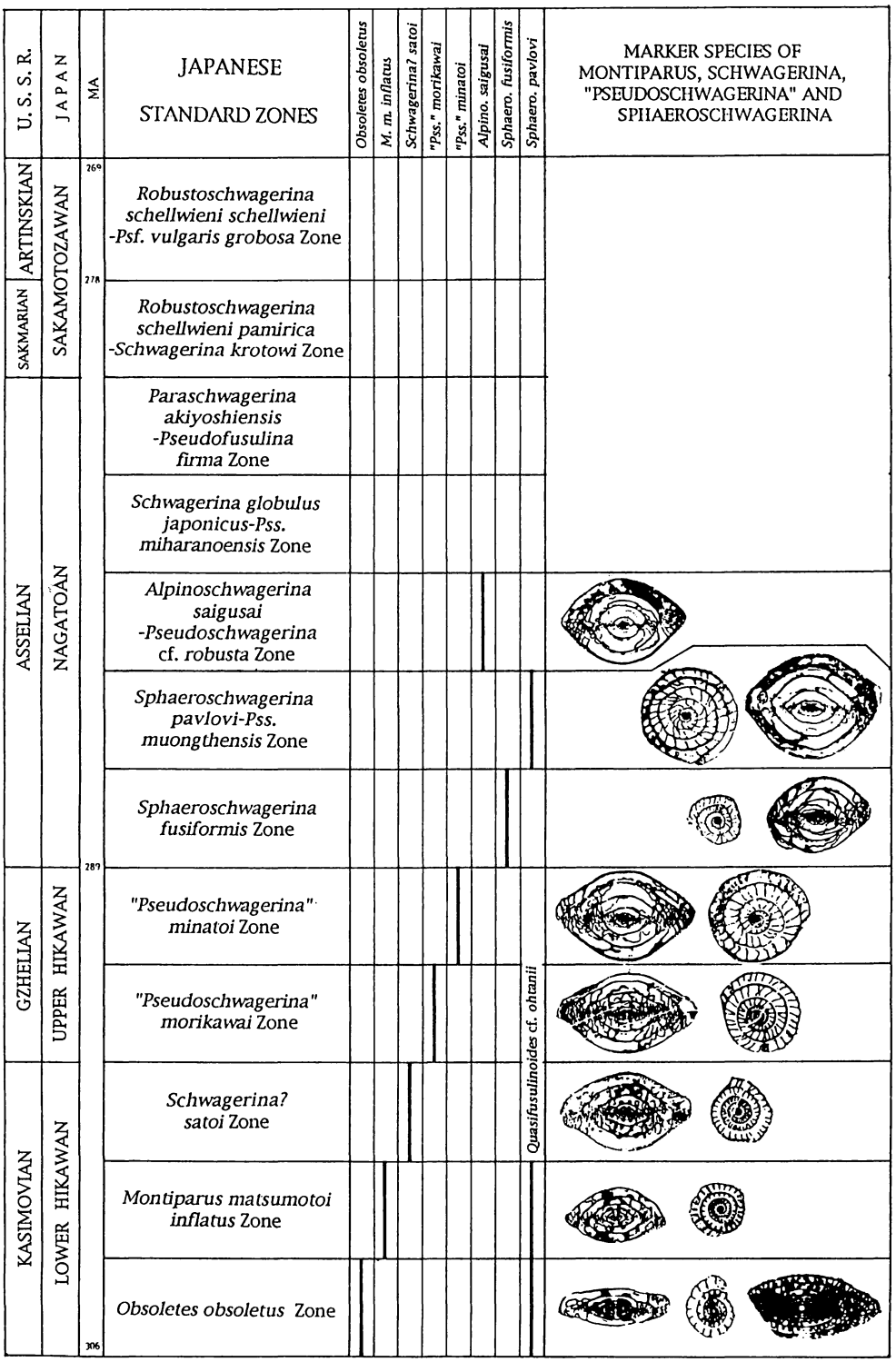

Fig. 23. Stratigraphic distribution of marker species of *Montiparus, Schwagerina?, "Pseudoschwagerina"* and *Sphaeroschwagerina* in the Lower and Upper Hikawan Stages and the lower part of the Nagatoan Stage.

contains *Quasifusulina longissima* (Moeller) and *Rugosofusulina alpina* (Schellwien). The latter contains *Schwagerina jugulensis* (Rauser) and *Rugosofusulina prisca* (Schellwien).

This zone occupies the lower part of the Upper Hikawan Stage in Japan and can be correlated with the *Triticites stuckenbergi* Zone of the standard divisions of Rotai (1979), the Lower Gzhelian Stage in Russia.

This zone is equivalent to the following units previously reported: *Pseudoschwagerina morikawai* Zone (Igo, 1957) of the Ichinotani Formation; *Pseudoschwagerina morikawai* Zone (Kanmera, 1958) of the Yayamadake Limestone Subgroup; *Triticites simplex* subzone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group; *Quasifusulina longissima ultima-"Pseudoschwagerina" nakazawai* Zone (Nogami, 1961a) of the Atetsu Limestone Group; *Pseudoschwagerina* Zone (Takaoka, 1966) and the *Pseudoschwagerina morikawai* Zone (Morita, 1984 MS) of the Futagoyama Limestone.

5) "*Pseudoschwagerina*" *minatoi* Zone

Figures 5, 9, 16, 28–31, 42, 46

This zone is applied to the stratigraphic interval between the first appearance of "*Pseudoschwagerina*" *minatoi* and that of *Sphaeroschwagerina fusiformis* (Krotow).

This zone is typically distributed in Section B on the Akiyoshi Limestone Plateau (Fig. 2) and the Hiate-Section of the Yayamadake Limestone (Kanmera, 1952). In these sections, this zone is 20–80 meters thick and is composed of white to dark-grey biomicrite.

The lower part of this zone yields "*Pseudoschwagerina*" *minatoi* Kanmera, *Paraschwagerina shimodakensis* Kanmera, *Pseudofusulina douvillei* (Colani) of Fujimoto (1937), and *Schwagerina longus formosus* (Rosovskaya). The upper part of this zone contains *Daixina sokensis* (Rauser-Chernousova), *Pseudofusulina kumasoana* Kanmera, *Schwagerina magnus* (Rosovskaya), and *Pseudofusulina santyuensis* (Hujimoto).

This zone is assigned to the upper part of the Upper Hikawan Stage in Japan and is correlative with the *Triticites jigulensis* Zone-*Daixina sokensis* Zone of the Carboniferous standard divisions (Rotai, 1979), and Middle and Upper Gzhelian Stage in Russia.

This zone was known only in the type section of the *Pseudoschwagerina minatoi* Zone (Kanmera, 1958, 1978) of the Yayamadake Limestone Subgroup, but recently this zone and the fauna indicating this zone have been recognized to distribute more widely as follows: *Pseudoschwagerina orientale* Funa (Fujimoto, 1937) of the Tsukumi Limestone at Furen Cave; *Pseudoschwagerina* Zone (Kanuma, 1958) of the Okumyogata Formation; *Pseudoschwagerina morikawai* Zone (Igo, 1957) of the Mizuyagatani Formation; *Triticites simplex* subzone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group; *Quasifusulina longissima ultima-"Pseudoschwagerina" nakazawai* subzone (Nogami, 1961) of the Atetsu Limestone Group; *Pseudoschwagerina* Zone (Takaoka, 1966) and the *Pseudoschwagerina minatoi* Zone (Morita, 1984 MS) of the Futagoyama Limestone; *Pseudoschwagerina minatoi* Fauna (Yanagida and Hirata, 1969) of the Ohnogahara Formation; *Pseudoschwagerina minatoi* Zone (Ozawa, 1975; Igo, 1978) of the Kitaosogi Formation; and *Pseudoschwagerina minatoi* Zone (Watanabe, this paper) of the Omi Limestone Group.

6) *Sphaeroschwagerina fusiformis* Zone

Figures 4–5, 8, 32, 34, 47

The lower boundary of this zone is defined by the first appearance of *Sphaeroschwagerina fusiformis* (Krotow) and the disappearance of "*Pseudoschwagerina*" *minatoi* Kanmera and *Quasifusulina longissima ultima* Kanmera. The top of this zone is placed just below the lowest occurrence of *Pseudoschwagerina muongthensis* (Deprat). The diagnostic constituents of this zone are *Sphaeroschwagerina fusiformis* (Krotow), *Schwagerina stabilis* (Rauser-Chernousova), *Eoparafusulina ellipsoidalis* (Toriyama), and *Rugosofusulina prisca* (Schellwien).

The most complete section of this zone is seen in Section B on the Akiyoshi Limestone Plateau, where this zone is 5 meters thick and consists of massive grey to dark-grey biomicrite.

This zone indicates the Lower Nagatoan Stage in Japan, and corresponds to the *Schwagerina fusiformis* Zone of the Carboniferous standard divisions of Rotai (1979), the Lower Asselian Stage in Russia.

This zone is identical with the following zones previously reported: *Pseudoschwagerina muongthensis* Zone (Ozawa, 1925; Hasegawa, 1958; Ota, 1977) of the Akiyoshi Limestone Group; *Pseudoschwagerina kanmerai* Zone (Sada, 1965) of the Atetsu Limestone Group; *Sphaeroschwagerina fusiformis* Zone (Watanabe, this paper) of the Omi Limestone Group.

7) *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone

Figures 4, 5, 9, 32, 34–37

This zone is distinguished from the subjacent zone by the occurrence of *Pseudoschwagerina muontthensis* (Deprat) and *Sphaeroschwagerina pavlovi* (Rauser-Chernousova) and from the superjacent zone by the disappearance of those species and the appearance of "*Alpinoschwagerina*" *saigusai* (Nogami). In this zone, besides the zone species, *Pseudofusulina stabilis* (Rauser-Chernousova), *Triticites samaricus* (Rauser-Chernousova), and *Eoparafusulina ellipsoidalis* (Toriyama) are associated.

This zone is typically exposed in Section B on the Akiyoshi Limestone Plateau, Section Morikuni A on the Atetsu Limestone and Section D on the Omi Limestone. In these sections, this zone attains a thickness of 15–30 meters and consists of grey to dark-grey biomicrite to algal biomicrite.

This zone corresponds the Middle Nagatoan Stage in Japan and is correlative with the *Schwagerina moelleri* Zone of the Carboniferous standard divisions of Rotai (1979), the Middle

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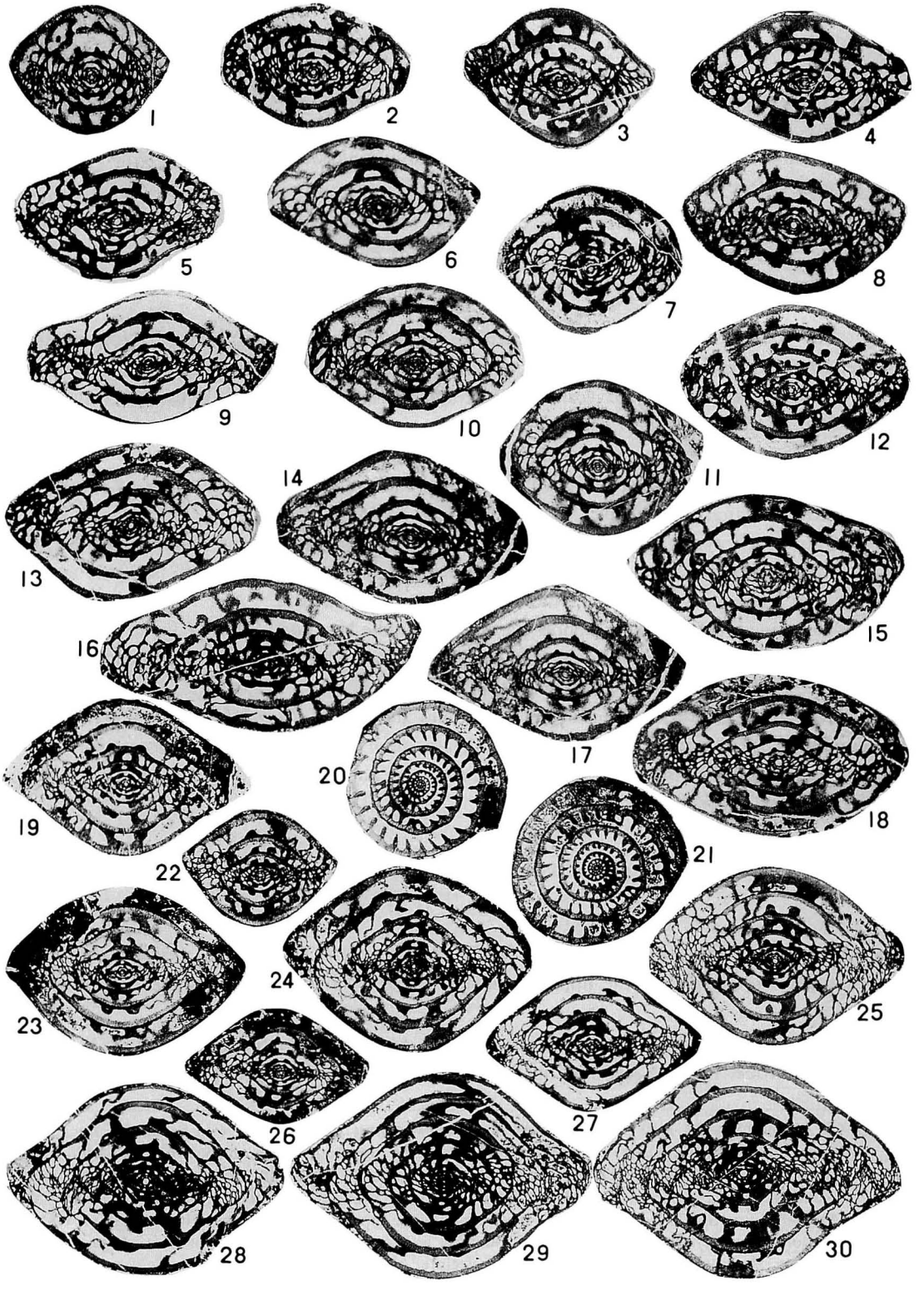
Fig. 24. All photographs ×10. **1–30:** ***Schwagerina? satoi*** **(Ozawa); 1–18:** Loc. B-4 to B-7 in Section B at Morikuni, and C-3 to C-15 in Section C at Shimo-yukawa, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **19–25:** Loc. a float sample (with *Triticites hidensis* Igo), upstream of Ichinotani valley, Fukuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture, Ichinotani Formation, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **26, 27:** a float sample (with *M. exculptus* (Igo)), upstream of Ichinotani valley, Fukuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture. Ichinotani Formation, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **28–30:** Loc. Ic-8 in Ichinotani-section, upstream of Ichinotani valley, Fukuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture. Ichinotani Formation, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series.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Asselian Stage in Russia.

This zone includes the following units: *Pseudoschwagerina muongthensis* Zone (Ozawa, 1925; Hasegawa, 1958; Toriyama, 1958; Ota, 19777 of the Akiyoshi Limestone Group; *Pseudoschwagerina kanmerai* Zone (Sada, 1965) of the Atetsu Limestone Group; *Pseudoschwagerina muongthensis-Sphaeroschwagerina moelleri* Zone (Morita, 1984 MS) of the Futagoyama Limestone; *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone (Watanabe, this pager) of the Omi Limestone.

8) "*Alpinoschwagerina*" *saigusai-Pseudoschwagerina* cf. *robusta* Zone

Figures 8, 12, 38, 42, 47

This zone is characterized by the occurrence of "*Alpinoschwagerina*" *saigusai* (Nogami) and *Pseudoschwagerina* cf. *robusta* (Meek), which are commonly associated with *Paraschwagerina* cf. *longa* Mikhailova, *P.* cf. *akiyoshiensis* Toriyama, *Pseudofusulina firma* Rauser-Chernousova, and *Parafusulina? lutugini* (Schellwien).

The base of this zone is marked by the disappearance of *Sphaeroschwagerina pavlovi* (Rauser-Chernousova) and is drawn just below the appearance of *Schwagerina globulus japonicus* Watanabe, n. subsp.

This zone is typically occur in Section C on the Akiyoshi Limestone Plateau, and Section Morikuni B on the Atetsu Limestone. In these sections, this zone is estimated to be 20–40 meters thick and comprises white grey, crinoidal biosparite to biomicrite.

This zone is referred to the upper part of the Middle Nagatoan Stage in Japan and can be correlated with the *Schwagerina moelleri* Zone of the Carboniferous standard divisions of Rotai (1975), the Middle Asselian Stage in Russia.

This zone includes the following zones and the fauna: *Pseudofusulina vulgaris* Zone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group; *Pseudoschwagerina kanmerai* Zone (Sada, 1965) of the Atetsu Limestone Group; *Pseudoschwagerina* sp. Fauna (Sada, 1967) of the Taishaku Limestone Group.

9) *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone

Figures 8, 41, 47

The base of this zone is defined by the first appearance of *Schwagerina globulus japonicus* Watanabe, n. subsp. and the upper boundary is marked by the disappearance of the same species.

This zone typically occur in Section C on the Akiyoshi Limestone, and Section B of the Omi Limestone. In these sections, this zone is 10–20 meters thick and is composed of white,

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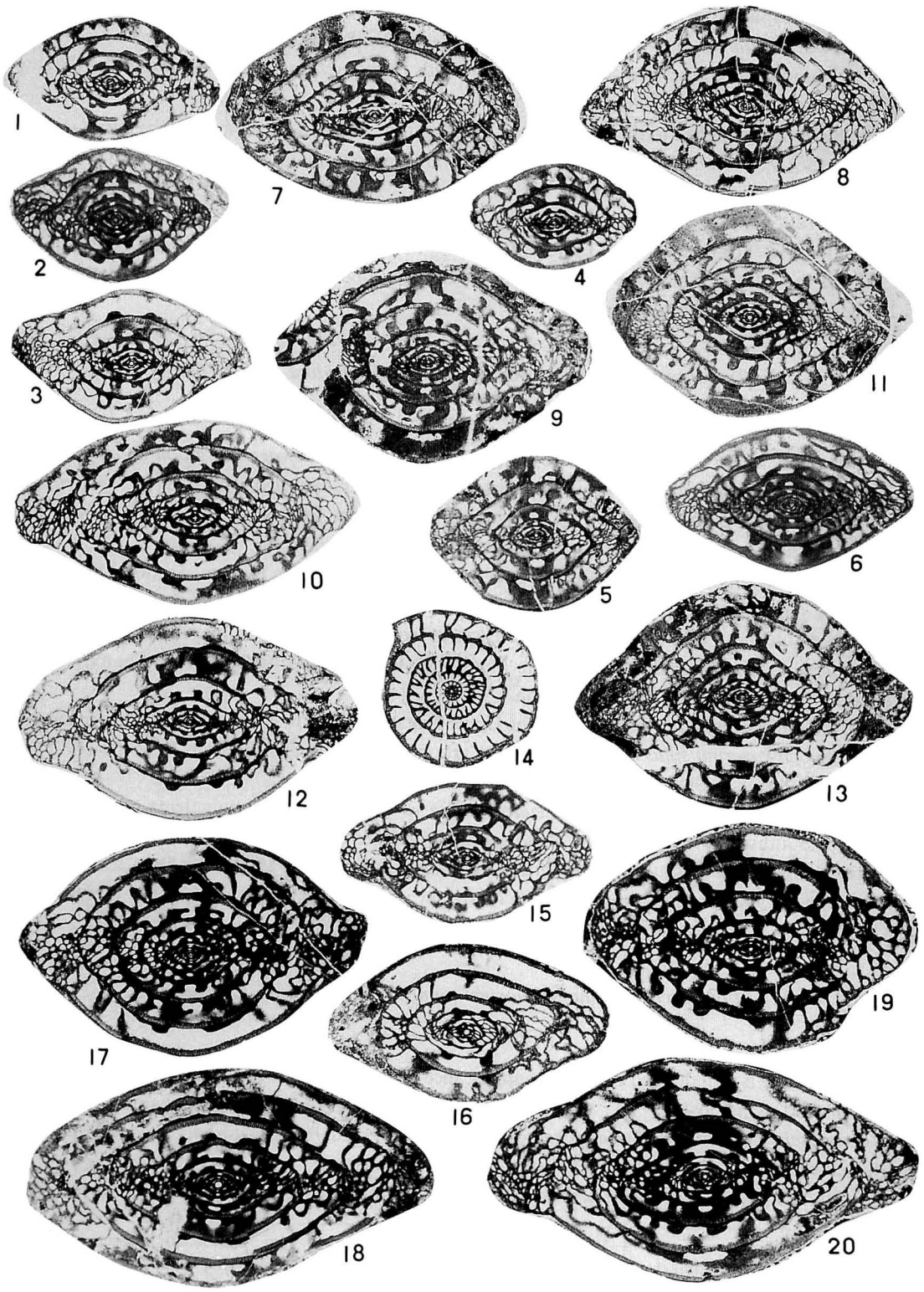
Fig. 25. All photographs ×10. **1–20:** ***Schwagerina? satoi*** **(Ozawa); 1–14:** Loc. B-26 in Section B, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **15–16:** Loc. AK-03 to AK-00 in Section A, northern part of Akiyoshi-dai Science Museum, Shubo-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series; **17–20:** Loc. AK-28 and -29 in Section B, northern part of Akiyoshidai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Schwagerina? satoi* Zone, upper part of the Lower Hikawan Stage, Upper Carboniferous Series.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crinoidal biosparudite. The crinoidal limestone contains *Schwagerina globulus japonicus* n. subsp., *Parafusulina? lutugini* (Schellwien) and *Pseudofusulina stabilis* (Rauser-Chernousova). The pelletoid micrite limestone in the upper part yields *Pseudoschwagerina miharanoensis* Akagi and *Paraschwagerina* cf. *longa* Mikhailova.

This zone is assigned to the lower part of the Nagatoan Stage in Japan and can be correlative with the *Schwagerina sphaerica* Zone of the Carboniferous standard divisions of Rotai (1979), the Upper Asselian Stage in Russia.

The following units are included in this zone: *Pseudofusulina vulgaris* Zone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group; *Pseudoschwagerina kanmerai* Zone (Sada, 1965) of the Atetsu Limestone Group; *Pseudofusulina vulgaris* Zone (Hasegawa and others, 1969) of the Omi Limestone Group.

10) *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone

Figures 8, 12, 43, 47

The base of this zone is defined by the disappearance of *Schwagerina globulus japonicus* Watanabe, n. subsp. and by the appearance of *Pseudofusulina firma* and *Paraschwagerina akiyoshiensis* Toriyama. The top of this zone is placed just below the lowest occurrence of *Robustoschwagerina schellwieni pamirica* Leven and Schelbovich.

This zone is well exposed in Section C on the Akiyoshi Limestone Plateau, Section Morikuni B of the Atetsu Limestone and Section D of the Omi Limestone. In these sections, this zone attains a thickness of 30 meters, and consists of white grey algal biomicrite and crinoidal biosparudite. The crinoidal biosparudite limestone yields *Pseudofusulina firma* Shamov and *Paraschwagerina akiyoshiensis* Toriyama.

This zone occupies the upper part of the Upper Nagatoan Stage in Japan, and can be correlated with the *Schwagerina sphaerica* Zone of the Carboniferous standard divisions of Rotai (1975), the Upper Asselian Stage in Russia.

This zone includes part of the *Pseudofusulina vulgaris* Zone and equivalents of the Inner Zone of Southwest Japan: namely, *Pseudofusulina vulgaris* Zone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone; *Pseudoschwagerina kanmerai* subzone (Sada, 1965) of the Atetsu Limestone; *Pseudofusulina vulgaris* Zone (Hasegawa and others, 1969) of the Omi Limestone Group.

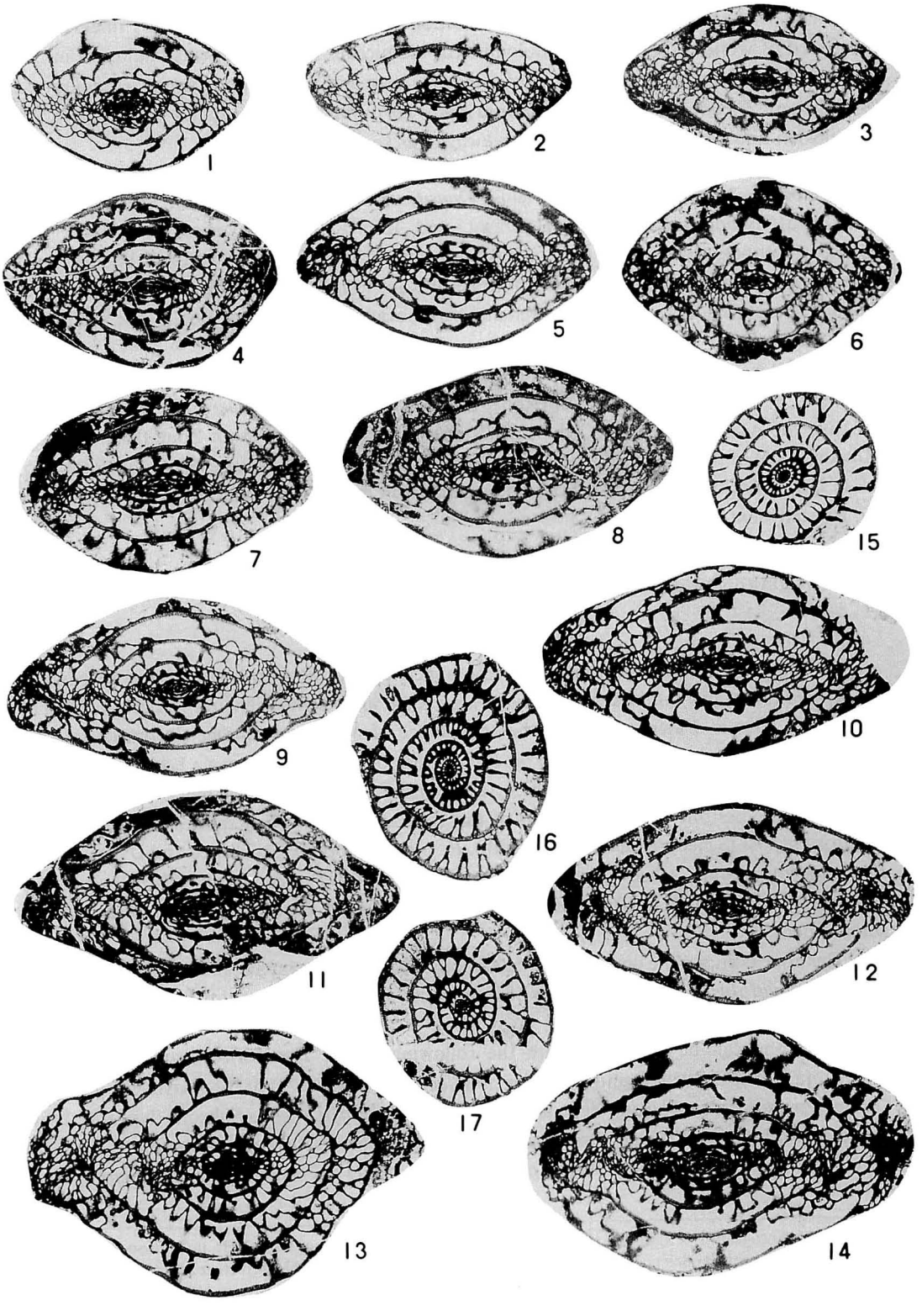
11) *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone

Figures 17, 21, 44, 48

This zone is well defined by the first appearance of *Robustoschwagerina schellwieni pamirica* Leven and Schelbovich. The top of this zone is placed just below the appearance of *Robustoschwagerina schellwieni schellwieni* (Hanzawa), and *Pseudofusulina vulgaris vulgaris* (Schellwien and Dyhrenfurth).

This zone is ascertained in Kaerimizu KI Section of the Akiyoshi Limestone and Shimoyukawa

Fig. 26. All photographs ×8. **1–14: *"Pseudoschwagerina" morikawai* Igo,** Loc. C-20 in Section C at Shimoyukawa, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *"Pseudoschwagerina" morikawai* Zone, lower part of the Upper Hikawan Stage, Upper Carboniferous Series.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Section of the Atetsu Limestone. In these sections, this zone is 60–170 meters thick and is composed of white to black, partly dolomitized, biomicrite. Faunal elements contained in this zone are *Robustoschwagerina schellwieni pamirica* Leven and Schelbovich, *Schwagerina krotowi* (Schellwien), *Pseudofusulina* ex gr. *globosa exilis Toriyama, Pseudofusulina* ex gr. *fusiformis* (Schellwien and Dyhrenfurth) and *Paraschwagerina kanmerai* Nogami.

This zone is also represented by thin- to thick-bedded, black bituminous algal limestone in the Kitakami Mountains, which yields *Quasifusulina cayeuxi* (Deprat), *Zellia nunosei* (Hanzawa), *Nipponitella explicata* Hanzawa, and *Acervoschwagerina endoi* (Hanzawa). This zone corresponds to the lower part of Sakamotozawan Stage in Japan and can be correlated with the *Robustoschwagerina schellwieni* Zone of Kahler (1974) and the *R. schellwieni* Zone in Fergana (Bensh, 1972) and Darvus (Leven and Schelbovich, 1978, 1980) of Russia, the Sakmarian Stage in Russia.

The following zones and faunas belong to this zone: *Pseudofusulina vulgaris* Zone (Toriyama, 1956; Ota, 1977) of the Akiyoshi Limestone; *Pseudoschwagerina subsphaerica* subzone (Nogami, 1961) of the Atetsu Limestone Group; *Zellia nunosei* Zone to the Barren Zone (Kanmera and Mikami, 1965) of the Lower Sakamotozawa Subformation; *Robustoschwagerina* Fauna (Fujimoto, 1941; Igo, 1964) of the Samegai Formation; *Robustoschwagerina* Fauna (Koike, 1963 MS) of the Ryozenyama Limestone.

12) *Robustoschwagerina schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone

Figures 45, 48

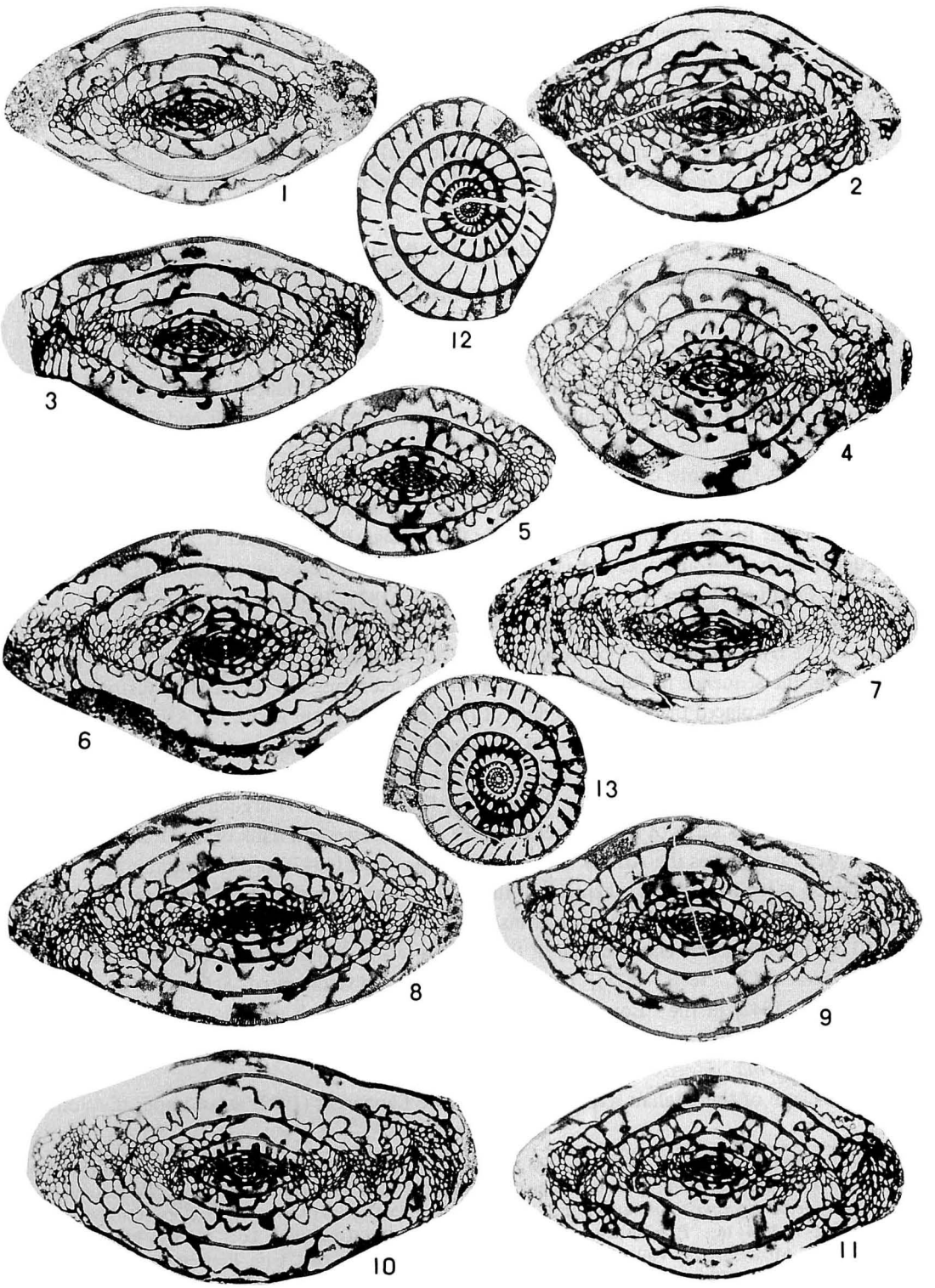
The base of this zone is marked by the appearance of *Robustoschwagerina schellwieni schellwieni* (Hanzawa) and *Pseudofusulina vulgaris globosa* (Schellwien and Dyhrenfurth). The top of this zone is drawn just below the appearance of *Misellina claudiae* (Deprat).

This zone is typically developed in the type section of the Sakamotozawa Formation. In this section, this zone is 85–100 meters thick, and consists of light grey to black biomicrite and biomicrudite limestone. Faunal elements of this zone are the following species: *Pseudofusulina vulgaris vulgaris* (Schellwien and Dyhrenfurth), *P. vulgaris globosa* (Schellwien and Dyhrenfurth), *Robustoschwagerina schellwieni schellwieni* (Hanzawa), *P. fusiformis* (Schellwien and Dyhrenfurth), *P. kraffti kraffti* (Schellwien and Dyhrenfurth), *P. kraffti magma* Toriyama and some others.

This zone occupies the upper part of Sakamotozawan Stage in Japan, and is exactly correlated with the *Pseudofusulina vulgaris* Zone of Kahler (1974), the Ulkian or the Artinskian Stage in Russia.

This zone can be compared with the following zones: *Pseudofusulina ambigua* Zone (Toriyama, 1958; Ota, 1977) and *Misellina claudiae* Zone (Ota, 1977) of the Akiyoshi Limestone Group; *Pseudofusulina vulgaria* Zone and *Pseudofusulina kraffti magma* Subzone (Nogami, 1961) of the Atetsu Limestone Group; *Pseudofusulina vulgaris* Zone, *P. fusiformis* Zone and *P. ambigua* Zone (Kanmera and Mikami, 1965) of the Sakamotozawa Formation; *Pseudoschwagerina*

Fig. 27. All photographs ×8. **1–13: *"Pseudoschwagerina" morikawai* Igo;** Loc. B-31 in Section B, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *"Pseudoschwagerina" morikawai* Zone, the lower part of the Upper Hikawan Stage, Upper Carboniferous Series.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schellwieni Zone, *Chalaroschwagerina vulgaris* Zone and *Pseudofusulina fusiformis* Zone (Choi, 1973) of the Sakamotozawa Formation at Setamai-Yahagi region; *Pseudoschwagerina* Zone (Chisaka, 1962) of the Nishikori Formation; *Acervoschwagerina endoi-Pseudofusulina isomiae* Zone and *Robustoschwagerina hidensis-Pseudofusulina kraffti magma* Zone (Igo, 1965) of the Sote Formation.

The successive stratigraphic distribution of the marker species stated in the Hikawan to the Sakamotozawan Stages are diagrammatically illustrated in Figs. 23, 33 and 40.

V. The Carboniferous and Permian Boundary

A. Boundary in the Type Region

1. Historical Review

The Carboniferous System was proposed by Conybeare and Phillips (1822) for the sediments comprised of the Old Red Sandstone, Mountain Limestone, Millstone Grit and Coal Measures in England. Later, the Old Red Sandstone was transferred into the Devonian System. The Carboniferous Limestone composed of marine sediments and the upper, Millstone Grit and Coal Measures consisting of non-marine sediments. An almost complete marine Carboniferous succession was found by Murchison (1841) in the Russian Platform and Ural Mountains, and the upper Carboniferous rocks there has been recognized as the type succession of marine rocks.

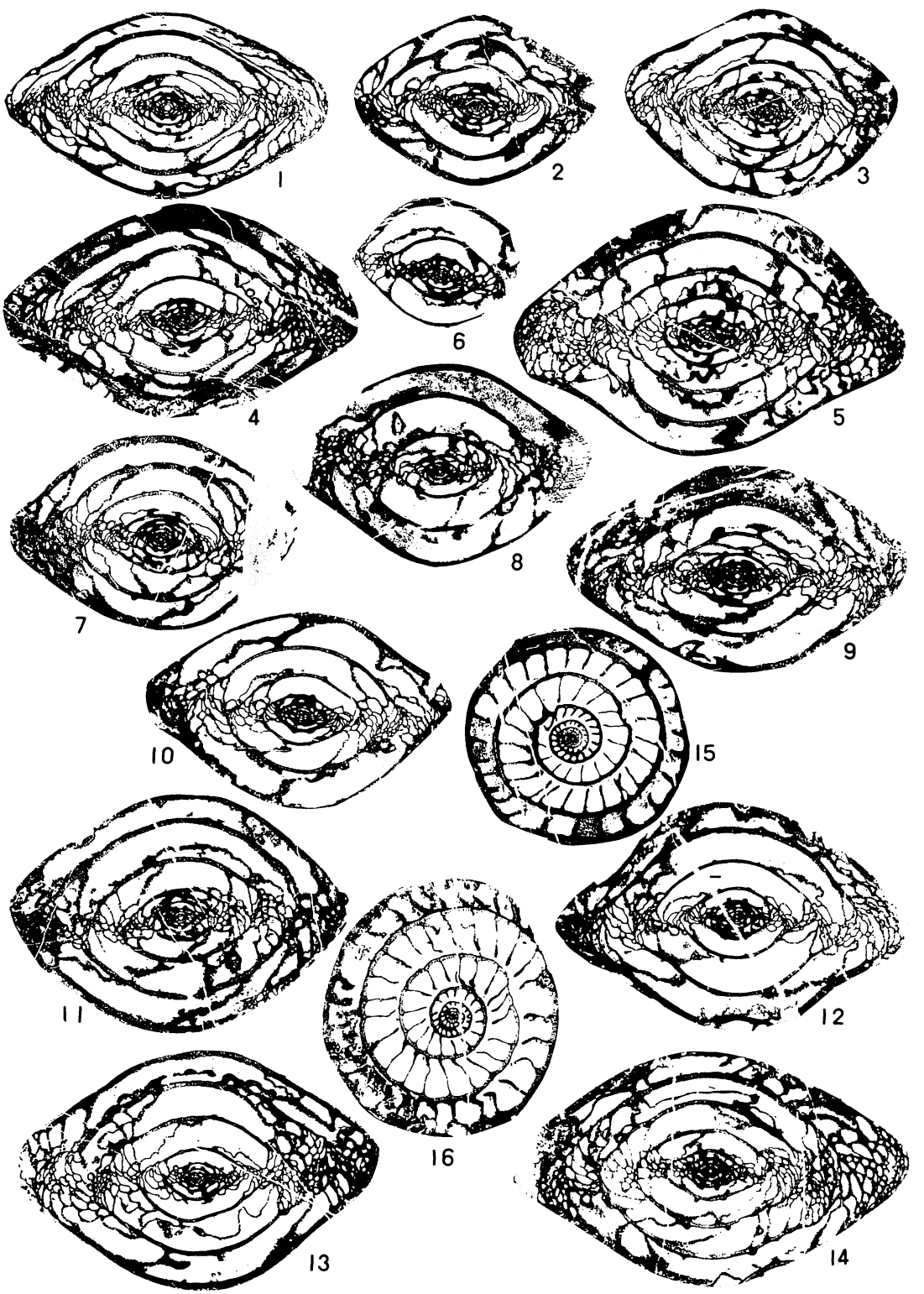
The Permian System was founded by Murchison (1835, 1841) for a thick series of marls, limestones, sandstones and conglomerates, which overlie the Carboniferous, along the western flank of the Ural Mountains. Consequently, the Carboniferous-Permian boundary-stratotype is located in the sequence in Russia, where the marine sediments are successively distributed.

