Carboniferous and Permian Stratigraphy of the Atetsu Limestone in West Japan

By

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with 4 Tables, 9 Text-figures and 1 Plate

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ABSTRACT: This paper treats of the stratigraphy, geologic structure, correlation of the fusulinid faunas of the Carboniferous and Permian Atetsu Limestone, and the stratigraphy of the non-calcareous sedimentary rocks cropping out to the south of this limestone plateau in Okayama Prefecture of West Japan. The Atetsu Limestone is divided into three groups and they are subdivisible into six formations. This limestone plateau is structually divided into two blocks, the northern and the southern, by a reversed fault dipping towards the north. The stratigraphical description of the non-calcareous rocks are given in the third chapter. The fusulinid zones established in the Atetsu Limestone are *Endothyra-Pseudoendothyra* zone, *Millerella bigemmicula-Eostaffella kanmerai* zone, *Profusulinella toriyamai* zone, *Fusulinella imamurai* zone, *Pseudoschwagerina* zone, *Parafusulina* zone, *Neoschwagerina douvillei* zone, *Yabeina shiraiwensis* zone and *Lepidolina imamurai* zone in ascending order, and among them the *Pseudoschwagerina* zone and the *Parafusulina* zone are subdivisible into two subzones, respectively. The international correlations of these fusulinid zones are given in the sixth chapter.

CONTENTS

I. INTRODUCTION

The non-metamorphic Palcozoic rocks, especially the limestones containing a large number of fusulinids which indicate the Carboniferous and Permian ages have been in the limelight as those which play an important role in order to elucidate the Palcozoic geologic history in Japan, since OZAWA (1925) brought out his stratigra-

phical and paleontological studies of the Akiyoshi Limestone in West Japan. In the so-called Kibi Highland of the Chugoku region belonging to the Inner Zone of West Japan, the large limestone plateaus such as the Taishaku, Oga and Atetsu ones have been well known as well as the Akiyoshi Limestone plateau and studied by many students from the stratigraphical and structural points of view. In 1941, in his "Sakawa Orogenic Cycle and its Bearing on the Origin of the Japanese Islands" KOBAYASHI concluded that each of limestone masses was the large Klippe lying on the contemporaneous but heterogeneous Paleozoic formations. The Atetsu Limestone plateau in Niimi City of Okayama Prefecture is situated in the northeasternmost district among the limestone plateaus in the Chugoku region and lies about 220 km. to the northeast of the Akiyoshi Limestone plateau. The Atetsu Limestone plateau originally mapped by SATO (1937) was studied by MOCHIZUKI (1938) and he gave the concise explanation of the stratigraphy of this limestone. Since 1958, the stratigraphical and paleontological knowledge of this limestone has been remarkably promoted by several workers such as OKIMURA (1958), IMAMURA (1959), SADA (1960), NOGAMI (1961), etc. However, many stratigraphical problems have remained unsolved. In the last nine years I have continued to make the stratigraphical studies of this limestone and its surrounding non-calcareous rocks and also the paleontological studies of the former fusulinid faunas. Up to the present day, I have published descriptions of fusulinids important for the purpose of the correlation and of the stratigraphy of the Upper Permian of the Atetsu Limestone. In this paper are given the stratigraphy, geologic structure and correlation of the fusulinid faunas of the Carboniferous and Permian Atetsu Limestone.

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My sincere thanks are due to Professor Ryuzo TORIYAMA and Assistant Professor Kametoshi KANMERA both of Kyushu University for their kind guidances in my paleontological studies, and their advices and encouragements during the course of this work. I wish to extend my special acknowledgment to Professors Hideyoshi TOYODA, Yoshiharu UMEGAKI and George KOJIMA of Hiroshima University for their constant encouragements.

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II. SHORT SUMMARY OF THE PREVIOUS WORKS

MOCHIZUKI (1938) under a KOBAYASHI's guidance studied the stratigraphy of the Atetsu Limestone and its surrounding Paleozoic rocks and he threw a little light on

the zoning of the limestone based on the fusulinid foraminifera and the stratigraphic sequence of the Carboniferous and Permian sedimentary rocks in this area. According to him, the Atetsu Limestone overlies the Namurian Ishiga formation conformably and is succeeded by the Upper Permian Terauchi formation, and includes five fusulinid zones, that is, the *Fusulinella* aff. *biconica* zone, the *Pseudoschwagerina* zone, the *Schwagerina* cf. *vulgaris* zone, the *Neoschwagerina* zone and the *Yabeina* zone in ascending order.

Studying the Atetsu Limestone, OKIMURA (1958) made an attempt to zone the lower part of this limestone by the endothyroid and plectogyroid foraminifera and discriminated the five zones as tabulated below.

5. *Atetsuella meandera* zone ..... Chesterian
4. *Endothyra symmetrica* zone
3. *Endothyra spiroides* zone ..... Meramecian
2. *Plectogyra primaeva* zone
1. *Plectogyra communis* zone ..... Osagian

These five zones were correlated with the Mississippian *Endothyra* and *Plectogyra* zones of the Cordilleran geosyncline region studied by ZELLER (1957).

IMAMURA (1959), in his comprehended study of the Carboniferous and Permian Limestones in Okayama Prefecture, gave the brief descriptions of the stratigraphy and the fusulinid zones of the Atetsu Limestone and summarized as follows:

Yukawa group
- Terauchi formation ..... *Lepidolina* zone / *Yabeina* zone
- Maki formation ..... *Neoschwagerina douvillei* zone

Unconf.

Sabushi group
- Kanikawa formation ... *Verbeekina verbeeki* subzone / *Pseudofusulina kraffti* subzone / *Pseudodoliolina ozawai* subzone
- Shoyama formation ..... *Pseudofusulina* zone
- Iwamoto formation ..... *Pseudoschwagerina* zone

Unconf.

Mitsudo group
- Kodani formation ..... *Fusulinella* zone / *Eoschubertella* zone / *Millerella* zone

Disconf.

- Nagoe formation ..... *Atetsuella meandera* zone / *Endothyra symmetrica* zone / *Endothyra spiroides* zone / *Plectogyra primaeva* zone / *Plectogyra communis* zone

Fault

At the same time, IMAMURA pointed out that the Maki formation overlay the Sabushi group unconformably and designated this unconformity as Pre-Maki Unconformity. Furthermore, he brought forward some geohistorical problems suggested by this unconformity.

Based on his biostratigraphical study of the lower part of the Akiyoshi Limestone, OKIMURA (1963) changed the names of the endothyroid zones from the *Plectogyra communis* zone, the *Plectogyra primaeva* zone, the *Endothyra spiroides* zone, the *Endothyra symmetrica* zone and the *Atetsuella meandera* zone to the *Endothyra* sp. A zone, the *Endothyra* sp. zone, the *Pseudoenothyra spiroides* zone, the *Pseudoendothyra symmetrica* zone and the *Atetsuella* zone, respectively. And he considered these endothyroid zones to be of the Lower Viséan to the Bashkilian ages.

Describing the Permian fusulinids of the Atetsu Limestone, NOGAMI (1961) divided the Permian of this plateau into the five fusulinid zones represented by the *Pseudoschwagerina subsphaerica-Quasifusulina longissima ultima* zone, the *Pseudofusulina vulgaris* zone, the *Parafusulina kaerimizensis-Pseudofusulina kraffti magna* zone, the *Neoschwagerina douvillei-N. craticulifera* zone, and the *Yabeina shiraiwensis* zone in ascending order. In 1962, he published a geological map of the northern part of this plateau.

III. STRATIGRAPHY

A. GENERAL REMARKS

The Carboniferous and Permian deposits in the studied area are represented by the following rocks, namely, the Atetsu Limestone including the Terauchi formation which forms the tableland, generally called "the Atetsu plateau," the non-metamorphic Ishiga formation, and the Taniai phyllite group referred to the Sangun metamorphic rocks distributed in the south of the plateau. The Carboniferous and Permian Atetsu Limestones can be divided into three groups and six formations as described below:

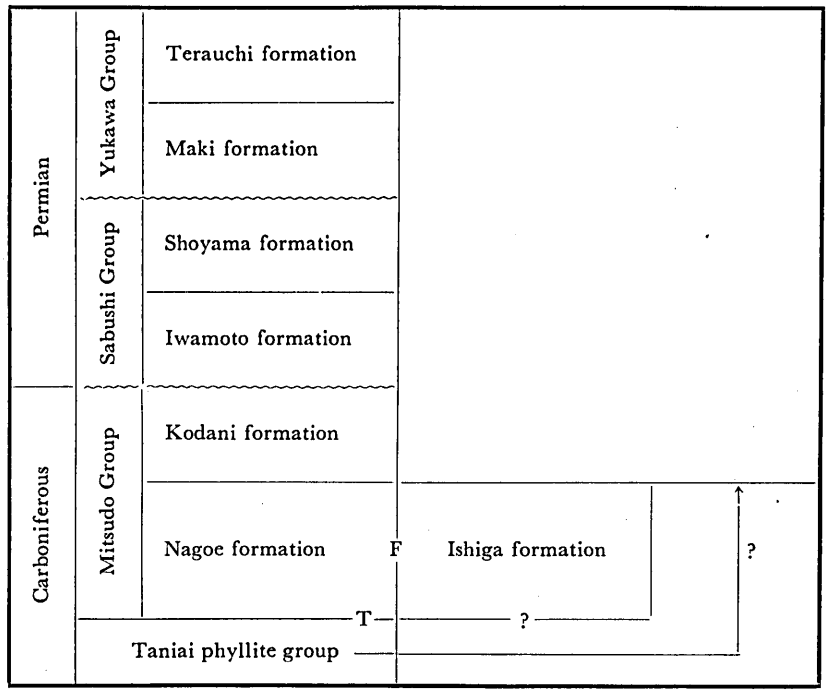
Yukawa g.*	Terauchi f.*	*Lepidolina imamurai* zone (Pu α)	Up. Permian	
		Yabeina shiraiwensis zone (Pm δ)	Mid. Permian	
	Maki f.	*Neoschwagerina douvillei* zone (Pm γ)		
	Unconf.			
Sabushi g.	Shoyama f.	*Paf.*	*Parafusulina kaerimizensis* subzone (Pm β)	
			Pseudofusulina kraffti magna subzone (Pm α)	
	Iwamoto f.	*Ps.*	*Pseudoschwagerina kanmerai* subzone (Pl β)	Low. Permian
			Rugosofusulina arctica subzone (Pl α)	
	Unconf.			
Mitsudo g.	Kodani f.		*Fusulinella imamurai* zone (Cu γ)	Mid. Pennsylvanian
			Profusulinella toriyamai zone (Cu β)	
			Millerella bigemmicula-Eostaffella kanmerai zone (Cu α)	Low. Pennsylvanian
	Nagoe f.		*Endothyra-Pseudoendothyra* zone (Cl α)	Mississippian
	Fault			

The Ishiga formation is mainly composed of sandstones, shales, schalsteins, cherts

* *Paf.* and *Ps.* indicate *Parafusulina* and *Pseudoschwagerina* zones, and g. and f. indicate group and formation, respectively.

and some small limestone lenses, and its geologic age based on the endothyroid foraminifera may be considered not to be younger than *Endothyra-Pseudoendothyra* zone of the Nagoe formation. The Taniai phyllite group consists of black and green phyllites with lenticular limestones. The aforementioned Atetsu Limestone, Ishiga formation, and Taniai phyllite group are bordered with faults each other as shown in TABLE. 1.

TABLE 1. STRATIGRAPHICAL DIVISION OF THE CARBONIFEROUS AND PERMIAN ROCKS IN THE ATETSU DISTRICT, OKAYAMA PREFECTURE.



"T" and "F" indicate thrust and fault, respectively.

B. MITSUDO GROUP

The Carboniferous deposits developed in this plateau were called the Mitsudo group (IMAMURA, 1959) and it is from the discovery of the most typical exposure comprising Carboniferous fusulinids at Mitsudo, Toyonaga-Cho, Niimi City, that the group has taken its name. This group comprises the following two formations, the lower Nagoe and the upper Kodani. The group mainly consists of schalsteins, banded limestones intercalated with cherts, and oolitic massive limestones, and is characterized by the *Endothyra*, *Pseudoendothyra*, *Millerella*, *Profusulinella* and *Fusulinella* faunas. The total thickness of the group is about 675 m.

Geological horizon — The *Endothyra-Pseudoendothyra* zone to the *Fusulinella imamurai* zone.

1. *Nagoe formation*

The Nagoe formation lies in both eastern and western parts of the Atetsu plateau. The type locality of the Nagoe formation which was originally designated by OKIMURA (1958), is the vicinity of Nagoe, Toyonaga-Cho, the eastern part of this plateau. The lower part of the Nagoe formation consists of schalsteins and limestones, and the upper part is composed of the alternation of schalsteins and limestones intercalated with cherts. The formation is about 350 m. in the whole thickness (FIG. 4), having the general strike of the northwest-southeast and the southward dips of 40–60 degrees. The strike of the formation in the Tarumi and Kusama areas, is the east-west with the dips of about 20–40 degrees towards the north.

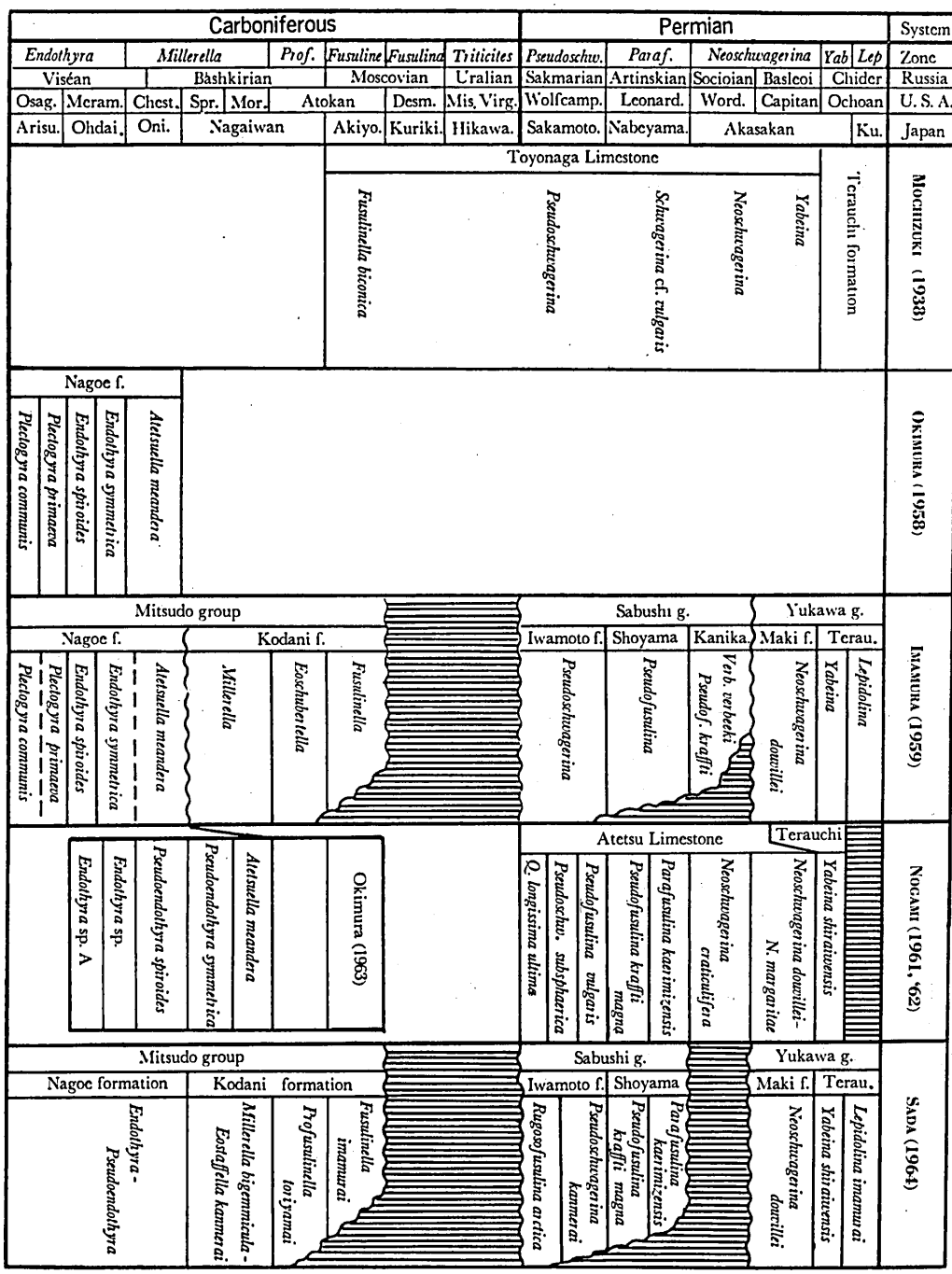
The limestones yield abundant endothyroid foraminifera. These were previously divided by OKIMURA (1958) into the *Plectogyra communis*, *P. primaeva*, *Endothyra spiroides*, *E. symmetrica* and *Atetsuella meandera* zones in ascending order, and he had an opinion that these five zones might be of the Osagian to the Chesterian ages. OKIMURA (1963), studying endothyroids from the lower part of the Akiyoshi Limestone, revised the *Plectogyra communis*, *P. primaeva*, *Endothyra spiroides*, *E. symmetrica* and *Atetsuella meandera* zones to *Endothyra* sp. A, *E.* sp., *Pseudoendothyra spiroides*, *P. symmetrica* and *Atetsuella* zones, respectively, and he explained that the five endothyroid zones stated above were of the Lower Viséan to the Bashkirian ages. Taking the faunal assemblage of endothyroids and their stratigraphic succession into consideration, the Nagoe formation studied by me including the *Endothyra* sp. A, *E.* sp. and *Pseudoendothyra spiroides* zones of OKIMURA is of the Mississippian age with a high degree of probability. The stratigraphical and paleontological problems of the formation will be mentioned by OKIMURA in the near future.

2. *Kodani formation*

The Kodani formation is best developing in the Kodani area, the eastern part of this plateau. The outcrops of the formation are present in several areas, viz., the western slope of Shimoazai, the northern flank of Hanagi, Taniai, the northern and southern parts of Tarumi, the northern and southern parts of Kusama, and Hongo. The Kodani formation, about 60 to 325 m. thick, generally consists of oolitic or dark greyish massive limestone and is unconformably overlain by the Iwamoto formation of the lower Sabushi group (See FIGS. 1–4, 6 and 7).

The lower part of the Kodani formation characterized by *Milleralla*, *Eostaffella* and *Pseudostaffella* was already designated as the *Millerella bigemmicula-Eostaffella kanmerai* zone in my preceding paper (1961, '63 and '64). Fusulinids obtained from this zone are *Millerella inflecta* THOMPSON, *M. bigemmicula* IGO, *Eostaffella kanmerai* (IGO), *E.* sp. A, *E.* sp. B, *E.*? sp. C, *E.* sp. D, and *Pseudostaffella* cf. *kanumai* IGO. On the other hand, in the middle to the upper part of the formation, the *Profusulinella toriyamai* zone and the *Fusulinella imamurai* zone in ascending order were recognized by me (SADA, 1961, '63, and '64), respectively. The *Profusulinella toriyamai* zone is characterized by *Profusulinella toriyamai* SADA, *P. rhomboides* (LEE et CHEN), *P.* cf.

TABLE 2. THE FUSULINID ZONES OF THE ATETSU LIMESTONE



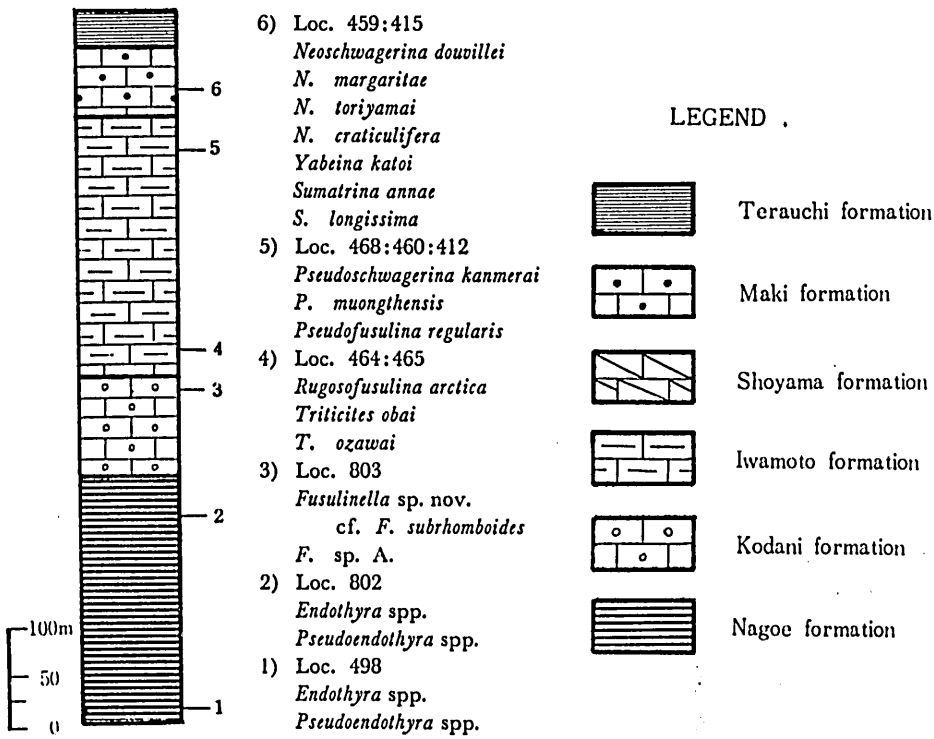


FIG. 1. Northern flank of Tarumi

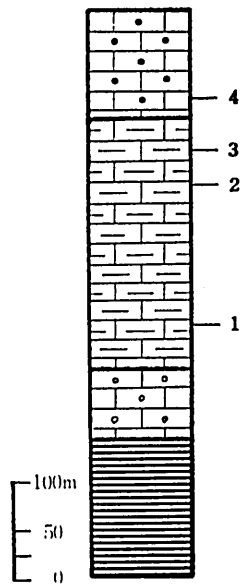
wangyüi SHENG, *P.* sp. A, P. sp. B, *Nankinella plummeri* THOMPSON, *Staffella powwowensis* THOMPSON, *Eoschubertella lata* (LEE et CHEN) and *E.* sp. The *Fusulinella imamurai* zone is characterized by *Fusulinella imamurai* SADA, *F.* sp. nov. cf. *F. subrhomboides* LEE and CHEN, *F. hirokoae* SUYARI, *F.* sp. A and *Fusulina* sp.