Murchison placed the lower boundary of the Permian System above the Artinsk grits, that is, at the base of beds now classified as the Kungurian Stage. The original Permian included the beds now embraced in the Kungurian, Kazanian, and Tartarian Stages, which are composed largely of the continental sediments. Meanwhile, Karpinsky (1889) argued that the ammonite faunas from a thick series of detrital rocks exposed along the western flank of the Ural Mountains, which were grouped as the Artinsk Stage in his earlier work (1847), are comparable with those recognized as the Permian in other part of the world. Thus the base of the Permian was lowered in its type region to the base of the Artinskian Stage.

The first systematic classification of the Carboniferous fusuline fossils in Russia was made by Moeller (1877, 1878, 1879), in which he (1877) discriminated *Schwagerina princeps* (Ehrenberg, 1842) in the "Lower Zone" of the Artinskian of Karpinsky (1847). The Upper Carboniferous marine sediments in Russia was divided by Nikitin (1890) into the Gzhelian and the "*Schwagerina*" Horizon.

The name of the Uralian was introduced by the Lapparent (1902) as an upper division of

Fig. 28. All photographs ×8. **3–5: "*Pseudoschwagerina*" *morikawai* Igo;** a float sample, upstream of Ichinotani valley, Fikuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture. Ichino-tani Formation, the "*Pseudoschwagerina*" *morikawai* Zone, the lower part of the Upper Hikawan Stage, Upper Carboniferous Series; **1, 2, 6–16: "*Pseudoschwagerina*" *morikawai-minatoi* Transition;** Loc. Mz-5 in Mizuyagadani Section, Mizuyagadani Valley, Fukuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture. Mizuyagadani Formation, the "*Pseudoschwagerina*" *morikawai* Zone, the lower part of the Upper Hikawan Stage, Upper Carboniferous Series.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the Carboniferous rocks of the western Europe. He thought that the Uralian was unconformably overlain by the Artinsk beds which were referred to the base of the Permian. The Uralian Stage was divided into two units as follows:

Upper: the limestone with "*Fusulina*" *verneuili* and "*Schwagerina*"

Lower: Gzhelian beds with "*Fusulina*" *longissima*

Thus, the upper limestone of the Uralian represents a facies of the Artinskian which was placed in the Permian.

In the same year, Tschernyschew (1902) published a monograph, "Die Oberkarbonischen Brachiopoden des Ural und des Timan", and he divided the "Upper Carboniferous" limestone into three units as follows:

C_3^3: "*Schwagerina*" Horizon

C_3^2: Cora Horizon

C_3^1: Omphalotrocus Horizon

The next higher horizon, the Artinskian was classified by him as the Permo-Carboniferous (CPg). This division brought about an unexpected and unfavourable result. Namely, although Tschernyschew did not use the term of Uralian, his division was immediately accepted as the standard for the Uralian. As the result, the Carboniferous-Permian boundary in the Russian section has come to be placed between the "*Schwagerina*" Horizon below and the Artinskian above.

Schellwien (1908) accepted Tschernyschew's work and studied fusuline distributions in C_3- and CPg-Horizons of the Moscow, Donetz, Wolga, Ural and Timan regions.

Deprat (1912–1915) presented stratigraphic and geographic distributions of Carboniferous and Permian fusulinids from China and Indochina.

In 1924, Beede and Knicker payed attention to the occurrence of "*Schwagerina*" (now termed *Pseudoschwagerina* and *Paraschwagerina*) in the Wolfcamp Formation of the Trans-Pecos, Texas and the Neva Limestone of Kansas. They advocated that the *Schwagerina* Zone can be recognized as the lowest subdivision of the Permian rocks, instead of being classified as the uppermost Carboniferous. Dunbar and Condra (1927) studied the Pennsylvanian fusulinids in Nebraska and proposed three fusuline generic zones, the Zones of *Fusulina, Triticites* and *Schwagerina* in the succession from the middle Pennsylvanian to the lower Permian.

A pioneer work of fusuline zonation in Japan was made by Ozawa (1923, 1925) in the Akiyoshi Limestone Group. He showed seven species zones ranging from the middle Carboniferous to the middle Permian as follows:

(Akiyoshi Limestone Group)

P_3 ..... *Sumatrina annae* Zone

P_2 ..... *Fusulina ambigua* Zone

P_1 ..... *Fusulina japonica* Zone

CPg ... *Fusulina lutugini* Zone

C_3^2 .... *Schwagerina princeps* Zone or *Fusulina vulgaris* Zone

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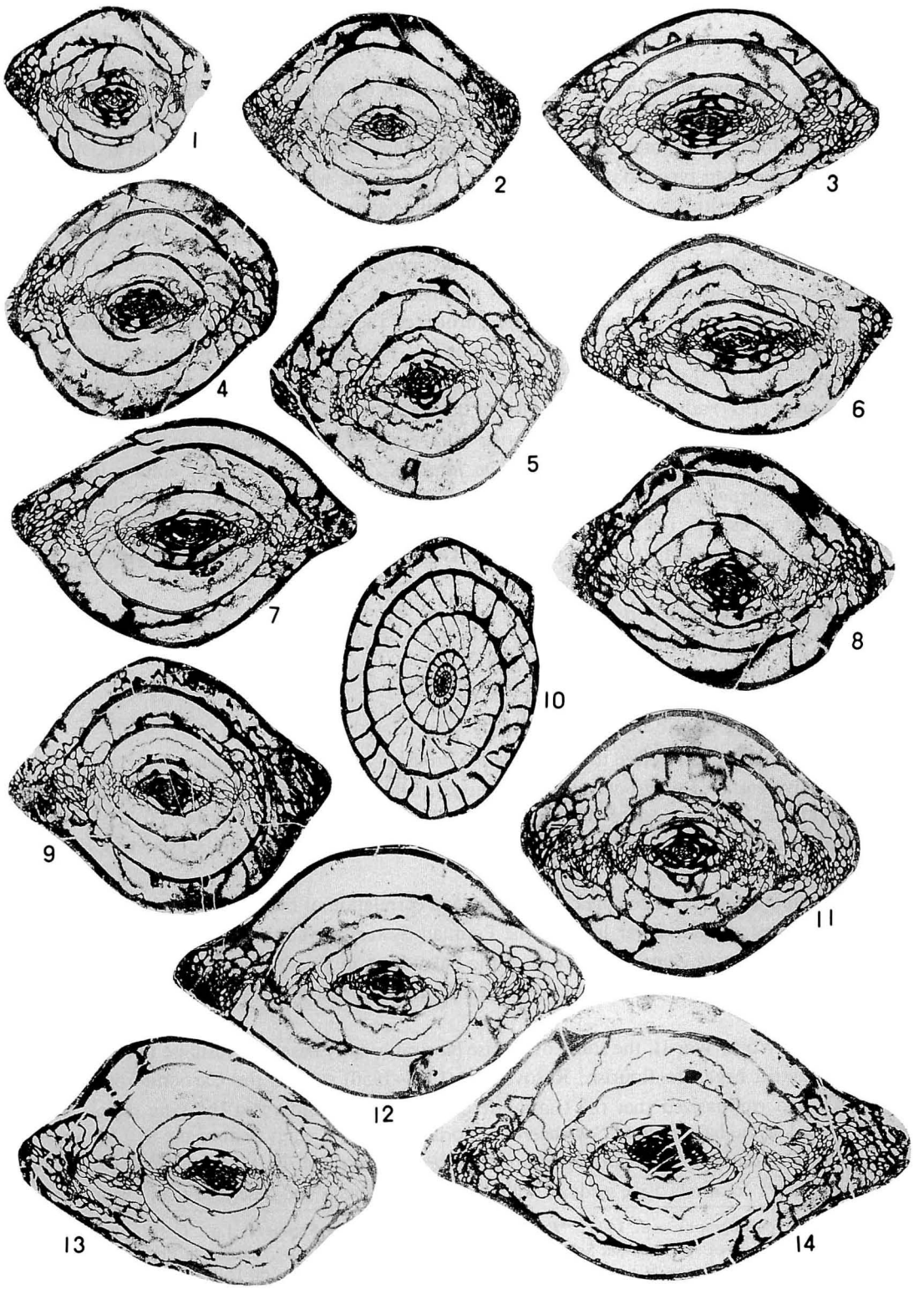
Fig. 29. All photographs ×8. **1–14:** "***Pseudoschwagerina***" ***minatoi*** **Kanmera; 1–10:** Loc. A-26 in Section A, Morikuni, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series; **11, 12:** Loc. R8–12 in Section R8, northern cliff along the Japan Sea, Itagamine area, Uta, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series; **13, 14:** Loc. a limestone conglomerate in Matsunagi Section, Matsunagi, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series.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C_3^1 .... *Schwagerina muongthensis* Zone
C_2 .... *Fusulinella bocki* Zone

In 1936, Dunbar and Skinner restudied the specimen of *Borelis princeps* Ehrenberg based on thin-sections. They noticed that Ehrenberg's original types of *Borelis princeps* were quite different from the form, commonly identified as *Schwagerina princeps. Schwagerina* was redefined in accordance with its type, taking the place of *Pseudofusulina,* which was suppressed as a synonym. The species currently identified as *Schwagerina* with a tightly coiled juvenarium were left unnamed. While, the new genus *Pseudoschwagerina* was proposed to the forms commonly identified as "*Schwagerina*" *princeps* of Schwager or "*Schwagerina*" *uddeni* of Beede and Knicker, and the new genus *Paraschwagerina* to the forms identified as "*Schwagerina*" *gigantea* White.

In the same year, Ruzhencev (1936) introduced the Sakmarian Stage for the beds of the *Pseudoschwagerina* Zone or the "Lower zone" of the Artinskian of Karpinsky (1874).

At the 17th International Geological Congress held at Moscow in 1937, Nalivkin and Ruzhencev (1937) advocated that the base of the Permian should be placed below the Sakmarian. While Licharev and Rauser-Chernousova (1937) placed it just above the Sakmarian, and others at the base of the *Pseudofusulina lutugini* Zone. At that time, among the Soviet geologists there was a wide difference of opinion as to where the base of the Permian should be drawn in its type region. The type "Uralian" of the Ufa Plateau was studied in detail by Rauser-Chernousova (1938) in the Ishimbaevo Oil Fields. She established the following succession of fusuline zones, in ascending order:

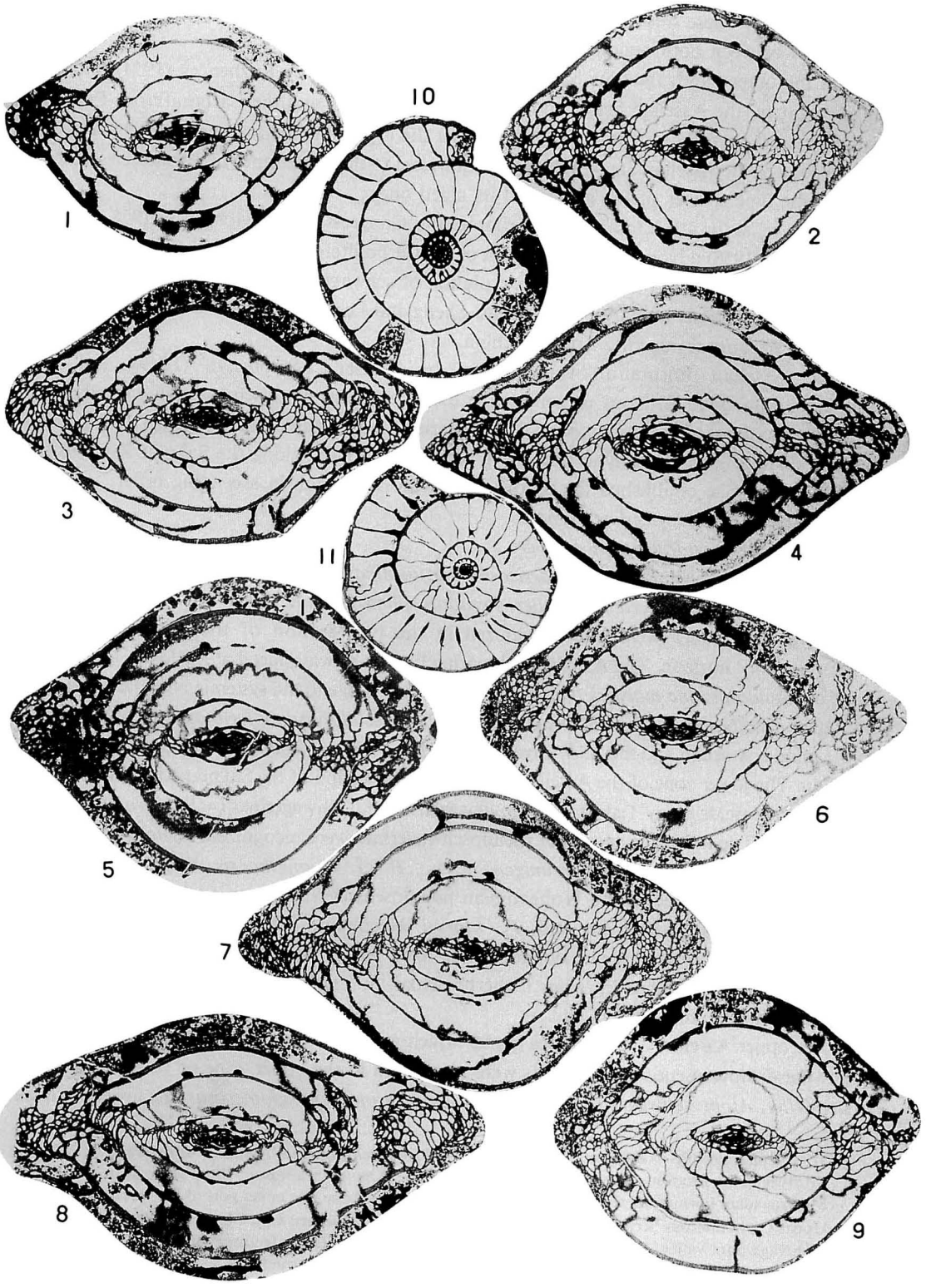
5. *Pseudofusulina lutugini* Zone
4. *Pseudofusulina andersoni* Zone
3. *Pseudofusulina moelleri* Zone
2. "*Schwagerina princeps*" Zone
1. *Triticites* Zone

Although the species referred to "*Schwagerina princeps*" Ehrenberg by Rauser-Chernousova was not equivalent to *Pseudoschwagerina princeps* (Schwager) as already suggested by Dunbar and Skinner (1936), most of the beds of the Ufa Plateau have come to be referred to as the Permian, and the Uralian was restricted to the underlying upper Carboniferous beds of the Zone of *Triticites.*

Dunbar (1940) reviewed the classification and correlation of the type Permian, and proposed that the most natural lower limit of the Permian System should be placed at the base of the *Pseudoschwagerina* Zone or the base of the Sakmarian in Russia. Moore (1940), in the same year, summarized the Carboniferous-Permian boundary problem on the basis of the stratigraphy in America.

After World War II, the study of precise biostratigraphy based on fusuline fossils in Russia and America began to flourish. Rosovskaya (1948–1950) studied the Carboniferous fusuline fossils and emphasized that the Carboniferous-Permian boundary in the type region should be placed at the base of the "*Schwagerina*" horizon, which is equivalent to the first appearance and rapid evolution of *Pseudoschwagerina* and *Pseudofusulina.* In America, Thompson (1948, 1954) made a comprehensive study of American fusuline fossils and described many Wolfcampian

Fig. 30. All photographs ×8. **1–11: "*Pseudoschwagerina*" *minatoi* Kanmera;** Loc. C-3121 in Section C, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series.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fusuline species. These studies have given direct effects on the boundary problem and the faunal differences between both regions.

On the other hand, the type Sakmarian Series was divided by Ruzhencev (1954) into two stages, namely, the Asselian below and the Sakmarian above, and the Carboniferous-Permian boundary in the Asselian stratotype was drawn at the top of the lower zone or the base of the middle zone of the Asselian Stage, which was equivalent to the appearance of *Pseudoschwagerina uddeni,* the type species of the genus and its allied ones.

However, at the 4th International Carboniferous Congress held at Moscow in 1958, Rauser-Chernousova (1958) advocated the placement of the Carboniferous-Permian boundary at the top of the Asselian Stage on the basis of the evolution of schwagerinids. Konishi (1960) supported her choice on the basis of marine algal floras. Sheng and Lee (1965) placed the boundary at the top of the *Pseudoschwagerina* Zone in China.

The Asselian Formation was studied by Rauser-Chernousova (1949) and was subdivided into three horizons or zones. The fusuline faunas of this formation were thought to be allied to those of the stratotype of the Sakmarian Stage. Rauser-Chernousova (1965) studied fusuline distributions in the type Sakmarian section distributed along the Sakmar River in the southern Ural. She established the following fusuline succession in ascending order:

4. Zone of *Pseudofusuline verneuili*
3. Zone of *Pseudofusulina moelleri*
2. Zone of *"Schwagerina" sphaerica-Pseudofusulina firma*
1. Zone of *"Schwagerina" moelleri-Pseudofusulina fecunda*

The lower two zones were also recognized in the type section of the Asselian Stage or *"Schwagerina"* horizon. The Asselian-Sakmarian boundary was placed at the lower limit of the Zone of *Pseudofusulina moelleri.* This boundary is equal in age to the systemic boundary proposed by Rauser-Chernousova. The *"Schwagerina" moelleri-Pseudofusulina fecunda* Zone is equivalent to the middle Asselian and the *"Schwagerina" sphaerica-Pseudofusulina firma* Zone to the upper Asselian. The lower zone of the Asselian is absent in this section of the Sakmar River. The middle Asselian zone yields many Tethyan pseudoschwagerines and schwagerinas (= *Sphaeroschwagerina* M.-Maklay). The following species of pseudoschwagerinas were recognized: *Pseudoschwagerina* aff. *intermedia* Rauser., *P.* cf. *primigena* Raus., *P.* cf. *muongthensis* (Deprat), etc. These species are closely allied to the Wolfcampian pseudoschwagerinas such as *Pseudoschwagerina beedei* Dunbar and Skinner and *P. morsei* Needham. The following schwagerinas (= *Sphaeroschwagerina*) were also obtained in the same zone: *"Schwagerina" sphaerica sphaerica* (Scherbovich), *"S." sphaerica gigas* (Scherbovich), *"S." pulchra* (Kahler and Kahler), *"S." carniolica* (Kahler and Kahler), etc.

The upper Asselian zone includes faunas which were subjected to local facies controls. The following distinct pseudoschwagerinas were recognized in the upper zone or its corresponding ones: *Zellia, Alpinoschwagerina,* and *Sphaeroschwagerina* ex gr. *glomerosa.* The lower Asselian

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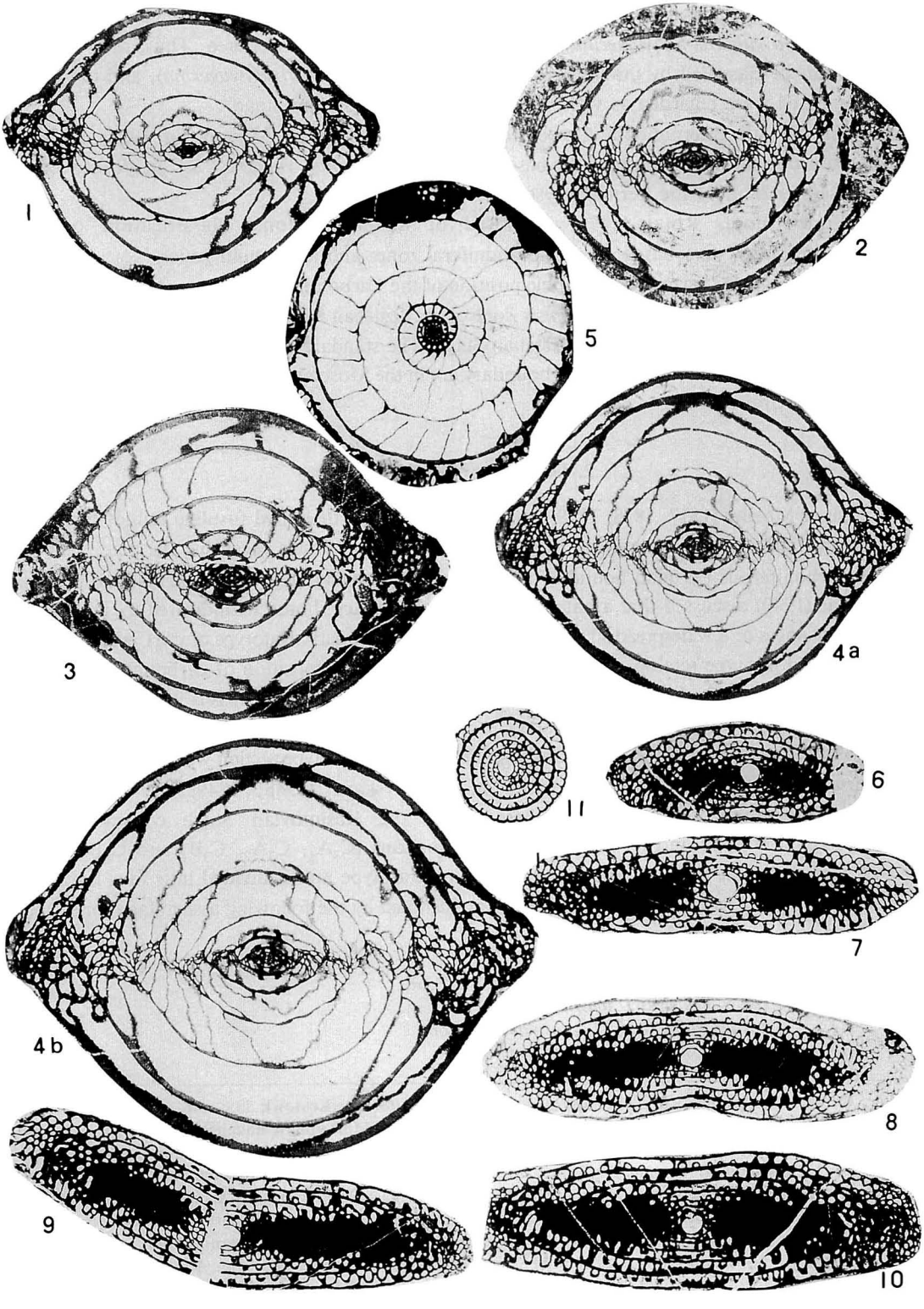
Fig. 31. All photographs ×8 (except 4b ×10). **1–5: *"Pseudoschwagerina" minatoi* Kanmera;** Loc. Mz-8 in Mizuyagadani Section, Mizuyaga-dani valley, Fukuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture. Mizuyagadani Formation, the *"Pseudoschwagerina" minatoi* Zone, the upper part of Upper Hikawan Stage, Upper Carboniferous Series; **6–11: *Quasifusulina longissima* (Moeller);** Loc. Mz-8 in Mizuyagadani Section, Mizuyaga-dani valley, Fukuji, Kamitakara-mura, Ohno-gun, Gifu Prefecture. Mizuyagadani Formation, the *"Pseudoschwagerina" minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series.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zone is scarce in schwagerinas. Kireeva and others (1972), however, established the Zone of *Schwagerina vulgaris-Schwagerina fusiformis* Zone in the type Assel area. Thus, the Asselian Stage can be classified by the lineages of *Schwagerina* (= *Sphaeroschwagerina*), and the three zones stated were regarded as valid subdivisions of the Asselian Stage.

At the 8th International Carboniferous Congress held at Moscow in 1975, Rauser-Chernousova and Rotai accepted the base of the "*Schwagerina*" *vulgaris*-"*S.*" *fusiformis* Zone as the lower limit of the Permian System.

Furthermore, Rotai (1979) proposed of an international classification of the Carboniferous System based on the foraminiferal zones and ammonoid zones.

At present, the formal stratigraphic position of the Carboniferous-Permian boundary in the U.S.S.R. is between the *Daixina sokensis* Zone of the Gzhelian Stage and the *Sphaeroschwagerina vulgaris-S. fusiformis* Zone of the Asselian Stage. The standard sections of the Carboniferous and Permian strata near the systemic boundary are in the Moscow Synclise and the Perm distirct of the Pre-Urals.

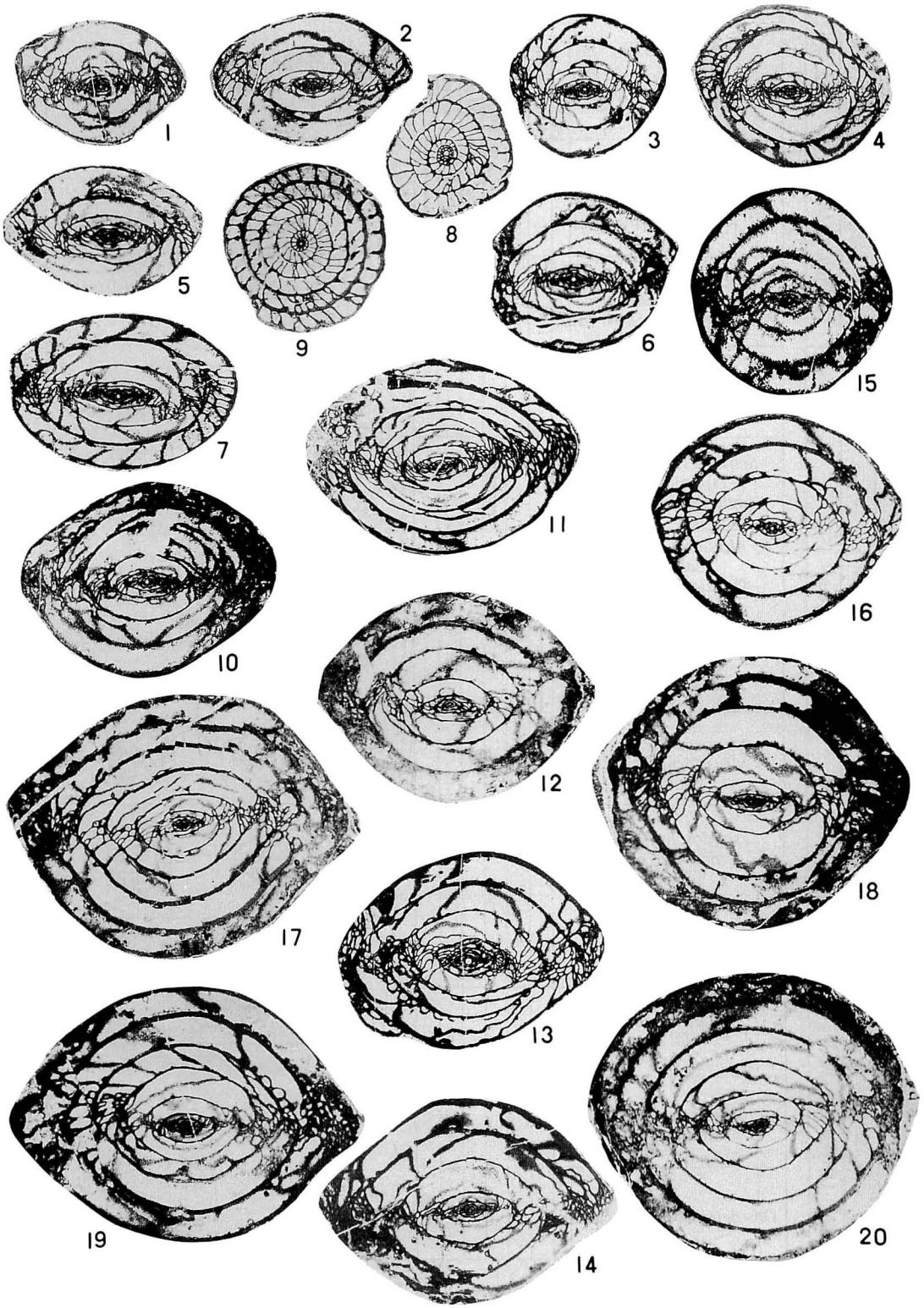
2. Definition of the Boundary

Since Moeller (1877, 1878, 1879) and Schellwien (1908) described fusuline faunas from the Russian Platform and some others regions, most of the proposals regarding the placement of the Carboniferous-Permian boundary have been based on the distribution of fusuline faunas. Dunbar (1940) discussed that a natural systematic boundary should be indicated by important faunal changes or a widespread stratigraphic hiatus. The boundary stratotype of the Carboniferous-Permian in the type section of Russia indicates continuous deposition of carbonate sediments (Lun'yak and others, 1980, etc). Thus, the faunal change of fusuline fossils is thought to be a good indicator to solve precise boundary.

Fusuline zonation of the Upper Carboniferous Series in the type section was made by Rauser-Chernousova (1938, 1941, 1974, etc) and Rosovskaya (1948, 1949a, 1949b, 1950a) and some others. According to these work, the Kasimovian Stage constitutes the composite-stratotype and is divided into four horizons (C_3A_1, C_3A_2, C_3B_1 and C_3B_2). The overlying Gzhelian Stage also forms a composite-stratotype and is divided into four horizons (C_3C_1, C_3C_2, C_3D and C_3E). These horizons are denoted by the following assemblage zones and a range zone in descending order:

C_3E – *Daixina sokensis-Pseudofusulina gregaria* Zone
C_3D – *Jigulites jigulensis-J. longus* Zone
C_3C_2 – *Triticites stuckenbergi-T. procolomensis* Zone
C_3C_1 – *Triticites irregularis-T. acutus* Zone

Fig. 32. All photographs ×8. **1–11: *Sphaeroschwagerina fusiformis* (Krotow);** Loc. AK-4110 in Section B, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Sphaeroschwagerina fusiformis* Zone, Lower Nagatoan Stage, Lower Permian Series; **12–15: *Sphaeroschwagerina fusiformis-pavlovi* Transition;** Loc. 5109 in Section A, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lowest part of the Middle Nagatoan Stage, Lower Permian Series; **16–20: *Sphaeroschwagerina pavlovi* (Rauser-Chernousova);** Loc. AK-41 in Section B, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series.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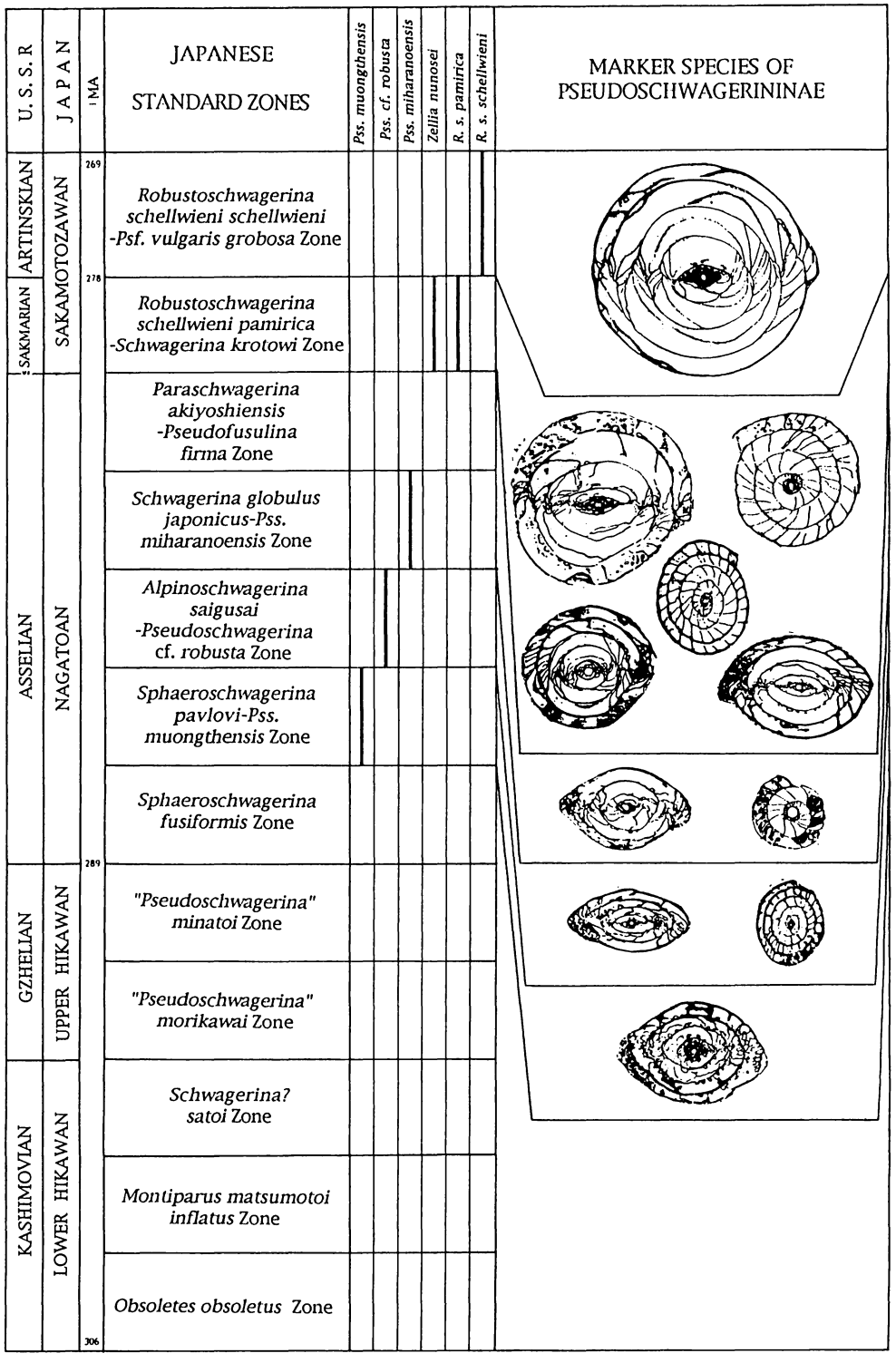

Fig. 33. Stratigraphic distribution of marker species of the Pseudoschwagerininae in the Nagatoan and Sakamotozawan Stages.

C_3B_2 – *Triticites ohioensis*-T. *arcticus* Zone
C_3B_1 – *Triticites rossicus-T. paraarcticus* Zone
C_3A_2 – *Montiparus montiparus* Zone
C_3A_2 – *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone

Rotai (1979) proposed an international biostratigraphic classification of the Carboniferous System based on ammonoid and foraminiferal fossils. In this classification, the Upper Carboniferous Series was divided into two stages, the Kasimovian Stage below and the Gzhelian Stage above. Each of these stages comprises the following three zones in descending order:

Gzhelian Stage .....
- U. *Daixina sokensis* Zone
- M. *Triticites ligulensis* Zone
- L. *Triticites stuckenbergi* Zone

Kasimovian Stage ....
- U. *Triticites arcticus-T. acutus* Zone
- M. *Triticites montiparus* Zone
- L. *Protriticites pseudomontiparus-Obsoletes obsoletus* zone

Fusuline zonation of the Lower Permian Series in the type section was established by Rauser-Chernousova (1938, 1965, and others) and others. This series is divided into three stages: the lower, the Asselian; the middle, the Sakmarian; the upper, the Artinskian. The unit-stratotypes of these three stages are subdivided into three zones, respectively, as tabulated below (Tschuvashov and Aleksne, 1980):

Artinskian Stage..
3. *Parafusulina solidissima* Zone
2. *Parafusulina lutugini* Zone
1. *Pseudofusulina concavatus* Zone

Sakmarian Stage..
3. *Pseudofusulina urdalensis* Zone
2. *Pseudofusulina verneuili* Zone
1. *Pseudofusulina moelleri* Zone

Asselian Stage....
3. "*Schwagerina*" *sphaerica-Pseudofusulina firma* Zone
2. "*Schwagerina*" *moelleri-Pseudofusulina fecunda* Zone
1. "*Schwagerina*" *vulgaris*-"*S.*" *fusiformis* Zone

Rauser-Chernousova, Schelgolev and others (1979) cited the following four opinions for the placement of the Carboniferous-Permian boundary based on fusuline faunas. The boundary may be drawn at either:

(a) the base of the *Daixina sokensis* Zone of the Gzhelian Stage, in which *Pseudofusulina* begins to appear (Rybakov, 1962; Lun'yak, 1962).

(b) the base of the Asselian Stage, in which considerable evolutionary changes in genera of the Fusulinidae took place (Rosovskaya, 1950).

(c) the base of the upper zone of the Asselian Stage, in which great diversifications of genera in various groups of marine fossils occurred (Barkhatova, 1970).

(d) the top of the Asselian Stage, in which distinctive development in evolutionary stages of the family Schwagerinidae are recognized (Rauser-Chernousova, 1960; Reitlinger, 1970).

The Carboniferous-Permian boundary that have arrived at the current consensus in the U.S.S.R. is between the *Daixina sokensis* Zone of the Gzhelian Stage and the "*Schwagerina*" *fusiformis*-"*S.*" *vulgaris* Zone of the Asselian Stage.

In the Japanese standard fusuline zonation proposed in this paper, I agree to this placement of the Carboniferous-Permian boundary at the base of the Asselian Stage defined by the first appearance species of *Sphaeroschwagerina*.

B. Boundary in Japanese Islands

1. Historical Review

Since Ozawa (1923, 1925) introduced fusuline biostratigraphy into the Akiyoshi Limestone in Japan, many fusuline zones have been established in the Japanese Carboniferous-Permian sediments of carbonate facies. With reference to Tschernyschew's scheme and Schellwien's study, Ozawa correlated the *Schwagerina* (=*Pseudoschwagerina*) *muongthensis* Zone in the Akiyoshi Limestone to the lower Uralian, and the *Schwagerina princeps* (=*Sphaeroschwagerina glomerosa*) Zone to the upper Uralian. This correlation resulted in the placement of the systemic boundary at the top of the *Schwagerina princeps* (=*Sphaeroschwagerina glomerosa*) Zone. At the present usage, the two zones can be precisely correlated with the middle and the upper part of the Asselian Stage in Russia.

Fujimoto (1936), who studied fusuline biostratigraphy of limestones in the Kanto massif, described two inflated schwagerinid species under the name of *Schwagerina* sp. (=*Robustoschwagerina* cf. *schellwieni pamirica* Leven & Scherbovich) and *Schwagerina kagaharensis* Huzimoto (=*Acervoschwagerina* cf. *endoi* Hanzawa). He considered the geologic age of these species as the Uralian of the upper Carboniferous. The use of the name of Uralian had become fairly familiar, and the Uralian embraced the upper Carboniferous with or without the *Schwagerina* Horizon (s.l.), or even with the lower Permian.

At the International Carboniferous Congress held at Heerlen in 1935, Yabe (1938) dealt with the problem of the boundary between the Carboniferous and the Permian of Japan, Manchuria and Korea. He divided the upper part of the "Titibu System" on the basis of the stratigraphical distribution and evolution of fusuline fossils into the following stages; *Yabeina, Neoschwagerina, Schwagerina* and *Fusulinella* stages. The Carboniferous-Permian boundary was roughly set between the *Schwagerina* and *Neoschwagerina* stages.