The fusulinid assemblages stated above indicate that the Kodani formation is of the Springeran to the early Desmoinesian age.

C. SABUSHI GROUP

The Lower Permian Limestones are widely present in this plateau, having their most typical development in Sabushi, Toyonaga-Cho, Niimi City. These limestones were formerly designated as the Sabushi group (IMAMURA, 1959; SADA, 1960 and '61), which can be subdivided into two formations of the lower Iwamoto and the upper Shoyama. This group overlies unconformably the Kodani formation of the upper part of the Mitsudo group. The Sabushi group is generally characterized by whitish to greyish conglomeratic limestones, massive limestones, thin-bedded cherts, and the occurrence of pseudoschwagerinids and parafusulinids. The total thickness of this group is about 120 to 325 m. in the Iwamoto area, showing considerable variation in other places.

Geological horizon — The *Pseudoschwagerina* zone to the *Parafusulina* zone.



4) Loc. Ku 15
Neoschwagerina douvillei
N. megaspherica
N. douvillei
N. craticulifera
Sumatrina annae
3) Loc. Ku 12
Pseudoschwagerina muongthensis
P. vulgaris
2) Loc. Ku 11
Pseudofusulina vulgaris
Schwagerina primigena
Chusenella sp.
1) Loc. Ku 4
Rugosofusulina arctica
Triticites obai
T. kawanoboriensis
T. sp. aff. *T. subventricosus*
Pseudofusulina sp.

FIG. 2. Northern flank of Kusama

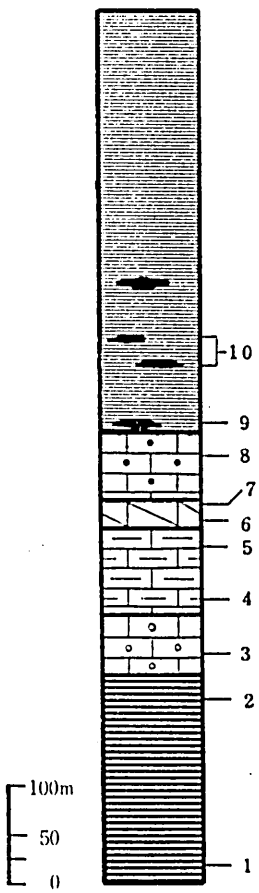
1. *Iwamoto formation*

The Iwamoto formation is the most conspicuous and the best-developed member in this plateau, where it crops out in both northern and southern blocks. The former block includes the areas of Iwamoto, Matsunagi, Niiyabara, the northern flank of Tarumi and Hirosé, and the latter one the areas of Yorikuni, Tarumi, Yokouchi, the north of Hanagi, Tateishi and the southern flank of Tarumi. The most typical exposure is found, however, at Iwamoto situated in the eastern part of the plateau. This formation is also developed in the Hongo area and generally composed of grayish to whitish limestone conglomerate and massive limestone. The former always predominates in this plateau and is partly intercalated with thin layers of schalstein having fossiliferous lenticular limestones. The lateral change of rock facies is conspicuous. This formation unconformably lies on the Kodani formation and is conformably succeeded by the Shoyama formation at its type locality, having its total thickness of about 90 to 260 m. (See FIGS. 1–5).

The formation is principally characterized by pseudoschwagerinids and it was designated as the *Pseudoschwagerina* zone (IMAMURA, 1959; SADA, 1960, '61, '63 and '64). This zone is subdivisible into two subzones, the lower *Rugosofusulina arctica* and the upper *Pseudoschwagerina kanmerai*. The former subzone contains *Rugosofusulina arctica* (SCHELLWIEN), *Triticites kawanoboriensis* HUJIMOTO, *T. obai* TORIYAMA, *T. ozawai* TORIYAMA, *T. montiparus* ((EHRENBERG) MÖLLER), *T.* sp. aff. *T. subventricosus* DUNBAR and SKINNER, *T.* sp. cf. *T. pseudosimplex* CHEN, *Chusenella? atetsuensis* SADA, and *Quasifusulina longissima ultima* KANMERA. On the other hand, the *Pseudoschwagerina kanmerai* subzone is characterized by *Pseudoschwagerina kanmerai*

SADA, *P. pavlovi* (RAUSER-CHERNOUSSOVA), *P. saigusai* NOGAMI, *P. muongthensis* (DEPRAT), *Pseudofusulina vulgaris* (SCHELLWIEN), *P. vulgaris globosa* (SCHELLWIEN), *P. regularis* (SCHELLWIEN), *Schwagerina primigena* NOGAMI, *S. okafuzii* (TORIYAMA), *Triticites kawanoboriensis* HUJIMOTO, and *Chusenella* sp. aff. *C. schwagerinaeformis* SHENG.

The fusulinid assemblages of the *Rugosofusulina arctica* and the *Pseudoschwagerina kanmerai* subzone suggest that the Iwamoto formation is of the Wolfcampian age.



10) Loc. Yu 11, 17, 18, 51, 52, Ym 12
Lepidolina imamurai
Yabeina yasubaensis
Y. shiraiwensis
Y. columbiana
Y. globosa
Y. katoi
Neoschwagerina douvillei
N. margaritae
N. megaspherica
N. toriyamai
N. craticulifera
Sumatrina annae
S. longissima
Verbeekina verbeeki
Pseudodoliolina pseudolepida
Codonofusiella sp.

9) Loc. Yu 13, Yu 24: Ym 11
Yabeina shiraiwensis
Y. columbiana
Y. globosa
Y. katoi
Neoschwagerina douvillei
N. megaspherica
N. margaritae
N. toriyamai
N. craticulifera
Sumatrina annae
S. longissima
Verbeekina verbeeki
Pseudodoliolina ozawai
P. pseudolepida

8) Loc. Yu 15: 22: Yu 23
Neoschwagerina douvillei
N. megaspherica
N. margaritae
N. minoensis
N. toriyamai
Yabeina katoi
Sumatrina annae
S. longissima
Verbeekina verbeeki
Parafusulina armstrongi
Pseudodoliolina pseudolepida

7) Loc. Sh 1
Parafusulina kaerimizensis
P. edoensis
P. armstrongi
Misellina sp.
Verbeekina sp.
Nagatoella kobayashii
Neoschwagerina craticulifera

6) Loc. M 12
Pseudofusulina kraffti magna
P. fusiformis
P. uralika sphaerica
Parafusulina semilucera
P. semilucera granda

5) Loc. Suk 13
Pseudoschwagerina kanmerai
P. pavlovi
Pseudofusulina vulgaris
P. sp.
Chusenella sp.
Triticites kawanoboriensis

4) Loc. SuK 12
Triticites obai
T. sp.

3) Loc. SuK 11
Fusulinella sp.

2) Loc. SuK 9
Endothyra spp.
Pseudoendothyra spp.

1) Loc. SuK 5
Endothyra spp.
Pseudoendothyra spp.

FIG. 3. Mitsumura-Terauchi

2. *Shoyama formation*

The Shoyama formation is present in a relatively limited area of this plateau. The formation is typically developed in the Shoyama area and its good exposures are found at Shimoyukawa, about 1.2 km. to the south of Terauchi, and at Iwamoto, about 900 m. to the east of Terauchi. The formation is composed of grayish to whitish massive limestone and estimated at about 30 to 125 m. in thickness (See FIG. 3).

The formation comprises abundant *Parafusulina* and *Pseudofusulina* and it was called *Parafusulina* zone (IMAMURA, 1959; SADA, 1960, '61, and '63). This zone is furthermore subdivisible into the *Pseudofusulina kraffti magna* subzone and the *Parafusulina kaerimizensis* subzone. The *Pseudofusulina kraffti* subzone is mainly characterized by *P. kraffti magna* TORIYAMA, *P. fusiformis* (SCHELLWIEN), *P. uralika sphaerica* BELJAEV, and *Parafusulina semilucera* (NOGAMI), and the *Parafusulina kaerimizensis* subzone by *Parafusulina kaerimizensis* (OZAWA), *P. edoensis* (OZAWA), *P. armstrongi* THOMPSON, *Verbeekina* sp., *Pseudodoliolina ozawai* YABE and HANZAWA, *Nagatoella kobayashii* THOMPSON, *Misellina* sp., and *Neoschwagerina craticulifera* (SCHWAGER). Judging from the above-listed fusulinids, the Shoyama formation may be considered to be of the Leonardian age in North America.

D. YUKAWA GROUP

The Middle and Upper Permian limestones designated as the Yukawa group (IMAMURA, 1959; SADA, 1960, '61 and '63) occur principally in the northern and

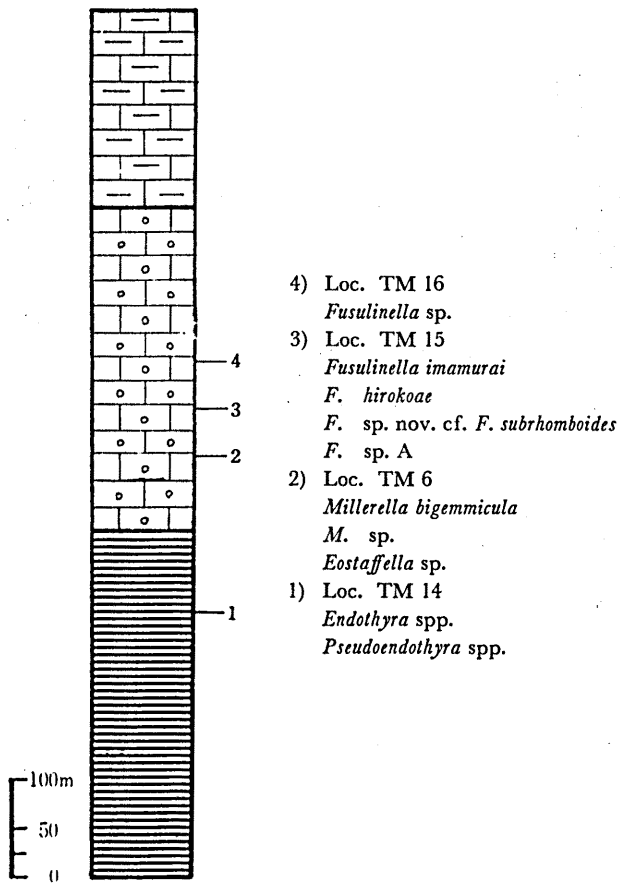
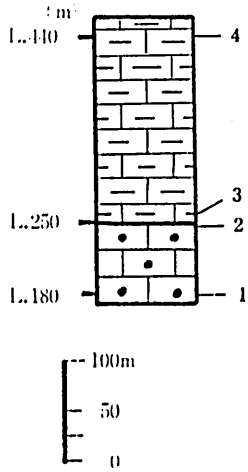


FIG. 4. Mitsudo



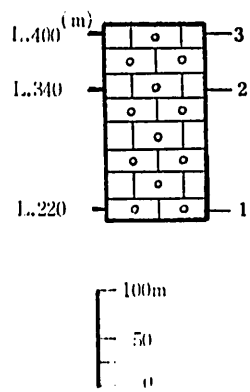
4) Loc. NK 17
Pseudoschwagerina kanmerai
P. saigusai
Pseudofusulina vulgaris
Schwagerina sp.

3) Loc. KT 5
Pseudoschwagerina pavlovi
P. saigusai
Pseudofusulina regularis

2) Loc. Az 9
Neoschwagerina douvillei
N. megaspherica
N. margaritae
N. craticulifera
Verbeekina verbeeki
Sumatrina annae

1) Loc. Az. 10
Neoschwagerina douvillei
N. megaspherica
N. margaritae
N. craticulifera
Verbeekina verbeeki

FIG. 5. Azai

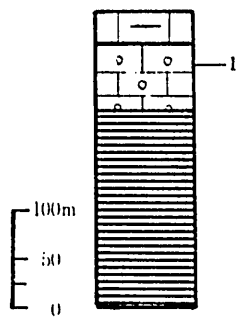


3) Loc. TN 11-14:16
Fusulinella imamurai
F. sp. nov.
cf. *F. subrhomboides*

2) Loc. TN 7-9
Profusulinella toriyamai
P. rhomboides
P. sp. A
P. sp. B
Nankinella plummeri
Staffella powwowensis
Eoschubertella lata
Endothyra spp.

1) Loc. TN 4
Millerella inflecta
M. bigemmicula
Eostaffella kanmerai
E. sp. A
E. sp. B
E.? sp. C
E. sp. D
Pseudostaffella cf. *kanumai*

FIG. 6. Taniai



1) Loc. H 109
Profusulinella toriyamai
P. rhomboides
P. cf. *wangyüi*
P. sp. A
P. sp. B
Eoschubertella sp.

FIG. 7. Hongo

southeastern parts of this plateau, and this group can be divided into two formations, the lower and the upper. The lower Maki formation is composed of limestone conglomerates, while the upper Terauchi formation consists of sandstones and shales with some small lenticular limestones. This group lies unconformably on the Iwamoto and the Shoyama formation of the Sabushi group and the unconformity observed between these two groups was named "Pre-Maki Unconformity" (IMAMURA, 1959) and will be described in detail in the fifth chapter. The total thickness of this group is about 820 m. at the type locality.

Geological horizon — The *Neoschwagerina douvillei* zone to the *Lepidolina imamurai* zone.

1. *Maki formation*

The Maki formation is most typically developed near Maki, Toyonaga-Cho and generally lies parallel to the overlying Terauchi formation. The formation extends from here westwards to Hirosé, Niimi City, though it is cut by some faults of the north-south trend. The good exposures of the formation are found at Yukawa, Tazu and Hirosé, all in the northern block of this plateau, and it is also distributed limitedly at Yorikuni and Azai of the southern block. In this formation the lateral changes of the lithofacies are remarkable. In the areas of Maki, Yukawa, Yorikuni and Tazu, the Maki formation is mainly composed of limestone conglomerates consisting of the pebbles of limestones, shales and cherts derived from the underlying Mitsudo and Sabushi groups, but in the Hirosé area the formation consists of coarse-grained and well bedded conglomeratic limestones including sandy material in matrix. A thin layer of chert lies at the uppermost horizon of this formation in the Yukawa, Tazu and Hirosé areas. This formation overlies unconformably the Iwamoto and Shoyama formations both in the northern and southern blocks of this plateau, and it is in turn followed by the Terauchi formation without any discordance. The formation is estimated at 60 to 110 m. in thickness (See FIGS. 1–3, and 5).

The Maki formation yields abundant neoschwagerinids, and they were formerly reported and described by me (1960 and '61) as *Neoschwagerina douvillei* OZAWA, *N. toriyamai* SADA, *N. megaspherica* DEPRAT, *N. margaritae* DEPRAT, *N. craticulifera* (SCHWAGER), *N. minoensis* DEPRAT, *Yabeina katoi* (OZAWA), *Afghanella* sp., *Verbeekina verbeeki* GEINITZ, *Parafusulina armstrongi* THOMPSON, *Sumatrina annae* VOLZ, *S. longissima* DEPRAT, and *Pseudodoliolina pseudolepida* (DEPRAT).

The Maki formation is characterized by the above-listed fusulinids generally thought to indicate the middle to the upper Middle Permian and it has been called *Neoschwagerina douvillei* zone (IMAMURA, 1959; SADA, 1960, '61, and '63).

IMAMURA (1959) established the Kanikawa formation overlying the Shoyama formation in the Kanikawa area, and designated it to be characterized by *Verbeekina verbeeki* GEINITZ. However, according to my study, the Kanikawa formation comprises not only *Verbeekina verbeeki* GEINITZ but also *Neoschwagerina douvillei* OZAWA, *N. megaspherica* DEPRAT, *N. margaritae* DEPRAT, etc. and it is identifiable in the specific composition to the Maki formation fully mentioned above. Therefore, I can hardly

avoid the conclusion that the Kanikawa formation should be referred to the Maki formation.

2. *Terauchi formation*

This formation crops out typically in the Terauchi area and forms a synclinorium generally pitching westwards, but the distribution of the strata is cut by the faults of the north-south trend. The formation is distributed at several small and isolated areas such as Tazu, Tarumi, Hirosé, Kanatsugi and Hanagi. The rocks of its lower part are black shales with small lenticular limestone conglomerates occurring in four stratigraphic horizons, the lower three of which yield abundant fusulinids, and its upper part consists of black shales, fine-grained and coarse-grained sandstones in ascending order. The formation at the type locality is about 750 m. in thickness (See FIGS. 1-3).

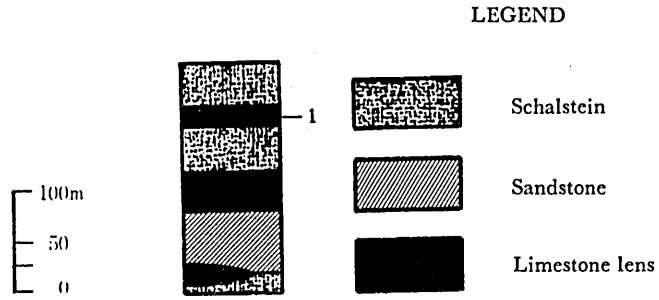
The small lenticular limestone conglomerates (Pm δ) of the basal part of this formation yield abundantly the following fusulinid species, viz., *Yabeina shiraiwensis* OZAWA, *Y. columbiana* (DAWSON), *Y. globosa* (YABE), *Y. katoi* (OZAWA), *Neoschwagerina craticulifera* (SCHWAGER), *N. margaritae* DEPRAT, *N. douvillei* (OZAWA), *N. megaspherica* (DEPRAT), *N. toriyamai* SADA, *N. minoensis* DEPRAT, *Sumatrina annae* VOLZ, *S. longissima* DEPRAT, *Verbeekina verbeeki* (GEINITZ), *Pseudodoliolina ozawai* YABE and HANZAWA, and *P. pseudolepida* (DEPRAT). The basal part of this formation characterized by the above-listed fusulinids was already defined as *Yabeina shiraiwensis* zone (SADA, 1961).

The lenticular limestone conglomerates (Pu α) of the lower Terauchi formation designated as the *Lepidolina imamurai* zone (SADA, 1960 and '61) contain abundant species of *Neoschwagerina*, *Yabeina*, *Lepidolina* and others. The fusulinids are as follows, viz., *Lepidolina imamurai* SADA, *Yabeina shiraiwensis* OZAWA, *Y. columbiana* (DAWSON), *Y. globosa* (DEPRAT), *Neoschwagerina craticulifera* (SCHWAGER), *N. douvillei* (OZAWA), *N. megaspherica* DEPRAT, *N. margaritae* DEPRAT, *Sumatrina annae* VOLZ, *S. longissima* DEPRAT, *Pseudodoliolina pseudolepida* (DEPRAT), *Codonofusiella* sp., and *Schwagerina* sp.

The fusulinid assemblages of Pm δ and Pu α reveal the Terauchi formation to be of the Ochoan age in North America.

E. ISHIGA FORMATION

The Ishiga formation was first studied by MOCHIZUKI (1938) and its stratigraphic position has been placed under the Atetsu Limestone. Afterwards KOBAYASHI (1950) expressed his opinion that the Ishiga formation should be considered in correlation with the Fuka and the Mihara-Otake formation of the Oga area which were formerly thought to be of the Namurian to Moscovian age. The Ishiga formation typically lies in the south of the plateau, having the general trend in a direction of the east-west, and it crops out limitedly in the narrow belt from Himebara to Kanikawa. The Ishiga formation estimated at 1,450 m. thick comprises two members, the lower and the upper. The about 1,220 m. thick lower member is composed of sandstones and black shales, while the about 230 m. thick upper member consists of schalsteins,



1) Loc. 426

Endothyra spp.

FIG. 8. Himebara

small lenticular limestones, sandstones, cherts and schalsteins in ascending order (See FIG. 8). The small lenticular limestones of the upper member yield some species of *Endothyra* and *Pseudoendothyra* referable to those of the Mississippian Nagoe formation. However, to determine more accurate geologic age, the further study of endothyroid foraminifera will be needed in future. The fossil localities are Himebara and Ihara. The formation forms an anticlinal fold in the Ishiga-Ihara area and its axis runs in a direction of NW–SE with the pitch to the west. The formation inclines apparently monoclinally towards the north with the angles of 20 to 80 degrees in the Himebara area and towards the south with the angles of 35 to 50 degrees in the Ihara area. The drag folds are commonly present in this formation but most of them are generally of moderate intensity. The folded Ishiga formation stated above is cut by the faults of the northeast-southwest trend.

F. TANIAI PHYLLITE GROUP

The phyllitic rocks in the Taniai area formerly called the Taniai (lower) and Ikura (upper) formations by MOCHIZUKI (1938) is newly designated here as the Taniai phyllite group. In his comprehended study of the Atetsu district, IMAMURA (1958) pointed out that this phyllite group might be referred to the so-called Sangun metamorphic rocks. On the other hand, the group in this area was mapped and briefly described by MITSUNO (1958) and he also provided the age of the sedimentation of this group without any paleontologic evidences. According to him, the geologic age was considered not to be younger than the lower Carboniferous. The group is mainly characterized by black phyllite and green phyllite with thin limestone lenses. The total thickness may attain to 1,105 m. Most of the intercalated thin limestone lenses in this group are crystalline and any fossil remains have not yet

been recorded in them. However, fortunate enough, I have been able to discover *Clisiopyllum* sp. cf. *C. awa* (MINATO) from an intercalated non-crystallized small limestone lens at Miyahara. The present species is known in the Nagoe formation of the Atetsu Limestone but the further study is needed for the definite determination of the geologic age of this group. The columnar section of this group is shown as FIG. 9.