As a result of studies on the Paleozoic stratigraphy in the Kesen district, southern part of the Kitakami Mountains, Northeast Japan, Onuki (1937) introduced the name of the Sakamotozawa Formation or Series for the Lower Permian. He correlated the *Pseudoschwagerina* Zone in the lower part of the Sakamotozawa Formation with C_3 Zone of the Akiyoshi Limestone (Ozawa, 1925) and Kanto Mountains (Fujimoto, 1936). He pointed out that the systemic boundary of the Carboniferous and the Permian should be placed between C_2 and C_3 Horizons. Thus, the systemic boundary has been set at the base of the Sakamotozawa Formation.

In the same year, a "Uralian" primitive pseudoschwagerinids was described by Fujimoto (1937) under the name of *Pseudoschwagerina orientale* Huzimoto from the Kawanobori, Ohno-gun, Ohita Prefecture, southern Kyushu.

Hanzawa (1939) also described *Pseudoschwagerina schellwieni* Hanzawa and

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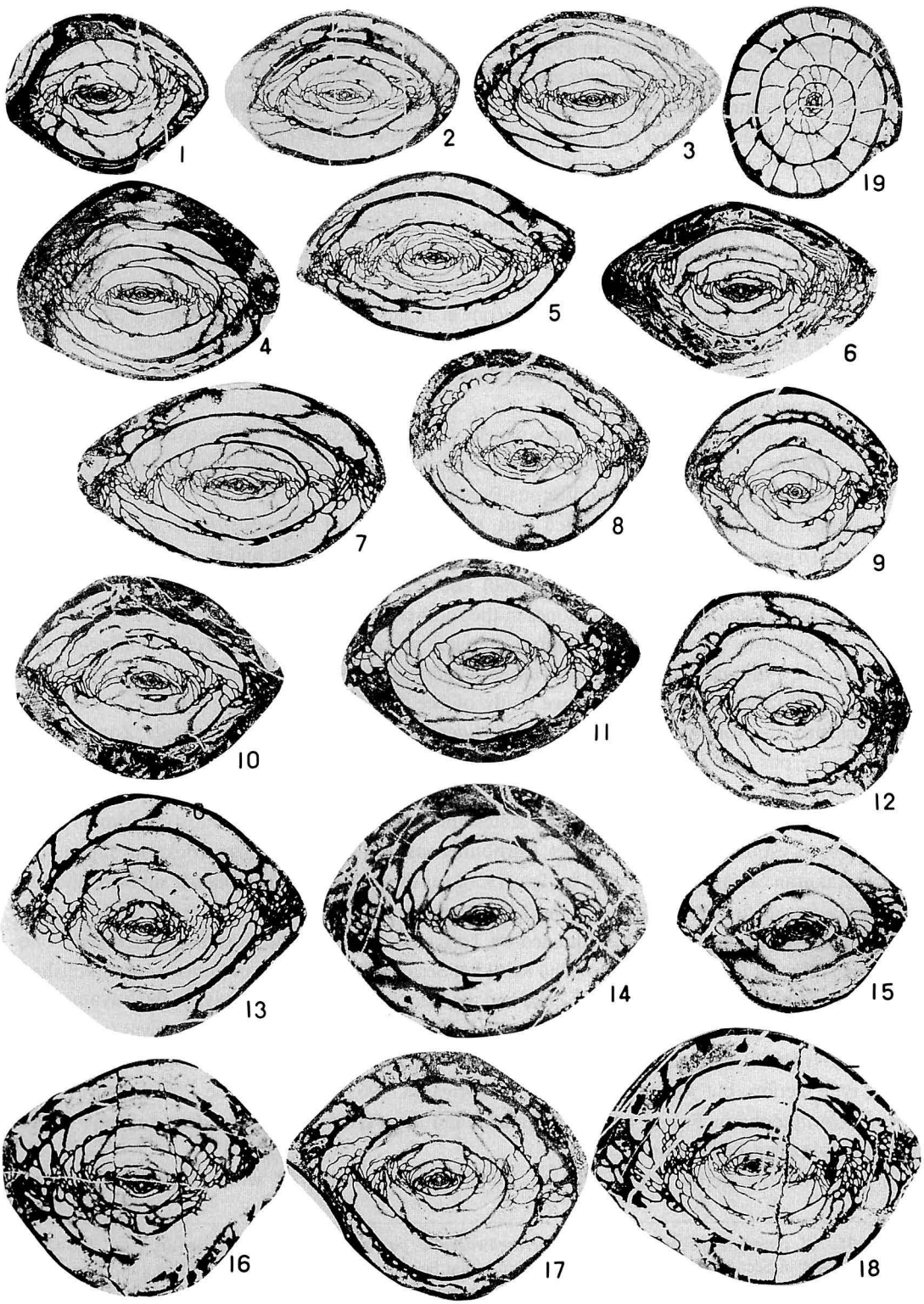
Fig. 34. All photographs ×8. **1–6: *Sphaeroschwagerina fusiformis* (Krotow)**; Loc. A-26 in Section A, Morikuni, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *Sphaeroschwagerina fusiformis* Zone, lowest part of the Lower Nagatoan Stage, Lower Permian Series; **7–12: *Sphaeroschwagerina fusiformis-pavlovi* Transition**; Loc. B-15 in Section B, Morikuni, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series; **13–19: *Sphaeroschwagerina pavlovi* (Rauser-Chernousova)**; Loc. R8–15 in Section R8, northern cliff along the Japan Sea, Itagamine area, Uta, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series.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Pseudoschwagerina nunosei Hanzawa, that is referable to *Zellia,* from the Sakamotozawa Formation and its equivalents. In 1941, Hanzawa first payed attention to the disconformable relationship between the *Fusulinella* and the *Pseudoschwagerina* Zone in the Liaotung Peninsula of South Manchuria, and discussed the Carboniferous-Permian boundary in Japan, Korea and Manchuria, having pointed out importance of the absence of the *Triticites* Zone. Minato (1942) confirmed remarkable unconformity beneath the base of the Sakamotozawa "Series" where the *Pseudoschwagerina* Zone directly overlies the *Profusulinella* or much lower zones. Thus, Minato set the lower limit of the Permian at the base of the Sakamotozawa Stage in Japan.

On the other hand, Fujimoto (1941) described the *Pseudoschwagerina schellwieni-P. samegaiensis* fauna from the Akasaka, Samegai and Nyukawa areas in Central Japan. He had a question whether the *Pseudoschwagerina* Zone in Japan could be correlated with the Sakmarian.

Soon after World War II, study of fusuline fossils in Japan began to flourish. The work by Thompson (1948, 1954) in America and Rosovskaya (1949, 1950) in Russia greatly influenced Japanese paleontologists.

During the period of 1950's many papers were published, and the discovery of the Zones of *Fusulinella, Triticites* and *Pseudoschwagerina* in the Kuma, Hida and Kanto massifs has again raised the problem on the Carboniferous-Permian boundary.

Kanmera (1952–1958) pointed out the presence of the *Fusulina, Triticites* and *Pseudoschwagerina* Zones in the Yayamadake Limestone Subgroup and described the fusuline fossils of these zones. Kanuma (1951–1960) also reported fusuline faunas of the *Fusulinella, Triticites* and *Pseudoschwagerina* Zones in the southern part of the Hida Mountains. Igo (1957) was successful in establishing the almost complete succession of the *Millerella, Profusulinella, Fusulinella, Fusulina, Triticites* and *Pseudoschwagerina* Zones in the Ichinotani Group. Toriyama (1954, 1958) published an exhaustive study of the Akiyoshi Limestone Group, in which he established the following fusuline zones: *Millerella, Profusulinella, Fusulinella* Zone in the Carboniferous and *Pseudoschwagerina, Parafusulina, Neoschwagerina* and *Yabeina* Zones in the Permian.

On the basis mainly of the studies stated the following regional chronostratigraphic units have been established for the upper Carboniferous and lower Permian rocks in Japan: the Kamitakaran Series was proposed by Igo (1956) for the *Millerella bigemmicula* subzone and the *Profusulinella fukujiensis* Zone in the Ichinotani Formation.

The Akiyoshian Series was founded by Toriyama (1960) on the *Fusulinella biconica* Zone in the Akiyoshi Limestone Group. The Kurikian Series and the Hikawan Series were established by Kanmera (1951) for the *Fusulina* Zone and the *Triticites* Zone, respectively, in the Yayamadake Limestone Subgroup. The Sakamotozawan Series for the Lower Permian in Japan was introduced by Onuki (1939) designating the *Pseudoschwagerina* Zone of the Sakamotozawa Formation as the type section, but was later emended by Toriyama (1963) to include the *Pseudoschwagerina morikawai* Zone in Fukuji and Yayamadake and the *Pseudofusulina vulgaris* subzone in the Sakamotozawa Formation.

During the period from 1954 to 1965, a large number of work dealt with fusuline

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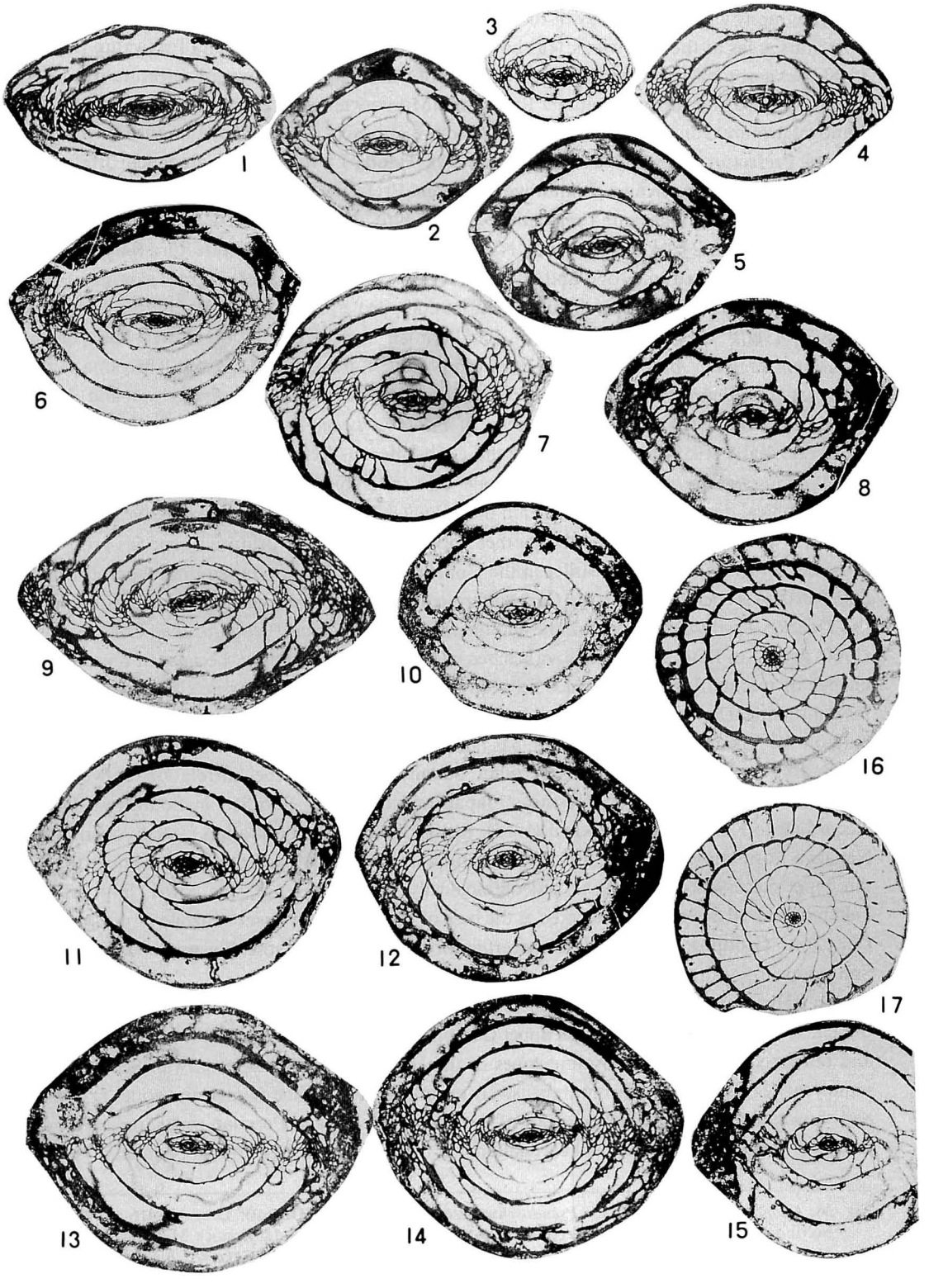
Fig. 35. All photographs ×8. **1–17: *Sphaeroschwagerina pavlovi* (Rauser-Chernousova);** Loc. AK-41 to AK-46 in Section B, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series.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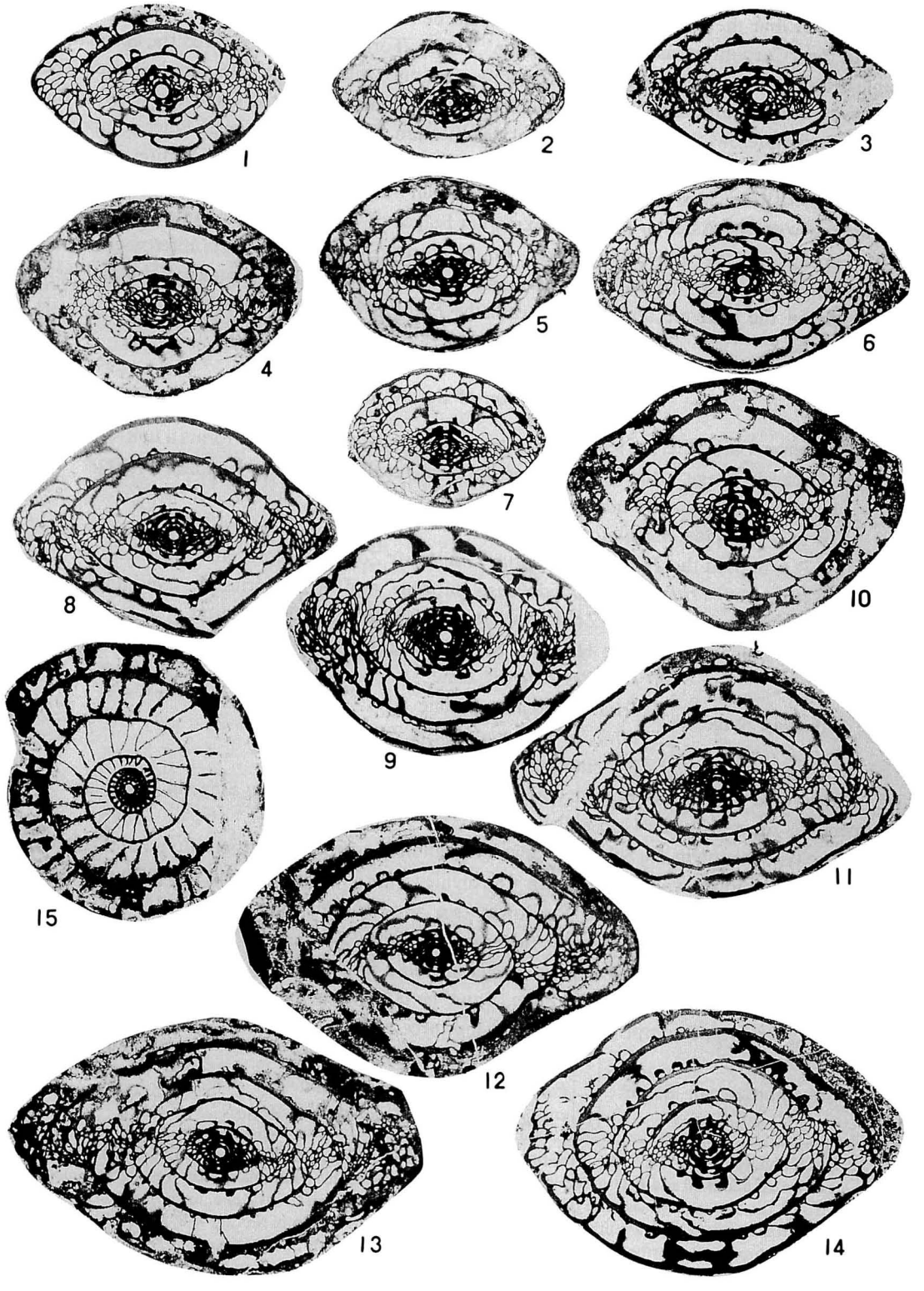
biostratigraphy and paleontology of the upper Carboniferous and lower Permian have been done in various areas as the followings: Taishaku Limestone Group in Hiroshima Prefecture (Akagi, 1958); Sakamotozawa Formation in the vicinity of Maiya-town in Miyagi Prefecture (Chisaka, 1962); Nakatsugawa area in Saitama Prefecture (Morikawa, 1953; Ishii, A. 1962): Ryoseki and Ohnogahara areas in Kochi and Ehime Prefecture (Ishizaki, 1962); Omi Limestone Group in Niigata Prefecture (Kawada, 1954; Fujita, 1958); Handa Limestone in Yamaguchi Prefecture (Kawano, 1961); Ibukiyama Limestone in Shiga Prefecture (Kobayashi, M. 1957); Atetsu Limestone Group in Okayama Prefecture (Nogami, 1961, 1962; Sada, 1964, 1965); Tamba region in Kyoto Prefecture (Sakaguchi, 1962); Nakagawa area in Tokushima Prefecture (Suyari, 1961, 1962); Futago-yama Limestone and adjacent regions in Saitama Prefecture (Takaoka, 1966).

The Carboniferous Research Subcommittee compiled a paper of "Carboniferous System of Japan" (1960), in which the base of the Permian was placed at the lower limit of the *Pseudoschwagerina morikawai* Zone (Igo, 1956, 1957; Kanmera, 1951, 1958; Toriyama, 1954, 1958), that is defined by the first appearance of the genus *Pseudoschwagerina* and faunal associations characterized by other species of *Pseudoschwagerina* and a number of *Triticites*. However, Yabe (1958) pointed out that the Carboniferous-Permian boundary drawn between the *Pseudoschwagerina* and *Triticites* Zone does not coincide with a plane of significant stratigraphical demarcation lying beneath the *Triticites* Zone in most of the representative areas. Kanuma (1960) also expressed another opinion that the primitive species-group of *Pseudoschwagerina* appeared earlier in the Upper Carboniferous of Japan than those in Russia and North America, and that the Carboniferous-Permian boundary should be placed between the *Triticites-Pseudoschwagerina* Zone and the *Pseudoschwagerina-Pseudofusulina* Zone. Konishi (1960) agreed to Rauser-Chernousova's scheme (1960) on the boundary, because of a prominent change of marine floras taken place between the Sakmarian and the Artinskian, rather than at the conventional Sakmarian-"Uralian" boundary. On the other hand, the available biostratigraphic data on the Sakamotozawa Formation has not been sufficient and reliable to allow us a definite conclusion on the Carboniferous-Permian boundary, and on the correlation between the Sakamotozawa Formation in Northeast Japan and the lower Permian in Southwest Japan. According to Kanmera and Mikami (1965), the Sakamotozawa Formation directly overlies the Nagaiwa Formation (Yamada, 1958) with distinct unconformity, and the basal member (Sa) of the type succession can not be paleontologically defined. Hence, the lower limit of the Sakamotozawan Series has been taken at the base of the *Triticites simplex* subzone of the Akiyoshi Limestone Group or the *Pseudoschwagerina morikawai* Zone of the Yayamadake Limestone Subgroup in Southwest Japan.

In "Historical Geology", a Japanese text-book published in 1967, Kanmera and Toriyama presented the correlation table of the upper Carboniferous and lower Permian formations in Japan and tabulated the standard fusuline zones of the Hikawan and Sakamotozawan Series. In the same year, Toriyama (1967) comprehensively examined the fusuline faunas and zones in Japan, and showed a detailed correlation chart of the Carboniferous and Permian rocks, indicating the problems concerning international correlation and the Carboniferous-Permian boundary. He also

Fig. 36. All photographs ×8. **1–15: *Pseudoschwagerina muongthensis* (Deprat);** Loc. AK-416 to AK-418 in Section B, and C-9 to C-12 in Section C, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series.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pointed out that the Series currently used should be lowered into Stage rank.

In the "Carboniferous Lexicon of Japan" (1978), Toriyama (1978) showed the correlation table of the Upper Carboniferous and concisely mentioned the systemic boundary in Japan. The Hikawan Stage comprising four fusuline zones was correlated with the Gzhelian Stage of the Upper Carboniferous Series in international classification. The Sakamotozawan Stage comprising four fusuline zones was correlated with the Gzhelian Stage of the Upper Carboniferous Series in the international classification. The Sakamotozawan Stage comprising four fusuline zones was compared with the Asselian and the Sakmarian Stages of the Lower Permian Series.

Throughout the Japanese Islands, no completely continuous Carboniferous-Permian succession has been confirmed by paleontologic evidence. Most of the Japanese biostratigraphers have placed the systemic boundary beneath the *Pseudoschwagerina morikawai* Zone and its equivalents.

2. Definition of the Boundary

The upper Carboniferous section in Yayamadake Limestone Subgroup forms a unit-stratotype of the Hikawan Stage, which was divided into two fusuline zones by Kanmera (1951):

Upper – *Triticites yayamadakensis* subzone

Lower – *Triticites matsumotoi* subzone

Igo (1957) proposed the *Triticites exculptus-T. hidensis* Zone at Fukuji, and regarded that this zone overlies the *Triticites yayamadakensis* subzone and is conformably overlain by the *Pseudoschwagerina morikawai* Zone. Kanmera (1967) accepted this opinion and included the following fusuline zones in the Hikawan Stage in descending order:

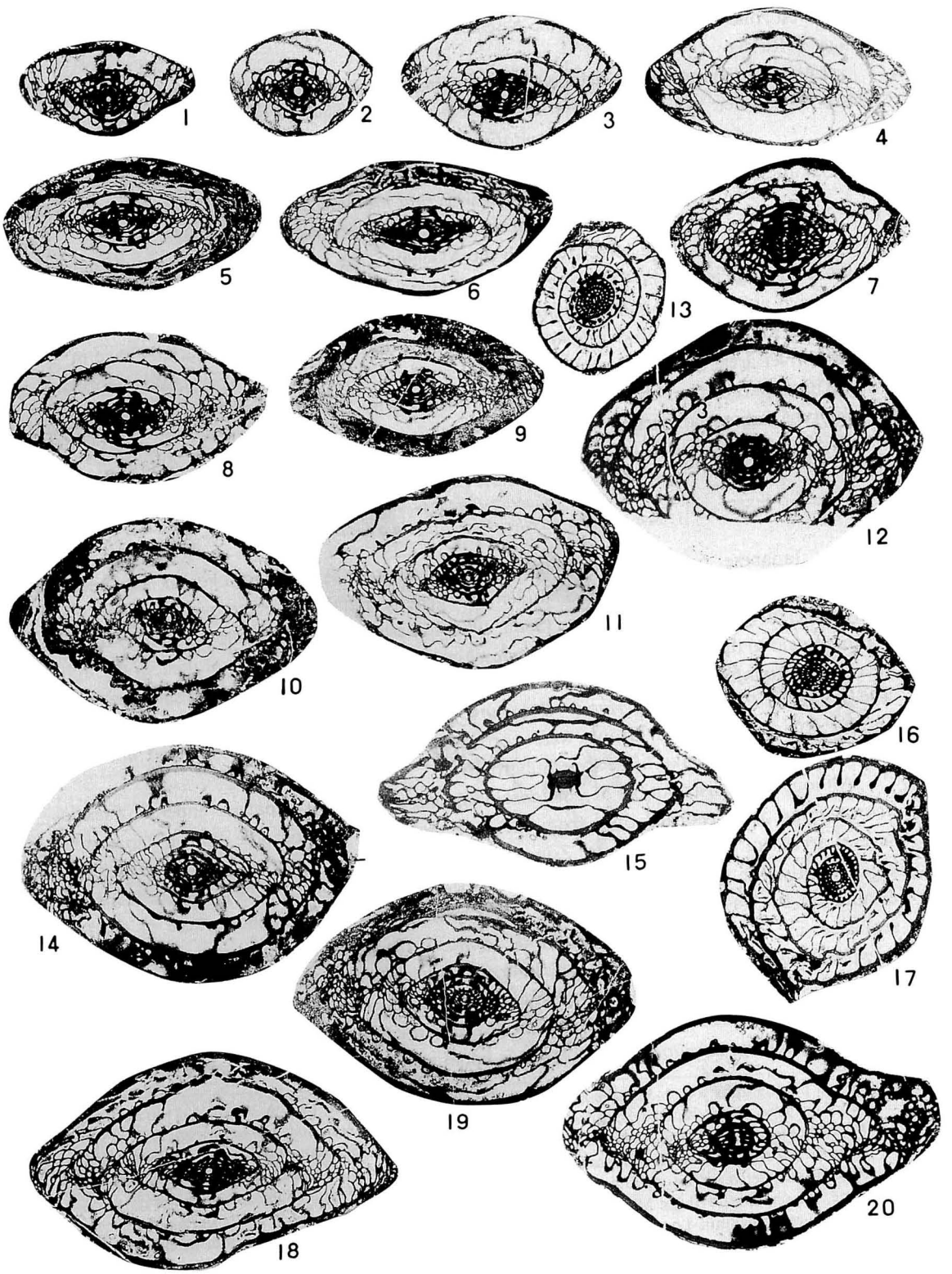
Hikawan Stage..
4. *Triticites hidensis* Zone
3. *Triticites exculptus* Zone
2. *Triticites yayamadakensis* Zone
1. *Triticites matsumotoi* Zone

The lower two fusuline zones were correlated with the Lower Gzhelian Stage in Russia and the upper two zones with the Upper Gzhelian.

The type section in the Sakamotozawa Formation constitutes a unit-stratotype of the Lower Permian Sakamotozawan Stage, which was divided into five fusuline zones as shown on page 35. Toriyama (1967) correlated the lower two zones (*Zellia nunosei* and *Monodiexodina langsonensis* Zones) with the *Pseudoschwagerina morikawai* Zone of the Yayamadake Limestone, and put together the upper two zones (*Pseudofusulina fusiformis* and *P. ambigua* Zones) into one zone, that is, the *P. ambigua* Zone. Thus, he designated the Sakamotozawan Stage as a composite-stratotype comprising the following three zones:

Sakamotozawan Stage..
3. *Pseudofusulina ambigua* Zone
2. *Pseudofusulina vulgaris* Zone
1. *Pseudoschwagerina morikawai* Zone

Fig. 37. All photographs ×8. **1–20: *Pseudoschwagerina muongthensis* (Deprat); 1–13.** Loc. A-28 to A-30 in Section A, and B-10 and B-11 in Section B, Morikuni area, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Naga-toan Stage, Lower Permian Series; **14–20.** Loc. R8–14 to R8–16 in Section R-8, and A-20 in Section A, Itagamine area, northern cliff along the Japan Sea, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone, lower part of the Middle Nagatoan Stage, Lower Permian Series.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The lowest zone was correlated with the Asselian Stage and the upper two zones with the Sakmarian Stage in Russia.

Later, Toriyama (1978) included the following four zones in the Sakamotozawan Stage in descending order:

Sakamotozawan Stage..
4. *Pseudofusulina ambigua* Zone
3. *Pseudofusulina vulgaris* Zone
2. *Pseudoschwagerina minatoi* Zone
1. *Pseudoschwagerina morikawai* Zone

The lower two zones were correlated with the Asselian Stage and the upper two zones with the Sakmarian Stage in Russia. Thus, the systemic boundary of the Carboniferous-Permian in Japan was drawn at the base of the *Pseudoschwagerina morikawai* Zone.

Since Rauser-Chernousova (1965) restudied the stratotype of the Sakmarian Stage in the Sakmar river area, southern Ural, the faunal elements of the so-called "*Schwagerina* Horizon" of the basal part of the Permian have been clarified in detail. She established the following zones in the type Sakmarian section.

Sakmarian Stage..
4. *Pseudofusulina verneuili* Zone
3. *Pseudofusulina moelleri* Zone

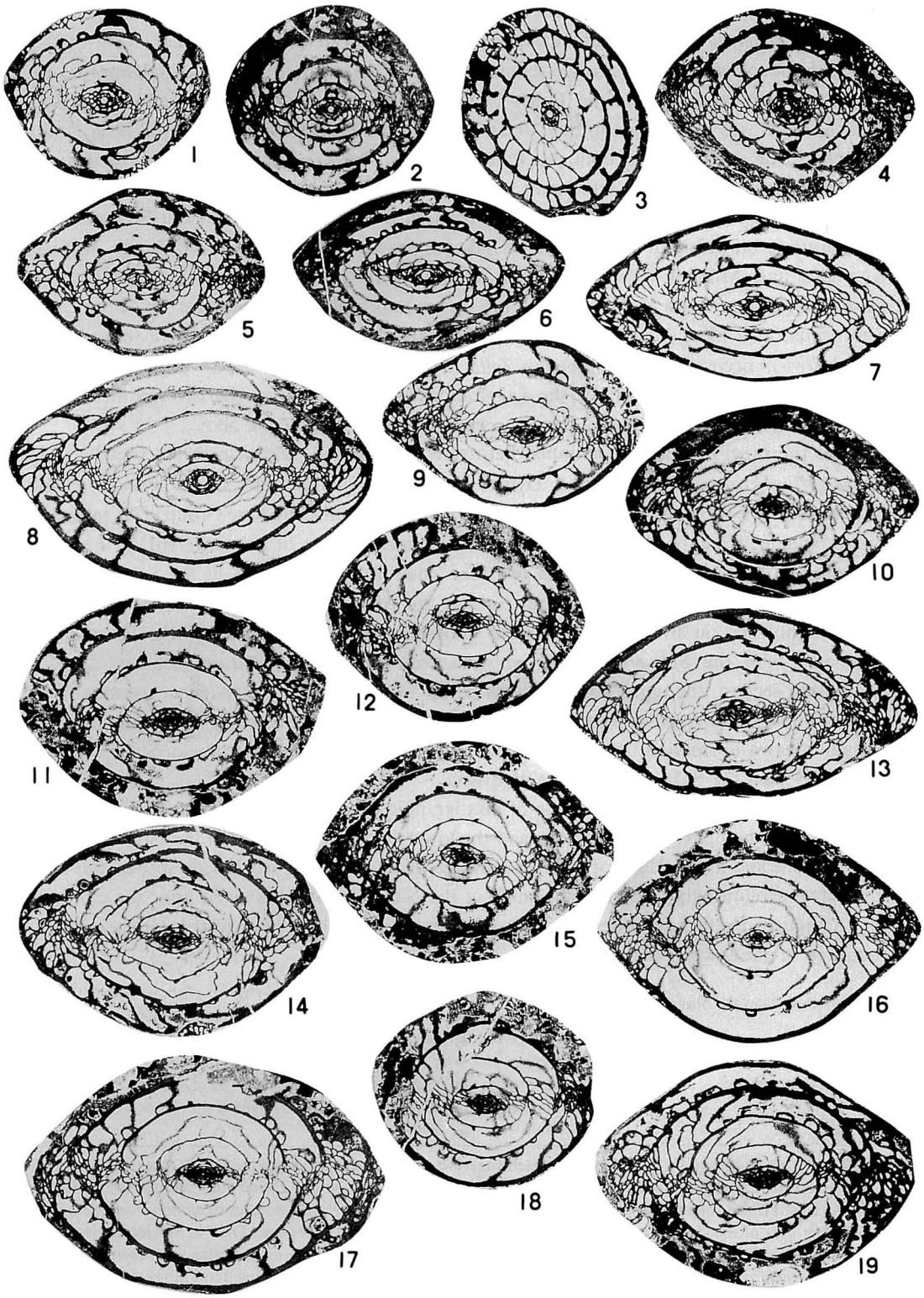
Asselian Stage....
2. *Schwagerina sphaerica-Pseudofusulina firma* Zone
1. *Schwagerina moelleri-Pseudofusulina fecunda* Zone

Among Japanese pseudoschwagerinas, the Asselian species of *Schwagerina* (=*Sphaeroschwagerina*) have been described under the generic name of *Pseudoschwagerina* from Akiyoshi (Toriyama, 1958) and Atetsu (Sada, 1964) Limestone Groups, but no particular attention has been paid to their distinction from *Pseudoschwagerina* and the difference of their stratigraphic levels. For example, the *Pseudoschwagerina* (=*Sphaeroschwagerina*) *kanmerai* subzone (Sada, 1964) and the *Pseudoschwagerina* (=*Robustoschwagerina*) *subsphaerica* Zone (Nogami, 1961) in the Atetsu Limestone Group were correlated with the *Pseudoschwagerina morikawai* Zone of the Yayamadake Limestone Subgroup.

Although the distribution of *Pseudoschwagerina minatoi,* a Japanese endemic *Pseudoschwagerina,* was recorded only from the type section, it has become known from other several areas not only in the Outer Zone, but also in the Inner Zone of Southwest Japan.

Recently, the *Schwagerina* (=*Sphaeroschwagerina*) *fusiformis-S.*(=*S.*) *vulgaris* Zone was established by Russian students (Rotai, 1979, etc.) in the lower Asselian Stage of the type sequence in Russia. I have found that *Sphaeroschwagerina fusiformis* occurs in the *Pseudoschwagerina muongthensis* Zone (Ota, 1977) in the Akiyoshi Limestone Group and the *Pseudoschwagerina kanmerai* subzone (Sada, 1964) in the Atetsu Limestone Group, and that each of these zones conformably overlies the *Pseudoschwagerina minatoi* Zones. Therefore, the *Pseudoschwagerina minatoi* Zone of Japan is apparently referable to the upper Carboniferous

Fig. 38. All photographs ×8. **1–5: "*Alpinoschwagerina*" *saigusai* (Nogami);** Loc. A-30 and A-31 in Section A, Morikuni area, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the "*Alpinoschwagerina*" *saigusai-Pseudoschwagerina* cf. *robusta* Zone, upper part of the Middle Nagatoan Stage, Lower Permian Series; **6–8: *Pseudoschwagerina* cf. *robusta* (Meek);** Loc. B-13 in Section B, Morikuni area, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the "*ALpinoschwagerina*" *saigusai-Pseudoschwagerina* cf. *robusta* Zone, the upper part of the Middle Nagatoan Stage, Lower Permian Series; **9–19: "*Alpinoschwagerina*" cf. *saigusai* (Nogami);** Loc. C-15 to C-19 in Section C, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the "*Alpinoschwagerina*" cf. *saigusai* Zone, upper part of the Middle Nagatoan Stage, Lower Permian Series.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in age. The "Uralian" containing primitive pseudoschwagerina (Fujimoto, 1941) and the *Triticites-Pseudoschwagerina* Zone of Kanuma (1960) are also equivalent to this zone.

Robustoschwagerina schellwieni (Hanzawa), an important element of the Sakamotozawan Stage, is widely recognized in the Tethys Province. The *Robustoschwagerina schellwieni* Zone (Bensh, 1972) was established in the Ulkian Series of the Fergana region, Central Asia, and is thought to be equivalent to both the *Pseudofusulina moelleri* Zone and the *Pseudofusulina urdalensis* Zone of the type Sakmarian sequence in Ural. Meanwhile the *R. schellwieni* Zone is well represented in the Sakamotozawa Formation in the Southern Kitakami Mountains.

Fusuline biostratigraphy of the type Sakamotozawa Formation was studied in detail by Kanmera and Mikami (1965), in which *Robustoschwagerina schellwieni* (Hanzawa) was described to range from Member Sb_2 of the Lower Subformation to Member Sc of the Upper Subformation. I have, however, found that *R. schellwieni pamirica,* a primitive subspecies of *R. schellwieni* occurs in association with *Zellia nunosei* (Hanzawa) in the lower part of Member Sb_1. Therefore the main part of the Sakamotozawa Formation can be divided into the *R. schellwieni pamirica* Zone below and *R. schellwieni schellwieni* Zone above.

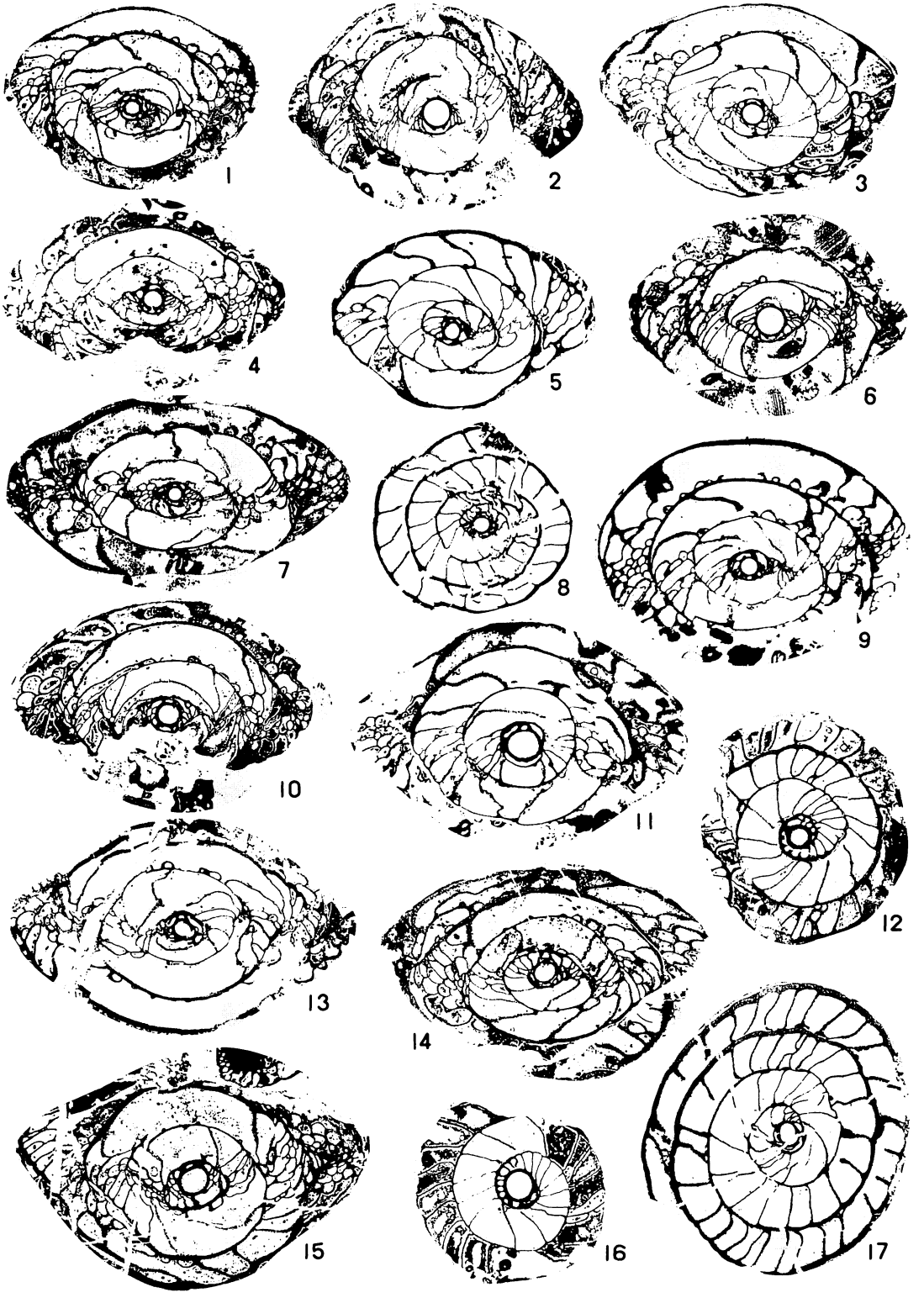
On the other hand, as mentioned before, *R. schellwieni pamirica* occurs together with *Schwagerina krotowi* (Schellwien & Dyhrenfurth) in the middle part of the *Pseudofusulina vulgaris* Zone of Toriyama (1958) and Ota (1977) in the Akiyoshi Limestone Group. This subspecies is also obtained from the *Pseudoschwagerina subsphaerica* subzone of Nogami (1961) in the Atetsu Limestone Group. The *R. schellwieni pamirica* Zone in the lower part of the Sakamotozawa Formation is correlated with the same zone in the Akiyoshi and Atetsu Limestones, which conformably lies on the *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone that is correlated with the *Sphaeroschwagerina sphaerica-Pseudofusulina firma* Zone in the type Sakmarian section, the upper zone of the Asselian Stage. As the *R. schellwieni pamirica* Zone and the superjacent *R. schellwieni schellwieni* Zone are best represented in the main part of the Sakamotozawa Formation, these two zones are defined as the Sakamotozawan Stage, which is correlated with the Sakamarian Stage in Russia.