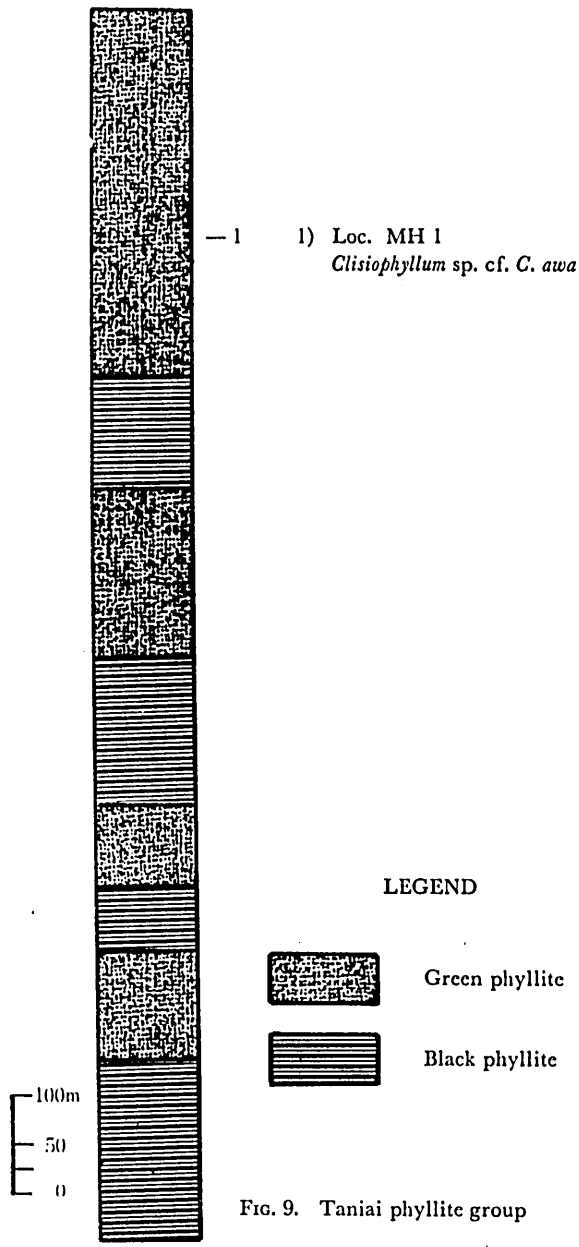


FIG. 9. Taniai phyllite group

IV. Geologic Structure

The Atetsu Limestone is divisible into two blocks, the northern and the southern, by a reversed fault that runs parallel with the striks of the limestone beds and dips towards the north. In the northern part of the Atetsu plateau, however, the reversed fault rapidly changes in its general trend from the east-west to the north-south, dipping towards the west at fairly high angles. Ordinarily, this reversed fault has been called "the Atetsu thrust" since it was pointed out by Imamura (1959).

In the northern block, the Mitsudo group is successively followed by the Sabushi group, and that in turn by the Yukawa group. These three groups in the western part of this plateau generally dip due north at 30 to 40 degrees, having a strike of the east-west, while in the northeastern part of the plateau they dip towards the west at about 50 degrees, giving a strike of the northwest-southeast. In this plateau it is noteworthy that the northern block thrusts up the Permian Sabushi group of the southern block at its schalstein beds which are the lowest part of the Nagoe formation of the lower Mitsudo group.

In the southern block, the massive limestones with the general strike of the east-west in the western part of this plateau are widely developed and their lowest part is for the most part represented by the Kodani formation of the upper Mitsudo group, which contains the *Millerella bigemmicula-Eostaffella kanmerai*, *Profusulinella toriyamai* and *Fusulinella imamurai* zones as stated before. The Kodani formation is overlain by the Sabushi group in the normal order in the western and northeastern parts and the lower part of the formation is in immediate contact with the Ishiga formation through the normal fault with a general trend of the east-west. In the Taniai and Hanagi areas the Atetsu Limestone forms an overturned fold, the axial plane of which is inclined at the low angles towards the north from the south. In the Kanikawa area where the stratigraphically lower fusulinid zones occur at the topographically higher positions, the lower wing of the overturned anticline has been observed as they are. In the Taniai area the southern block thrusts up the Taniai phyllite group and also in the Hanagi area thrusts up the Terauchi formation.

The Atetsu Limestone stated above in detail is cut by several faults with the general trends of the northeast-southwest or the north-south (See Pl. 1).

V. Carboniferous-Permian Boundary and Pre-Maki Unconformity

The *Pseudoschwagerina* zone most widely distributed in the Atetsu Limestone plateau and subdivisible into the *Rugosofusulina arctica* and *Pseudoschwagerina kanmerai* subzones, generally overlies the *Fusulinella imamurai* zone parallel with the general trend of the distribution of the underlying *Profusulinella toriyamai*, *Millerella bigemmicula-Eostaffella kanmerai*, and *Endothyra-Pseudoendothyra* zones. The Carboniferous of the Atetsu Limestone is represented by the three fusulinid zones and an endothyroid zone, and lacking in the rocks which may be referred to the *Fusulina* and *Triticites* zones indicat-

ing the Desmoinesian and the Missourian-Virgilian, respectively.

In the Permian of this limestone, the stratigraphic relation between the *Parafusulina kaerimizensis* zone and the *Neoschwagerina douvillei* zone has been recognized as the remarkable unconformity, the general characters of which were explained by IMAMURA (1959) and SADA (1960, '61 and '63), and IMAMURA (1959) called it Pre-Maki Unconformity. As stated before the *Neoschwagerina douvillei* zone directly overlies the *Parafusulina* zone or the *Pseudoschwagerina* zone. The *Neoschwagerina douvillei* zone is composed of the limestone conglomerate which contains the pebbles of limestone, chert and black shale, and all of them seem to be derived from the various horizons from the *Endothyra-Pseudoendothyra* zone to the *Parafusulina kaerimizensis* zone of the Carboniferous and Permian Atetsu Limestone. On the other hand, it is worthy to note that the *Parafusulina kaerimizensis* subzone developed under the hiatus cited above is much more limited in its distribution, while the *Neoschwagerina douvillei* zone occupies a rather considerably wide area in this plateau. From all these considerations, it would seem that the *Parafusulina kaerimizensis* subzone is the deposit in the time of the regression. The stratigraphic hiatus in the Middle Permian, which is equivalent to that of the Atetsu Limestone, has been observed in the stratigraphic boundary between the *Neoschwagerina* zone (*Neoschwagerina douvillei* zone) and the *Parafusulina* zone of the Taishaku Limestone (YOKOYAMA, 1958), between the *Neoschwagerina margaritae* zone and its underlying fusulinid zone of the Joé Limestone (SADA, 1963), and between the middle part and the lower part of P_2 zone of the Omi Limestone (FUJITA, 1958). It seems to me that these facts have the very important key to decipher what mean Pre-Maki Unconformity has in the Inner Zone of Southwest Japan.

VI. FUSULINID ZONES AND THEIR CORRELATIONS

A. GENERAL REMARKS

The species of fusulinids have been considered as index fossils for stratigraphic correlations in local areas and the ranges of genera have been employed for interregional as well as intercontinental correlations. THOMPSON (1948) designated nine fusulinid zones: the *Millerella* zone, the *Profusulinella* zone, the *Fusulinella* zone, the *Fusulina* zone, the *Triticites* zone, the *Pseudoschwagerina* zone, the *Parafusulina* zone, the *Neoschwagerina* zone and the *Yabeina* zone. Several years later, in his study of the Kuma faunas KANMERA (1954) established the *Lepidolina* zone in the Upper Permian of Japan. Besides them, ZELLER (1957) set up the *Endothyra* and the *Plectogyra* zone in the Mississippian of North America on the basis of his paleontological studies of the endothyroid foraminifera from the Cordilleran region. As stated before, the Atetsu Limestone is lacking in the typical *Fusulina* and *Triticites* zones. The stratigraphic ranges of fusulinids of this limestone are shown as TABLE 3.

TABLE 3. STRATIGRAPHIC RANGES OF FUSULINIDS OF THE ATETSU LIMESTONE

Specific Name / Fusulinid Zone		Cl$_\alpha$	Cu$_\alpha$	Cu$_\beta$	Cu$_\gamma$	Pl$_\alpha$	Pl$_\beta$	Pm$_\alpha$	Pm$_\beta$	Pm$_\gamma$	Pm$_\delta$	Pu$_\alpha$
	Age	Carboniferous				Permian						
1	*Endothyra* spp.											
2	*Pseudoendothyra* spp.											
3	*Millerella inflecta*											
4	*M. bigemmicula*											
5	*Eostaffella kanmerai*											
6	*E.* sp. A											
7	*E.* sp. B											
8	*E.*? sp. C											
9	*E.* sp. D											
10	*Pseudostaffella* cf. *kanumai*											
11	*Profusulinella toriyamai*											
12	*P. rhomboides*											
13	*P.* cf. *wangyüi*											
14	*P.* sp. A											
15	*P.* sp. B											
16	*Nankinella plummeri*											
17	*Staffella powwoensis*											
18	*Eoschubertella lata*											
19	*E.* sp.											
20	*Fusulinella imamurai*											
21	*F.* sp. nov. cf. *F. subrhomboides*											
22	*F. hirokoae*											
23	*F.* sp. A											
24	*Fusnlina* sp.											
25	*Triticites kawanoboriensis*											
26	*T. obai*											
27	*T. ozawai*											
28	*T. montiparus*											
29	*T.* sp. cf. *T. pseudosimplex*											
30	*T.* sp. aff. *T. subventricosus*											
31	*Rugosofusulina arctica*											
32	*Chusenella*? *atetsuensis*											
33	*C.* sp. aff. *C. schwagerinaeformis*											
34	*Quasifusulina longissima ultima*											
35	*Pseudoschwagerina kanmerai*											
36	*P. pavlovi*											
37	*P. saigusai*											
38	*P. muongthensis*											
39	*Pseudofusulina vulgaris*											
40	*P. vulgaris globosa*											
41	*P. regularis*											
42	*Schwagerina primigena*											
43	*S. okafujii*											
44	*Pseudofusulina kraffti magna*											
45	*P. fusiformis*											
46	*P. uralika sphaerica*											
47	*Parafusulina semilucera*											
48	*P. semilucera granda*											
49	*P. kaerimizensis*											
50	*P. edoensis*											
51	*P. armstrongi*											
52	*Nagatoella kobayashii*											
53	*Misellina* sp.											
54	*Verbeekina* sp.											
55	*V. verbeeki*											
56	*Pseudodoliolina ozawai*											
57	*P. pseudolepida*											
58	*Codonofusiella* sp.											
59	*Neoschwagerina craticulifera*											
60	*N. dowillei*											
61	*N. toriyamai*											
62	*N. megaspherica*											
63	*N. minoensis*											
64	*N. margaritae*											
65	*Yabeina katoi*											
66	*Y. globosa*											
67	*Y. shiraiwensis*											
68	*Y. yasubaensis*											
69	*Y. columbiana*											
70	*Lepidolina imamurai*											
71	*Sumatrina annae*											
72	*S. longissima*											
73	*Afghanella* sp.											