To sum up, the following scheme of stratigraphic classification and terminology is newly proposed for the upper Carboniferous and the lower Permian in Japan on the basis of vertical distributions and associations of inflated schwagerinids, which are worldwide spread and show distinctive evolutionary lineages. The name of the Nagatoan Stage is given after the old name of Yamaguchi Prefecture, where the Akiyoshi Limestone, which is provided with a complete sequence of the lower Permian fusulinid zones, is located.

Sakamotosawan Stage...
2. *Robustoschwagerina schellwieni schellwieni-Psf. v. globosa* Zone
1. *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone

Nagatoan Stage.....
5. *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone
4. *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone
3. *"Alpinoschwagerina" saigusai-Pseudoschwagerina* cf. *robusta* Zone
2. *Schaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone
1. *Sphaeroschwagerina fusiformis* Zone

Fig. 39. All photographs ×8. **1–17:** ***Pseudoschwagerina miharanoensis* Akagi; 1–14, 17:** Loc. C-20 and D-8 in Section C, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone, lower part of the Upper Nagatoan Stage, Lower Permian Series; **15, 16:** Loc. D-20 in Section D, Itagamine area, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* zone, lower part of the Upper Nagatoan Stage, Lower Permian Series.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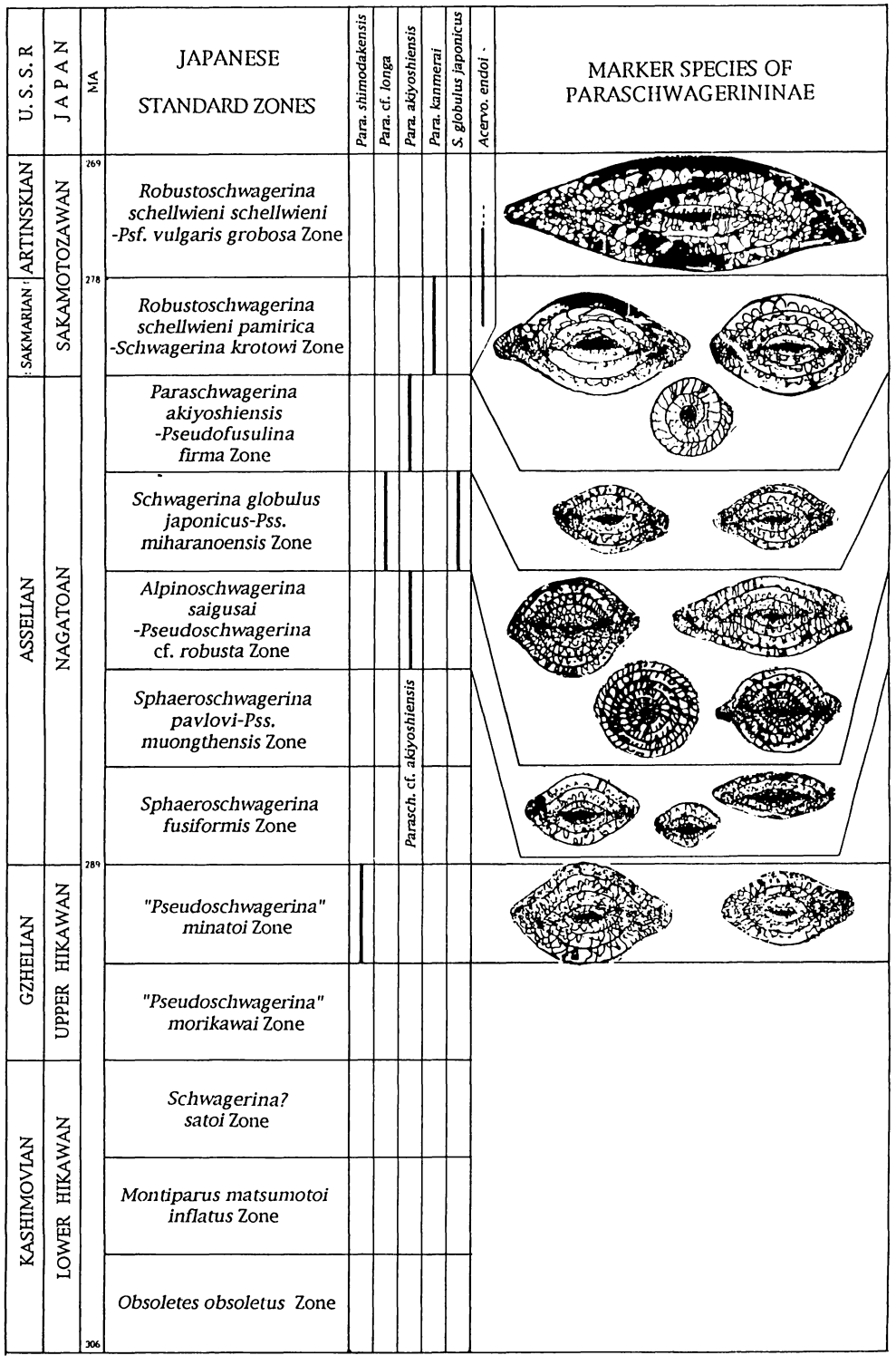

Fig. 40. Stratigraphic distribution of marker species of the Paraschwagerininae in the Upper Hikawan, Nagatoan and Sakamotozawan Stages.

Upper Hikawan Stage...
2. "*Pseudoschwagerina*" *minatoi* Zone
1. "*Pseudoschwagerina*" *morikawai* Zone

Lower Hikawan Stage...
3. *Schwagerina? satoi* Zone
2. *Montiparus matsumotoi inflatus* Zone
1. *Obsoletes obsoletus* Zone

In this scheme the Carboniferous-Permian boundary is placed at the boundary between the "*Pseudoschwagerina*" *minatoi* Zone and the *Sphaeroschwagerina fusiformis* Zone, where species of the "*Pseudoschwagerina*" *minatoi*-lineage disappear and species of the *Sphaeroschwagerina pavlovi*-lineage appear. This boundary coincides with the conventional Carboniferous-Permian boundary. The boundary between the above-mentioned two zones in the Akiyoshi Limestone Group, that is, in the sections (Section A, B and C; Figure 2) in the northeastern part of the Akiyoshidai Natural Science Museum, Akiyoshi-dai, Shuho-cho, Minegun, Yamaguchi Prefecture, is designated as the boundary-stratotype between the Carboniferous and the Permian.

3. Revision of the Hikawan and Sakamotozawan Stages and Establishment of the Nagatoan Stage

The new scheme of fusuline zonation of the upper Carboniferous and lower Permian in Japan, presented in the preceding chapters, inevitably requires revision of the previously named regional stage-units, the Hikawan and Sakamotozawan Stages, and establishment of a new unit, the Nagatoan Stage in the lower Permian.

(a) Lower Hikawan Stage

This stage comprises three fusuline zones: the lower, *Obsoletes obsoletus* Zone; the middle, *Montiparus matsumotoi inflatus* Zone; the upper, *Schwagerina? satoi* Zone. The middle and upper zones are equivalent to the original Hikawan Series (Kanmera, 1951, 1955; lowered to stage rank in this paper), which included the *Triticites matsumtoi* Zone below and the *Triticites yayamadakensis* Zone above, in the Yayamadake Limestone at Yayamadake, Izumi-mura, Yatsushiro-gun, Kumamoto Prefecture, southern Kyushu. The *Triticites yayamadakensis* Zone is correlative with the lower part of the *Schwagerina? satoi* Zone, which is typically developed in the Akiyoshi Limestone.

The two zones are about 150 m in thickness, composed of white to grey massive limestone, locally pisolitic to oolitic and dolomitic or silicious, and overlies the Kurikian Stage of the Middle Carboniferous Series, and also is disconformably overlain by the "*Pseudoschwagerina*" *morikawai* Zone.

The Lower, *Obsoletes obsoletus* Zone has not been distinguished in the type section, but is well developed in the Akiyoshi Limestone. Thus this stage is formed of composite-stratotypes.

This stage is correlated with the Kasimovian Stage in Russia and Missourian Stage in North America.

(b) Upper Hikawan Stage

This stage is equivalent to the rock strata formerly included in the Lower Sakamotozawan "Series" of the Lower Permian (Toriyama, 1978).

This stage includes two zones: the lower, "*Pseudoschwagerina*" *morikawai* Zone; and the upper, "*Pseudoschwagerina*" *minatoi* Zone. The two zones in the Yayamadake Limestone are designated as the type section of this stage, where the lower zone is about 50 m thick and the upper zone 60 m thick. These zones are composed of white to white grey, unstratified biosparitic limestone.

In the type section, this stage disconformably overlies the Lower Hikawan Stage and is covered by unfossiliferous pyroclastics, but in the Akiyoshi and Atetsu Limestones, it conformably overlies the Lower Hikawan Stage and is conformably overlain by the *Sphaeroschwagerina fusiformis* Zone of the Nagatoan Stage.

This stage can be correlated with the whole Gzhelian Stage in Russia and the Virgilian Stage in North America.

(b) Nagatoan Stage (New Name)

This stage is newly established as a regional stage-unit for the lower part of the lower Permian of Japan, and comprises the following five fusuline zones in ascending order: the *Sphaeroschwagerina fusiformis, Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis, Alpinoschwagerina saigusai-Pseudoschwagerina* cf. *robusta, Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis,* and *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zones.

These zones are well defined in the continuous sequence in the Akiyoshi Limestone Group to the north of the Akiyoshi-Dai Science Museum, Akiyoshi-dai, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Hence, this sequence is designated as the type section. The type section is about 90 m thick, and is composed of dark grey, mostly unstratified and partly thin-bedded, biomicritic limestones in the lower two zones, crinoidal biosparudite in the middle, and white, biosparitic limestones in the upper two zones.

This stage conformably overlies the Upper Hikawan Stage and is unconformably overlain by the *Robustoschwagerina shellwieni pamirica* Zone of the Sakamotozawan Stage.

This stage is correlated with the whole Asselian Stage in Russia and the Wolfcampian Stage in North America.

(d) Sakamotozawan Stage

The Sakamotozawan Stage comprises two zones: the lower *Robustoschwagerina schellwieni pamirica* Zone and the upper *Robustoschwagerina schellwieni schellwieni* Zone. These zones are well defined in the successive sequence in the northern slope of the Tashiroyama along the Sakamotozawa valley, Sakamoto, Hikoroichi-machi, Ofunato-shi, Iwate Prefecture, northeast

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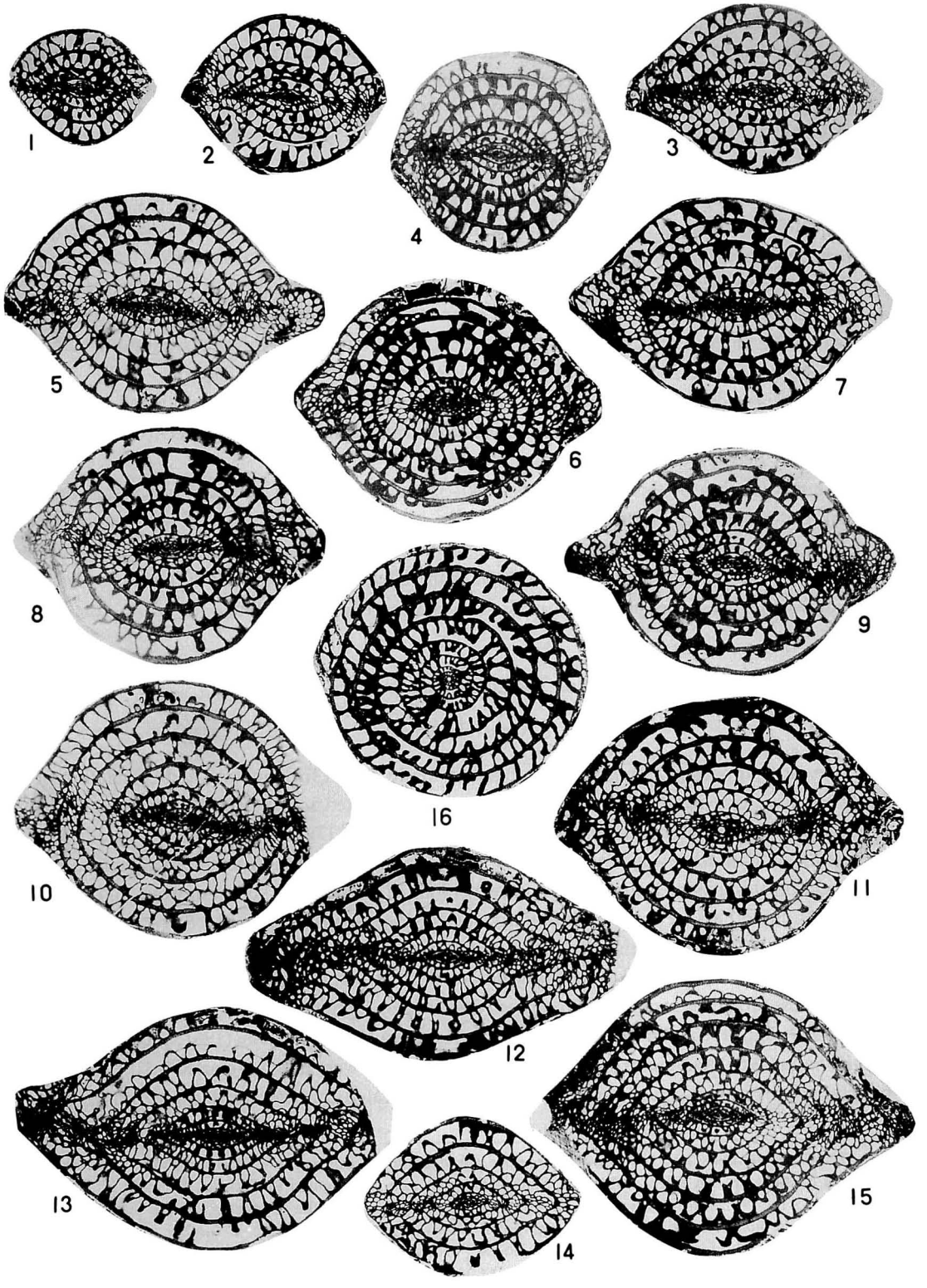
Fig. 41. All photographs ×8. **1–16:** ***Schwagerina globulus japonicus* Watanabe, n. subsp; 1–13.** Loc. 3108 to 3114 in Section D, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yama-guchi Prefecture. Akiyoshi Limestone Group, the *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone, lower part of the Upper Nagatoan Stage, Lower Permian Series; **14.** Loc. A-35 in Section Morikuni A, Niimi-shi, Okayama Prefecture, Atetsu Limestone Group, the *Schwagerina globulus japonicus* Zone, lower part of the Upper Nagatoan Stage, Lower Permian Series; **15, 16.** Loc. R8–20 in Section R-8, Itagamine area, Uta, northern face along the Japan Sea, Omi-machi, Nishikubiki-gun, Niigata Prefecture. Omi Limestone Group, the *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone, lower part of the Upper Nagatoan Stage, Lower Permian Series.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Japan. Here this sequence is designated as the type section.

The type Sakamotozawa Formation is subdivided by Kanmera and Mikami (1965) into seven fusuline zones and two barren zones as follows in ascending order: the Barren Zone (Member Sa), the *Zellia nunosei* Zone (Member Sb_1), the *Monodiexodina langsonensis* Zone (Member Sb_2), the Barren Zone (Member Sb_3), the *Pseudofusulina vulgaris* Zone (Member Sc), the *Pseudofusulina fusiformis* Zone (lower part of Member Sd) and the *Pseudofusulina ambigua* Zone (upper part of Member Sd). The lower boundary of this stage cannot be drawn in the type section, but is defined in the Akiyoshi and Atetsu Limestones, in which the *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone of the Nagatoan Stage is conformably succeeded by the *Robustoschwagerina schellwieni pamirica* Zone, which is composed of white to white grey, dolomitized biomicritic limestones. The upper boundary also cannot be defined in the type section, because of the absence of fusulines in the overlying beds, but in the Akiyoshi Limestone comes the *Misellina claudiae* Zone at 40 m above the *R. schellwieni pamirica* Zone.

On the basis of inflated schwagerinids, this formation, however, can be divided into two zones of *Robustoschwagerina* stated above, and the stratigraphic relationship between these two divisions has been given in the preceding chapter.

The type section of this stage is about 240–320 m thick, and is composed of black, thin- to thick-bedded muddy and dolomitic limestones.

This stage can be correlated with the Sakmarian Stage, or the *Robustoschwagerina-Paraschwagerina* Horizon, and the Artinskian or the Ulkian Stage (the *Pseudofusulina vulgaris* Zone and *Misellina* Zone) at Darvus in Russia, and the Leonardian Stage in North America.

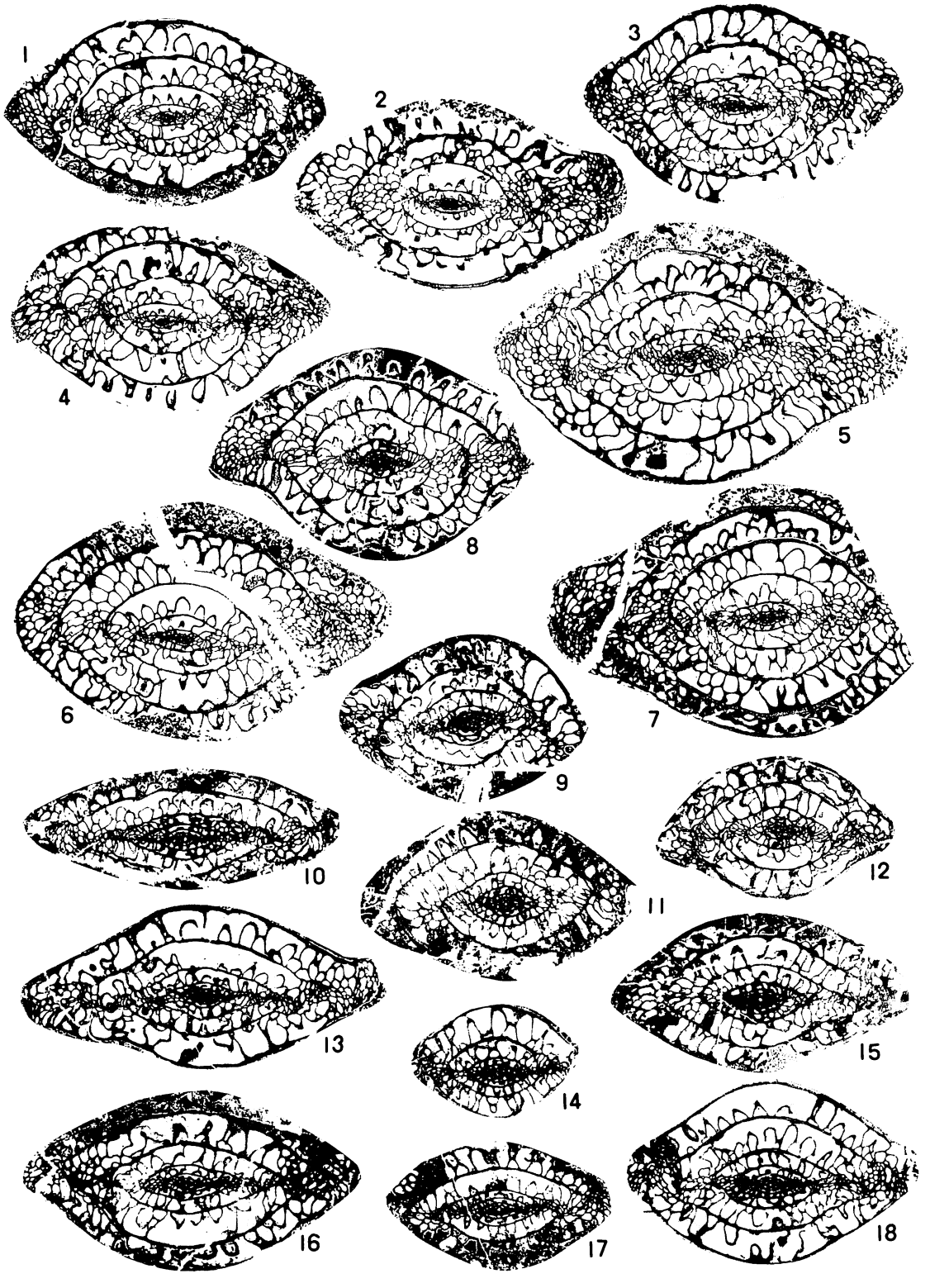
VI. Notes on Pseudoschwagerinae from Japan

1. General Remarks

The most important element among fusuline fossils useful for zonation and correlation of Early Permian or Nagatoan-Sakamotozawan rocks is inflated schwagerinids belonging to the subfamily Pseudoschwagerininae. Since F. and G. Kahler (1937) pioneered work on the faunal succession of *Pseudoschwagerina* in southern Europe and Southern Asia, much attention has been paid on this group. Rauser-Chernousova (1960), Rosovskaya (1966), Anosova and others (1964), among others, revised the taxonomy and phylogeny of the inflated "Schwagerinidae". Ross (1962, 1970) described the phylogeny, distribution, and migration of some species-lineages of *Pseudoschwagerina* and *Paraschwagerina* based on American specimens.

Japanese inflated schwagerinids have been described by Fujimoto (1936, 1937, 1941), Hanzawa (1938, 1939), Igo (1957, 1964), Toriyama (1958), Kanmera (1958), Nogami (1961, 1965), Kanuma (1961), Sada (1965) and many others. Many of these studies were mainly focused on the regional biostratigraphy and faunal descriptions. Kanuma advocated that the stratigraphic position of

Fig. 42. All photographs ×8. **1–7: *Paraschwagerina shimodakensis* Kanmera;** Loc. 3121 in Section D, northern part of Akiyoshi-dai Science Museum, Shuho-cho Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the "*Pseudoschwagerina*" *minatoi* Zone, upper part of the Upper Hikawan Stage, Upper Carboniferous Series; **9–18: *Paraschwagerina* cf. *akiyoshiensis* Toriyama;** Loc. C-7 in Section C, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture, Akiyoshi Limestone Group, the *Alpinoschwagerina saigusai* Zone, the upper part of the Middle Nagatoan Stage, Lower Permian Series.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primitive pseudoschwagerinid species of *morikawai*-type should be included in late Carboniferous time.

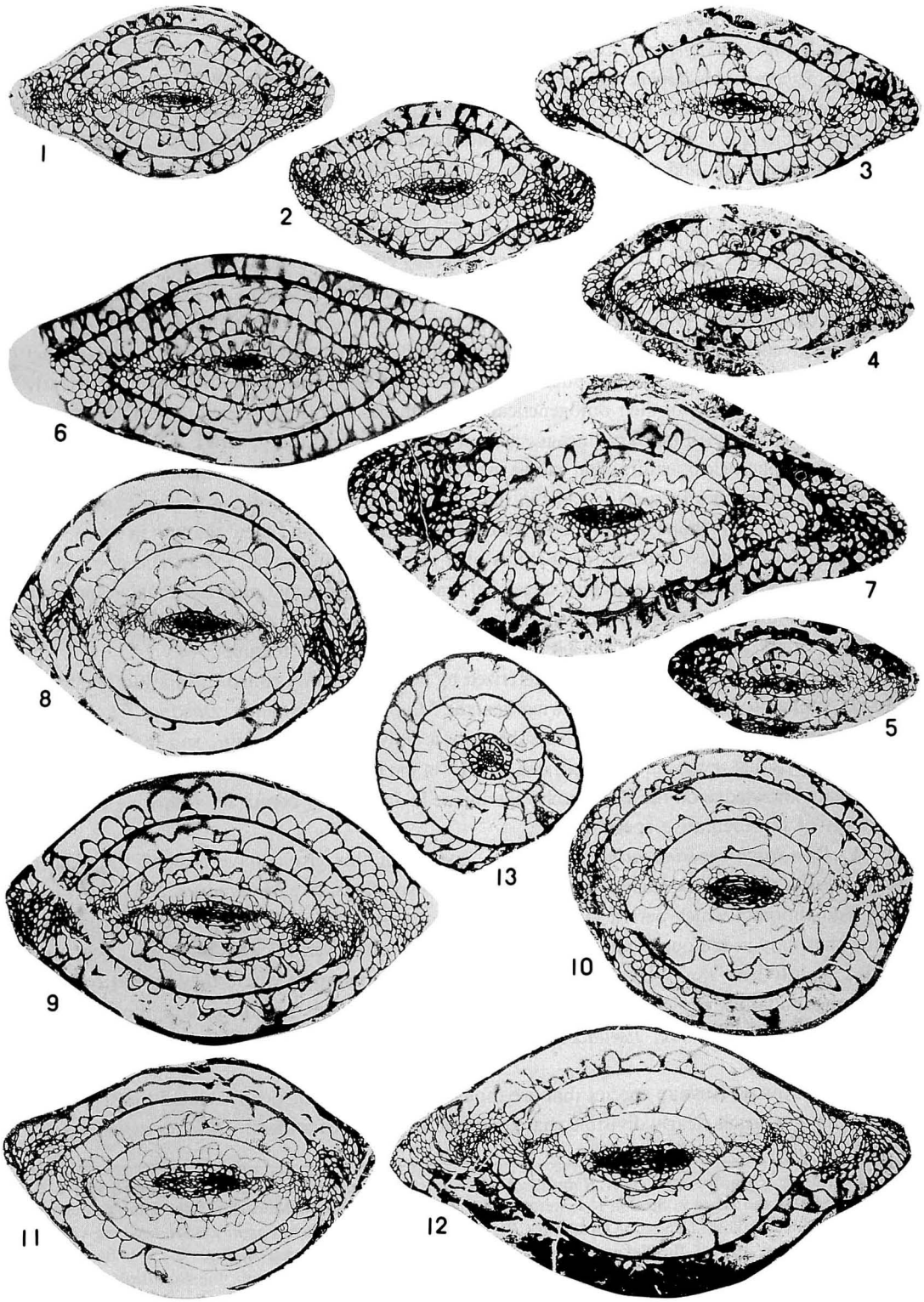
Akagi (1958) analyzed the ontogeny of *Pseudoschwagerina miharanoensis* from the Taishaku Limestone Group and referred to the general mode of morphological development of fusulines. Igo (1964) revised Rauser-Chernousova's opinion (1960) on the stratigraphic distributions and phylogeny of *Pseudoschwagerina* and allied genera and discussed those of some *Pseudoschwagerina* and *Zellia* from Japan. The phylogeny of the Schwagerinidae was concisely summarized by Toriyama (1978) and Kanmera and others (1976). Recently, the detailed paleo-biogeographic distributions of the early to middle Permian schwagerinids and neoschwagerinids were discussed by Sheng, Rui and Chen (1985), Ishii, Okimura and Ichikawa (1985) and Ozawa, T. *et al.* (1985) in the lights of plate-tectonic theory. It is the purpose of this chapter to discuss the stratigraphical and geographical distributions, and the phylogeny of the inflated subwagerinids described from the Japanese Islands.

2. Pseudoschwagerinid Species from Japan

Since Ozawa, Y. (1925) described "*Schwagerina*" *muongthensis* (Deprat) from the Akiyoshi Limestone Group, the following 20 species have been known from Japan. Some 19 species of them are now referable to the genus, *Pseudoschwagerina, Sphaeroschwagerina, Alpinoschwagerina* and *Robustoschwagerina,* and the remaining one to the genus *Chalaroschwagerina*;

1. *Schwagerina muongthensis* (Deprat); Ozawa, 1925
2. *Schwagerina* sp. Huzimoto, 1936
3. *Pseudoschwagerina orientale* Huzimoto, 1936
4. *Pseudoschwagerina schellwieni* Hanzawa, 1938
5. *Pseudoschwagerina* (*Zellia*) *nunosei* Hanzawa, 1938
6. *Pseudoschwagerina samegaiensis* Huzimoto, 1941
7. *Pseudoschwagerina morikawai* Igo, 1957
8. *Pseudoschwagerina minatoi* Kanmera, 1958
9. *Pseudoschwagerina miharanoensis* Akagi, 1958
10. *Pseudoschwagerina* sp. Toriyama, 1958
11. *Pseudoschwagerina uddeni* (Beede & Kniker); Kanuma, 1959
12. "*Pseudoschwagerina*" *nakazawai* Nogami, 1961
13. *Pseudoschwagerina saigusai* Nogami, 1961
14. *Pseudoschwagerina subsphaerica* Nogami, 1961
15. *Pseudoschwagerina* aff. *geyeri* Kahler & Kahler; Suyari, 1962
16. *Pseudoschwagerina kanmerai* Sada, 1964
17. *Pseudoschwagerina pavlovi* (Rauser.); Sada, 1964

Fig. 43. All photographs ×8. **1–5: *Paraschwagerina akiyoshiensis* Toriyama;** Loc. 3115 in Section D, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone, upper part of the Upper Nagatoan Stage, Lower Permian Series; **6, 7: *Paraschwagerina* cf. *longa* Mikhailova;** Loc. 3116 in Section D, northern part of Akiyoshi-dai Science Museum, Shuho-cho, Mine-gun, Yamaguchi Prefecture. Akiyoshi Limestone Group, the *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone, upper part of the Upper Nagatoan Stage, Lower Permian Series; **8–13: *Paraschwagerina kanmerai* Nogami;** Loc. M-3, Matsunagi Section, Matsunagi area, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *Robustschwagerina schellwieni pamirica* Zone, lower part of the Sakamotozawan Stage, Lower Permian Series.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18. *Pseudoschwagerina* (*Robustoschwagerina*) *hidensis* Igo, 1964

19. *Pseudoschwagerina katoi* Choi, 1973

20. *Sphaeroschwagerina vulgaris ashensis* Schelbovich; Hasegawa, 1979

Stratigraphically, the above 19 species of *Pseudoschwagerina* in Japan have been recognized to range from the Lower to Upper Sakamotozawan which are now classified into the Upper Hikawan, Nagatoan and Sakamotozawan, which are correlated respectively with the Gzhelian, Asselian and Sakmarian (s.s.) in the type sequence.

In fusuline fossils, the shell structures of a juvenile part including a proloculus and inner one to usually four, rarely five volutions, are generally closely similar to those of more primitive or ancestral forms. Practically in successive strata of the same lithofacies, we can often find out in the subjacent beds some species whose shell structures closely resemble those of the juvenile part of a given species in higher horizons, although the latter is represented as a more compact form. This fact suggests that the shell characters of ancestral species are retained sufficiently in young growth stages of their ontogenetical development. This is considered to be an important clue to search for evolutionary lineages among related species and genera.

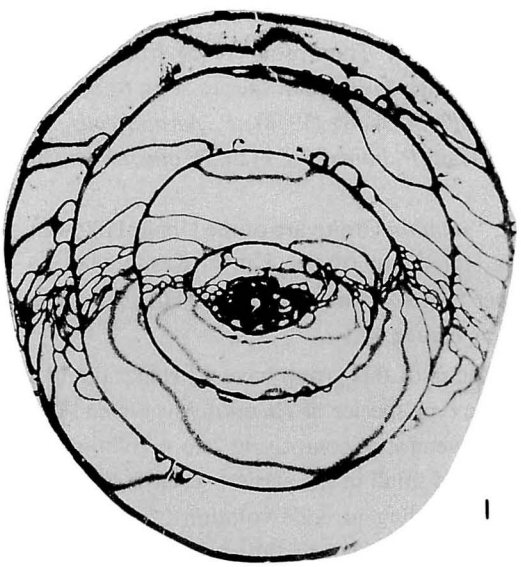
The morphological features that can be used to trace an evolutionary lineage and to distinguish it from other lineages in specific rank in the Pseudoschwagerininae are as follows; (a) size of proloculus; (b) shell-shape and mode of coiling in a juvenarium and their changes in succeeding volutions; (c) thickness and microstructures of a spirotheca; (d) mode, extent and complexity of septal fluting in relation to growth stages; (e) shape of chomata and pseudochomata, and their changes in outer volutions; (f) size, shape and number of volutions of a shell. The distinctions in generic rank are judged on the basis of combination of these features.

The Pseudoschwagerininae is characterized by having a tightly coiled juvenarium, which is closely similar to either of the following genera; *Montiparus, Triticites, Daixina, Chusenella, Eoschubertella* and *Schubertella*. This subfamily is polyphyletic in origin, and includes many species-groups that are distinctive from one another in the features mentioned above. For example, up-to-date knowledge on the Pseudoschwagerininae in Japan may permit the following grouping in terms of representative species.

1. *Pseudoschwagerina minatoi* Group:– Species of this group have a small thin-walled proloculus, a rather thick-walled juvenarium of 4 to 5 volutions, like *Montiparus,* and have broad and high chomata which persist into the inflated volutions. Inflation of the shell is abrupt and diminishes only in the outer one or a half volution where the wall thickens markedly. Septa are folded slightly near their poles and near the base of the chambers where they extend forward into long and low projections. The species belonging to this group among the Japanese Pseudoschwagerininae are; *Pseudoschwagerina minatoi, P. morikawai, P. orientale,* and *P. nakazawai.*

The following Russian species that are thought to be phylogenetically related to *P. minatoi* Group have no such clearly divisible changes in the height of chambers: *Triticites expressus, T.*

Fig. 44. All photographs ×10. **1–6: *Robustoschwagerina schellwieni pamirica* Leven & Schelbovich; 1–5.** Loc. K1–3 and K1–4 in Section K-I, western part of Kaerimizu Doline, Mito-cho, Mine-gun, Yamaguchi Prefecture, Akiyoshi Limestone Group, the *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone, lower part of the Sakamotozawan Stage, Lower Permian Series; **6.** Loc. C-25 in Section C, Shimoyukawa area, Niimi-shi, Okayama Prefecture. Atetsu Limestone Group, the *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone, lower part of the Sakamotozawan Stage, Lower Permian Series.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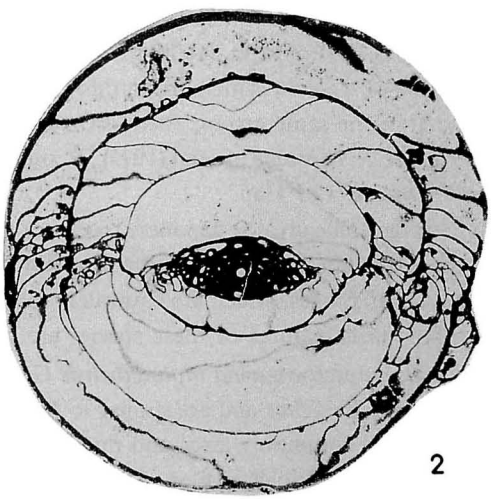
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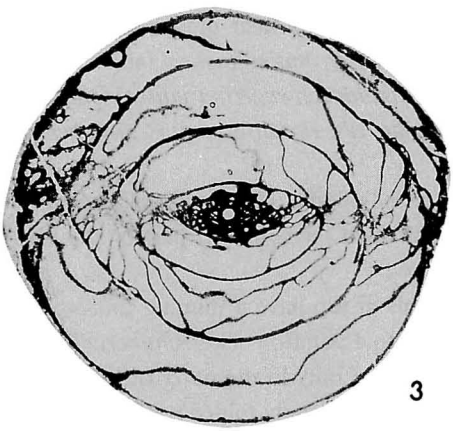
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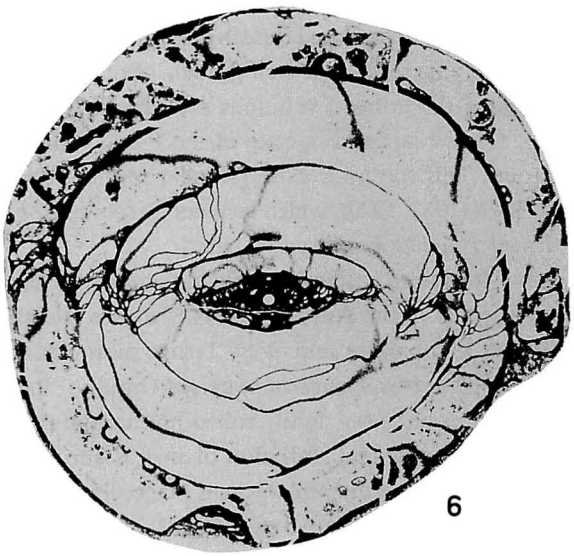
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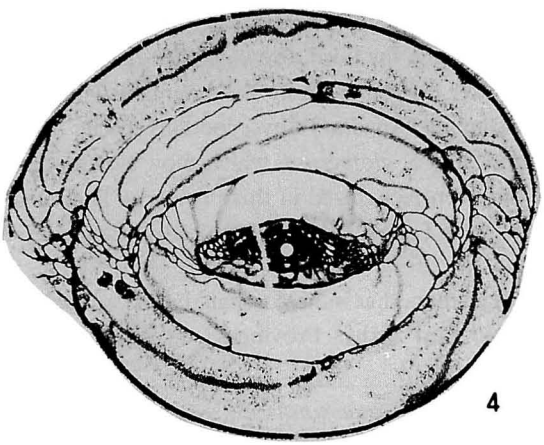
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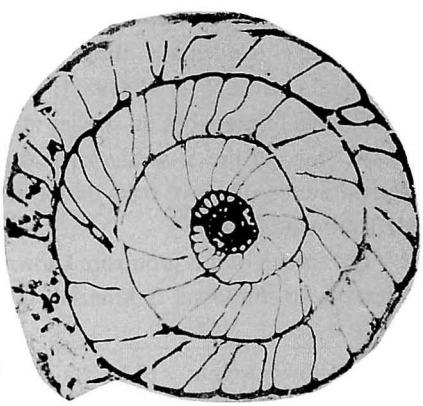
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expressus pressula, Occidentoschwagerina ex gr. *primaeva, O. paraprimaeva, Schwagerina* ex gr. *vulgaris* of Polosova (1979). *Pseudoschwagerina arta* of Thompson (1965) from British Columbia of Canada is included in this group. The following Mongolian species seem to be also included in the same group; *Pseudoschwagerina borealis* of Sheng (1958), *P. paraborealis, P. macronata, P. constans* of Han (1975), *P. sphaerica* of Han, *P. borealis* of Han, *P. macrohamata,* and *P. moelleri* of Han.

Stratigraphically, the Japanese species of the "*P.*" *minatoi* Group are of the Upper Hikawan or the Gzhelian Stage, while the Russian species stated are of the Upper Kasimovian to Orenburgian Stages, which are equivalent to the upper Lower Hikawan to Upper Hikawan. The morphological features of these species are shown in Figure 49.

2. ***Pseudoschwagerina muongthensis* Group:**– Species of this group have a juvenarium like *Daixina* and *Triticites* and are similar to *P. uddeni,* the type species of *Pseudoschwagerina.* The proloculus is commonly large and thick-walled. The juvenarium comprising 2 to 4 volutions is loosely coiled and thick-walled. Chomata are narrow and small in the earliest several chambers in the first volution and massive and broad in the succeeding juvenile volutions, but become indistinct in the inflated outer volutions. The thickness of spirotheca and the height of volutions gradually increase as a shell growth. Septa may undulate irregularly above the basal folds, and those of the inflated volutions are strongly folded at their poles and near their basal margin.

Of the Japanese species of the Pseudoschwagerininae only *P. muongthensis* falls into this group. This species is closely similar to the species of the *Pseudoschwagerina uddeni* Complex of Ross (1962, 1970), which includes *P. beedei, P. beedei afganensis, P. californica, P. aktjubensis, P. intermedia, P. gerontica,* etc.

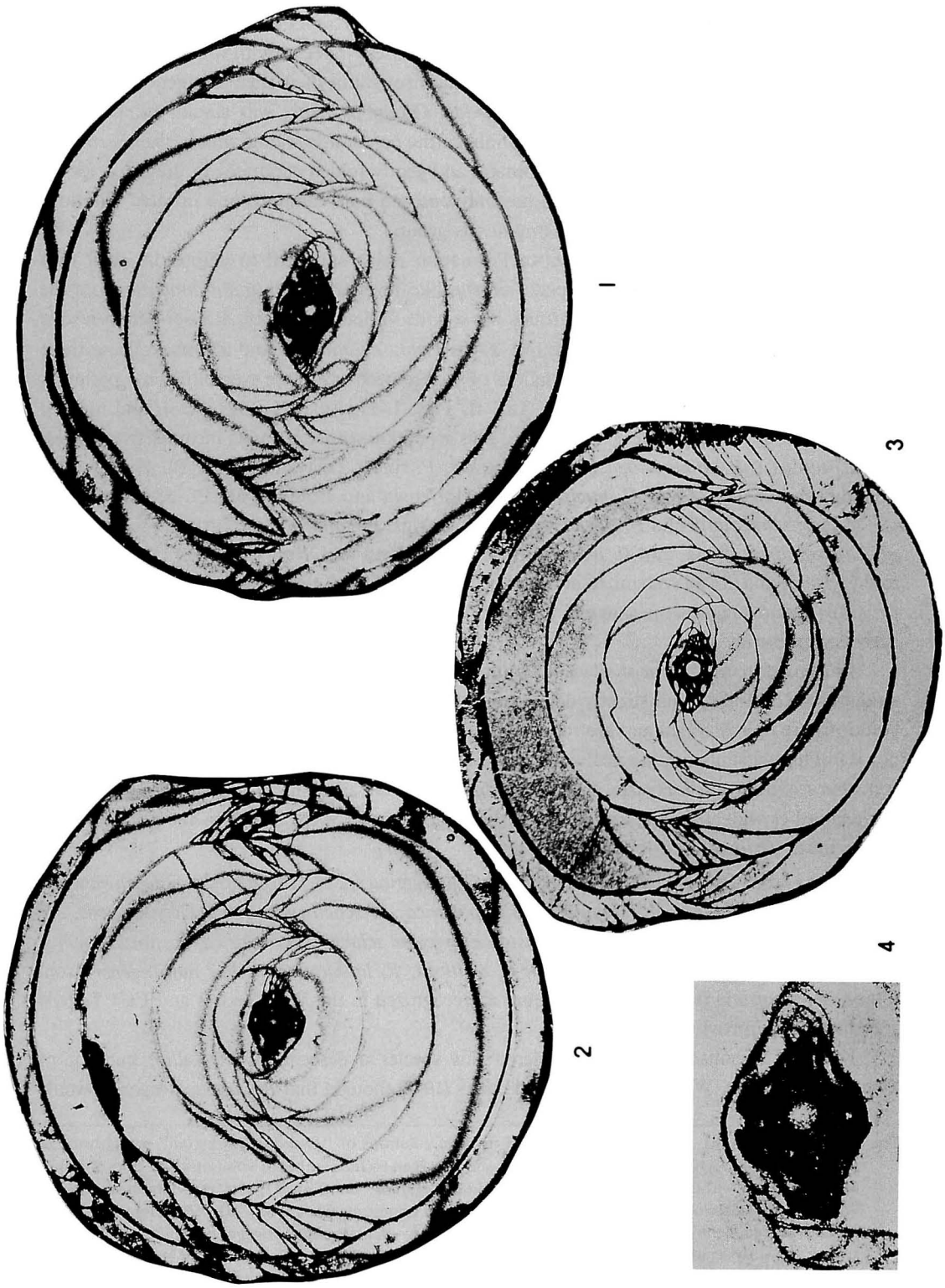
This group is characteristic in the middle Nagatoan or the middle to upper Asselian Stages, and occurs in the Angara-Tethys Province (North Domain) and the southern part of the East Tethys-Panthalassa and West Tethys subprovinces.

3. ***Sphaeroschwagerina pavlovi* Group:**– Species of this group have a minute, thin-walled proloculus and very tightly coiled juvenarium comprising 3 to 4 volutions like *Schubertella* and have small chomata. Inflation of shell is abrupt and diminishes only in the outer one and half volutions, where the wall thickens markedly. Septa are slightly to strongly folded near their poles.

Rauser-Chernousova (1960) recognized three species-lineages in the genus "*Schwagerina*"(= *Sphaeroschwagerina*); the first, *S. vulgaris-S. pavlovi* lineage; the second, *S. vulgaris-S. moelleri* (or *constans*)-*S. sphaerica* lineage; and the third, *S. vulgaris-S. fusiformis-S. nitida* lineage. Incidentally, three Tethys Provinces were discriminated by Tollmann and Tollmann (1982) and Ozawa, T. *et al.* (1985). The Northern Domain (Angara-Tethys) contains species of the *S. sphaerica* lineage, but no species of *S. subrotunda* and *S. glomerosa,* which show evolutionary the last stage of the *S. sphaerica* lineage, have not been recognized in this province. These two species have been known from the Central Domain [West Tethys (IIA) and East Tethys-Panthalassa (IIB) subprovinces].

The species of this group are known from the Nagatoan, that is the Asselian, but *S. subrotunda* ranges up to the lower Sakmarian in the West and East Tethys Provinces.

Fig. 45. All photographs ×10 (except 4 ×25). **1–4: *Robustoschwagerina schellwieni schellwieni* (Hanzawa);** north of Maiya High School, Maiya, Thowa-cho, Tome-gun, Miyagi Prefecture. Nishikori Formation, the *Robustoschwagerina schellwieni-Pseudofusulina vulgaris globosa* Zone, upper part of the Sakamotozawan Stage, Lower Permian Series.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4. *Zellia amedaei* Group:– This group has nearly planar septa, gradual inflation of shell, and a thick wall. The wall gradually increases in thickness. Species with an inflated fusiform to a subsphaerical shell have rudimentary chomata throughout their shell and generally closely spaced septa. The ancestor of the *Zellia amedaei* Group probably was similar in shape and construction of its shells to the juvenile volutions of the *beedei-uddeni* and *muongthensis-robusta* groups which have a thick wall, large chomata, and gently folded chomata. In these species the proloculus is large, and the juvenarium has only one and half volutions and inflated volutions have gently folded septa as in the *muongthensis* group.

Z. nunosei from the Sakamotozawa Formation has a spherical to ellipsoidal shell with depressed poles and a poorly developed *Triticites*-like juvenarium. *P. miharanoensis* from the Taishaku and Akiyoshi Limestone Groups has a wide variation of shell. Rauser-Chernousova (1960) subdivided *Zellia* into three groups: *Z. heritschi, Z? amedaei* and *Z? mira.* These three species, however, also show marked variations of shell respectively as are exemplified by specimens illustrated by Kahler and Kahler (1937, Taf. II, Figs. 1–11, Taf. III, Figs. 7, 8), and may be lumped into one and the same species group. This group known from Japan includes five species: *P.* (*Z.*) *nunosei, P. miharanoensis,* P. aff. *geyeri, P.* sp. of Toriyama (1958, Pl. 19, Figs. 10, 11 only) and *Z. nunosei* (=*P. nucleolata*) of Morikawa and Isomi (1961, Pl. 3, Figs. 1, 2).

Z. heritschi colanii and *P. elegans* from Karnic Alps, *P. galatea* from Turkey, *P. nucleolata prisca* from Yugoslavia, and *P. minutaeformis* from North and West China are closely similar to this group, and are all recognized in the West Tethys and East Tethys-Panthalassa subprovinces.

This group suggests the range in age from late Asselian to Artinskian or late Nagatoan to early Sakamotozawan.

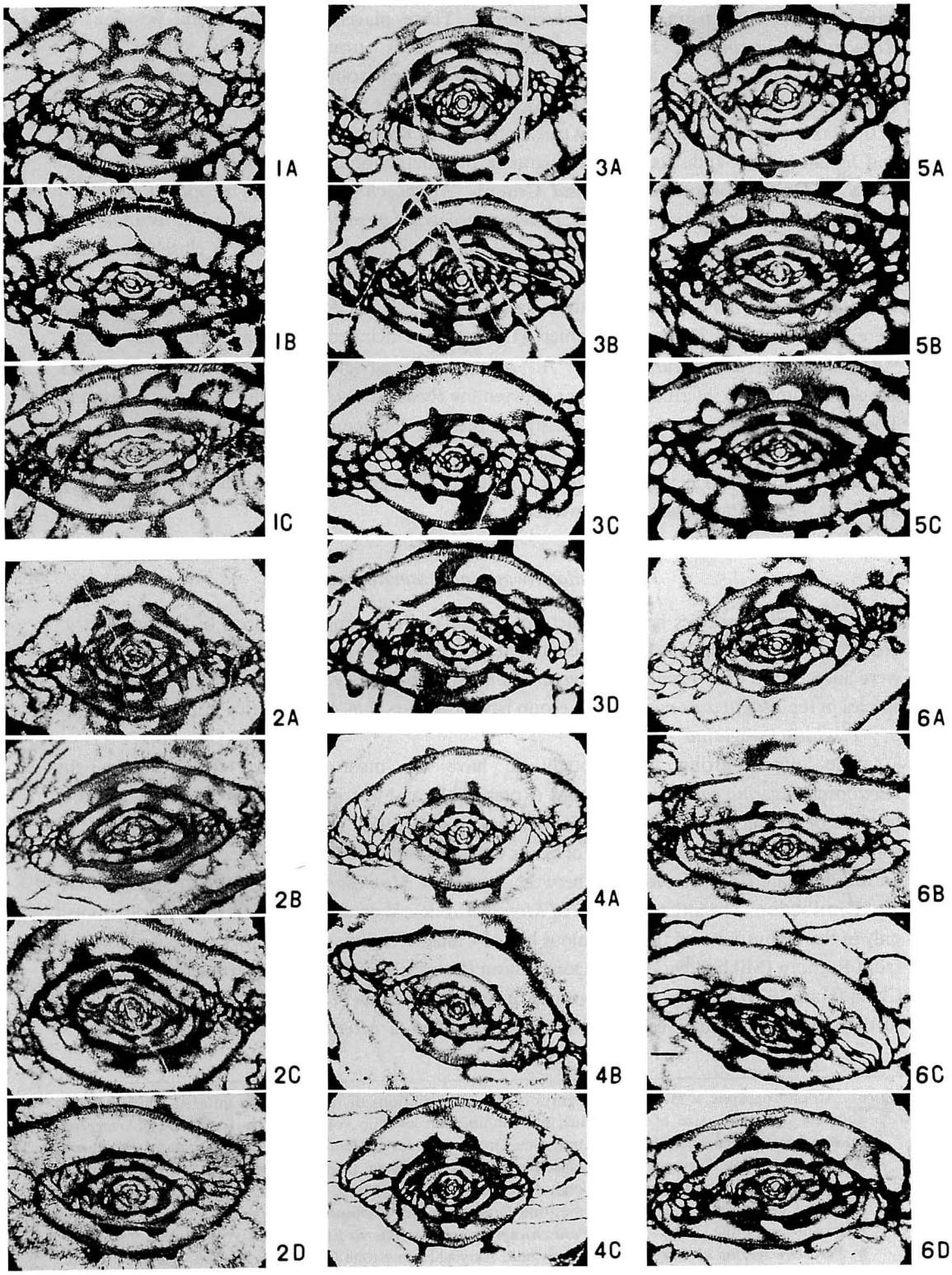
5. *Robustoschwagerina shellwieni* Group:– The shell is large and sphaerical, and has a straight axis of coiling and slightly depressed poles. The juvenile volutions consisting of 2 to 3 volutions are tightly coiled and are followed by inflated fusiform volutions with acutely pointed poles and highly vaulted sphaerical volutions. The final volution usually decreases in height. The spirotheca is thin, but increases in thickness toward outer volutions. The septa are numerous, but are rather widely spaced and unfluted throughout the growth, except in the polar regions of the inner *Triticites*-like juvenarium.

Seven species fall into this group, including *Schwagerina* sp. of Huzimoto, *Pseudoschwagerina samegaiensis, P. uddeni* of Kanuma, *P. subsphaerica, P. schellwieni* and *P.*(*R.*) *hidensis.*

This group is closely similar to *Robustoschwagerina schellwieni pamirica, R. tumidiformis, R. tumida* from Darvus, *R. intraplicata, R. spatiosa, R. laohutaiensis, R.? nanjingensis* from China, *R. stanislavi* from Texas, which are all recognized in the West Tethys and East Tethys-Panthalassa subprovinces.

Rauser-Chernousova (1960) considered this species a descendant of *Zellia,* but not of *Pseudoschwagerina.* Whereas Kanmera and others (1976) thought that *Robustoschwagerina* would

Fig. 46. All photographs ×25. enlarged figures of juvenile volutions of "*Pseudoschwagerina*" *morikawai* Igo and "*Pseudoschwagerina*" *minatoi* KANMERA, showing shell form, number of volutions, size of proloculus, and a variation within a species. **1A–1C: "*Pseudoschwagerina*" *morikawai* Igo,** Atetsu Limestone Group; **2A–2D: "*Pseudoschwagerina*" *minatoi* Kanmera,** Atetsu Limestone Group; **3A–3D: "*Pseudoschwagerina*" *morikawai* Igo,** Ichinotani-Mizuyagadani Formations; **4A–4C: "*Pseudoschwagerina*" *minatoi* Kanmera,** Ichinotani-Mizuyagadani Formations; **5A–5C: "*Pseudoschwagerina*" *morikawai* IGO,** Akiyoshi Limestone Group; **6A–6D: "*Pseudoschwagerina*" *minatoi* Kanmera,** Akiyoshi Limestone Group.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have been derived from *Sphaeroschwagerina*. These placement phylogenetic positions of *Robustoschwagerina* is, however, questionable. This group is closely similar to the *Pseudoschwagerina* group and is thought to have evolved from *Pseudoschwagerina* forming a single lineage of *P. rotundata-R. schellwieni pamirica-R. s. schellwieni-R. tumida*. It appeared in the Sakmarian and ranged in the Artinskian rocks of Karnic Alps, Yugoslavia, Darvus, China, and Japan. Igo (1964) discussed the stratigraphic distribution of all species of *Robustoschwagerina*.

6. *"Alpinoschwagerina" saigusai* Group:– *Alpinoschwagerina* was proposed by Bensh (1972) with *A. turkestanica* from the *Sphaeroschwagerina moelleri-Pseudofusulina fecunda* Zone of the middle Asselian in Fergana, Russia as the type species. This group is closely similar to *Sphaeroschwagerina moelleri* of Chen (1934) from Guangxi. The species of the *"Pseudoschwagerina" minatoi* Group in Japan and *P. confini, P. aequalis* and *P. turbida* which were described by Kahler & Kahler (1937) were included by Bensh into this genus. *"Alpinoschwagerina" rotundata* and *"A." maclayi* as the advanced representatives of this genus, are closely similar to intermediate forms between the *Pseudoschwagerina* and *Robustoschwagerina*. Then Leven and Schelbovich (1978) assigned them to the genus *Pseudoschwagerina*.

I believe that these forms have no distinct differences from typical *Sphaeroschwagerina,* except for the shell shape and slightly stronger septal fluting. This group is distributed in the West Tethys and East Tethys-Panthalassa subprovinces.

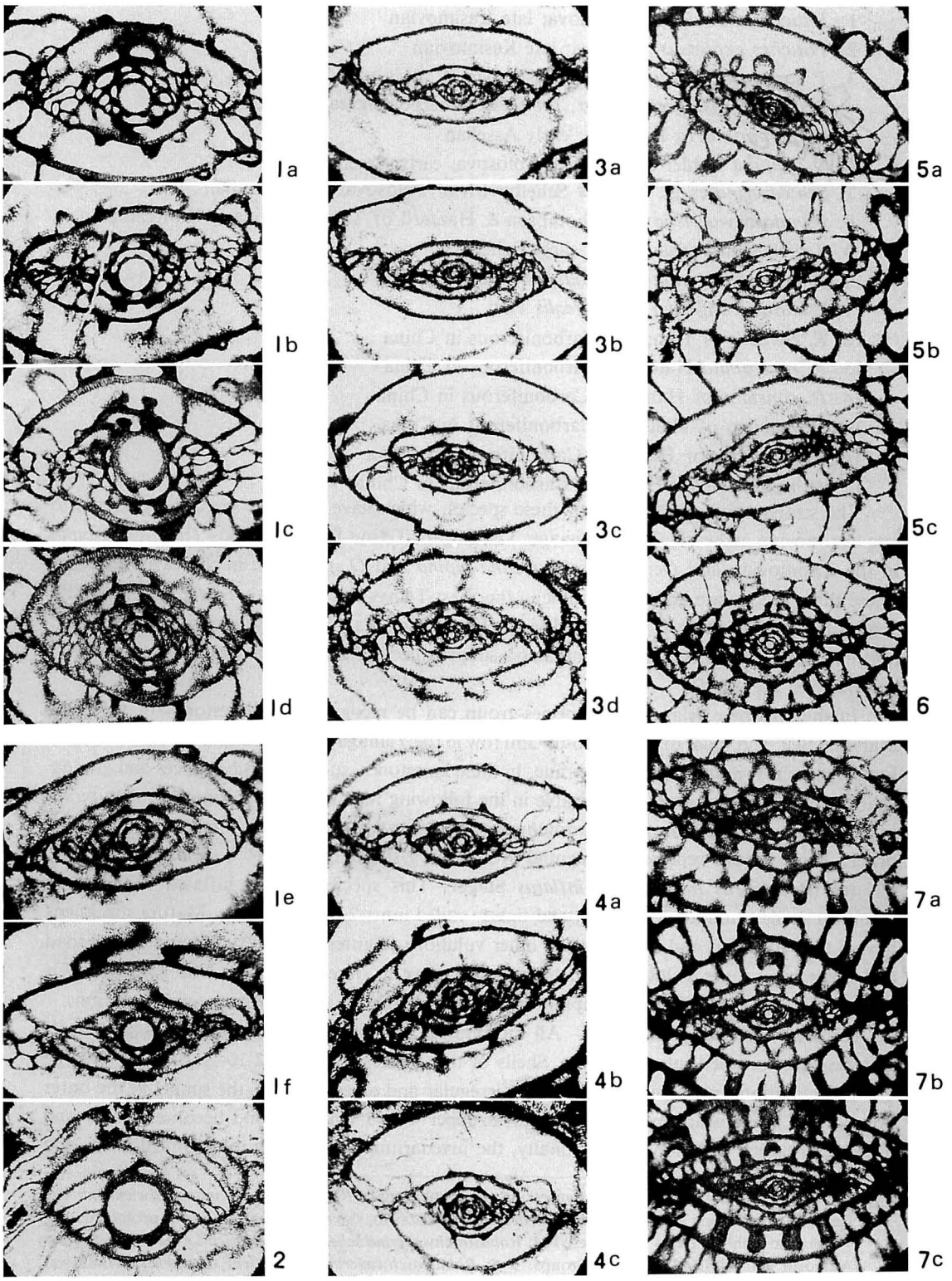
3. *"Pseudoschwagerina" minatoi*-lineage

Schwagerinid species having structures similar to the juvenile volutions of the *morikawai*-group, in which the wall is thick, the chomata are large, and the septa gently folded, probably were ancestral to the *"Pseudoschwagerina" minatoi* Group. Several of the larger, more globose species in the *Montiparus matsumotoi*-group have structures that would fit this primordial ancestor of *"Pseudoschwagerina" minatoi*.

The *minatoi*-group was thought to have the most primitive shells among the *Pseudoschwagerina carniolica* Complex (Ross, 1970), and was included into the genus *Triticites* because of having undivisible juvenile volutions (Bensh, 1969, 1972). Polosova (1979) described some similar species under the name of genus *Occidentoschwagerina*. This species-group represents an intermediate stage of evolution between species of *Montiparus* and inflated schwagerinids.

Distribution: The inflated species of *Montiparus* described until the presentday are distributed only in the Tethys Sea and the anomalous belt of Canada Regions. The following species described from Pechora (Mikhailova, 1974), Donez Basin (Polosova, 1979), Fergana (Bensh, 1969, 1972), China (Han, 1975), and the anomalous belt of British Columbia (Thompson, 1965) can be assigned to the species group derived from the inflated species of *Montiparus*.

Fig. 47. All photographs ×25. enlarged figures of juvenile volutions of the following inflated schwagerinids, showing ontogeny, size of proloculus, and number of juvenile volutions. **1a–1c: *Pseudoschwagerina muongthensis* (Deprat)**, Akiyoshi Limestone Group. **1d–1e: *"Alpinoschwagerina" saigusai* (Mogami)**, Atetsu Limestone Group. **1f: *Pseudoschwagerina* cf. *robusta* (Meek)**, Atetsu Limestone Group. **2: *Pseudoschwagerina miharanoensis* Akagi**, Akiyoshi Limestone Group. **3a–3d: *Sphaeroschwagerina pavlovi* (Rauser-Chernousova)**, Akiyoshi Limestone Group. **4a–4c: *Alpinoschwagerina* cf. *saigusai* (Nogami)**, Akiyoshi Limestone Group. **5a–5c: *Paraschwagerina shimodakensis* Kanmera** Akiyoshi Limestone Group. **6: *Paraschwagerina* cf. *akiyoshiensis* Toriyama**, Akiyoshi Limestone Group. **7a–7c: *Schwagerina globulus japonicus* Watanabe, n. subsp.**, Akiyoshi Limestone Group.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1. *Triticites globoides* Mikhailova; late Kasimovian
2. *Triticites expressus* Anosova; late Kasimovian
3. *T. expressus pressula* Bensh; Kasimovian
4. *Occidentoschwagerina* ex gr. *primaeva* Scherbovich; early Asselian
5. *O. paraprimaeva* Polosova; early Asselian
6. *O.? alpina* Kahler & Kahler of Polosova; early Asselian
7. *Schwagerina* ex gr. *vulgaris* Schelbovich of Polosova; early Asselian
8. *Pseudoschwagerina arta* Thompson & Hazzard of Thompson; early Wolfcampian
9. *Triticites gusanicus* Bensh; early Gzhelian
10. *Pseudoschwagerina toriyamai* Igo; early Permian
11. *Pseudoschwagerina paraborealis* Han
12. *P. borealis* of Han; late Carboniferous in China
13. *P. mucronata* Han; late Carboniferous in China
14. *P. constans* of Han; late Carboniferous in China
15. *P. moelleri* of Han; late Carboniferous in China
16. *P. sphaerica* of Han; late Carboniferous in China
17. *P. macrohamata* Han; late Carboniferous in China

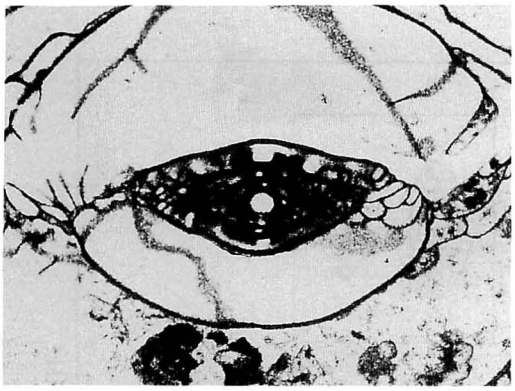
The stratigraphic distribution of these species, which have unfluted septa, is restricted to late Kasimovian and early Gzhelian in age. The Angara-Tethys Province yields *Triticites globulus* in the Kasimovian and *Occidentoschwagerina alpina* and *O. primaeva* in the early Asselian. These three species are not recognizable in the West-Tethys Province, whereas a closely similar species named *T. expressus* is reported in the East Tethys-Panthalassa subprovince. Especially, northern part of the East Tethys-Panthalassa subprovince is prolific in the species group of "*P.*" *minatoi* (see Figure 49).

In the Japanese Islands, this species-group can be recognized in limestones of the Hida Marginal Belt, and those of the Akiyoshi-Omi row in the Yamaguchi Terrane and the Yayamadake-Futagoyama row in the Chichibu Terrane. In these limestones, successive occurrences and gradual changes of morphology are recognizable in the following four species: *Montiparus matsumotoi inflatus, Schwagerina? satoi,* "*Pseudoschwagerina*" *morikawai* and "*P.*" *minatoi*, in ascending order. These species represent sequential evolutionary stages of the "*P.*" *minatoi*-lineage.

(a) ***Montiparus matsumotoi inflatus*** **Stage:**– This species has an inflated fusiform or biconical shell, a minute proloculus, and tightly coiled inner 2 or 3 volutions. Mature specimens have 6 to 7 volutions and thick walls in outer volutions (Figures 22-12–13). Chomata are broad and massive in inner volutions and high and massive in outer volutions. The juvenarium is undivisible, but the shell rather rapidly increases in height in the fourth to outer volutions.

(b) ***Schwagerina? satoi*** **Stage:**– All morphological characters existing in the *matsumotoi inflatus*-stage proceed into this stage. Shells of this species (Figures 22-10–11) rapidly enlarge in 7 to 8 volutions, and the septal fluting is irregular and extend to near the tunnel in the outer volutions. Chomata are massive and high in upper 4 to 5 volutions and become smaller and narrower in outer volutions. Occasionally, the juvenarium which has a minute proloculus and

Fig. 48. All photographs × 25. enlarged figures of juvenile volutions of *Robustoschwagerina schellwieni pamirica* Leven & Schelbovich and *R. schellwieni schellwieni* (Hanzawa), showing ontogeny, size of proloculus, and a variation within the two subspecies. **1–4: *Robustoschwagerina schellwieni pamirica* Leven & Schelbovich,** Akiyoshi and Atetsu Limestone Groups. **5–8: *Robustoschwagerina schellwieni schellwieni* (Hanzawa),** Nishikori Formation.



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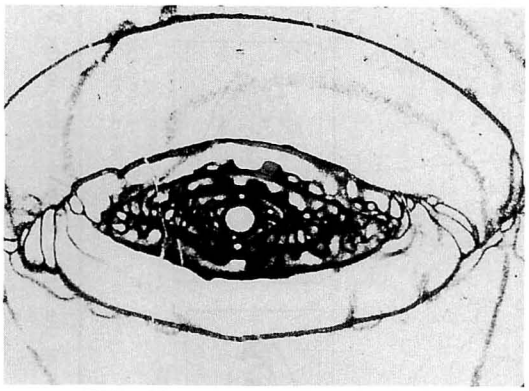

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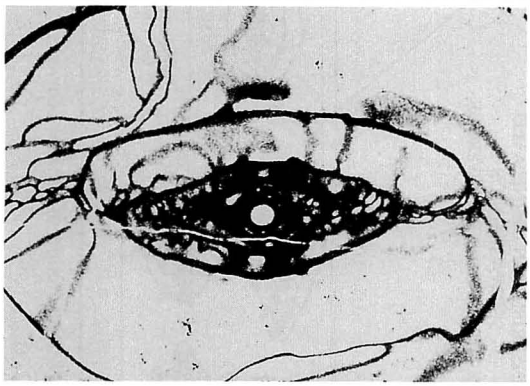

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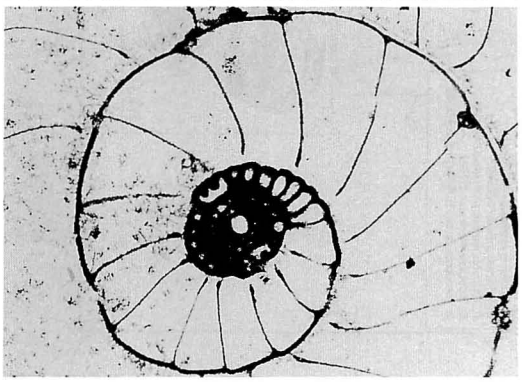

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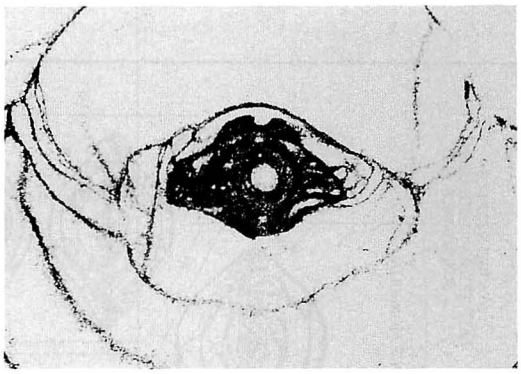

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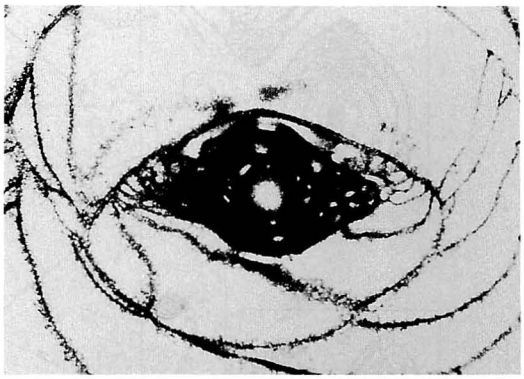

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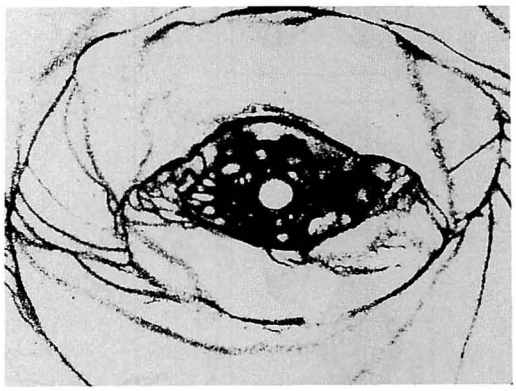

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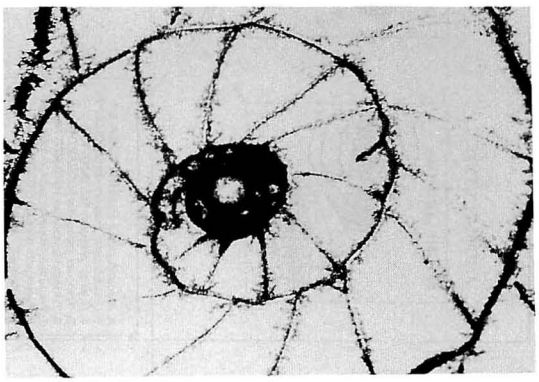

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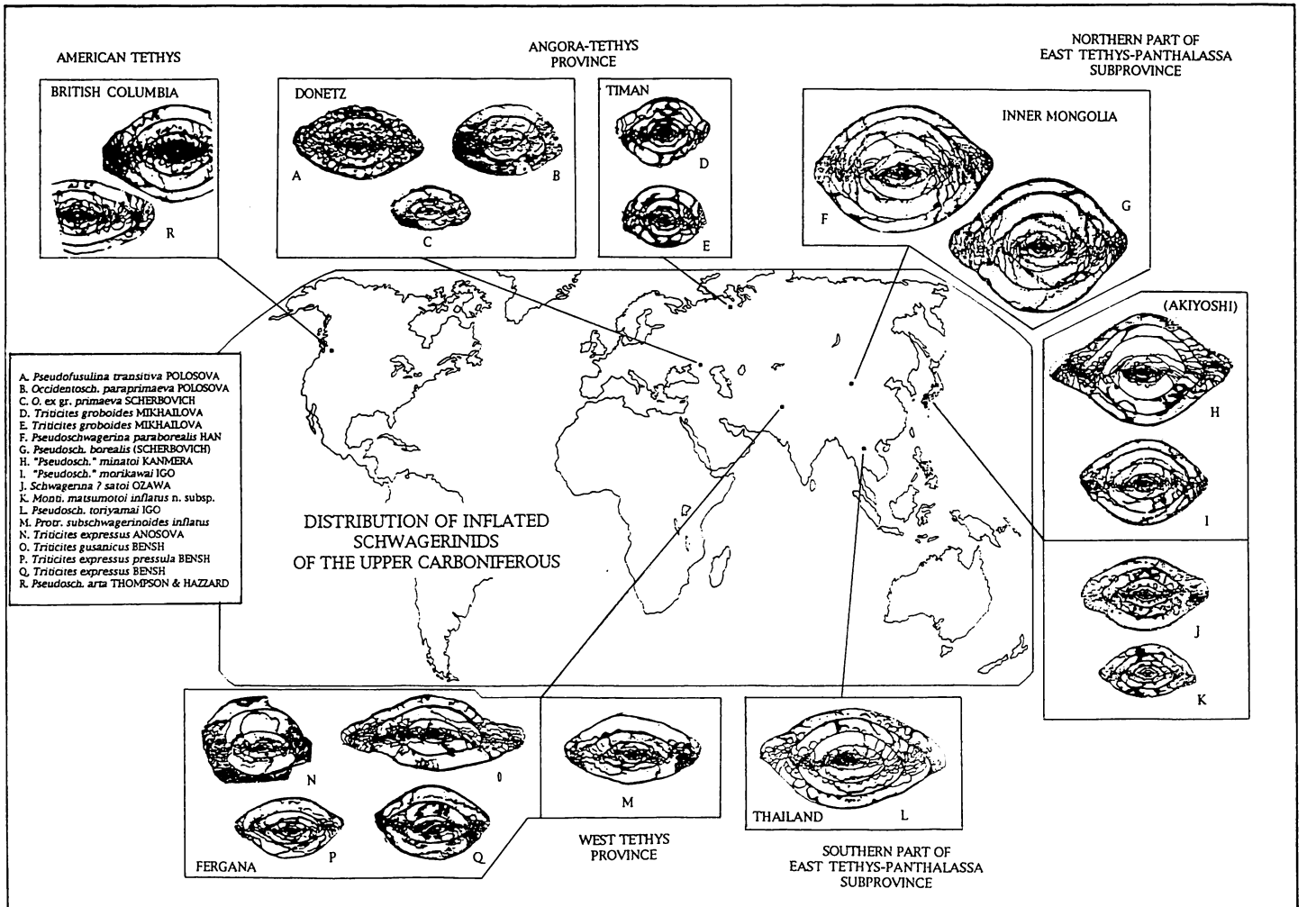

Fig. 49. Distribution of inflated Schwagerinids of the Upper Carboniferous in the World.

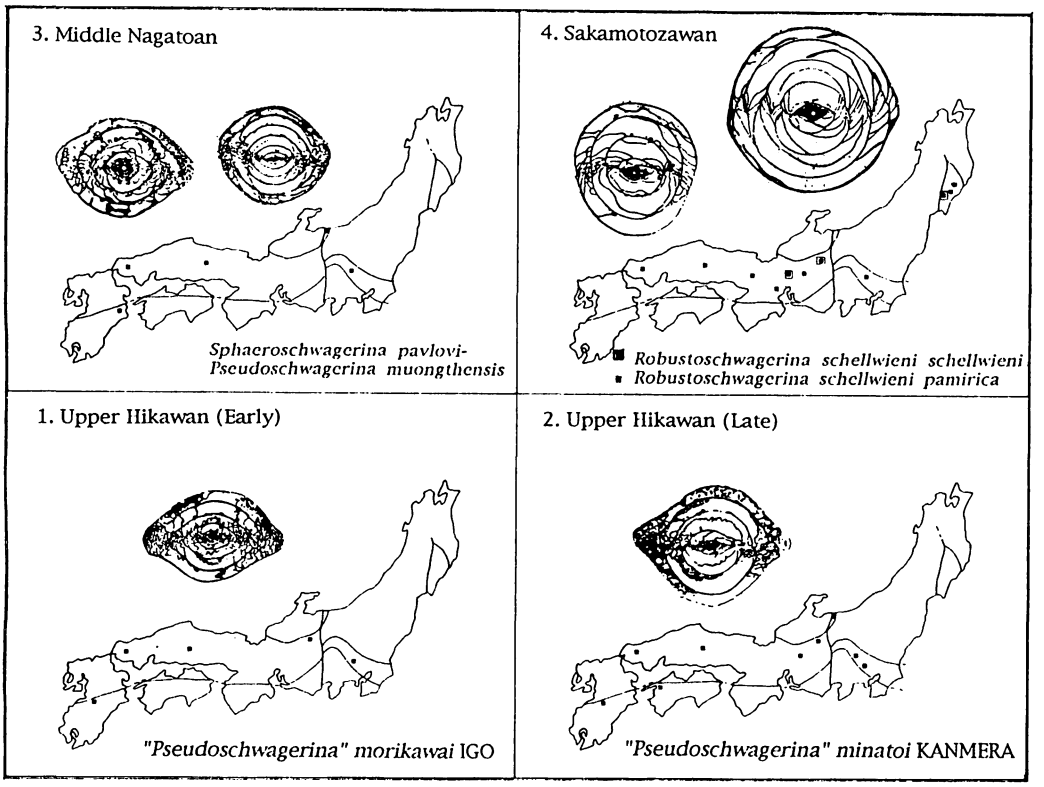

Fig. 50. Distribution of "*Pseudoschwagerina*" *morikawai*, "*P.*" *minatoi* in the Upper Hikawan; *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* association in the middle Nagatoan; *Robustoschwagerina schellwieni pamirica, R. schellwieni schellwieni* in the Sakamotozawan Stages in Japan.

tightly coiled 3 to 4 volutions is divisible.

(c) "***Pseudoschwagerina***" ***morikawai*** **Stage:**– The juvenarium consisting of 3 to 5 volutions is apparently divisible in this stage (Figures 46-1A–1C, 3A–3D, 5A–5C). Spirotheca thin in the juvenarium but very thick in outer volutions. Septa narrowly fluted in extreme polar regions, but weak and rather irregular. Chomata massive in inner volutions and rudimentary in outer volutions. Mature specimens reach 8 to 8 and half volutions.

(d) "***Pseudoschwagerina***" ***minatoi*** **Stage:**– This stage has the most distinctive juvenarium like *Montiparus* and reaching 4 to 5 volutions (Figure 46-2A–2D, 4A–4C, 6A–6D). The outer 5th to 6th volutions have highly expanded chambers but the last volution decrease again in height. Wall thin in inner, but thick in outer volutions. Septa closely spaced, almost plane in inner, but irregularly fluted in outer volutions.