B. Fusulinid Zones

1. *Endothyra-Pseudoendothyra Zone (Cl α)*

The Nagoe formation is characterized by many species of endothyroid foraminifera. Okimura (1958) divided the lower part of the Atetsu Limestone into the *Plectogyra communis* zone, the *Plectogyra primaeva* zone, the *Endothyra spiroides* zone, the *Endothyra symmetrica* zone, and the *Atetsuella meandera* zone from the lower to the upper, and described thirteen species of endothyroids such as *Plectogyra communis* (Rauser-Chernoussova), *P. primaeva* (Rauser-Chernoussova), *P.* aff. *omphalata* (Rauser-Chernoussova and Reitlinger), *Endothyra discoidea* (Igo), *E.* aff. *radiata* Brady var. *tateana* Howchin, *E. spiroides* Zeller, *E. symmetrica* Zeller, *Granuliferella pauciseptata* Okimura, *Paraplectogyra masanae* Okimura, *P. longiseptata* Okimura, *P. gigantea* Okimura, *Atetsuella imamurai* Okimura and *A. meandera* Okimura. As a result of his study, Okimura was of the opinion that these five zones might be correlated with the Osagian to the Chesterian endothyroid ones described by Zeller (1957) from the Cordilleran region in North America. Having studied the lower part of this limestone, I concluded that the *Atetsuella meandera* zone should be referred to the Middle Pennsylvanian *Profusulinella toriyamai* zone (Sada, 1961). In his recent study of the Akiyoshi Limestone Okimura (1963) inclined to the view that the *Plectogyra communis* zone, the *P. primaeva* zone and the *Endothyra spiroides* zone indicated the geologic age ranging from the Lower Viséan to the Upper Viséan and that *Endothyra symmetrica* zone indicated the Lower Bashkirian. At the same time, *Plectogyra communis*, *P. primaeva* and *Endothyra spiroides*, all of them are zone fossils, were transferred to *Endothyra* sp. A, *E.* sp., and *Pseudoendothyra spiroides*, respectively. The Nagoe formation studied by me is represented by the *Endothyra* sp. A, *E.* sp. and *Pseudoendothyra spiroides* zones.

A large number of the specimens of endothyroid foraminifera were obtained by me from the Nagoe formation in the Atetsu plateau but the paleontological study of these materials has not yet been carried out. Therefore, so far as the geologic age of this zone is concerned, I would like to support the opinion that the endothyroid fauna is similar to the Mississippian endothyroid faunas of North America.

2. *Millerella bigemmicula-Eostaffella kanmerai Zone (Cu α)*

The informations as to the *Millerella* zones of Japan have been imparted by such workers as Kanmera (1952), Minato (1953) and Igo (1957). In the Atetsu Limestone, the lowest part of the Kodani formation, the upper part of the Mitsudo group, was tentatively called the *Millerella* zone (Imamura, 1959). Therefrom *Millerella inflecta* Thompson, *M. bigemmicula* Igo, *Eostaffella kanmerai* (Igo), *E.* sp. A, *E.* sp. B, *E?* sp. C, *E.* sp. D, and *Pseudostaffella kanumai* Igo were described by me (1964) and then the lowest part of this formation containing above-cited species was newly designated as *Millerella bigemmicula-Eostaffella kanmerai* zone. The zone was also correlated to the North American Lower Pennsylvanian *Millerella* zone.

From his stratigraphical and paleontological studies, KANMERA (1952) described corals and fusulinids from the lower part of the Kakisako formation distributed in a narrow belt of ENE–WSW trend in the Kakisako area of Kyushu. Corals are *Dibunophyllum* cf. *kankouensis* YÜ, *Kueichophyllum* cf. *latifossulatum* KANMERA, *Diphyphyllum platiforme kakisakoense* KANMERA, *Siphonodendron* sp., and *Hexaphyllia* sp. A. Fusulinids are *Millerella japonica* KANMERA, *M. gigantea* KANMERA, *M.* spp. A and B, *Endothyra* sp. and *Saccamminopsis carteri* (BRADY). KANMERA thereby concluded that the Kakisako fauna stated above was correlated with the Chesterian *Millerella* zone of North America.

MINATO (1953) reported fusulinids and some smaller bodies of foraminifera in association with a large number of corals and brachipods from the Upper Viséan Onimaru formation in the Kitakami Massif, which is mainly composed of limestones accompanied by black slates and alternation of clayslate and limestone. Fusulinids and smaller foraminifera were listed as *Millerella* sp. *Eostaffella* sp., *Endothyra parvra* MÖLLER, *E.* sp., *Cribrostomum texturiforme* MÖLLER, *C. panderi* MÖLLER and *Saccamminopsis carteri* (BRADY).

As understood by the facts described above, the Atetsu fauna can be distinguished from both Kakisako and Onimaru faunas in the faunal assemblage and the specific comparison.

The abundant species of *Millerella* and *Eostaffella* occur in the lower part of the Ichinotani formation (IGO, 1957) in the Fukuji district and this part was already designated as *Millerella* zone (IGO, 1957). Furthermore, this zone was subdivided into two subzones, the lower *Eostaffella kanmerai* subzone and the upper *Millerella bigemmicula-Pseudostaffella kanumai* subzone. The faunal assemblage of the *Eostaffella kanmerai* subzone is somewhat unique and mainly characterized by *Eostaffella kanmerai* (IGO), *Millerella komatui* IGO, *M. discoidea* IGO in association with corals to indicate the Chesterian age. Most of the species of *Eostaffella kanmerai* subzone are different from the species described from the *Millerella bigemmicula-Eostaffella kanmerai* zone of the Kodani formation of Atetsu. However, from *Millerella bigemmicula-Pseudostaffella kanumai* subzone the following species have been discriminated: *Millerella bigemmicula* IGO, *M.* cf. *marblensis* THOMPSON, *M.* sp., *Eostaffella* (=*Paramillerella*) sp., *Nankinella* cf. *plummeri* THOMPSON, *Staffella* sp., *Pseudostaffella kanumai* IGO and *P. kanumai pauciseptata* IGO. Of these, *Millerella bigemmicula* and *Pseudostaffella kanumai* including *P. kanumai pauciseptata* have also been found in the *Millerella-Eostaffella* zone of the Kodani formation. Judging from the assemblage of the species of fusulinids, the *Millerella bigemmicula-Eostaffella kanmerai* zone of the Kodani formation may be approximately equivalent to the *Millerella bigemmicula-Pseudostaffella kanumai* zone.

TORIYAMA (1958) descriminated the rocks comprising the species of *Millerella* from the lower part of the Akiyoshi Limestone and designated it as the *Millerella* sp. α zone. Recently, MURATA (1961) reported some species of *Millerella* under the names of *Millerella komatui* IGO, *M. uzurensis* MURATA (MS) and *M.* cf. *marblensis* THOMPSON from the TORIYAMA's *Millerella* sp. α zone and he correlated this zone

with the Chesterian to the Morrowan *Millerella* zone of North America. From his stratigraphical and paleontological studies of the Carboniferous rocks of the Akiyoshi Limestone in the Okubo area, OKIMURA (1963) reported the species of *Millerella* which was closely similar to *M. marblensis* THOMPSON. As stated above, the *Millerella* fauna of the Akiyoshi Limestone includes the identical or the allied species to those of the fauna of the Kodani formation.

THOMPSON (1942–1948) described *Millerella inflecta* THOMPSON, *M. circuli* THOMPSON and *M. marblensis* THOMPSON from the Lower Pennsylvanian formations of Texas, Arkansas, Kansas, Colorado, Utah, and New Mexico in North America. Of these species, the first one is the same as that of the Atetsu fauna and the second is somewhat allied in the general development of the shell to *Eostaffella kanmerai* (IGO) described by me. These facts indicate that the *Millerella bigemmicula-Eostaffella kanmerai* zone may probably be contemporaneous with the Lower Pennsylvanian *Millerella* zone of North America.

3. *Profusulinella toriyamai Zone (Cu β)*

IMAMURA (1959) pointed out the presence of *Eoschubertella* and *Profusulinella* in the middle part of the Kodani formation and tentatively defined it *Eoschubertella* zone. In 1961, from the same zone I described *Profusulinella toriyamai* SADA, *P. rhomboides* (LEE et CHEN), *P.* cf. *wangyüi* SHENG, *P.* sp. A, *P.* sp. B, *Nankinella plummeri* THOMPSON, *Staffella powwowensis* THOMPSON, *Eoschubertella lata* (LEE et CHEN) and *E.* sp., among which *Profusulinella toriyamai* is the most characteristic and important for the biostratigraphic zonation. On the other hand, genus *Eoschubertella* was unsuitable for the international correlation, so the present name of the zone was given by me (1961). The *Profusulinella* zones similar to the *Profusulinella toriyamai* zone of the Atetsu Limestone have been known exactly from the Akiyoshi Limestone, the Ichinotani formation of the Fukuji area, and the Omi Limestone in Niigata Prefecture in the Inner Zone of Japan. Having an eye to the Carboniferous fusulinid faunas of North America, there are many faunas described from various localities and most of them are characterized by the typical forms of *Profusulinella* and its associated fusulinids.

Profusulinella beppensis zone (Cm α) of the Akiyoshi Limestone develops in the eastern and southeastern parts of the Akiyoshi plateau and is composed of the massive limestone. From this zone TORIYAMA (1958) described some species of *Profusulinella* and their associated fusulinids such as *Profusulinella beppensis* TORIYAMA, *P. rhomboides* (LEE et CHEN), *P.* sp. A, *Akiyoshiella ozawai* TORIYAMA, *A.* sp., *Fusulinella* sp., *Nankinella* sp., *Staffella akagoensis* TORIYAMA, *Eoschubertella obscula* (LEE et CHEN), and *E.* sp. A. Of these, *Profusulinella rhomboides* is commonly found in the *Profusulinella toriyamai* zone of the Kodani formation and *P.* sp. A was already designated as the holotype of *P. toriyamai* SADA from the same formation. *Profusulinella beppensis* is somewhat similar to *P. toriyamai* in the general stage of evolution. *Eoschubertella* sp. A of TORIYAMA (1958, pp. 27–28, pl. 1, figs. 15–16) resembles *E.* sp. (SADA, 1961, p. 112,

pl. 10, figs. 16–21) of the *Profusulinella toriyamai* zone in some respects. *Akiyoshiella* has not yet been found in this zone.

The *Profusulinella toriyamai* zone of the Kodani formation can be correlated with the *Profusulinella beppensis* zone of the Akiyoshi Limestone based on the species discussed above.

The *Profusulinella fukujiensis* zone (IGO, 1957) of the Ichinotani formation in the Hida Massif overlies the *Millerella bigemmicula-Pseudostaffella kanumai* subzone and carries the following fusulinids, viz., *Profusulinella fukujiensis* IGO, *Pseudostaffella* sp., *Eostaffella ampla* (THOMPSON), *Millerella* cf. *marblensis* THOMPSON and *M.* sp. In some biocharacters *Profusulinella fukujiensis* IGO has a remarkable resemblance to *P. toriyamai* SADA but they are not the same species. From the occurrences of *Profusulinella fukujiensis* and its associated primitive fusulinids, I have arrived at the conclusion that the *Profusulinella toriyamai* zone corresponds with the *P. fukujiensis* zone of the Ichinotani formation.

SAKAGAMI (1963) reported and described *Profusulinella* sp. from the *Millerella*-Coral-Brachiopod zone (FUJITA, 1958) of the Omi Limestone in Niigata Prefecture. As stated by SAKAGAMI, this species somewhat resembles *Profusulinella beppensis* TORIYAMA from the Akiyoshi Limestone and its related species, viz., *Profusulinella fukujiensis* IGO from the Ichinotani formation which resembles somewhat *P. toriyamai* SADA from the Atetsu Limestone. Since *Profusulinella* has proved of such value for age determination, the occurrence of the genus in the Omi Limestone seems to be worthy of special consideration.

In North America a number of the typical species of *Profusulinella* and its associated fusulinids have been described. THOMPSON (1958) described *Profusulinella regia* THOMPSON, *P. decora* THOMPSON, *P. munda* THOMPSON, *P. copiosa* THOMPSON, *P.* sp. A, *Staffella powwowensis* THOMPSON, *S. depressa* THOMPSON, *Nankinella* sp. and *Millerella marblensis* THOMPSON from the upper part of the Green Canyon group in Powwow Canyon, Texas. From the Apodaca formation of the upper part of the Green Canyon group in southern New Mexico, THOMPSON (1958) described two species of *Profusulinella*, viz., *P. apodacensis* THOMPSON and *P. spicata* THOMPSON. THOMPSON and ZELLER (1956) reported the lower Derryan *Profusulinella* fauna, which overlay the Morrowan *Millerella-Staffella* fauna, of the Conger Mountains of the Confusion Range, Western Utah. Therefrom they described *Profusulinella regia* THOMPSON, *P. apodacensis* THOMPSON and *P. spicata* THOMPSON, and correlated the lower Derryan *Profusulinella* fauna of Utah with the lower Derryan *Profusulinella* fauna of Hueco Mountains of Texas. In his stratigraphical and paleontological studies of the Pre-Desmoinesian Pennsylvanian rocks in Llano Uplift, Texas, THOMPSON (1947) brought to light the *Profusulinella* faunas from the lower part of the Big Saline Limestone of Honey Creek in Mason County and the upper part of the Marble Falls Limestones in Rough Creek and Mcannelly's Bend area in San Saba County. According to him the upper part of the Marble Falls Limestones of Rough Creek and Mcannelly's Bend areas contains a prolific fauna of fusulinids composed of *Millerella*

marblensis, *Staffella*? sp., *Nankinella plummeri*, *Eoschubertella texana*, *Profusulinella marblensis*, and *Pseudostaffella* aff. *P. needhami* THOMPSON, and the lower part of the Big Salin Limestone of Honey Creek contains *Profusulinella* sp. A and *P.* sp. B. And he concluded these faunas were of the equivalent age to those of the type Derryan of New Mexico and of the Hueco Mountains of Texas. As already described in my preceding paper (1961), the *Profusulinella toriyamai* zone of the Atetsu Limestone includes many species allied to those of the North American *Profusulinella* zone, for example, *Profusulinella toriyamai* has the similarity to *P. copiosa* THOMPSON in the shell-shape, the spirothecal structure of *P. rhomboides* (SADA, 1961, p. 99, pl. 9, figs. 14–34) seems to be somewhat similar to those of *P. decora* THOMPSON and *P. munda* THOMPSON, and *P.* sp. A (SADA, 1961, pp. 104–105, pl. 10, figs. 4–8) closely resembles *P. regia* THOMPSON. These facts strongly suggest that both the *Profusulinella toriyamai* zone and the North American *Profusulinella* zones may be of the equivalent age.

4. *Fusulinella imamurai Zone* (*Cu* γ)

Discovering the *Fusulinella* fauna in the lower part of the Atetsu Limestone, MOCHIZUKI (1938) named this part *Fusulinella biconica* zone. However, no *F. biconica* has been collected from any localities of the Atetsu Limestone plateau. IMAMURA (1959) suggested the occurrence of *Fusulinella* and tentatively called the upper part of the Kodani formation the *Fusulinella* zone. The Imamura's *Fusulinella* zone was studied in detail by me (1964) and it was newly designated as the *Fusulinella imamurai* zone.

This zone occupies the upper part of the Kodani formation and includes the following species, viz., *Fusulinella imamurai* SADA, *F.* sp. nov. cf. *F. subrhomboides* LEE and CHEN, *F. hirokoae* SUYARI, *F.* sp. A and only one indeterminable species of *Fusulina*. In Japan, the equivalent zones in age to the *Fusulinella imamurai* zone chiefly occur in the following areas, namely, the *Fusulinella biconica* zone of Akiyoshi, the *Fusulinella* zone of the Ichinotani formation in the Hida Massif, the *Fusulinella* zone of Omi, and the *Fusulinella* zones of Shikoku. In China the *Fusulinella* faunas have been reported by LEE and CHEN, and SHENG from the Huanglung Limestone and the Taitzeho Valley, respectively. On the other hand, THOMPSON described a large number of species of *Fusulinella* from various localities and established the *Fusulinella* zones in North America.

The assemblage of the species of the *Fusulinella biconica* zone of Akiyoshi (TORIYAMA, 1954, '58) is somewhat similar to that of the *Fusulinella imamurai* zone of the Atetsu Limestone, comprising *Fusulinella biconica* (HAYASAKA), *F. itoi* OZAWA, *F.* cf. *bocki* MÖLLER, *F.* cf. *pseudobocki* (LEE et CHEN), *F. subspherica* TORIYAMA, *F.* spp. A, B and C, *Fusulina akiyoshiensis* TORIYAMA and *Fusiella* cf. *typica* LEE et CHEN, which indicate the upper Derryan of North America. The identical species is not observable in both zones. However, *Fusulinella itoi* of TORIYAMA (1958, pp. 48–52, pl. 4, figs. 3–6) is somewhat similar to *F.* sp. nov. cf. *F. subrhomboides* LEE and CHEN (SADA, 1964, pp. 237–239, pl. 23, figs. 1–4, 6) and *F.* cf. *bocki* (1958, pp. 39–43, pl. 2,

figs. 20–22) resembles somewhat *F.* sp. A (SADA, 1964, pp. 240–241, pl. 23, figs. 5, 7) of the Atetsu Limestone in the general stage of the development of the shell, and furthermore the association of the primitive species of *Fusulina* is seen in the *Fusulinella imamurai* zone as well as the *F. biconica* zone. These facts strongly suggest that both zones are of the same age.

In the Ichinotani formation the *Fusulinella* zone established by IGO (1957) was subdivided into two subzones, the lower *Fusulinella kamitakarensis* and the upper *F. asiatica.* Therefrom he discriminated the following species, viz., *Fusulinella kamitakarensis* IGO, *F. pseudobocki* (LEE and CHEN), *F. jamesensis* THOMPSON, *F. asiatica* IGO, *F.* cf. *gracilis* KANMERA, *F. hanzawai* IGO, *Staffella powwowensis* THOMPSON, *Eoschubertella lata* (LEE and CHEN), *E. obscura* (LEE and CHEN), and *Fusiella typica* LEE and CHEN. Among them, as already pointed out by me (1964), *Fusulinella hanzawai* is allied to *F. hirokoae* in its shell-characters. *Fusulinella gracilis* of IGO is somewhat similar to *F. imamurai* in some features and these two species appear to be of closely similar age.

The *Fusulinella bocki-Fusulinella prolifica* subzone (SUYARI, 1962), the lower part of the *Fusulinella-Fusulina* zone of the Shogase and the Daigo group in Shikoku, contains *Fusulinella bocki* (MÖLLER), *F. schwagerinoides* (DEPRAT), *F. prolifica* THOMPSON, *F. hirokoae* SUYARI, *Beedeina* spp. A and B. Of these, *Fusulinella bocki* is one of the most well-known species in Japanese *Fusulinella* zones, associating with the typical species of *Fusulinella* and the primitive species of *Fusulina. Fusulinella* sp. A (SADA, 1964, pp. 240–241, pl. 23, figs. 5 and 7) which is more or less deformed, may be comparable with *F. bocki* of SUYARI. *Fusulinella hirokoae* (SADA, 1964, pp. 239–240, pl. 23, figs. 12–15) has been described from the *Fusulinella imamurai* zone of the Kodani formation of Atetsu.

It_1, It_2 and It_3 zones of the Itadorigawa Limestone (ISHII, 1961) in Shikoku contain abundant species of *Fusulinella*, several species of *Fusulina* and their associated species of other genera. The species of *Fusulinella* are *F. bocki* MÖLLER, *F. bocki rotunda* ISHII, *F. bocki biconiformis* ISHII, *F. simplicata* TORIYAMA, *F. simplicata onoi* ISHII, *F. simplicata* var. α, *F. simplicata* var. β, *F. pygmae* ISHII, and *F. elegantula* ISHII. These species of *Fusulinella* has no close similarity to the species from the Kodani formation of Atetsu. However, *F. bocki* and *F. simplicata* are the important species for the zonal subdivision and correlation of the middle Middle Pennsylvanian rocks in the province of eastern Asia, and these two species are quite common in the *Fusulinella biconica* zone of Akiyoshi, associating with some other typical species of *Fusulinella* and *Fusulina.* Taking the assemblage of the species and their general stage of evolution into the consideration, the It_1, It_2 and It_3 zones of the Itadorigawa Limestone may probably be equivalent in age to the *Fusulinella imamurai* zone of the Kodani formation.

KAWADA (1954) and FUJITA (1958) independently reported *Fusulinella biconica* (HAYASAKA), *F. bocki* MÖLLER and *F.* cf. *girtyi* (DUNBAR et CONDRA) from the *Fusulinella* zone of the Omi Limestone in Niigata Prefecture. *Fusulinella biconica* and

F. bocki, which are typical of the genus, are well known and the valuable species for the correlation of the Japanese *Fusulinella* zones. The occurrence of these species in the Omi Limestone strongly suggests that the *Fusulinella* zone defined by KAWADA and FUJITA is of the middle Middle Pennsylvanian age.