The four species described above show successive and gradational morphological changes through their ontogeny from *Montiparus matsumotoi inflatus* via *Schwagerina? satoi* and "*Pseudoschwagerina*" *morikawai* to "*P.*" *minatoi*. Each of them can be regarded as a segment or a stage of development in a phylogenetical evolutionary line, that is the "*P.*" *minatoi*-lineage (see Figure 51), named after the latest form of this lineage. Their important evolutionary courses are represented by the following orthogenetical trends:

1. the shells enlarge through the stages

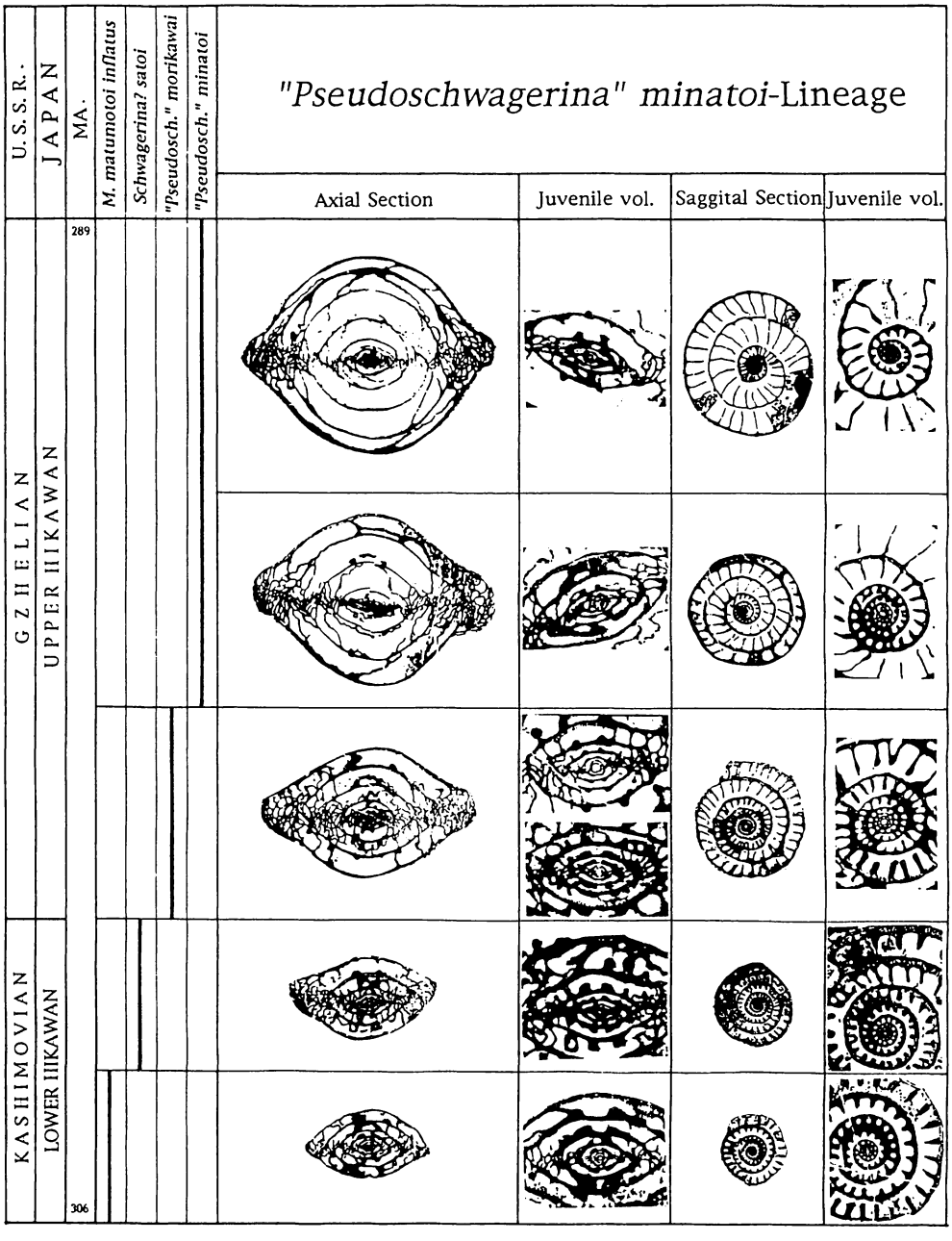

Fig. 51. Phylogenetic development of the species of "*Pseudoschwagerina*" *minatoi*-lineage.

2. the shell increase in number of volutions from 6 to 8 through the stages
3. the juvenarium becomes distinctive in later stages in association with rapid expansion of chambers
4. the septal fluting and chomata become to weaker and smaller in relation to the increase of height of chambers

5. populational study suggests that variations in size and inflation of the shell seem to be geographical variations

Figure 51 diagrammatically illustrates the phylogenetic development of shell structures and stratigraphic distribution of the species of the "*Pseudoschwagerina*" *minatoi*-lineage.

VII. Correlation

1. Correlation within the Japanese Islands

Among the upper Carboniferous and lower Permian fusuline fossils, inflated schwagerinids are short-ranged and occur successively almost throughout the sequence of those ages. The species lineage of *Montiparus matsumotoi inflatus-*"*Pseudoschwagerina*" *minatoi* is most noticeable and useful for biostratigraphic divisions and correlation within the Japanese Islands. Based on this lineage, the upper Carboniferous formations in Japan are divisible into the following zones in ascending order: the *Montiparus matsumotoi inflatus* Zone, the *Schwagerina? satoi* Zone, the "*Pseudoschwagerina*" *morikawai* Zone, and the "*Pseudoschwagerina*" *minatoi* Zone.

On the other hand, the species lineage of *Sphaeroschwagerina vulgaris-S. moelleri-S. sphaerica* was recognized by Rauser-Chernousova (1960, p.15) as an indicator within the Asselian Stage. Another lineage of *Sphaeroschwagerina vulgaris-S. pavlovi* is a good index for correlation of early Permian rocks of the Tethys region including Japan. The *Pseudoschwagerina muongthensis-P. robusta-P. subrotunda* lineage and the *Robustoschwagerina schellwieni pamirica-R. schellwieni schellwieni-R. tumida* lineage also are important indicators ranging from the Asselian to the Artinskian Stages in the Tethys region. Pseudoschwagerinid species of these two lineages are commonly found in the Nagatoan and Sakamotozawan Stages.

The species belonging to the lineages stated above are successively evolved with gradual morphological changes, but are divisible into some stages on the nature and magnitude of the form-change. The appearance and disappearance and evolutional changes of the species are very useful for correlation of strata in which they are contained. On this points of view, key horizons or datum levels based on the appearance and disappearance are defined and are applicable to the biostratigraphic divisions. The following datum levels can be recognized in the upper Carboniferous and lower Permian sediments of Japan.

(a) *Obsoletes obsoletus* Datum Level

The *Obsoletes obsoletus* Datum Level is drawn at a plane of the first appearance of the named species and is ascertained in the mentioned sections of the Akiyoshi, Omi and Futagoyama Limestone Groups. It lies just above the top of the *Pulchrella pulchra* and *Kanmeraia prolifica* Zones, at which these species disappear. *Obsoletes obsoletus* appears behind the disappearance of *P. pulchra* in the Akiyoshi and Omi Limestone Groups, and that of *K. prolifica* in the Futagoyama Limestone.

Remarks: The boundary between the Middle and Upper Carboniferous Series or the Moscovian-Kasimovian Stage boundary of Russia is placed at the first appearance of *Protriticites pseudomontiparus* Putrya and *Obsoletes obsoletus* (Schellwien). the Kurikian-Hikawan Stage boundary in Japan corresponds to this datum level. *Pulchrella pulchra,* an uppermost Moscovian species, appears just above the disappearance of *Fusulinella biconica* (Hayasaka

in the section of the Omi Limestone Group, where *P. pulchra* is associated with *Fusulinella gracilis* Kanmera, a characteristic species of the Upper Kurikian Stage.

This datum level is recognized at the base of the following zones: *Triticites opparensis* subzone (Kanuma, 1958) of the Oppara Formation; *Triticites* Zone (Morikawa, 1953; A. Ishii, 1962) of the Nakatsugawa Formation; *Protriticites* sp. nov. Zone (Ozawa, 1975) of the Kitaosogi Formation; *Triticites* Zone (Niikawa, 1978) and *Protriticites variavilis* Zone (Igo, 1978) of the Ichinotani Formation; *Protriticites obsoletus* zone (Morita, 1984 MS) of the Futagoyama Limestone Group; *Obsoletes obsoletus* Zone (Watanabe, in this paper) of the Omi Limestone Group; *Triticites matsumotoi* Zone (Ota, 1977) of the Akiyoshi Limestone Group.

(b) *Montiparus matsumotoi inflatus* Datum Level

This datum is marked by the lowest occurrence of *M. matsumotoi inflatus,* and is ascertained in the measured sections of the Omi and Akiyoshi Limestone Groups. This level lies directly above the top of the *Obsoletes obsoletus* (Schellwien).

Remarks: The boundary between the Lower and Upper Kasimovian Stage in Russia is placed at the first appearance of *Montiparus montiparus* (Ehrenberg em. Moeller). As this species is associated with *M. matsumotoi inflatus* n. subsp. in the measured sections of the Omi Limestone Group, the *M. matsumotoi inflatus* Datum Level is equivalent to the lower limit of the middle part of the Kasimovian Stage in Russia. *M. matsumotoi inflatus* is closely allied to *Fusulinella biconiformis* Niikawa from the uppermost part of the Upper *Fusulinella-Fusulina* Zone (Niikawa, 1978) in the Ichinotani Formation, which was correlated with the Upper Mjachikovian Stage in Russia. This species also similar to *Protriticites subschwagerinoides inflatus* Bensh described from the *Montiparus montiparus* Zone (Bensh, 1972) of the Middle Kashimovian Stage in the Fergana region, Russia.

The *M. matsumotoi inflatus* Datum Level marks the base of the following zones: *Triticites matsumotoi* Zone (Kanmera, 1955) of the Yayamadake Limestone Subgroup; *Triticites matsumotoi* Zone (Ota, 1977) of the Akiyoshi Limestone Group; *Triticites opparensis* subzone (Kanuma, 1958) of the Oppara Formation; *Triticites* Zone (Suyari, 1961) of the Miyanokuchi Formation; *Protriticites* sp. nov. Zone (Ozawa, 1975) of the Kitaosogi Formation; *Montiparus matsumotoi inflatus* Zone (Watanabe, in this paper) of the Omi Limestone Group.

(c) *Schwagerina? satoi* Datum Level

The *Schwagerina? satoi* Datum Level is defined by the first occurrence of the named species, and is ascertained in the lower limit of the *Schwagerina? satoi* Zone in the measured sections of the Omi, Atetsu, Akiyoshi and Futagoyama Limestone Groups, and Ichinotani Formation. This datum level marks the boundary between the Lower and Upper Hikawan Stage.

Remarks: The *Schwagerina? satoi* Datum Level accords with the first appearance of *Montiparus exculptus* (Igo), *T. sinuosus* Rosovskaya and the disappearance of *Quasifusulinoides ohtanii* (Kanmera) and *M. sinuosus alaicus* Bensh are closely similar to these species and which are the characteristic species of *Triticites arcticus-T. acutus* Zone of the Upper Kashimovian Stage in the Fergana region, Russia. Thus, the datum level can be correlated with the boundary of the Middle and Upper Kasimovian Stage in Russia.

The *Schwagerina? satoi* Datum Level marks the base of the following zones: *Triticites*

kiyomiensis subzone (Kanuma, 1958) of the Oppara Formation; *Triticites* Zone (Sakaguchi, 1962) of the Tamba Group; *Triticites* Zone (Morikawa, 1953; A. Ishii, 1962) of the Ishifune Formation; *Triticites simplex* subzone (Toriyama, 1958) of the Akiyoshi Limestone Group; *Quasifusulina longissima ultima-"Pseudoschwagerina" nakazawai* subzone (Nogami, 1961) of the Atetsu Limestone Group; *Triticites* Zone (Kawada, 1954; Fujita, 1958; Hasegawa *et al.*, 1969) of the Omi Limestone Group; *Triticites exculptus-T. hidensis* subzone (Igo, 1957, 1978) and *Triticites* Zone (Niikawa, 1978) of the Ichinotani Formation; *Triticites* Zone (Takaoka, 1964) and *Schwagerina? satoi* Zone (Morita, 1984 MS) of the Futagoyama Limestone Group.

(d) *"Pseudoschwagerina" morikawai* Datum Level

This datum level, defined by the first occurrence of the named species, is ascertained at the base of the *"Pseudoschwagerina" morikawai* Zone in the measured sections of the Akiyoshi and Atetsu Limestone Groups and the Yayamadake Limestone Subgroup.

Remarks: The first appearance of *Jigulites formosus turanicus* Bensh defines the Kasimovian-Gzhelian boundary in Fergana, Russia (Bensh, 1972). This species is closely similar to *Triticites elongatus* Niikawa described from the *"Pseudoschwagerina" morikawai* Zone of the Ichinotani Formation. On the other hand, the *Triticites rossicus-Jigulites formosus turanicus* Zone of the early Gzhelian in Fergana yields *Triticites gusanicus* Bensh, which is closely similar to *"Pseudoschwagerina" morikawai* Igo. Then, some problems concerning generic assignments and distinctions of highly vaulted forms of *Triticites* and small forms *Pseudoschwagerina* still remain as already assumed by Kanuma (1960a).

The *"Pseudoschwagerina" morikawai* Datum Level marks the base of the following zones: *Pseudoschwagerina morikawai* Zone (Igo, 1957) and *Pseudoschwagerina* Zone (Niikawa, 1978) of the Ichinotani Formation; *Pseudoschwagerina morikawai* Zone (Kanmera, 1958, 1978) of the Yayamadake Limestone Subgroup; *Quasifusulina longissima ultima-"Pseudoschwagerina" nakazawai* subzone (Nogami, 1961) of the Atetsu Limestone; *Triticites simplex* subzone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone; *Pseudoschwagerina morikawai* Zone (Morita, 1984 MS) of the Futagoyama Limestone Group.

(e) *"Pseudoschwagerina" minatoi* Datum Level

This datum level is defined by the first appearance of *"P." minatoi* Kanmera and *Paraschwagerina shimodakensis* Kanmera. It is ascertained at the base of the *"Pseudoschwagerina" minatoi* Zone in the Yayamadake Limestone Subgroup, a standard sequence for the latest Hikawan in Japan.

Remarks: The boundary between the middle and upper Gzhelian in Russia is placed at the appearance of *Daixina sokensis* (Rauser). *Paraschwagerina archaica* Leven and Schelbovich also occur from the upper part of the *Jigulites jigulensis* Zone, the middle Gzhelian in Fergana, Russia. *Paraschwagerina shimodakensis* is closely similar to *P. archaica*. In the Yayamadake Limestone. *Daixina sokensis* is associated with *"Pseudoschwagerina" minatoi* Kanmera at 20 m above the datum level. Thus, the *"P." minatoi* Datum Level is roughly correlated with the lower limit of the upper Gzhelian.

The *"P." minatoi* Datum Level is drawn at the base of the following zones and beds: *"Pseudoschwagerina" minatoi* Zone (Kanmera, 1958, 1978) of the Yayamadake Limestone

Subgroup; *Pseudoschwagerina orientale* faunule (Fujimoto, 1936) of the Tsukumi Limestone Group; *Pseudoschwagerina* Zone (Kanuma, 1958) of the Okumyogata Formation; *Quasifusulina longissima ultima-"Pseudoschwagerina" nakazawai* subzone (Nogami, 1961) of the Atetsu Limestone; *Triticites simplex* subzone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group; Beds containing *Pseudoschwagerina minatoi* faunule (Yanagida & Hirata, 1969) of the Ohnogahara Formation; Beds containing *Pseudoschwagerina minatoi* faunule (Kashima, 1969) of the Tanosugi Formation; *Pseudoschwagerina morikawai* Zone (Igo, 1957) and *Pseudoschwagerina* Zone (Niikawa, 1978) of the Ichinotani Formation; *Pseudoschwagerina* Zone (Takaoka, 1966) and *Pseudoschwagerina minatoi* Zone (Morita, 1984 MS) of the Futagoyama Limestone Group; *Triticites simplex* subzone (Hasegawa *et al.*, 1969) of the Omi Limestone Group.

(f) *Sphaeroschwagerina fusiformis* Datum Level

The *Sphaeroschwagerina fusiformis* Datum Level is marked by the lowest occurrence of the named species, and is ascertained directly above the top of *Pseudoschwagerina minatoi* Zone in the Akiyoshi Limestone. The base of the Asselian Stage or the conventional boundary of the Carboniferous and Permian Systems is placed at the first appearance of this species. This datum level is set as the Japanese Carboniferous-Permian systemic boundary, that is the base of the Nagatoan Stage in Japan.

Remarks: As *Sphaeroschwagerina* has three or four juvenile volutions as in *Schubertella,* it can be differentiated from other inflated genera of the Schwagerininae. The type Asselian Stage is subdivided into three units, the Lower, Middle and Upper, every unit of which is characterized by the following distinct species whose ranges are within the limit of individual units; *Sphaeroschwagerina vulgaris* and *S. fusiformis* of the Lower, *S. moelleri* or *S. pavlovi* of the Middle and *S. sphaerica* and *S. glomerosa* of the Upper. *S. fusiformis* and *S. pavlovi* also characterize each of the lower two zones in the Nagatoan Stage.

The *S. fusiformis* Datum Level marks the base of the following zones: *Pseudoschwagerina muongthensis* Zone (Ozawa, 1925; Toriyama, 1958; Hasegawa *et al.*, 1969; Ota, 1977) of the Akiyoshi Limestone Group; *Pseudoschwagerina kanmerai* subzone (Sada, 1965) of the Atetsu Limestone Group.

(g) *Pseudoschwagerina muongthensis* Datum Level

This datum level is defined by the first appearance of *Pseudoschwagerina muongthensis* (Deprat) and associated *Sphaeroschwagerina pavlovi* (Rauser-Chernousova). It is ascertained in the measured sections of the Akiyoshi, Atetsu and Omi Limestone Groups.

Remarks: The association of pseudoschwagerinas and sphaeroschwagerinas is widely recognized in the Tethys region, and the central Russian Platform. In the latter area, where the standard section of the Lower Permian rocks is present, the base of the middle Asselian is placed at the horizon of the first appearance of *P. muongthensis volgensis* Scherbovich and associated *Sphaeroschwagerina moelleri* (Rauser-Chernousova) and *S. pavlovi* (Rauser-Chernousova). The base of the Middle Nagatoan Stage is also well defined by the identical and similar species. Thus, the *Pseudoschwagerina muongthensis* Datum Level coincides with the base of the Middle Asselian Stage. *Pseudoschwagerina muongthensis* (Deprat) described by Toriyama (1958, Pl. 18, Fig. 8; Pl. 19, Fig. 1, 4, 5, 6) and Ota (1977, Pl. 2, Fig. 11; 1985, Pl.

1–8, Fig. 17) is identical with *Sphaeroschwagerina pavlovi* (Rauser).

The *Pseudoschwagerina muongthensis* Datum Level is drawn at the base of the following zones: *P. muongthensis* Zone (Ozawa, 1925; Toriyama, 1958; Hasegawa *et al.*, 1969; Ota, 1977) of the Akiyoshi Limestone Group; *Pseudoschwagerina kanmerai* subzone (Sada, 1965) of the Atetsu Limestone Group; *Pseudoschwagerina muongthensis-Sphaeroschwagerina* sp. faunule (Nishida and others, 1982; Watanabe, in the present paper) of the Tsukumi Limestone; *Pseudoschwagerina muongthensis-Sphaeroschwagerina moelleri* Zone (Morita, 1984 MS) of the Futagoyama Limestone Group; *Sphaeroschwagerina pavlovi-Pseudoschwagerina muongthensis* Zone (Watanabe, in the present paper) of the Omi Limestone Group.

(h) *Schwagerina globulus japonicus* Datum Level

This datum level is defined by the first appearance of *Schwagerina globulus japonicus* Watanabe n. subsp., and is ascertained at the base of the *Schwagerina globulus japonicus* Zone in the measured sections of the Akiyoshi, Atetsu and Omi Limestone Groups.

Remarks: This datum level is found in the white crinoidal biosparudite limestone horizon just above the zone of *Alpinoschwagerina saigusai* Nogami and *P.* cf. *robusta* (Meek). *Schwagerina* sp. C of Toriyama (1958) from the *Pseudofusulina vulgaris* Zone in the Akiyoshi Limestone Group and *Paraschwagerina gigantea* of Morikawa and Isomi (1961) from the Samegai Formation are referable to *Schwagerina globulus japonicus* Watanabe, n. subsp. *Pseudofusulina globulus* Rauser, *P. krotowi nux* (Schellwien), *P. krotowi sphaeroides* Rauser and *Schwagerina princeps* (Ehrenberg) are essentially similar to *Schwagerina globulus japonicus.* These four Russian species were described from the Middle to Upper Asselian Stage in the Pechora and Central Russian Platform regions. The Japanese species is more evolved than the Russian ones, and is associated with *Pseudoschwagerina miharanoensis* Akagi. Thus, the *Schwagerina globulus japonicus* Datum Level is tentatively set at the base of the middle part of the upper Nagatoan Stage and is roughly correlated with the upper Asselian Stage in Russia. The *S. globulus japonicus* Datum Level marks the base of the following zones: *Pseudofusulina vulgaris* subzone (Toriyama, 1958) and *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone (Watanabe, this paper) of the Akiyoshi Limestone; *Schwagerina globulus japonicus* Zone (Watanabe, in this paper) and *Quasifusulina longissima ultima-Pseudoschwagerina subsphaerica* subzone (Nogami, 1961) of the Atetsu Limestone Group; *Pesudofusulina vulgaris* subzone (Hasegawa and others, 1969) and *Schwagerina globulus japonicus-Pseudoschwagerina miharanoensis* Zone (Watanabe, in this paper) of the Omi Limestone Group.

(i) *Robustoschwagerina schellwieni pamirica* Datum Level

The *Robustoschwagerina schellwieni pamirica* Datum Level is drawn at a plane of the first appearance of the named species and is ascertained in the measured sections of the Akiyoshi Limestone Group and at the base of the Sakamotozawa Formation. This datum level is also ascertained in the lowest part of the *Robustoschwagerina schellwieni* Zone at the base of the Trogkofel Stufe in Karnic Alps (Kahler, 1974b) and the Sakmarian beds in the Fergana region in Russia (Bensh, 1972).

Remarks: The Sakmarian and Artinskian strata of the Akiyoshi Limestone Group in Japan are divided into the *Pseudofusulina vulgaris* Zone, the *Pseudofusulina ambigua* Zone and *Misellina*

U. S. S. R.			JAPAN		JAPANESE STANDARD ZONES (Present Paper)	INNER ZONE OF SOUTHWEST JAPAN			HIDA MT.		KUMA MT.	KANTO	KATAKAMI
						Akiyoshi	Atetsu	Omi	Fukuji	Oppara	Yayamadake	Futago	Sakamotozawa
LOWER PERMIAN	ARTINSKIAN	Upper	SAKAMOTOZAWAN	Upper	*Rob. schellwieni schellwieni -Psf. vulgaris vulgaris*			*vulgaris -vulgaris*	*schellwieni schellwieni -vulgaris vulgaris*				*schellwieni schellwieni -vulgaris vulgaris*
	SAKMARIAN	Lower		Lower	*Rob. schellwieni pamirica -Schwagerina krotowi*	*schellwieni pamirica -krotowi*	*schellwieni pamirica -krotowi*			*schellwieni pamirica -krotowi*		*schellwieni pamirica -krotowi*	*schellwieni pamirica -nunosei*
	ASSELIAN	Upper	NAGATOAN	Upper	*Paraschwagerina akiyoshiensis -Psf. firma*	*akiyoshiensis -firma*	*akiyoshiensis -firma*	*akiyoshiensis -firma*				*Sphaerosch. sp.*	
					Sch. globulus japonicus-Pss. miharanoensis	*globulus japonicus -miharano -ensis*	*globulus japonicus*	*globulus japonicus -miharano -ensis*					
		Middle		Middle	*Alpin.saigusai Pss. cf. robusta*	*saigusai*	*saigusai- cf. robusta*	*cf. robusta*				f.	
					Sph. pavlovi-Pss. muongthensis	*pavlovi- muongthensis*	*pavlovi- muongthensis*	*pavlovi- muongthensis*				*moellei- muongthensis*	
		L		L	*Sphaeroschwag. fusiformis*	*fusiformis*	*fusiformis*	*fusiformis*				f.	
UPPER CARBONIFEROUS	GZHELIAN	Upper	UP. IIIKAWAN	Upper	*"Pseudoschwag." minatoi*	*minatoi*	*minatoi*	*minatoi*	*minatoi*	*minatoi*	*minatoi*	*minatoi*	
		L		L	*"Pseudoschwag." morikawai*	*morikawai*	*morikawai*	*morikawai*	*morikawai*		*morikawai*	*morikawai*	
	KASIMOVIAN	Upper	LOW. IIIKAWAN	Upper	*Schwagerina ? satoi*	*satoi*	*satoi*	*satoi*	*satoi- exculptus*	*satoi*	*yayamadak- ensis*	*satoi*	
							f.			f.		f.	
		Middle		Middle	*Montiparus matumoti inflatus*	*matsumotoi inflatus*		*matsumotoi inflatus*		*matsumotoi inflatus*	*matsumotoi inflatus*		
		L		L	*Obsoletes obsoletus*	*obsoletus*		*obsoletus*	*variabilis*	*obsoletus*	*obsoletus*	*obsoletus*	
					Pulchrella pulchra	*pulchra*		*pulchra*	*biconiformis*	*prolifica*	*Kanmerala prolifica*	*prolifica*	

Table 4. Fusuline Zones and correlation of the representative limestones in Japan. f: fault relation, wavy line: discomformity, vertical line: stratigraphic break, horizontal line: unexposed.

claudiae Zone, in ascending order. I have found that *Robustoschwagerina schellwieni pamirica* first appears in the lower part of the *Pseudofusulina vulgaris* Zone, and that the *Pseudofusulina vulgaris* Zone lying just below the *R. schellwieni pamirica* Datum Level contains the Upper Asselian pseudoschwagerinas. Thus, the *Pseudofusulina vulgaris* Zone above this datum level, *P. ambigua* Zone and *Misellina claudiae* Zone are correlated with the Sakmarian and Artinskian Stages in Darvus region in Russia. These zones above the datum level in the Akiyoshi Limestone Group can be correlated with the whole part of the Sakamotozawa Formation. If the *R. schellwieni* Datum Level coincides with the base of the Sakamotozawa Formation in the type sequence, the Lower Sakamotozawa Formation will be correlated with the Sakmarian and the Lower Artinskian Stage and the Upper Sakamotozawa Formation with the Upper Artinskian Stage.

The *R. schellwieni pamirica* Datum Level marks the base of the following zones: *Pseudoschwagerina* Zone (Hanzawa, 1938; Chisaka, 1962) of the Nishikhori Formation; *Pseudoschwagerina* Zone (Fujimoto, 1941; Igo, 1965) of the Samegai Formation; *Pseudofusulina vulgaris* Zone (Kanuma, 1960) of the Okumyogata Formation; *Pseudoschwagerina schellwieni* Zone (Choi, 1973) of the Sakamotozawa Formation at Setamai-Yahagi areas; Chichibu Paleozoic Formation (Fujimoto, 1936); *R. schellwieni-Pseudofusulina vulgaris* Zone (Igo, 1965) of the Sote Formation; the Sb_1 to Sc-members of the Sakamotozawa Formation (Kanmera and Mikami, 1965); *Pseudoschwagerina subsphaerica* subzone (Nogami, 1961) of the Atetsu Limestone Group; *Pseudoschwagerina* Zone (Koike, 1963) of the Ryozenyama Limestone; *P. vulgaris* Zone (Toriyama, 1958; Ota, 1977) of the Akiyoshi Limestone Group.

The fusuline zones and correlation based on the datum levels stated of the representative limestones in Japan are summarized in Table 4.

2. International Correlation

The international and Tethyan provincial fusuline zones of the Carboniferous and Permian Systems were summarized by Rotai (1975, 1979) and Kahler (1974), respectively.

The Upper Carboniferous Series is divided into the Kasimovian Stage below and the Gzhelian Stage above. The Lower Permian Series consists of the Asselian Stage of the lower, the Sakmarian Stage of the middle, and the Artinskian Stage. Each of these five stages includes one to three fusuline zones, which are as follows in descending order:

B. Lower Permian Series

3. Artinskian Stage .....
- 12. *Misellina* Zone
- 11. *Pseudofusulina vulgaris* Z.

2. Sakmarian Stage ..... 10. *Robustoschwagerina schellwieni* Zone

1. Asselian Stage .....
- 9. *Zellia* Zone
- 8. *Pseudoschw. confini* Zone
- 7. *Pseudoschw. alpina* Zone

A. Upper Carboniferous Series

2. Gzhelian Stage .....
- 6. *Daixina sokensis* Zone
- 5. *Triticites jigulensis* Zone
- 4. *Triticites stuckenbergi* Z.

1. Kashimovian Stage .....
- 3. *T. arcticus-T. acutus* Zone
- 2. *Triticites montiparus* Zone
- 1. *Protri. pseudomontiparus-Obsoletes obsoletus* zone

The Japanese regional stages revised and newly established in this paper can be correlated with the international stages as follows:

4. Sakamotozawan Stage (emended) { a. Upper: ... Artinskian Stage; b. Lower: ... Sakmarian Stage }
3. Nagatoan Stage (new name) ..... Asselian Stage
2. Upper Hikawan Stage (new name) ..... Gzhelian Stage
1. Lower Hikawan Stage (amended) ..... Kasimovian Stage

On the following lines, problems on the correlation between the standard fusuline zones in Japan and those in Soviet Russia, China, Thailand and America are discussed.

a. Soviet Russia

1. Timan Region

The upper Carboniferous and lower Permian strata widely crop out in the Central Timan region. Grozdilova and Lebedeva (1961) described fusuline faunas from the Upper Asselian and the Lower Artinskian Stages in this region. Grozdilova (1966) also described fusuline faunas from the Kasimovian through the Asselian. They showed a generalized succession of the upper Carboniferous and lower Permian in Timan as follows:

B. Lower Permian Series (P_1)
8. Artinsky Horizon ..... { a. Upper; b. Lower }
7. Sterlitamaksky Horizon
6. Tastubsky Horizon
A. Upper Carboniferous Series (C_3)
5. Nenetsuky Horizon ..... b. Upper *Schwagerina* Horizon
4. Indigsky Horizon ..... a. Lower *Schwagerina* Horizon
3. Aljuvinsky Horizon
2. Odesky Horizon ..... { b. Upper; a. Lower }
1. Burkemsky Horizon

The lowest Burkemsky Horizon includes the following fusuline species: *Obsoletes obsoletus* (Schellwien), *Protriticites plicatus* Kireeva, *Quasifusulina longissima solida* Grozdilova, and *Pseudotriticites brazhnikova* Putrja. This fauna represents the *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone of the Lower Kasimovian Stage in the type section.

The Odesky Horizon contains the following many species: *Triticites umboplicatus* Rauser., *T. montiparus* (Schellwien), *T. subcrassulus* Rosovskaya, and *T. sinuosus* Rosovskaya in the lower part; *Triticites arcticus* (Schellwien), *T. acutus* Dunbar and Condra, *T. fortissimus* Rosovskaya, and *T. pausus* Grozdilova in the upper part. The lower and upper Odosky faunas are comparable respectively with the fusuline association of *Montiparus montiparus* Zone of Middle Kasimovian Stage and the *Triticites arcticus-T. acutus* Zone of the Upper Kasimovian Stage in the type section.

The Aljuvinsky Horizon yields the following many species: *Triticites vetustus* (Schellwien), *T. pseudoarcticus* Rauser., *T. rossicus* (Schellwien), *T. noinsky* Rauser., *T. jigulensis* Rauser., *T. stuckenbergi* Rauser., *Pseudofusulina sokensis* Rauser., and so on. These species indicate that the Aljuvinsky Horizon corresponds to the succession ranging from the *Triticites stuckenbergi* Zone to the *Daixina sokensis* Zone, that is the whole of the Gzhelian Stage in the

type section.

Thus, the Burkemsky plus Odesky Horizons can be correlated with the Lower Hikawan Stage, and the Aljuvincky Horizon with the Upper Hikawan Stage of the Upper Carboniferous Series in Japan.

The Indigsky Horizon contains the following primitive and evolved schwagerinids: "*Schwagerina*" *fusiformis* Krotow, "*S.*" *vulgaris* Scherbovich, "*S.*" *moelleri* Rauser., "*S.*" *borealis* Scherbovich, "*S.*" *pavlovi gerontica* Grozdilova, and so on. These "*Schwagerina*" are referable to *Sphaeroschwagerina* in the present usage. These species are the elements of the "*Schwagerina*" *fusiformis*-"*S.*" *vulgaris* Zone and the "*S.*" *moelleri* Zone respectively of the lower and the middle part of the Asselian Stage in the type section.

The Nenetsuky or the upper "*Schwagerina*" Horizon yields the following species: "*Schwagerina*" *sphaerica* Scherbovich, *Pseudofusulina firma* Schamov, *P. krotowi nux* (Schellwien), *P. krotowi globulus* Rauser., *P. sulcatus* Korzh., and *P. tschernyschewi* (Schellwien). Formerly, this fauna was assigned to the *Pseudofusulina uralica* Horizon, but the Ninetsuky fauna is known to be equivalent to the elements the "*Schwagerina*" *sphaerica* Zone of the Upper Asselian Stage in the type section.

Grozdilova and Lebedeva (1961) and Grozdilova (1966) classed the Indigsky and Nenetsuky Horizons among the Upper Carboniferous Series. The Carboniferous-Permian boundary in this region, however, should be placed at the lower limit of the Indigsky Horizon. On the basis of the faunal elements, the Indigsky and Nenetsuky Horizons can be correlated with the Nagatoan Stage in Japan.

The next Tastubsky Horizon contains the following species of the genus *Pseudofusulina*: *Pseudofusulina moelleri* (Schellwien) in the lower part; *Pseudofusulina uralica* (Krotow), *P. perplexa* Grozdilova & Lebedeva, *P. tschernyschewi* (Schellwien) in the upper part. These species indicate that the lower Tastubsky Horizon is correlated with the *Pseudofusulina moelleri* Zone, and the upper Tastubsky with the *Pseudofusulina verneuili* Zone, both of the Lower Sakmarian Stage in the type section.

The Sterlitamaksky Horizon yields *Pseudofusulina urdalensis abnormis* Rauser. and *P. plicatissima* Rauser. This fauna is comparable with the Sterlitamaksky elements of the *Pseudofusulina urdalensis* Zone of the upper part of the Sakmarian Stage. Thus, the Tastubsky and Sterlitamaksky Horizons are equivalent to the Sakmarian Stage.

Bensh (1972) established the *Robustoschwagerina schellwieni* Zone in the lower Ulkian Horizon in the Fergana region of Central Asia, in which he found *Pseudofusulina moelleri,* an index species of the type Sakmarian. Thus, the *R. schellwieni* Zone in Fergana is recognizable to be equivalent to that of the type Sakmarian Stage. Consequently, the Tastubsky plus Sterlitamaksky Horizons can be indirectly correlated with the lower part of the Sakamotozawan Stage in Japan.

The Artinsky fusuline fauna recognized as the uppermost horizon in this region is characterized by the appearance of *Parafusulina lutugini* (Schellwien), *P. vissarinovae* Rauser., and *P. concavatus delicata* Rauser., *P. concavatus* Rauşer. is a zonal index species of the Burchevsky Horizon, the lowest Artinskian Stage in the type section. *Parafusulina lutugini* (Schellwien) is also a good index species of the Irginsky Horizon, the middle part of the Artinskian Stage.

2. Pechora Region

Fusuline biostratigraphy of the Pechora region was studied by Mikhailova (1974). She established one of the standard fusuline zones ranging from the Kasimovian to the Asselian Stages, as shown below:

B. Lower Permian Series (P_1)
  Tastubsky Horizon (P_1ts)
A. Upper Carboniferous Series (C_3)
  C_3as_3 ..... "*Schwagerina*" *sphaerica-Pseudofusulina firma* Z.
  C_3as_2 ..... "*Schwagerina*" *moelleri-Psf. fecunda* Zone
  C_3as_1 ..... "*Schwagerina*" *vulgaris*-"*S.*" *fusiformis* Zone
  C_3E ..... *Daixina sokensis* Zone
  C_3D ..... *Jigulites jigulensis* Zone
  C_3C ..... *Triticites rossicus* Zone
  C_3B ..... *Triticites arcticus-T. acutus* Zone
  C_3A ..... *Montiparus montiparus* Zone
  C_3O ..... *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone

The upper Carboniferous strata of the Pechora region generally rest conformably on the middle Carboniferous strata and are conformably overlain by the Asselian deposits. The Kasimovian rocks of this region are subdivided into the Burkemsky Horizon including C_3O and the Odesky Horizon comprising C_3A and C_3B. The Aljuvinsky Horizon, which corresponds to the Gzhelian Stage in the type section, is divisible into the *Triticites rossicus* (C_3C) and the *Daixina sokensis* (C_3E) Zone. The *Triticites rossicus* Zone (C_3C) is correlative with the *Triticites stuckenbergi* Zone (C_3C) and the *Jigulites jigulensis* Zone (C_3D) in the type section.

The Asselian rocks of this region are subdivided into the Indigsky Horizon comprising Zones C_3as_1 and C_3as_2 and the Nenetsuky Horizons of Zone C_3as_3.

The Tastubsky Horizon of the Lowest Permian in this region yields *Pseudofusulina tschernyschewi* (Schellwien), *P. moelleri* (Schellwien) and *Paraschwagerina longa* Mikhailova. *Pseudofusulina moelleri* is a zonal index species of the lower part of the type Sakmarian section.

Mikhailova (1974) placed Zones C_3as_1 to C_3as_3 in the upper Carboniferous, but the Carboniferous-Permian boundary should be placed at the base of Zone C_3as_1.

It should be noted that there are many species similar to each other between the faunas of Pechora and Japan, as follows:

(PECHORA)	(JAPAN)
Protrit. globulus (C_3O)	*Mont. matsumotoi inflatus*
Montiparus sinuosus (C_3A)	*M. exculptus*
Triticites globulus (C_3B)	*Schwagerina? satoi*
T. s. schwageriniformis (C_3B)	*T. yayamadakensis*
Jigulites jigulensis (C_3C)	*S. jigulensis*
Pseudofusulina andersoni (C_3E)	*Schwagerina stabilis*
Daixina sokensis (C_3E)	*P.(D.) sokensis*
Schwagerina fusiformis (C_3as_1)	*Sphaerosch. fusiformis*
Psch. intermedia (C_3as_2)	*Ps. muongthensis*
Schwagerina meolleri (C_3as_2)	*Sphaerosch. pavlovi*
Pseudofusulina nux (C_3as_2)	*Sch. globulus japonicus*
P. globulus (C_3as_2)	*Sch. globulus japonicus*
P. tschernyschewi (P_1)	*Monodiexodina langsonensis*
Schwagerina moelleri (P_1)	*Paraschwagerina* cf. *longa*
Parasch. vuktylensis (P_1)	*Pseudof.* cf. *globosa*

The close similarity of the species tabulated above indicates that Zones C_3O to C_3B Zones can be correlated with the three lower Hikawan zones and Zones C_3D-C_3E with the two upper Hikawan zones. The three Asselian zones (Zones C_3as_1 to C_3as_3) are equivalent to the three Nagatoan zones, and the Tastubsky fauna (P_1ts) is comparable with the Lower Sakamotozawan fauna.

3. Russian Platform

The upper Carboniferous in the Russian Platform is subdivided into two stages, the Kasimovian of the lower and the Gzhelian of the upper. The upper Carboniferous succession in the greater part of the Russian Platform is only known from many boreholes. Therefore, these stages form a composite-stratotype. The zonal scheme based on fusuline fossils was worked out by Rauser-Chernousova (1941) and others, Zones C_3A_1, C_3A_2, and C_3B in the Kasimovian Stage and Zones C_3C, C_3D, and C_3E in the Gzhelian Stage were discriminated (Rosovskaya, 1950; Ivanova and Rosovskaya, 1967). Rauser-Chernousova and others (1979) showed a generalized succession of the upper Carboniferous as follows:

B. Gzhelian Stage (60–140 m)
- 4. Noginsky Horizon ..... C_3E: *Daixina sokensis-Pseudofusulina gregaria* Z.
- 3. Pavlovo-Posadsky H. ..... C_3D: *Jigulites jigulensis-J. longus* Zone
- 2. Amerevsky Horizon ..... C_3C_2: *Triticites* (*Rauselites*) *stuckenbergi* -*T.*(*R.*) *proculomensis* Z.
- 1. Rusavkinsky Horizon ..... C_3C_1: *Triticites rossicus-T.*(*R.*) *pararcticus* Zone

A. Kashimovian Stage (50–70 m)
- 4. Yauzsky Horizon ..... C_3B_2: *T. irregularis-T. acutus* Zone
- 3. Dorogmomilovsky H. ..... C_3B_1: *T. arcticus-T. ohioensis* Z.
- 2. Khamovniresky H. ..... C_3A_2: *Montiparus montiparus* Zone
- 1. Krevyakinsky H. ..... C_3A_1: *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone

It is noteworthy that the fusuline faunas of these two stages include many species similar to and identical with the species of the upper Carboniferous of Japan as tabulated below:

(Kasimovian Fauna)	(Lower Hikawan Fauna)
Protrit. subschwagerinoides	*Obsoletes obsoletus*
Montiparus p. paramontiparus	*M. matsumotoi inflatus*
Montiparus montiparus	*M. matsumotoi matsumotoi*
Montiparus umboplicatus	*M. exculptus*
Montiparus rhombiformis	*Schwagerina? satoi*
Protriticites globulus	*M. matsumotoi matsumotoi*
M. paramontiparus mesopachus	*M. matsumotoi inflatus*
M. sinuosus	*M. exculptus*
T. schwageriniformis	*S.? satoi*

(Gzhelian Fauna)	(Upper Hikawan Fauna)
T. schwagerinoides mosquensis	*Schwagerina? satoi*
T. (*Rauserites*) *stuckenbergi*	*T. stuckenbergi*
T. (*R.*) *paraarcticus*	*T. paraarcticus*
T. rossicus	*T. rossicus*
Jigulites jigulensis	*S. jigulensis*
J. longus formosus	*Schwagerina grandensis*
Daixina magma	*Psf.* (*D.*) *magma*
D. sokensis	*Psf.* (*D.*) *sokensis*
Rugosofusulina praevia agregia	*Pseudofusulina kumensis*
Rugosof. stabilis	*Schwagerina stabilis*

Pseudofusulina paragregaria	*Schwagerina stabilis*
Quasifusulina longissima	*Q. longissima*

The close resemblance and common association of the faunas of both regions indicate that the Kasimovian and Gzhelian Stages are correlated with the Lower and Upper Hikawan Stages, respectively.

The type sequence of the lower Permian sediments are widely exposed in the western part of the Perm basin, in the eastern part of the Russian Platform. the fusuline zonation by Rauser-Chernousova (1965) and stratigraphical division established in 1968 (Stratigraphic Schema of Ural in Tschuvashov, Aleksne and Polozova, 1980) and 1977 (Stratigraphic Scheme III in Tschuvashov and others, 1980) are as follows in descending order:

C. Artinskian Stage
- 4. Salaninsky Horizon ..... *Bairdia reussiana* Zone
- 3. Saragansky Horizon ..... *Parafusulina solidissima* Zone
- 2. Irginsky Horizon ..... *Parafusulina lutugini* Zone
- 1. Burchevsky Horizon ..... *Pseudofusulina concavatus* Zone

B. Sakamarian Stage
- 2. Sterlitamaksky H. ..... *Pseudofusulina urdalensis* Zone
- 1. Tastubsky Horizon ..... L: *Pseudofusulina verneuili* Zone; U: *Pseudofusulina moelleri* Zone

A. Asselian Stage
- *Schwagerina* Horizon ..... U: *Schwagerina sphaerica-Pseudofusulina firma* Zone; M: *Schwagerina moelleri-Pseudofusulina fecunda* Zone; L: *Schwagerina fusiformis-S. vulgaris* Zone

Fusuline biostratigraphy ranging from the middle part of the "*Schwagerina*" Horizon to the Sterlitamaksky Horizon was worked out by Rauser-Chernousova (1965), and that of the Sterlitamaksky to the Irginsky Horizon was also given by Rauser-Chernousova (1937, 1941, 1949). The remaining, the lowest "*Schwagerina*" fusuline fauna was studied by Kireeva and others (1971). The upper Sakmarian and Artinskian fusuline faunas were restudied, among others, by Rauser-Chernousova and Izotowa (1980), Morozova and others (1980), Konovalova and others (1980), and Shirinkina and others (1980).

Among the lower permian fusuline faunas, the Asselian ones include some species similar to and identical with those known from the Nagatoan Stage of Japan, as shown below:

(Asselian Fauna)	(Nagatoan Fauna)
Schwagerina fusuformis	*Sphaerosch. fusiformis*
S. pavlovi	*Sphaerosch. kanmerai*
Pseudoschwagerina intermedia	*Pseudosch. muongthensis*
P. primigena	*P. muongthensis*
Pseudof. krotowi sphaeroidea	*Sch. globulus japonicus*
Pseudofusulina firma	*Pseudofusulina vulgaris*
P. differta	*P. vulgaris*

The same or closely similar species indicate that the lower to upper *Schwagerina* Horizons can be correlated with those of the Nagatoan Stage in Japan. Excepting the species of the *Pseudofusulina moelleri* Zone, the Sakmarian and Artinskian fusuline faunas are characterized by many species that are endemic to the Russian Platform. On the other hand, Bensh (1972) established the *Robustoschwagerina schellwieni* Zone in the Fergana region, Central Asia, and thought that the *R. schellwieni* Zone is correlative with the *Pseudofusulina moelleri* Zone in the

type Sakmarian sequence. Leven and Schelbovich (1978, 1980), who described many species from the Darvus region, Central Asia, supported this correlation. The lower Permian fusuline faunas of Japan show little affinity with the type Sakmarian and Artinskian faunas, so that the correlation of the lower Permian of those two provinces can be made through that of the Central Asia faunistically lying between the Russian Platform and the Tethys region including Japan. Kahler, F. (1974b) tried to correlate the Permian strata of the Russian Platform with those of the Tethyan region as shown below:

(Russian Platform)	(Central Asia)
a. *Pseudofusulina solidissima* Z. + *Psf. makarovi* Zone	*Misellina* Zone
b. *Pseudofusulina lutugini-Psf. concavutus* Zone	*Pseudofusulina vulgaris* Zone
c. *Pseudofusulina urdalensis-Psf. plicatissima* Zone + *Pseudofusulina verneuili-Psf. moelleri* Zone	*Robustoschwagerina schellwieni* Zone

If this correlation is acceptable, the two lower Artinskian Zones and the upper Artinskian Zone will be regarded as equivalent to the *Pseudofusulina vulgaris* Zone and the *Misellina* Zone, respectively. The two or three Sakmarian Zones are also regarded as equivalent to the *Robustoschwagerina schellwieni* Zone. Kahler's *R. schellwieni* is now identical with *R. schellwieni pamirica*. Therefore, the *R. schellwieni* Zone in Central Asia can be correlated with the *R. schellwieni pamirica-Schwagerina krotowi* Zone of the Lower Sakamotozawan Stage in Japan. The *Pseudofusulina vulgaris* Zone of Darvus includes *R. tumida,* which is similar to or identical with *R. schellwieni schellwieni* of the *R. schellwieni schellwieni-Pseudofusulina vulgaris globosa* Zone of the Upper Sakamotozawan Stage in Japan. Hence, the Lower Sakamotozawan Stage can be correlated with the Sakmarian and the Upper Sakamotozawan Stage is also correlative with the Lower and Upper Artinskian Stage, respectively.

4. Central Asia (Darvus-Fergana region)

Since Schellwien (1909) described fusuline fossils from Darvus, the following areas of Central Asia, from north to south, were investigated in detail: Tien-shan (Chang, 1963) in China; Fergana (Bensh, 1972); Pamir (Leven, 1967); Darvus (Leven, 1967; Kalmykova, 1967; Leven & Schelbovich, 1978, 1980); Gissar (Bensh, 1969); Afganistan (Leven, 1971).

The most complete upper Carboniferous and lower Permian sequence is found in the Karachartyr range of South Fergana, where Bensh (1972) worked out the following stratigraphical divisions based on rich fusuline faunas.

B. Lower Permian Series
- 3. Kubergandian Stage ..... *Cancellina* Zone
- 2. Ulkian Stage .....
  - 2. *Misellina* Zone
  - 1. *Pseudofusulina vulgaris* Zone
- 1. Karachatyrskian Stage .....
  - 4. *Robustoschwagerina schellwieni* Zone
  - 3. *Schwagerina glomerosa* Zone
  - 2. *S. moelleri-Psf. fecunda* Z.
  - 1. *Occidentoschwagerina alpina* zone

A. Upper Carboniferous Series
- 3. Dastarskian Stage .....
  - 3. *Pseudof. ferganensis* Zone
  - 2. *Daixima sokensis* Zone
  - 1. *T. rossicus-Jig. jigulensis* Z.
- 2. Utchbulakskian Stage .....
  - 2. *T. arcticus-T. acutus* Zone
  - 1. *Montiparus montiparus* Zone
- 1. Djilginsaskian Stage ..... *Protri. pseudomontiparus-Obsoletus obsoletus* Zone

The lower Permian "Stage"-names were proposed by Licharev and M.-Maklay (1964) as to represent the standard succession in the Caucasus-Sinian paleobiogeographical realm.

The upper Carboniferous faunas of Fergana contain many species which are closely similar and conspecific to those of Japan, as shown below:

(Djilginsaskian Fauna)	(Lower Hikawan Fauna)
Obsoletes? *ovoides*	*Obsoletes obsoletus*
Protri. aff. *globulus*	*M. matsumotoi inflatus*
P. globulus turkestanicus	*M. matsumotoi inflatus*
P. subschwagerinoides inflatus	*M. matsumotoi inflatus*

(Utchbulakskian Fauna)	(Lower Hikawan Fauna)
Montiparus montiparus	*M. m. matsumotoi*
Quasifusulinoides sp. no. 1	*Quasifusulinoides ohtani*
Montiparus umboplicatus	*M. exculptus*
Triticites fusuformis	*T. yayamadakensis*
T. perlongus	*T. y. evectus*
T. schwageriniformis baisuensis	*Schwagerina? satoi*

(Dastarskian Fauna)	(Upper Hikawan Fauna)
Rugosof. prisca ovoidea	*Rugosofusulina alpina*
Jig. formosus turanicus	*Schwagerina formosus turanicus*
Jig. sp. no. 1	*S. jigulensis*
Rugosof. dastarensis	*Daixina* cf. *sokensis*
Daixina sokensis	*D. sokensis*
Triticites gusanicus	*"Pseudoschwag." morikawai*
Paraschwagerina archaica	*Parasch. shimodakensis*
Alpinoschwag. paranitida	*P. shimodakensis*
Triticites fornicatus	*Triticites fornicatus*

The faunal similarity between Central Asia and Japan indicates that the lower two stages, the Djilginsaskian and Utchbulakskian, and the upper one, the Dastarskian, can be correlated with the Lower and the Upper Hikawan Stages, respectively. Furthermore, the Karachatyrskian faunas of Fergana can be compared with the faunas of the Nagatoan and the lower part of the Sakamotozawan Stages in Japan, as are exemplified by the following species:

(Karachatyrskian Fauna)	(Nagatoan Fauna)
Alpinoschwag. equalis	*Sphaeroschwag. pavlovi*
Schwagerina kalmykovae	*S. pavlovi*
Pseudoschwagerina uddeni	*Pseudosch. muongthensis*
P. robusta	*P. muongthensis*
Alpinosch. saibulakensis	*A. saigusai*
A. turkestanica	*A. saigusai*
Pseudosch. explorata	*P. muongthensis*
Pseudosch. robusta	*P. miharanoensis*

(Karatschatyrskian Fauna)	(Lower Sakamotozawan Fauna)
Zellia crassislveola	*Z. nunosei*
Robustosch. schellwieni pamirica	*P. subsphaerica*
Pseudofusulina moelleri	*Paraschwagerina* cf. *longa*
Rugosof. stabilis	*Pseudofusulina stabilis*
Pseudofusulina pandjiensis	*P. stablis*
Rugosof. arianica	*Parafusulina lutugini*
R. aff. *devexa*	*Psf. vulgaris megasphaerica*
Psf. acuteata	*Schwagerina* cf. *compacta*

Parafusulina pamirica	*Schwagerina* sp. Kanmera
Rugosof. sp. A LEVEN	*R. alpina*
Daixina? mutabilis	*R. alpina*

The next, Ulkian Stage, which is typically exposed in the Pamir region, yields the following species which are closely comparable with the species of the upper part of the Sakamotozawan Stage of Japan.

(Ulkian Fauna)	(Upper Sakamotozawan Fauna)
Robustoschwagerina tumida	*R. schellwieni schellwieni*
Paraf. vulgarisformis	*Psf. vulgaris vulgaris*
Paraf. zulmartensis	*Psf.* aff. *japonica*
Psf. procera	*Psf. ambigus*
Psf. postkraffti	*Psf. fusiformis*
Psf. kraffti	*Psf. kraffti*
Rugosof. vulgariformis	*Psf.* sp. Kanmera
Darvasites contractus	*Nagatoella* sp. Kanmera
D. zulumartensis	*N. minatoi*
Monodiexodina shiptoni	*M. kumensis*
Psf. aff. *ambigua*	*Paraf.* aff. *japonica*
Paraf. zulmartensis	*Paraf.* aff. *japonica*
Misellina otakiensis	*M. otakiensis*
M. claudiae	*M. claudiae*

The stratigraphic classification based on fusuline faunas of the Permian strata in the Darvus region was shown by Leven and Schelbovich (1978), and the lower Permian was divided as follows:

B. Kushansky Series:

Tchisjansky Stage .....
- 3. *Misellina termieri* Zone
- 2. *M. parvicostata* Zone
- 1. *M. dyhrenfurth* Zone

A. Jaiksky Series:

3. Artinskian Stage ..... *Pseudofusulina-Parafusulina* Zone

2. Sakmarian Stage ..... *Robustoschwagerina schellwieni* Zone

1. Asselian Stage .....
- 3. "*Schwagerina*" *sphaerica-Pseudofusulina firma* Zone
- 2. "*Schwagerina*" *moelleri-Pseudofusulina fecunda* Zone
- 1. "*Schwagerina*" *fusiformis*-"*Schwagerina*" *vulgaris* Zone

This classification is different in the divisions of Stage and Series rank from that of the Darvus region, but the divisions of both regions can be correlated with each other as follows:

(Fergana region)	(Darvus region)
Ulkian Stage	U. Tchisjansky Stage L. Artinsky Stage
Karachartyrian Stage	U. Sakmarian Stage L. Asselian Stage

Noteworthy is that the Asselian faunas of the Darvus region are closely comparable with those of the type section in the Russian Platform, but that the faunas of the higher levels are characterized by distinctive Tethyan associations as those of the Fergana region.

5. Russian Far East (Sikhote-Alin Mountains)

The upper Carboniferous and the lower Permian deposits in the Sikhote-Alin Mountains

are mainly tuffaceous and silicious rocks with blocks and lenses of bioclastic and biohermal limestone (Rauser-Chernousova *et al.*, 1979).

Nikitina (1974) established the upper Paleozoic biostratigraphy. Sosnina and Nikitina (1977) described the upper Carboniferous foraminifers of the Primorie region. Kireeva (1974) reported the upper Paleozoic stratigraphy of the Sikhote-Alin. Sosnina (1965) described the lower to middle Permian fusuline faunas of this region. Fusuline biostratigraphy from the upper Carboniferous to the lower Permian in these areas are summarized as follows:

B. Lower Permian Series
  5. *Misellina claudiae* Zone
  4. *Pseudofusulina vulgaris-P. kraffti* Zone
  3. "*Schwagerina*" *sphaerica gigas-Acervoschwagerina indolsa* Zone
A. Upper Carboniferous Series
  2. *Triticites* Zone ..... { *Triticites stuckenbergi* faunule / *Triticites arcticus* faunule / *Triticites montiparus* faunule }
  1. *Obsoletes-Protriticites* Zone

Fusuline faunas from the Shikhote-Alin include many species which closely resemble the species known from Japan, as shown below:

(Shikhote-Alin Fauna)	(Japanese Fauna)
Fusulina (*Quasifusulinoides*) *elatisinuosa*	*Quasifusulinoides ohtanii*
F. (*Q.*) *turgida*	*Q. ohtanii*
F. (*Q.*) *apiculata*	*Q. ohtanii*
Obsoletes normalis	*Obsoletes obsoletus*
O. normalis	*O. obsoletus*
Triticites vetrennikovi	*Montiparus m. matsumotoi*
T. schwageriniformis	*T. yayamadakensis*
T. sp. 1	*Schwagerina? satoi*
T. aculeatus	*Pseudoschwagerina morikawai*
T. samarkensis	*Pseudofusulina kumensis*
Acervoschwager, indolsa	*Paraschwager, kanmerai*

The similarity suggest that the *Obsoletes-Protriticites* Zone to the *Schwagerina sphaerica gigas-Acervoschwagerina indolsa* Zone can be roughly correlated with the Lower and Upper Hikawan Stages in Japan. The *Schwagerina sphaerica gigas-Acervoschwagerina indolsa* Zone is correlative with the upper Asselian to Sakmarian in Russian Platform. No lower Asselian fusuline faunas have been known in these areas. On the other hand, the Artinskian fauna has been listed by Nikitina (1974) and Kireeva (1974) as follows: *Biwaella omiensis* Morikawa and Isomi, *Toriyamaia laxiseptata* Kanmera, *T. cyrindrica* n. sp., *T. compacta* n. sp., *Sphaerulina primitiva* Sosnina, *Misellina claudiae* (Deprat), *M. orbiculata* n. sp., *M. minutissima* n. sp., *Pseudofusulina guembeli omensis* Sakagami and Omata, *P. postcallosa* Bensh, *P. kraffti* (Schellwien and Dyhrenfurth), *P. globosa* (Schellwien and Dyhrenfurth), and so on.

This fauna contains many species recorded from Darvus in Central Asia and Japan. Therefore, the *Pseudofusulina vulgaris-P. kraffti* Zone and the *Misellina claudiae* Zone can be exactly correlated with those of the Ulkian Stage of the Caucasus-Sinian Realm, and the Upper Sakamotozawan Stage in Japan.

The inter-regional correlation of the upper Carboniferous and lower Permian fusuline zones within Russia and correlation with the Japanese standard zonal divisions are shown in Table 5.

SUBSYSTEM	U. S. S. R.		STANDARD FUSULINIDS ZONES: INTERNATIONAL FUSULINIDS ZONE Kahler (1974) Rotai (1975)	STANDARD FUSULINIDS ZONES: RUSSIAN PLATFORM & URALS	SOVIET RUSSIA: PECHORA & TIMAN GROZDILOVA et al. (1980) MIKHAILOVA (1974)	SOVIET RUSSIA: FERGANA Bensh (1972)	SOVIET RUSSIA: DARVUS Leven & Scherbovich (1978, 1980)	SOVIET RUSSIA: FAR EAST Sosnina (1960) Nikitina (1978)	JAPANESE STANDARD ZONES (Present Paper)	JAPAN	
LOWER PERMIAN	ARTINSKIAN	Upper	*Misellina*	*Parafusulina solidissima*	*Parafusulina solidissima*		*M. termieri*	*M. claudiae*	*Robustoschwag. schellwieni schellwieni -Psf. vulgaris vulgaris*	SAKAMOTOZAWAN	LOWER PERMIAN
				Parafusulina makarovi			*M. parvicostata*				
		Lower	*Pseudofusulina vulagris*	*Parafusulina lutugini*	*Parafusulina lutugini*		*M. dyhrenfurthi*				
				Pseudofusulina cocavatus	*Pseudofusulina concavatus*		*Pseudofusulina -Parafusulina*				
	SAKMARIAN		*Robustoschwag. schellwieni*	*Pseudofusulina urdalensis*	*Pseudofusulina uralensis*	*Robustoschwag. schellwieni*	*Robustoschwag. -Paraschwag.*	*Acervoschwag. indolasa -"S." sphaerica gigas*	*Robustoschwag. schellwieni pamirica -Schwagerina krotowi*		
				Pseudofusulina verneuili	*Pseudofusulina vernouilli*						
				Pseudofusulina moelleri	*Pseudofusulina moelleri*						
	ASSELIAN	Upper	*Zellia*	*"Schwagerina" sphaerica -Psf. firma*	*"Schwagerina" sphaerica -Psf. firma*	*"Schwagerina" glomerosa*	*"Schwagerina" sphaerica -Psf. firma*		*Par. akiyoshiensis -Psf. firma*	NAGATOAN	
									S. globulus japnicus -Pss. miharanoensis		
		Middle	*Pseudoschwag. confini*	*"S." moelleri -Psf. fecunda*	*"S." moelleri -Psf. fecunda*	*"S." moelleri -Psf. fecunda*	*"S." moelleri -Psf. fecunda*		*Alpino. saigusai -Pss. cf. robusta*		
									Sphaero. pavlovi -Pss. muongthensis		
		Low.	*Pseudoschwag. alpina*	*"S." fusiformis -"S. "vulgaris*	*"S." fusiformis -"S." vulgaris*	*Occidentosch. alpina*	*"S." fusiformis -"S." vulgaris*		*Sphaeroschwag. fusiformis*		
UPPER CARBONIFEROUS	GZHELIAN	Up.	*Daixina sokensis*	*Daixina sokensis*	*Daixina sokensis*	*Pseudofusulina ferganaensis*	*Psf. gregaria -D. sokensis*		*"Pseudoschwag." minatoi*	UP. HIKAWAN	UPPER CARBONIFEROUS
		Mid.	*Triticites jigulensis*	*Jigulites jigulensis*	*Triticites rossicus*	*Daixina asiatica*	*Jigulites jigulensis*				
		Low.	*Triticites stuckenbergi*	*Triticites stuckenbergi*		*Tr. rossicus- J. f. formosus*	*Triticites stuckenbergi*	*Triticites*	*"Pseudoschwag." morikawai*		
	KASIMOVIAN	Up.	*Tr. arcticus -Tr. acutus*	*Tr. arcticus -Tr. acutus*	*Tr. arcticus -Tr. acutus*	*Tr. arcticus -Tr. acutus*	*Tr. arcticus -Tr. acutus*		*Schwagerina? satoi*	LOWER HIKAWAN	
		Mid.	*Triticites montiparus*	*Montiparus montiparus*	*Montiparus montiparus*	*Montparus montiparus*	*Montiparus montiparus*		*Mont. matsumotoi Inflatus*		
		Lower	*Prot. pseudo-montiparus -Obsoletes obsoletus*	*Prot. pseudo-montiparus -Obsoletes obsoletus*	*Prot. pseudo-montiparus -Obsoletes obsoletus*	*Prot. pseudo-montiparus -Obsoletes obsoletus*	*Prot. pseudo -montiparus -Obsoletes obsoletus*	*Protriticites -Obsoletes*	*Obsoletes obsoletus*		

Table 5. Inter-regional correlation of the Upper Carboniferous and Lower Permian fusuline zones in Russia.

b. China

Since the classical work of Schwager (1883), considerable progress has been made in the study of fusuline faunas near the boundary of the Carboniferous and the Permian in China.

The Gzhelian fauna was described by Sheng (1958) and Han (1976) from Inner Mongolia of North China. Recently, Chen & Wang (1983) described many Kasimovian to Asselian fusuline species from the Maping Limestone of the Guangxi district. The Asselian fauna was reported by Schwager (1883), Lee (1927), Chen (1934), Sheng (1949) and Chang (1963). The Sakmarian and Artinskian faunas were described by Schwager (1883), Lee (1927), Chen (1934), Chang (1963), Han and Guo (1979) and others.

On the other hand, regional paleontological atlases carring much new information on Carboniferous and Permian fusuline fossils of the following seven regions including the Shin-Kiang of West China (Chang, 1963) have been published; the Zhinhai region (Sheng, 1975), the Inner Mongolia region (Han, 1975, 1976), the Kueicho part of South-west region (Liu and others, 1978), the Central south region (Lin and others, 1977), the Suchang part of Southwest region (Zhen and Yang, 1978), the Northeast region (Han, 1980), the Xizang region (Wang and others, 1981),

and Shaan-Gan-Ning part of the Northwest region (Sun and others, 1983).

Since Lee (1927) proposed the *Pseudoschwagerina* Zone at the top of the Carboniferous, the zone has currently been accepted by Chinese geologists and paleontologists to belong to the Carboniferous System. Then, the Carboniferous-Permian boundary has been placed at the base of the Chihsia Formation in South China and the Shansi Formation in North China. The Carboniferous-Permian boundary problem was discussed by Yang and Wang (1956), Yang and others (1962), Sheng (1962, 1963), Sheng and Lee (1964) and Yang *et al.* (1979).

1. South China

The Carboniferous and Permian deposits in South China consist of marine limestones, which contain abundant fusuline fossils. A remarkable physical and faunal break has been recognized between the Maping Formation of the *Pseudoschwagerina* Zone and the overlying Chihsia Formation of the *Misellina* Zone. Thus, the systemic boundary in South China has been placed between these two formations (Sheng and Lee, 1964).

At the 9th International Congress of Carboniferous Stratigraphy and Geology held at Illinois of America, Zhang (1979, 1984) showed the following species zones in the Upper Carboniferous Series or the Mapingian Series in descending order:

3. *Robustoschwagerina schellwieni* Zone
2. *Sphaeroschwagerina* Zone
   b. *Sphaeroschwagerina glomerosa* subzone
   a. *Sphaeroschwagerina constans* subzone
1. *Triticites* Zone

In this division, the Carboniferous-Permian boundary is drawn at the top of the *Robustoschwagerina schellwieni* Zone. It may, however, be placed at the base of the *Sphaeroschwagerina constans* subzone or the upper limit of the *Triticites* Zone.

On the other hand, Chen and Wang (1983) studied the fusuline fauna of the Maping Limestone in the Yishan district of Guangxi and divided this formation into the following species zones:

3. *Staffella* Zone
2. *Sphaeroschwagerina* Zone
   b. *Eoparafusulina bocki* subzone
   a. *Sphaeroschwagerina sphaerica gigas* subzone
1. *Triticites* Zone
   b. *Triticites simplex* subzone
   a. *Triticites paramontiparus mesopachys* subzone

The Carboniferous-Permian boundary in this district was placed at the upper limit of the *Staffella* Zone, but it should be placed between the *Triticites simplex* subzone and the *Sphaeroschwagerina sphaerica gigas* subzone.

The lower Permian Chihsia Formation in southeastern Hunan was studied by Zhou (1982, 1984), who established a fusuline biostratigraphy as shown below:

B. Lower Permian Series: Chihsia Formation
   4. *Parafusulina multiseptata* Zone
   3. *Misellina claudiae* Zone
   2. *Staffella vulgaris* Zone
   1. *Schwagerina cushmani* Zone

b. *Darvasites* subzone
a. *Nagatoella* subzone
A. Upper Carboniferous Series: Chuanshan Formation
Pseudoschwagerina Zone

The *Pseudoschwagerina* Zone of this area yields *Sphaeroschwagerina moelleri* (Rauser), *Schwagerina* cf. *gregaria* Lee, and *Eoparafusulina* cf. *proba* Skinner & Wilde. The *Nagatoella* subzone conformably overlies the *Pseudoschwagerina* Zone. The Hunan fauna is very important in correlation of Japan and China, as it contains many species similar to those of Japan as follows:

(Hunan)	(Japan)
Schwagerina cushmani	*Schwagerina* sp. Kanmera
Pseudofusulina unregularis	*S.* aff. *compacta*
P. unstabilis	*Rugosof.* aff. *serrata*
P. vulgaris crassispira	*Psf. vulgaris vulgaris*
P. gallowayi	*Psf. vulgaris globosa*
Darvasites sinensis	*Nagatoella minatoi*
Nagatoella liudongensis	*Schwagerina krotowi*
Eoparafusulina pusillus	*Mondodiexodina langsonensis*
Misellia claudiae	*M. claudiae*

Especially worthy to note is that *Schwagerina krotowi* is characteristically associated with *Robustoschwagerina schellwieni pamirica* Leven and Schelbovich in the Akiyoshi Limestone Group. The other Japanese species tabulated above were described from the Sakamotozawa Formation. Furthermore, *Misellina claudiae* (Deprat) was described by Choi (1972) from the upper part of the Sakamotozawa Formation. Therefore, besides the *Staffella vulgaris* fauna, the *Schwagerina cushmani* Zone to the *Misellina claudiae* Zone in the Chihsia Formation can be correlated with the Sakamotozawan Stage in Japan. The base of the *Nagatoella* subzone in Hunan is equivalent to that of the *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone of the Japanese standard divisions presented in this paper.

2. North China

The Upper Carboniferous Taiyuan Formation in North China is composed of sandstones, and shales with intercalations with coal seams and lenticular marine limestones. The Lower Permian Shansi Formation consists mainly of terrestrial sandstones and shales with coal seams and some calcareous marine shales accompanied by lenticular limestones.

The Upper Carboniferous Amshan Formation is mainly distributed in the northern part of Inner Mongolia. This formation was studied by Sheng (1958), Han (1975, 1976) and Han and Guo (1979), and three distinctive schwagerinid faunas were described from the Amshan or Beyin-obo area (Sheng, 1958; Han, 1975, 1976), the Zhanxian-Baiqilinchang area (Han, 1976), and the Sonid Right Banner or Qusunite-youqi area (Han and Guo, 1979). They are as follows in descending order:

3. *Zellia colaniae-Nipponitella explicata* Fauna
2. *Sphaeroschwagerina sphaerica gigas* Fauna
1. *Pseudoschwagerina borealis* Fauna

On the basis of the occurrence of comparable species, the strata containing the *Pseudoschwagerina borealis* fauna can be exactly correlated with the "*Pseudoschwagerina*" *minatoi*

Zone of the upper part of the Upper Hikawan Stage in Japan and the Upper Gzhelian Stage in the type section of the Russian Platform. The *Sphaeroschwagerina sphaerica gigas* fauna is comparable with the Russian "*Schwagerina*" fauna of the *Sphaeroschwagerina sphaerica* Zone of the Upper Asselian Stage, which is equivalent to the Upper Nagatoan Stage in Japan. The *Zellia colaniae-Nipponitella explicata* fauna is apparently comparable to the Sakamotozawan fauna, and the strata containing this fauna are exactly correlative with the *Zellia nunosei* Zone to the *Monodiexodina langsonensis* Zone or the *Robustoschwagerina schellwieni pamirica* Zone of the lower Sakamotozawan Stage in Japan and the upper part of the Karachartyrian Stage in the Fergana region, Russia. The lower to middle Asselian or Nagatoan fauna has not been recognized in the Amshan Formation. Therefore, the Carboniferous-Permian boundary in the Amshan Formation can be set between the strata containing the "*P.*" *borealis* fauna and the *S. sphaerica gigas* fauna.

While, Xia (1981) worked out the zonation of the early Permian fusuline-bearing strata in Inner Mongolia of North China, and showed the following zones in descending order:

4. *Schwagerina quasipactiruga-Codonofusiella pseudoextensa* Zone
3. *Schwagerina quasiregularis-Codonofusiella simplicata* Zone
2. *Monodiexodina* Zone
1. *Misellina ovalis-Parafusulina splendens* Zone

The *Misellina ovalis-Parafusulina splendens* Zone (MS-Zone) was recognized in a limestone lens in the lower part of the Sanmianjing Formation, which unconformably overlies the *Pseudoschwagerina borealis* Zone in the Amshan Formation of the uppermost Carboniferous. Therefore, the Carboniferous-Permian boundary in North China will be placed at the base of the Sanmianjing Formation, or the top of the Amshan Formation, that is between the *Zellia colaniae-Nipponitella explicata* Zone below and the *Misellina ovalis-Parafusulina splendens* Zone above. This systemic boundary accepted in China exactly coincides with the base of Member Sc of the Upper Sakamotozawa Formation.

On the following lines, the faunal comparison and correlation based on fusulines of the representative sections in China with those in Japan and Russian are discussed.

a. Shinkiang region

Chang (1963a, 1963b) studied the fusuline biostratigraphy in the Shinkiang region in West China, where the "Upper Carboniferous" was called the Kangkelin Formation. This formation was subdivided into three subzones in descending order:

3. *Paraschwagerina inflata* subzone
2. *Pseudofusulina valida* subzone
1. *Pseudoschwagerina parasphaerica* subzone

These three subzones were correlated with the whole part of the "*Schwagerina*" Horizon in the Russian Platform and the "*Pseudoschwagerina*" *morikawai* Zone in the Mizuyagadani Formation of Japan (Chang, 1963a, b). The general stratigraphy of this region was shown by Chang (1963a) as follows:

Lower Permian: Balikelike Group
. . . . . conformity ? . . . . . .
Upper Carboniferous: Kangkelin Formation
. . . . . unconformity . . . . . .
Devonian: Shalayimu Group

The Kangkelin Formation is distributed in the Keping-subashen, Keping-shanqu, and Xikunlun-shanqu areas. The fusuline biostratigraphy was established in the Keping-subashen area. As to inflated schwagerinids, the Kangkelin Formation yields *Pseudoschwagerina parasphaerica,* which is closely similar to "*Schwagerina*" *sphaerica* Rauser. from the Upper Asselian in the Darvus region, Russia. *Paraschwagerina gigantes* (White) closely resemble *Pseudofusulina moelleri* (Schellwien) from the lower Sakmarian in the Darvus region, Russia. *Darvasites contractus* (Schellwien), *D. ovatus* (Chang), *D. shengi* (Chang) and *D. parashengi* (Chang) from the *P. inflata* subzone are known from the *Misellina* Zone of the Pamir region, Russia. *Schwagerina pailensis* (Schellwien) of the *Pseudofusulina valida* subzone is closely similar to *Monodiexodina langsonensis* (Saurin) in Members Sb_1 and Sb_2 of the Lower Sakamotozawa Formation. Therefore, the *Pseudoschwagerina parasphaerica* subzone of the Kangkelin Formation is correlative with the Upper Asselian Stage in Russia. The next higher units, the *Pseudofusulina valida* and *Paraschwagerina inflata* subzone can be correlated with the Sakmarian and the lower part of the Artinskian Stages of Central Asia.

The Keping-shanqu fauna of the Kangkelin Formation contains the following species: *Robustoschwagerina schellwieni* (Hanzawa), *Zellia crassialveola* Chang, "*Pseudoschwagerina*" *nitida* Kahler & Kahler, and "*Pseudoschwagerina*" *glomerosa* (Schwager). These species are the well known species in the *Robustoschwagerina schellwieni* Zone of the Karachatyrskian Stage in the Fergana region, and the Sakmarian Stage in the type section of the Russian Platform.

The Muziduke fauna of the Kangkelin Formation contains the following inflated schwagerinids: *Robustoschwagerina schellwieni* (Hanzawa), "*Pseudoschwagerina*" *subrotunda* (Ciry), "*Pseudoschwagerina*" *nitida* Kahler & Kahler, *Paraschwagerina gigantea* (White). These species suggest that the Kangkelin Formation of the Muziduke area is equivalent to the Sakmarian Stage.

The Xikunlun fauna of the Kangkelin Formation have a species association similar to Muziduke area as follows: "*Pseudoschwagerina*" *subrotunda* (Ciry). This fauna also indicates a Sakmarian age.

To sum up, the fusuline faunas of the Kangkelin Formation, which has been referred to the "Upper Carboniferous", suggest that the formation ranges in age from the late Asselian to the Artinskian and is correlative with the Nagatoan to the upper part of the Sakamotozawan Stage in Japan. The boundary of the Carboniferous-Permian is unable to determine in this region.

b. Qinghai region

The Qinghai fusuline fauna was monographed by Sheng (1982) in one of the regional paleontological atlases. He described some inflated schwagerinids, namely, "*Pseudoschwagerina*" *subrotunda* (Ciry), *Zellia* cf. *galatea* (Ciry), *Paraschwagerina ginghaiensis* Chang, *P. vesta* Sheng and Sun, and *P. renoides* Sheng and Sun. These species are closely similar to those of the upper part of the Kangkelin Formation which is correlated with the Sakmarian Stage in Russia or the Sakamotozawan Stage in Japan. The upper Carboniferous fusuline fauna in this region is represented by *Protriticites fusulinoides* Sheng and Sun, *Montiparus minutus* Chang. These species suggest the early Kasimovian age.

c. Central-South region

The paleontological atlas of this region was compiled by Lin and others (1977). They described many important schwagerinids from the Chuanshan and Maping Formations of the "Upper Carboniferous" in Chinese division. Recently, Zhou (1982, 1984) established a fusuline biostratigraphy of the Lower Permian Chihsia Formation in southeastern Hunan.

The Chuanshan Formation yields the following inflated schwagerinids: *Sphaeroschwagerina postvulgaris* (Bensh), *Pseudoschwagerina beedei* Dunbar and Skinner, *Occidentoschwagerina fusulinoides* (Schellwien), *O. fusulinoides exilis* (Chen) in the lower part; *Pseudoschwagerina linwuensis* Zhou, *Zellia heritschi heritschi* Kahler and Kahler in the upper part. Thus, the lower Chuanshan fauna indicates the middle Asselian and the upper fauna suggests the upper Asselian.

The Maping Formation contains the following species: *Sphaeroschwagerina moelleri* (Rauser.), *S. sphaerica* (Rauser-Chernousova & Scherbovich), *Occidentoschwagerina texana* (Dunbar and Skinner), *Pseudoschwagerina primigena* Rauser., *Zellia fluxa* (Li), *Z. magnae-sphaerae* (Colani), *Acervoschwagerina inusitata* Lin, and *Robustoschwagerina spatiosa* Lin.

This species association indicates that part of the Maping Formation ranges from the Middle Asselian to the Sakmarian and is correlative with the Middle Nagatoan to the Sakamotozawan Stage in Japan. In addition, the fusulines of early and middle Kasimovian ages are also recognized in the Maping Formation. They are *Protriticites daxinensis* Lin, *P. hunanensis* Lin, *P. regularis* Lin, *Montiparus deboensis* Li, and *Triticites succinctus* Lin. Therefore, the upper Kasimovian to the lower Asselian strata seem to be absent in this region.

The stratigraphy near the Carboniferous-Permian boundary was described by Zhou (1982) from the southern Hunan as follows:

Lower Permian: Chihsia Formation
a. *Schwagerina cushmani* Zone
2. *Darvasites* subzone
1. *Nagatoella* subzone
. . . . . conformity . . . . . .
Upper Carboniferous: Chuanshan Formation
Sphaeroschwagerina moelleri Fauna

In this succession, a stratigraphical or faunal break may be present between the Chihsia Formation and underlying the Chuanshan Formation, because of the absence of the upper Asselian fauna. Furthermore, the *Nagatoella* fauna in the lowest part of the Chihsia Formation can be comparable with the fauna of the *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone in Japan. Hence, the *Schwagerina cushmani* Zone will be correlative with the lower part of the Sakamotozawa Formation in Japan. The systemic boundary shown by Zhou (1982) corresponds to the Asselian-Sakmarian boundary in Russia and the Nagatoan-Sakamotozawan boundary in Japan.

d. Southwest region

The Suchang fauna in Southwest region was studied by Chen and Yang (1978), and the Kueicho fauna by Liu and others (1978). The upper Carboniferous deposits in this region was called the Maping Formation. The formation in Suchang yields rare fusulines such as *Sphaeroschwagerina sphaerica ovoides* Scherbovich, and that of Kueicho contains many important species such as *Sphaeroschwagerina moelleri* (Rauser.) and *Pseudoschwagerina muongthensis* (Deprat) which indicate the Middle Asselian, and *Sphaeroschwagerina sphaerica* (Scherbovich), *S. subrotunda* (Ciry), *Pseudoschwagerina miharanoensis* Akagi, *Zellia galatea* (Ciry), *Z. magnae-sphaerae* (Colani), *Z. colaniae* Kahler and Kahler, and *Z. chenkungensis* Sheng which indicate the upper Asselian to Sakmarian.

The middle and upper Kashimovian faunas are represented by *Montiparus longissima* Lin,

Xiao & Dong, *M. huishuensis* Lin, Xiao & Dong, *M. weiningica* Chang. No Gzhelian and lower Asselian faunas have been known in this region.

e. Xizang region

Fusuline fossils from the Xizang region were described by Wang and others (1981). They discriminated some inflated schwagerinids from the upper part of the Licha Group of the "Upper Carboniferous"; *Pseudoschwagerina muongthensis* (Deprat), which characterizes the Middle Asselian; *Sphaeroschwagerina glomerosa* (Schwager), which indicates the Upper Asselian, and *Robustoschwagerina* sp. Wang, Sheng & Zhang, which is referable to *Pseudoschwagerina robusta* (Meek).

The lower part of the Licha Group and the Lungmuchu Formation in West Xizang yield the following species: *Triticites parvus* (Schellwien), *T. variabilis* Rosovskaya, *T. arcticus* (Schellwien), *T. ferganensis* M.-Maklay, and *Quasifusulina* sp. This fauna suggests the Asselian. Thus, the middle and upper Asselian faunas are recognized in this region, but the Kasimovian to the lower Asselian faunas seem to be absent.

f. Northeast region

Fusulinids from the Northeast region were described by Han (1980). He discriminated some inflated schwagerinids from the upper Carboniferous Taiyuan, Amshan and Shanxiuling Formations such as *Pseudoschwagerina aequalis* Kahler & Kahler, *P. borealis* (Scherbovich), and *Paraschwagerina texana ultima* (Dunbar and Skinner). These species indicate the Gzhelian. The Gzhelian and the upper Asselian faunas are recognized in this region, but the lower Kasimovian and lower to middle Asselian ones appear to be absent in this region.

g. Inner Mongolia region

Fusuline faunas of the Upper Carboniferous Amshan Formation in this region were studied by Sheng (1958), Han (1975, 1976) and Han and Guo (1979). Three different inflated schwagerinid faunas were discriminated, that is, the lower Amshan; the middle Zhanxian-baiqilin-chang: and the upper Sonid Right Banner fauna.

The Amshan fauna:– Han (1975, 1976) descriminated eight species of *Pseudoschwagerina* including *Pseudoschwagerina sphaerica* (Scherbovich) and *P. borealis* (Scherbovich). All the species noted are closely similar to "*Pseudoschwagerina*" *minatoi* Kanmera from the Upper Hikawan Stage in Japan.

The associated species of *Quasifusulina, Triticites* and *Pseudofusulina* are also much allied to those of the *Schwagerina*? *satoi* Zone to the "*Pseudoschwagerina*" *minatoi* Zone.

The Zhanxian-Baiqilinchang fauna:– *Sphaeroschwagerina sphaerica gigas* (Scherbovich) is the only species from the Amshan Formation. This species is known from the Upper Asselian Stage of the Russian Platform.

The Carboniferous-Permian boundary in this region has been placed between the Amshan Formation below and the Sanmianjing Formation above. However, the *Misellina ovalis-Parafusulina splendens* Zone (Xia, 1981) occupies the lowest part of the Sanmianjing Formation. The faunal succession stated above indicate that the Amshan Formation ranges from the Upper Hikawan to the Sakamotozawan Stage, or the Gzhelian to the Lower Artinskian Stage in the type section.

The Sonid Right Banner fauna:– Han and Guo (1979) discovered a *Nipponitella* fauna from the middle and upper part of the Amshan Formation. Prior to this discovery, *Nipponitella* had been known only from the Sakamotozawa Formation in Japan. *Pseudoschwagerina aequalis*

USSR		CHINA		SOUTH-CHINA STANDARD ZONES Zhang (1980) Zhou (1962)	SHIN-KIANG Chang (1963)	QING-HAI Sheng (1975)	MID-SOUTH CHINA (1977,1980)	WEST-SOUTH CHINA (1977,1980)	INNER MONGOLIA Han(1975) Han & Guo(1979)	NORTH-EAST CHINA (1980)	JAPAN	
LOWER PERMIAN	ARTINSKIAN	LOWER PERMIAN	CHUANGSHAN	*Misellina claudiae*							SAKAMOTOZAWAN	LOWER PERMIAN
				Staffella vulgaris								
				Schwagerina cushmani *Darvasites*								
				Nagatoella					*Chal. nelsoni*			
	SAKMAR	UPPER CARBONIFEROUS	MAPINGIAN	*Robustoschwag. schellwieni*	*Rob. schellwieni* *Sph. subrotunda*	*Psf. vulgariss* *Sph. subrotunda* *Zellia galatea*	*Sph. subrotunda* *Zellia galatea* *Sph. sphaerica* *Zellia colaniae* *Z. heritschi* *Z. magnae* *-sphacae* *P. miharanoensis*	*Acerv. inusitata* *Rob. spatiosa*	*Zellia colaniae* *Pss. aequalis* *Nip. explicata*	*Par. fuxianensis* *Par. leei*		
	ASSELIAN			*Sphaeroschwag. glomerosa*	*Sph. glomerosa* *Z. colaniae* *P. miharanoensis*			*Sph. sphaerica* *Zellia fluxa* *Z. heritschi* *Z. magnae-spharae*	*Sph. sphaerica*	*Sph. aequalis* *Psf. vulgaris*	NAGATOAN	
				Sphaeroschwag. constans			*P. muongthensis* *Sph. moelleri*	*Pss. uddeni* *Pss. moelleri* *Pss. beedei*				
UPPER CARBONIFEROUS	GZHELIAN			*Triticites*					*Pss. paraborealis* *Pss. borealis* *Psf. nelsoni* *Parasch. gigantea* *Parasch. aluqiensis* *Tr. jugulensis* *Tr. lalaotuensis* *Tr. laxus* *Tr. ohioensis*	*Pss. borealis* *Tr. ferganensis* *Prot. dahingan-lingensis*	U. IIKAWAN	UPPER CARBONIFEROUS
	KASIMOVIAN					*Mont. minutus.* *Protriticites fusulinelloides*	*Q. longissima* *Tr. irregularis* *M. longissima* *M. zuishoensis*				L. IIKAWAN	

Table 7. Inter-regional correlation of the Upper Carboniferous and Lower Permian fusuline zones in China.

Kahler and Kahler and *Zellia colaniae* (Deprat) were obtained from the lower part of the Upper Amshan Formation, and is associated with *Quasifusulina cayeuxi* (Deprat). This association is equivalent in age to that of the *Zellia nunosei* zone in the lowest part (Member Sb_1) of the Sakamotozawa Formation. The *Nipponitella explicata* Hanzawa was found in the middle and upper part of the Amshan Formation, and is associated with many schwagerinids identical with the Sakamotozawan elements, although *Robustoschwagerina schellwieni* (Hanzawa) has not been found. The Upper Amshan Formation can be exactly correlated with Members Sb_1 to Sc of the Sakamotozawa Formation and the Sakmarian to the Artinskian Stages in type section.

The inter-regional correlation of the upper Carboniferous and lower Permian fusuline zones in China are summarized in Table 7.

c. Thailand

The geological and paleontological knowledge on the Carboniferous and Permian of Thailand has been summarized by Toriyama and others (1975) and Ingavat and others (1980). The Carboniferous and Permian deposits in Thailand consist mainly of marine limestones, and are named the Ratburi Limestone or Ratburi Group.

The Carboniferous and Permian fusuline zones were compiled by Ingavat and others (1980). This zonation is regarded as representing the standard biostratigraphic division in Southeast Asia, although some problems still remain unsolved. The zones are as follows:

B. Lower Permian Series

b. Artinskian .....
11. *Maklaya saraburiensis* Zone
10. *Misellina confragaspira* Zone
9. *Misellina otai-M.* cf. *termieri Z.*

Barren

a. Asselian ..... 8. *Triticites ozawai-Paraschwagerina yanagidai* Zone

A. Upper Carboniferous Series

Barren

Kasimovian ..... 7. *Protriticites tethydis* Zone

The *Protriticites tethydis* Zone established by Igo (1972) in the Ban Pha Boi section of North Thailand is apparently correlative with the *Protriticites pseudomontiparus-Obsoletes obsoletus* Zone of the Lowest Kasimovian Stage in Russian Platform and the *Obsoletes obsoletus* Zone of the lowest Lower Hikawan Stage in Japan. No species of *Montiparus* characterized the middle Kasimovian fauna has, however, been known from this section.

The *Triticites ozawai-Paraschwagerina yanagidai* Zone which was referred to the Lowest Permian was established by Igo (1972) in the Ban Num Lum and Tham Nam Maholan sections of North Thailand. Rocks of Collection LS-4 of the Ban Num Lum section consist of tuff and tuff breccia, and yield *Pseudoschwagerina toriyamai* Igo, *Rugosofusulina egregia* Schlykova, *R. praevia* Schlykova. Those of Collection LS-5 are composed of red, hematitic, and partly brecciated limestones, and contain *Paraschwagerina yanagidai* Igo, *Pseudofusulina* (*Daixina*) *pechabuensis* Igo, *P.* (*D.*) *lalaotuensis* Igo, *Triticites* aff. *haydeni* (Ozawa), *T. ozawai* Kanmera, *T. samaricus* Rauser., and *T.* sp. C.

Pseudoschwagerina toriyamai is closely similar to a form of *Pseudoschwagerina morikawai-P. minatoi* transition in the middle part of the Upper Hikawan Stage. *Rugosofusulina praevia* is somewhat similar to *R. cylindrica* Sosnina known from the Uppermost Kasimovian Stage in Fergana. The fauna of Collection LS-4 can be assigned to the middle Upper Hikawan Stage in Japan and the Middle Gzhelian Stage in Russia.

Paraschwagerina yanagidai is closely similar to *Paraschwagerina shimodakensis* Kanmera of the "*Pseudoschwagerina*" *minatoi* Zone in the upper part of the Upper Hikawan Stage in Japan. The associated species, *Pseudofusulina* (*Daixina*) *pechabuensis* and *P.* (*D.*) *lalaotuensis* resemble *Jigulites longus longus* Rosovskaya and *J. longus formosus* Rosovskaya, and *Rugosofusulina uralensis* Rosovskaya, respectively. These two Russian species came from Zones C_3D to C_3E in the upper part of the Gzhelian Stage in type section. Hence, the fauna of Collection LS-5 is referable to the Upper Hikawan Stage in Japan.

The Tham Nam Maholan section consists of massive and bedded limestones. Yanagida (1966) described a brachiopod fauna from this section and correlated it with the Sakmarian (s.l.) Stage in Russia. Collection LE-11 and LE-12 yielded the following fauna: *Quasifusulina tenuissima* (Schellwien), *Triticites pseudolaxas* Igo, *T.* sp. A, *Daixina regularis* (Schellwien) and *Paraschwagerina indigesta* Igo.

Paraschwagerina indigesta is somewhat similar to *Alpinoschwagerina paranitida* Bensh from the lower part of the Asselian Stage in Fergana. Although no diagnostic species are contained in this fauna, the strata from which Collection LE-11 and -12 came are roughly correlative with the lower part of the Asselian Stage.

The fusuline fauna described by Pitakpaivan (1965) from the Noankowtok section near Phechaboon in Central Thailand comprises *Sphaeroschwagerina sphaerica* (Rauser-Chernousova and Schelbovich), *Pseudoschwagerina* aff. *muongthensis rossica* Rauser.

and Schelbovich and others.

Sphaeroschwagerina sphaerica is a zonal index species of the upper part of the Asselian Stage in the type section. *Pseudoschwagerina muongthensis rossica* is similar to *P. beedei uralensis* Rauser. in the middle part of the type Asselian Stage. The Noankowtok fauna is clearly correlative with the upper part of the Asselian Stage in Russia and the Upper part of the Nagatoan Stage in Japan.

The *Robustoschwagerina schellwieni* Fauna was found in the northern part of Noankowtok. *R. schellwieni* is a representative species of the Sakmarian Stage in Central Asia and the Sakamotozawan Stage in Japan.

The other Sakmarian fusuline fauna was described by Sakagami and Iwai (1974) from the Pha Duk Chik Limestone in the southern part of Loei in North Thailand. The following species were discriminated. *Pseudofusulina vulgaris globosa* (Schellwien), *P. valida* (Lee), *P. krotowi* Schellwien), *Chusenella cervicalis* (Lee), *Staffella* aff. *moelleri* Ozawa, *S.* sp., and *Mesoschubertella thompsoni* Sakagami.

Both of the species named *Staffella* aff. *moelleri* and *S.* sp. of Sakagami and Iwai are referable to *Pamirina darvasica* LEVEN, which is a pioneer of Verbeekinidae and defines the top of the Lower Ulkian Stage in Central Asia (Leven and Scherbovich, 1978). *Pseudofusulina vulgaris globosa* is also of the same horizon. The limestone containing these species is unconformably overlain by the limestone conglomerate named the Huai Lat Formation. The Pha Dak Chik Limestone is correlative with the Lower Ulkian Stage in Central Asia and the Upper Sakamotozawan Stage in Japan.

The *Misellina otai – M.* cfr. *termieri* Zone was established by Toriyama and others (1974) in the Khao Phrong Phrab section of the Phra Phuttabat area, Sara Buri, Central Thailand. *Misellina otai* of a zonal index is closely similar to *Misellina dyhrenfurthi* (Dutkevich) from the *M. dyhrenfurthi* Zone (Leven and Scherbovich, 1978) in the lowest Upper Ulkian Stage or the lowest Upper Artinskian Stage in Russia.

Next higher, the Zone of *Misellina confragspira* established by Toriyama and others (1974) in the same section was correlated with the lower part of the *Misellina claudiae* Zone of the Akiyoshi Limestone Group and its equivalents in Japan. In the worldwide correlation, the present zone is correlative with the middle Upper Ulkian Stage or the middle Upper Artinskian Stage in Russia.

The uppermost, the Zone of *Maklaya saraburiensis* was established by Toriyama and others (1974) in the same section. This zone was correlated with the upper part of the *Misellina claudiae* Zone in Akiyoshi Limestone Group and the upper part of the Upper Ulkian Stage or the upper part of the Upper Artinskian Stage in Russia.

From the available data mentioned above, the fusuline biostratigraphy from the upper Carboniferous to the lower Permian in Thailand can be summarized as follows:

B. Lower Permian Series:

4. Upper Artinskian .....
   - c. *Maklaya saraburiensis* Zone
   - b. *Misellina confragspira* Zone
   - a. *M. otai-M.* cf. *termieri* Zone

3. Lower Artinskian ..... *Psf. vulgaris globosa* Fauna

2. Sakmarian ..... *Rob. schellwieni* Fauna

1. Asselian .....
   - c. *Sphaeroschw. sphaerica* Fauna
   - b. Barren Zone
   - a. *Paraschw. indigesta* Fauna

A. Upper Carboniferous Series:
2. Upper Gzhelian ..... *Paraschwagerina yanagidai-Triticites ozawai* Zone
Barren zone
1. Lower Kasimovian ..... *Protriticites tethydis* Zone

d. North America

The type sections of the Missourian and Virgilian Stages of the Upper Pennsylvanian Series are located in eastern Kansas, and those of the Wolfcampian and Leonardian Stages of the Lower Permian Series lie in the Glass Mountains of Texas. The fusuline zones of these units do not serve as the standard for correlation of interregional to worldwide scope, because of the presence of many barren interzones and the provincialities of the contained faunas. The Lower Permian of West Texas belongs to Yancy's Grandian Province containing a tropical biota, and no species are common to those not only of the lower Permian standard of European Russia, but also of the Tethys Province including Japan, and the Pacific Margin of North America, which is designated as the Anomalous Province by Yancy (1976). Nevertheless, the evolutionary stage of common and related fusuline genera affords a clue to approximate correlation among the units of those provinces.

On the other hand, the fusuline faunas of the Pacific Margin of North America, which is designated as the Anomalous Province by Yancy (1976), are closely similar to and in common with those of the Tethys Province and Japan. In the following are dealt with correlation of representative sections of North America.

1. Kansas

The Upper Pennsylvanian rocks in Kansas contain the type sections of the Missourian and Virgilian Stages. The Missourian Stage is represented by three groups of the Plessanton, Kansas City, and Lansing, and the Virgilian Stage by the Douglas, Shawnee, and Wabaunsee Groups, both in ascending order (Ebanks and others, 1979). The basal Missourian rocks rest unconformably on the Desmoinesian rocks of the Upper Marmaton Group. The Virgilian rocks conformably overly the Missourian rocks. The lower Permian rocks in most places conformably cover the top of the Virgilian rocks. Problem on the Pennsylvanian-Permian boundary in Kansas was discussed by Moore (1940) in detail. Later, Mudge and Yochelson (1962) placed the boundary at the top of the Brownville Limestone Member of the Wood Siding Formation of the Wabaunsee Group belonging to the Virgilian Stage. Since then, this placement has been a subject of controversy, mainly because of difference in opinions between paleontologists and palynologists (Wilde, 1975; Ebanks and others, 1979). Studies of palynomorphs have led some workers to recognize that the whole of the Gearyan Stage (Lower Permian) be included in the Pennsylvanian, and that the systemic boundary be placed at a much higher level in Kansas (Clendening, 1971, 1975). The boundary proposed by palynologists coincides with the Asselian-Sakmarian boundary in the type Permian sequence proposed by Rauser-Chernousova in 1960.

The stratigraphic classification of the upper Carboniferous and the lower Permian in Kansas is summarized as follows:

B. Lower Permian Series:
3. Nippewalla Group
2. Sumner Group
1. Gearyan Group .....
c. Chase Form.: *Pseudoschw. texana* F.
b. Council Grove F.: *P. texana-Pa.kansanensis* F.
a. Admire Formation: Barren

A. Upper Carboniferous Series:
2. Virgilian .....
c. Wabaunsee G ..... *Dunbarinella* Zone.
b. Shawnee G.
a. Douglas G.
1. Missourian .....
c. Lansing G. ..... *Waeringella-Kanasanella* Zone
b. Kansus City G.
a. Pleasanton G. ..... *Eowaeringella* Zone

Ebanks and others (1979) correlated the Missourian and Virgilian Stages with the Kasimovian and Gzhelian Stages of the Russian Platform, respectively. While, the Gearyan Group composed of the Admire, Councile Grove, and Chase Formations was correlated by Wilde (1971, 1975) with the Neal Ranch Formation and King's Bed 2 of the Gray Limestone Member in the type section of the Wolfcampian Stage in Texas.

Pseudoschwagerina texana Dunbar and Skinner is the only species of *Pseudoschwagerina* described from the Neva Limestone in the middle part of the Councile Grove Formation and the Florence Limestone in the upper part of the Chase Formation. *Paraschwagerina kansanensis* (Beede and Knicker) is one of the important indices of the lower Permian in Kansas and abundant in the upper part of the Neva Limestone in the middle part of the Councile Grove Formation.

The Sumner Group was correlated with the Lenox Hills Formation and the Dicie Ranch Member of the Skinner Ranch Formation (Wilde, 1975). The Wolfcampian-Leonardian boundary in Kansas was placed by him at the top of the Sumner Group.

On the basis of the occurrence of the type Wolfcampian fauna, the Gearyan Group can be correlated with the Asselian Stage and the Sumner Group with the Sakmarian Stage in the type section, Russia.

2. Texas

The type sections of the Wolfcampian and Leonardian Stages of the Lower Permian Series in America are located in the Glass Mountains of West Texas. The fusuline fauna from the upper Carboniferous to the lower Permian is known in northcentral Texas (White, 1932; Thompson, 1954; Myers, 1960; Kauffman and Roth, 1966), the Glass Mountains and Hueco Mountains in West Texas (Dunbar and Skinner, 1936; Ross, 1962, 1965; Williams, 1963, 1966).

The upper Pennsylvanian Gaptank Formation (Ross, 1965) in the Glass Mountains reaches 650 feet in the type section and contains many limestone beds. The limestone beds have been designated by informal letters A to J, of which A to F were correlated with the Cisco Group in Central Texas. Bed J at the top of the Gaptank Formation includes Bed 2 of King's Gray Limestone Member (Ross, 1965). The Gaptank Formation is overlain with a distinct stratigraphic break by the Wolfcampian Neal Ranch Formation. Ross (1965) placed the Pennsylvanian-Permian boundary within this break. The Gaptank Formation was subdivided by Ross (1965) into eight fusuline subzones with several barren interzones as shown in the following table.

	Beds
B. Virgilian Stage	
8. *Triticites nealensis* subzone	(Bed J)
Barren Zone	
7. *T. cameratoides* subzone	(I)
Barren Zone	
6. *T. turgidus* subzone	(H)
5. *T. moorensis* subzone	(G)
Barren Zone	
4. *T. acutuloides* subzone	(F)
Barren Zone	
A. Missourian Stage	
3. *T. joensis* subzone	(C)
2. *T. collus subzone*	(B)
Barren Zone	
1. T. celebroides subzone	(A)

The *Triticites celebroides* subzone was compared with the Cherryvale Shale Member of the middle part of the Kansas City Group (Middle Missourian Stage) in Kansas (Thompson, 1957). The *T. acutuloides* subzone indicates the Lowest Vergilian Stage. According to Ross, *T. acutuloides* Ross is similar in evolutional development to *T. newelli* Burma from the Stanton Limestone at the top of the Lansing Group of the Upper Missourian Stage, and also to *T. iatanensis* THOMPSON from the Iatan Limestone Member in the Stranger Formation of the Douglas Group of the Lower Virgilian Stage in Kansas. The *Triticites nealensis* subzone is the highest Gaptank fusuline subzone and includes *T. cullomensis* Dunbar & Condra and *T. capaxoides* Ross, and so on. Some of the illustrated specimens of *T. capaxoides* (Ross, 1962, 1965) are similar to *Triticites plummeri* Dunbar & Condra from the Speck Mountains Limestone Member in the basal part of the Thrifty Formation of the Cisco Group in Central Texas. This subzone was correlated with the lower and the middle part of the Wabaunsee Group of the Upper Virgilian Stage in the Kansas.

Dunbarinella skinneri Kauffman & Roth described from the Balch Ranch Limestone in Texas is closely allied to *Schwagerina douvilleri* (Colani) of Fujimoto (1936), and *S. stabilis* (Rauser) of Kanmera (1958), both of which occur from the "*Pseudoschwagerina*" *minatoi* Zone (Upper Hikawan Stage) in Japan. The Balch Ranch Limestone was correlated with interval between Beds I and J of the Gaptank Formation (Ross, 1965) which corresponds to the lower part of the Wabaunsee Group in Kansas.

The type Wolfcampian Stage is divided into the Neal Ranch Formation below and the Leonox Hills Formation above. The Neal Ranch Formation unconformably overlies lenticular limestones of the Gaptank Formation, and is unconformably overlain by the Leonox Hills Formation along the base of the Glass Mountain escarpment. The type Leonardian Stage is also located at the Glass Mountains, where the Skinner Ranch Formation of the Basal Leonardian Stage unconformably overlies white grey limestones of the Leonox Hills Formation.

The fusuline fauna of the Neal Ranch Formation includes the following species: *Pseudoschwagerina uddeni* Dunbar and Skinner, *Paraschwagerina gigantea* Dunbar and Skinner, and *Pseudofusulina huecoensis* Dunbar and Skinner. The Leonox Hills fauna consists of *Monodiexodina linearis* (Dunbar and Skinner), *Pseudoschwagerina gerontica* Dunbar and Skinner, *P. convexa* Thompson, *Schwagerina diversiformis* Dunbar and Skinner, and *Chalaroschwagerina nelsoni* (Dunbar and Skinner).

The Decie Ranch Member o the Basal Skinner Ranch Formation in the western Glass Mountains was considered to belong to the Wolfcampian rather than to the Leonardian (Wilde,

1971). This member is dominated by the following species: *Schwagerina hawkinsi* Dunbar and Skinner, and *S. hessensis* Dunbar and Skinner. Also *Monodiexodina linearis* (Dunbar and Skinner) has been cited as occurring in the Decie Ranch Member as well as in the Leonardian (Ross, 1962). Wilde (1971, 1975) considered that the base of the Leonardian in the Skinner Ranch Formation be placed at the first appearance of *Schwagerina crassitectoria* Dunbar and Skinner. Namely, the Wolfcampian-Leonardian boundary drawn by Wilde (1971, 1975) lies between the *Monodiexodina linearis* and the *Schwagerina crassitectoria* Assemblage-Zones, and also is at the level of the first appearance of the *Schwagerina crassitectoria-S. franklinensis* fauna in the upper part of the Alacran Mountain Formation in the Hueco Group in the Diablo Platform, West Texas (Williams, 1963).

Thompson (1954) and Williams (1963) discussed the Wolfcampian stratigraphy in the Hueco Mountains and described fusuline faunas.

The Hueco Canyon Formation, the lowest of the Hueco group, is separated from the underlying Barsum Beds by an unconformity, which is marked by the basal conglomerate of the Powwow Member of the formation. Fusulines from the Powwow Member were described by Dunbar and Skinner (1936) and Williams (1963). Williams identified *Schwagerina emaciata* (Beede), *S. bellula* Dunbar and Skinner, and *Triticites powwowensis* Dunbar and Skinner. *Schwagerina bellula* occurs also in Bed-8 of the Neal Ranch Formation in the Glass Mountains. Fusulines of the Hueco Canyon Formation also include at least four other species in common with those of the Neal Ranch Formation. They are the following species: *Pseudoschwagerina uddeni* Beede and Knicker), *P. beedei* Dunbar and Skinner, *P. texana* Dunbar and Skinner and *Pseudofusulina huecoensis* (Dunbar).

The Cerro Alto Formation, which overlies the Huecco Canyon Formation, yields only two species of *S. eolata* Thompson and *S. neolata* Thompson. The next higher, the Alacran Mountain Formation contains the following schwagerinids: *Pseudoschwagerina gerontica* Dunbar and Skinner, *P. convexa* Thompson, *Chalaroschwagerina nelsoni* (Dunbar and Skinner) and *Schwagerina diversiformis* Dunbar and Skinner. Ross (1969) thought that the Alacran Mountain Formation is not represented in the Glass Mountains succession and possibly be equivalent to the lower part of the Bone Spring Formation of late Leonardian age.

Faunal comparisons for correlation of the Wolfcampian and Leonardian with the Japanese Lower Permian are shown in the following table:

West Texas Neal Ranch Fm.	**Hueco Mt.** Hueco Canyon Fm. Cello Alto Fm.	**Japan** Nagatoan *Pss. muongthensis* Z.
Pss. uddeni	*P. uddeni*	*P. muongthensis*
Psf. huecoensis	*Psf. huecoensis*	
Parasch. gigantea		
(Lenox Hills Fm.)	(Alacran Mt. Fm.)	(Sakamotozawan)
Monod. linearis		*M. kumasoana*
Pss. gerontica	*Pss. gerontica*	*Pss. robusta*
S. diversiformis	*S. diversiformis*	*Psf. diversiformis*
Chal. nelsoni	*Chal. nelsoni*	*Psf. v. globosa*
(Dicie Ranch Fm.)		(Sakamotozawan)
Monod. linearis		*M. kumasoana*
S. howkinsi		*S. howkinsiformis*
S. hessensis		
(Skinner Ranch Fm.)	(Alacran Mt. Fm.)	(Sakamotozawan)
S. crassitectoria	*S. crassitectoria*	*Psf.* sp. A
	S. howkinsi	*S. howkinsi*
	Rob. stanislavi	*R. schellwieni*

The *Pseudoschwagerina gerontica* lineage (Williams, 1963) is thought to be similar to in evolutional development to the *Pseudoschwagerina muongthensis-P. miharanoensis* lineage in Japan. The former comes from the Neal Ranch Formation to the Lenox Hills Formation. The latter occures from the Middle to Upper Asselian and the Middle to Upper Nagatoan Stage in the Permian of Tethys Province. Hence, the Wolfcampian Stage may be roughly correlated with the Asselian and the Nagatoan Stage.

Schwagerina diversiformis Dunbar and Skinner from the Lenox Hills Formation is similar to *Pseudofusulina diversiformis* (Dunbar and Skinner) and *P. pseudopointeri* Rauser. described by Bensh (1972) and Leven and Scherbovich (1978) from the Middle to Upper Asselian deposits in Russia. *Chalaroschwagerina nelsoni* (Dunbar and Skinner) from the Alacran Mountain Formation, which corresponds to the Lenox Hills Formation, resembles *Dutkevitchia splendida* Leven and Scherbovich from the Upper Asselian formation in the Darvus region of Central Asia.

Schwagerina crassitectoria Dunbar and Skinner, an index species of the base of the Leonardian Stage, is similar to *Pseudofusulina* sp. A and *S. crassitectoria* from the *Acervoschwagerina* subzone (Kobayashi, 1957) of the Ibukiyama Limestone Group in Japan. Also, this species resembles *S. cushmani* (Chen) described by Zhou (1982) from the Chihsia Formation in southeastern Hunan, China.

Robustoschwagerina stanislavi (Dunbar) associated with *S. crassitectoria* in the lower Bone Spring Formation is closely similar to *R. schellwieni pamirica* Leven and Schelbovich from the Akiyoshi Limestone Group of Japan.

To sum up, the Leonardian Stage can be exactly correlated with the Sakmarian Stage in Russia and the Sakamotozawan Stage in Japan.

3. Pacific margin of North America

This region belongs to the Anomalous Province of Yancy (1976) containing many Tethyan elements besides endemic ones. The Cache Greek Group and the Calaveras Formation in California yield many Tethyan fusulines, which were described by Thompson and others (1953), Thompson (1965), Skinner and Wilde (1966a-c), Douglass (1967), Ross (1984) and so on. The Middle Carboniferous faunas from Central British Columbia in Canada (Thompson and others, 1953; Thompson, 1965) are closely similar to those of the Kamitakaran, Akiyoshian, Kurikian and Lower Hikawan faunas in Japan. On the other hand, the upper part of the Lower Permian fauna, which was described by Douglass (1967) from the Calaveras Formation in California, corresponds to that of the uppermost part of the Sakamotozawa Formation in Japan. *Sphaeroschwagerina* and *Acervoschwagerina* as the typical Tethyan elements were found from the Nakina area, northern British Columbia (Ross, 1984) and Dog Creek, Oregon, respectively. These two genera indicate the interval of the Middle Nagatoan and the Upper Sakamotozawan Stages. Following table shows mutually related species between the faunas from Cache Creek and Japan.

(Species of Loc. BC-15)	(Kurkian Fauna)
Schubertella popensis	*Fusulinella gracilis*
Quasifusulina popensis	*Fusulina ohtanii* or *Fusulina kurikiensis*
(Species of Loc. BC-21,53)	(L. Hikawan Fauna)
Triticites pinchiensis	*Schwagerina ? satoi*
T. stuartensis	*T. ozawai*
Pseudoschwagerina arta	*P. morikawai*
Quasifusulina americana	*Q. longissima*

(Species of Loc. f23657)	(U. Sakamotozawan Fauna)
Schubertella giraudi	*Schubertella giraudi*
Misellina californica	*M. claudiae*
Parafusulina impresa	*P.* cf. *edoensis*

Equivalence in age of the beds of Locs. BC-6, -14 and -23 and the *Profusulinella beppensis* Zone of the Akiyoshi Limestone is cut off of the question because of the presence of identical species. The faunas of Locs. BC-48 and -49 are somewhat related with those of the *Fusulinella simplicata* Zone of the Akiyoshian to the *Beedeina higoensis* Zone of the Kurikian Stages in Japan. The fauna of Loc. BC-18 is comparable with that of the *Fusulina ohtanii* and *F. kurikiensis* Zones of the Upper Kurikian Stage. The faunas at Locs. BC-21 and BC-53 from in the uppermost part of the Cache Creek Group are closely allied respectively to those the *Schwagerina*? *satoi* Zone of the upper part of the Lower Hikawan and the *Pseudoschwagerina morikawai* Zone of the Upper Hikawan Stage in Japan.

Close faunal affinity with Japanese species is recognized also in the Lower Permian fusulines

U.S.S.R.		U.S.A.		INTERNATIONAL FUSULINIDS ZONE Kahler (1974) Rotai (1975)	CALIFORNIA Skinner & Wilde (1965) Douglass (1967)		BRITISH COLUMBIA Thompson (1965) Ross (1962)		WEST TEXAS Williams(1965) Ross (1965)		KANSAS Ebanks et al. (1979)		JAPAN	
LOWER PERMIAN	ARTINSKIAN	LOWER PERMIAN	LEONARDIAN	*Misellina*	H	*Misellina californica*	CACHE CREEK TERRANE	*Misellina*	BONE SPRING FORMATION	*Schwagerina howkinsi*			SAKAMOTOZAWAN	Upper
						Chalaroschwag. inflata		*Brevaxina*						
				Pseudofusulina vulgaris	G	*Schwagerina corpulensis*								
	SAKMARIAN			*Robustoschwag. schellwieni*	F	*Paraschwag. crassitheca*				*Robustoschwag. stanislavi*				Lower
						Klamathina elongata		*Acervoschwag.*		*Schwagerina crassitectoria*				
	ASSELIAN		WOLFCAMPIAN	*Zellia*	E	*Eoparafusulina gracilis*			HUECO LIMESTONE	*Pseudoschwag. gerontica*	CHASE		NAGATOAN	Upper
						Paraschwag. fax						*Paraschwag. kansanensis*		
						Pseudoschwag. robusta					COUNCIL GROVE			
				Pseudoschwag. confini	D	*Paraschwag. magma*				*Pseudoschwag. uddeni*		*Pseudoschwag. texana*		Middle
					C	*Pseudoschwag. californica*		*Sphaeroschwag.*		*Pseudoschwag. beedei*				
				Pseudoschwag. alpina	B						ADMIRE			Lower
UPPER CARBONIFEROUS	GZHELIAN	PENNSYLVANIAN	VIRGILIAN	*Daixina sokensis*	A						WABA.	*Dunbarinella*	UPPER IIIKAWAN	Upper
				Triticites jigulensis	McCLOUD LIMESTONE				GAPTANK FORMATION	*Tr. nealensis* *Tr. cameratoides* *Tr. turgidus* *Tr. moorensis* *Tr. acutuloides* *Tr. joensis* *Tr. collus* *Tr. celebroides*	DOU.			
				Triticites stuckenbergi			CACHE CREEK LIMESTONE	*Pseudoschwag. arta*			SIA.	*Kansanella*		Low.
	KASIMOVIAN		MISSOURIAN	*Tr. arcticus -Tr. acutus*				*Tr. stuartensis* *Tr. pinchiensis* *Qfna. americana*			LANS.	*Waeringella*	LOWER IIIKAWAN	Up.
				Triticites montiparus							KANSAS			Mid.
				Protr. pseudo-montiparus -Obsoletes obsoletus				*Qfna. popensis*			PLEASAN.	*Eowaeringella*		Lower

Table 8. Stratigraphic divisions and typical fusulines of the representative Upper Carboniferous and Lower Permian strata in North America and their correlation with the standard fusuline zones and Japanese divisions.

of the Calaveras Formation. Table shows similear and identical species in the bed of Loc. f23657 in the Calaveras Formation and *Misellina claudiae* Zone of the Akiyoshi Limestone Group in Japan.

Table 8 summarizes the stratigraphic divisions and typical fusulines of the representative upper Carboniferous and lower Permian strata in North America and their correlation with the standard fusulines zones and the Japanese divisions.

VIII. Summary and Conclusions

In this paper have been dealt with the following points:

1) establishment of fusuline zones mainly based on inflated schwagerinids in the upper Carboniferous and lower Permian of Japan.

2) correlation of the fusuline zones of Japan established with those of the stratotypes in the Urals and other relevant provinces from where inflated schwagerinids are recorded to occur.

3) placement of the boundary between the Carboniferous and Permian Systems and setting of boundary-stratotype in Japan.

4) recognition of evolutionary lineages of inflated schwagerinids whose stratigraphic distribution could be clarified in detail, and analysis of their mode of evolutionary development.

Inflated schwagerinids including 19 pseudoschwagerinas and 7 paraschwagerinas were described from Japan during the years from 1925 to 1964. Many of these species have been utilized as indices of the lower Permian of Japan, but their ranges and the horizons of first appearance and last disappearance have not been confirmed because of their sporadical occurrence. Therefore, it is requisite to know their detailed stratigraphic and geographic distributions in continuous successions in Japan. In this connection, sampling of rocks containing fusulines was made as close-spaced as possible from measured sections crossing the upper Carboniferous and lower Permian part of the Akiyoshi, Atetsu and Omi Limestones in the Akiyoshi Terrane. Supplementary collections came from several limestone masses in the Mino, Chichibu, southern Kitakami and Hida Marginal Terranes. More than fifty thin sections were prepared from each of collections for populational analysis of inflated schwagerinids to justify their taxonomic identification and morphologic variations in rates of evolution.

The results of this study are summarized as follows:

1. It has turned out that inflated schwagerinids belonging to the genera *Montiparus, Schwagerina, "Pseudoschwagerina", Sphaeroschwagerina, "Alpinoschwagerina", Robustoschwagerina* and *Paraschwagerina* (incl. *Acervoschwagerina*) occur continually and abundantly through the upper Carboniferous and lower Permian in almost all of the limestones examined.

2. On the basis of inflated schwagerinids stated, the upper Carboniferous and lower Permian rocks in Japan can be divided into the following twelve zones in ascending order: (1) *Obsoletes obsoletus* Zone, (2) *Montiparus matsumotoi inflatus* Zone, (3) *Schwagerina? satoi* Zone, (4) *"Pseudoschwagerina" morikawai* Zone, (5) *"Pseudoschwagerina" minatoi* Zone in the upper Carboniferous Series, (6) *Sphaeroschwagerina fusiformis* Zone, (7) *Sph. pavlovi-Pseudoschwagerina muongthensis* Zone, (8) *"Alpinoschwagerina" saigusai-Pseudoschwagerina* cf. *robusta* Zone, (9) *Schwagerina globulus japonicus-Pss. miharanoensis* Zone, (10) *Paraschwagerina akiyoshiensis-Pseudofusulina firma* Zone, (11) *Robustoschwagerina schellwieni pamirica-Schwagerina krotowi* Zone, and (12) *Rob. schellwieni schellwieni-Pseudofusulina vulgaris globosa*

Zone in the Lower Permian Series. The lower limit of each of these named zone-species, which can be designated as a datum level.

3. Faunal comparison of the fusulines of these zones with those of the stratotypes in the Urals reveals that Zones 1 to 3 are correlated with the Kasimovian, Zones 4 and 5 with the Gzhelian, Zones 6 to 10 with the Asselian, Zone 11 with the Sakmarian and Zone 12 with the Artinskian Stage. Significant faunal changes through the zones established are recognized at the boundary between Zones 5 and 6, where the "*Pseudoschwagerina*" *minatoi*-Lineage disappears and the *Sphaeroschwagerina pavlovi*-Lineage first appears. Consequently the Carboniferous-Permian boundary-stratotype is set at that horizon in the Akiyoshi Limestone Group.

4. The new scheme of fusuline zonation of the upper Carboniferous and lower Permian in Japan inevitably requires the revision of the previously named chronostratigraphic units, the upper Carboniferous Hikawan Series and the lower Permian Sakamotozawan Series. The upper Carboniferous is newly divided into two stages, the Lower Hikawan Stage including Zones 1 to 3, and the Upper Hikawan Stage comprising Zones 4 and 5. The Nagatoan Stage is newly established to cover Zones 6 to 10 and corresponds to the Asselian Stage. the Sakamotozawan Stage is revised to include Zones 11 and 12.

5. Among the zones established, Zones 2 to 5 are defined as lineage-zones represented by successive taxons of an evolutionary line, developed from *Montiparus matsumotoi inflatus* through *Schwagerina? satoi* and "*Pseudoschwagerina*" *morikawai* to "*P.*" *minatoi*. This lineage, named "*P.*" *minatoi*-Lineage, shows the following graded changes of forms:

a) The shell increases in size, number of volutions and height of chambers.

b) The features of the earliest species of this lineage, *M. matsumotoi inflatus,* are palingenetically retained in the juvenarium of the succeeding species.

c) A notable feature of this lineage is the rapid inflation of shell in outer volutions. This feature is accelerated with the evolution of this lineage, and the species in which the inflation of shell has become distinctive immediately after the juvenile stage are referred to as the genus *Pseudoschwagerina.*

d) In contrast with the accelerated evolution stated, degenerative evolution represented by the weakening of chomata and septal fluting, and the thinning of spirotheca are recognized.

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