The fusulinids from the lower part of the Huanglung Limestone in southeastern China (LEE, CHEN and CHU, 1930) are *Fusulinella parva* LEE et CHEN, *F. parva convoluta* LEE et CHEN, *F. bocki* (MÖLLER), *F. pseudobocki* LEE et CHEN, *F. fluxa* LEE et CHEN, *F. schwagerinoides* (DEPRAT), *F. subrhomboides* LEE et CHEN, *F. chuanshanensis* LEE et CHEN, *F. chuanshanensis ellipsoides* LEE et CHEN, *F. colaniae* LEE et CHEN, and some species of *Fusulina*. These Huanglung species are typical of genus *Fusulinella* in the internal characters and their evolutional stage. *Fusulinella imamurai* (SADA, 1964, pp. 235–237, pl. 23, figs. 8–11) and *F.* sp. A (SADA, 1964, pp. 240–241, pl. 23, figs. 5, 7) somewhat resemble *F. chuanshanensis* (LEE et CHEN, 1930, pp. 126–127, pl. 11, figs. 4–6) and *F. bocki* (LEE et CHEN, 1930, pp. 121–122, pl. 8, figs. 8–15; pl. 9, figs. 1–9), respectively, in the shell-shape and some internal characters, and at the same time some species of *Fusulina* first appear in this horizon in association with the typical species of *Fusulinella*. These facts show that the faunal assemblage of the Huanglung Limestone has the similarity to that of the *Fusulinella imamurai* zone of the Kodani formation of Atetsu.

From the Penchi series of the Taitzeho Valley, Liaoning in China, SHEN (1958) described a great number of fusulinids and he has zoned the series by fusulinids. The *Fusulina schellwieni* and *F. konnoi* subzones (SHENG, 1958) are characterized by the species of *Fusulinella*, *Fusulina*, *Fusiella*, *Ozawainella*, etc. The species of *Fusulinella* are as follows: *Fusulinella bocki* MÖLLER, *F. bocki timanica* RAUSER, *F. pseudobocki* LEE et CHEN, *F. obesa* SHENG, *F. laxa* SHENG, *F. provecta* SHENG, *F. helenae* RAUSER, *F. vozhgalensis molokovensis* RAUSER, and *F.* cf. *fluxa* LEE et CHEN. The Taitzeho fusulinids have closely related species, if not identical, to those of the *Fusulinella imamurai* zone of the Kodani formation. Therefore I roughly correlate the *Fusulinella imamurai* zone with the *Fusulina schellwieni* and *F. konnoi* subzones of Taitzeho Valley.

In North America, the Upper Atokan or the Upper Derryan *Fusulinella* faunas have been described from various districts such as southern New Mexico, Texas, southern Missouri, Ohio, Illinois, Wyoming, etc. THOMPSON described many species of *Fusulinella*; *F. fugax* THOMPSON, *F. acuminata* THOMPSON, *F. proxima* THOMPSON, *F. famula* THOMPSON, *F. juncea* THOMPSON, *F. devexa* THOMPSON, and *Fusulina insolita* THOMPSON from the Mud Spring group of southern New Mexico (1958); *Fusulinella acuminata* THOMPSON and *F.* sp. A from Powwow Canyon, Texas (1958); *Fusulinella primaeva* (SKINNER), *F. llanoensis* (THOMAS) and *F.* sp. from Llano Uplift, Texas (1947); *Fusulinella clarki* THOMPSON, *F. fugax* THOMPSON, *F. devexa* THOMPSON, *F. primaeva* (SKINNER), *F. velmae* THOMPSON and *F. searighti* THOMPSON from southern Missouri (1953); *Fusulinella searighti* THOMPSON, *F. iowensis* THOMPSON, *F. iowensis stouti* THOMPSON and *F. carmani* THOMPSON from Ohio (1936); *Fusulinella iowensis* THOMPSON and *F. stouti* THOMPSON from the Illinois basin (1959); *Fusulinella furnishi*

THOMPSON, *F. acuminata* THOMPSON, *F. dakotensis* THOMPSON, *F. velmae* THOMPSON, *F. velmae protensa* THOMPSON and *F. diminutiva* THOMPSON from the Black Hills and the adjacent areas in Wyoming. As described above, the Upper Atokan fusulinids of North America are remarkably similar in general aspects over wide areas, and it is noteworthy that *Fusulina* first appears in the Cuchillo Negro formation, the upper part of the Mud Spring group in southern New Mexico. Although the identical species in both the Atetsu and North American faunas are not observable, the striking similarities between *Fusulinella imamurai* and *F. velmae* THOMPSON, between *F. hirokoae* and *F. velmae protensa* THOMPSON, and between *F.* sp. nov. cf. *F. subrhomboides* LEE and CHEN and *F. iowensis* THOMPSON, indicate that the *Fusulinella imamurai* zone of Atetsu may be equivalent in age to the *Fusulinella* zone of North America.

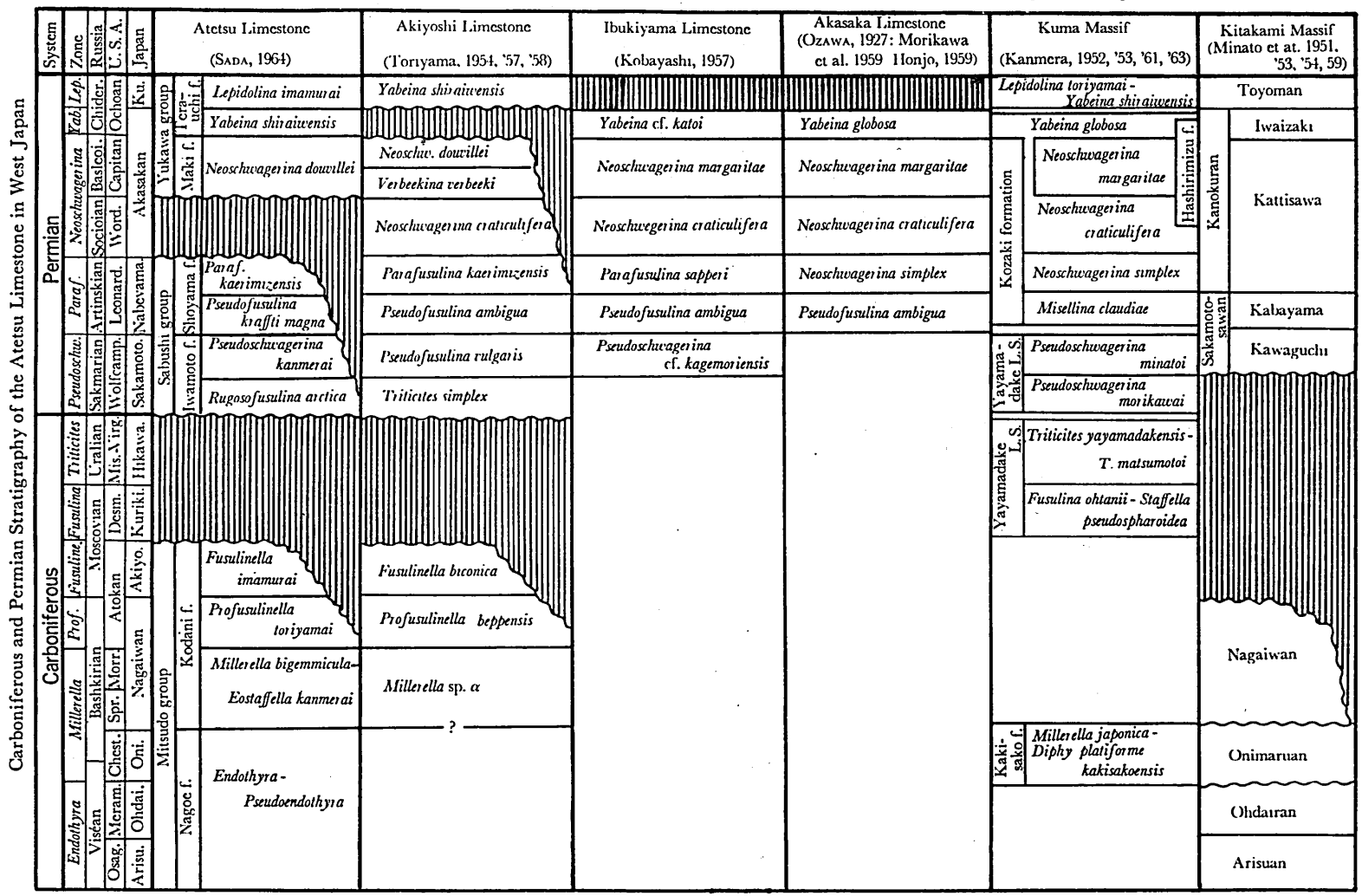
5. *Pseudoschwagerina Zone (Pl)*

The name of the present zone was first employed by IMAMURA (1959) for the Lower Permian of the Atetsu Limestone. A few years later NOGAMI (1961) established the *Pseudoschwagerina subsphaerica-Quasifusulina longissima* zone, but the name of this zone seems to me to be unsuitable because of the reasons which will be mentioned in this chapter. Very recently, the IMAMURA's *Pseudoschwagerina* zone was subdivided by me (1964) into two subzones, the lower *Rugosofusulina arctica* and the upper *Pseudoschwagerina kanmerai*.

a) *Rugosofusulina arctica* subzone (Pl α). The *Rugosofusulina arctica* subzone is represented by the lower part of the Iwamoto formation in the Atetsu area and from this subzone the following characteristic species are discriminated, viz., *Triticites kawanoboriensis* HUZIMOTO, *T. obai* TORIYAMA, *T. ozawai* TORIYAMA, *T. montiparus* ((EHRENBERG) MÖLLER), *T.* sp. aff. *T. subventricosus* DUNBAR and SKINNER, *T.* sp. cf. *T. pseudosimplex* CHEN, *Rugosofusulina arctica* (SCHELLWIEN), *Chusenella*? *atetsuensis* SADA, and *Quasifusulina longissima ultima* KANMERA. Of these, *Rugosofusulina arctica* is the most characteristic species and has a short duration. The name of the subzone derives from this species. NOGAMI (1961) set up the *Quasifusulina longissima ultima-Pseudoschwagerina nakazawai* subzone in the same limestone. However, *Quasifusulina longissima* including *Q. longissima ultima* has been well known from the Upper Carboniferous in Tethys region and *Pseudoschwagerina nakazawai* is referable to genus *Triticites* rather than genus *Pseudoschwagerina*. Moreover, these two species are very rare in this subzone of the Atetsu Limestone. Therefore, the designation by NOGAMI is hardly accepted.

The early Permian fusulinid zones similar to the *Rugosofusulina arctica* subzone of this limestone which indicates the lower part of *Pseudoschwagerina* zone occur in the Inner and Outer Zones of Southwest Japan. They are well known in the following limestone masses and formations, viz., the Akiyoshi Limestone, the Handa Limestone, the Okumyokata formation, the Mizuyagadani formation in the Inner Zone and the Yayamadake Limestone in the Outer Zone. Furthermore, the

TABLE 4. CORRELATION OF THE SUBDIVISION AMONG SELECTED CARBONIFEROUS AND PERMIAN SEQUENCES IN JAPAN



Rugosofusulina arctica fauna may be related to the faunas of the lower part of the Chuanshan Limestone in China, the faunas of the lower part of the Wolfcampian rocks of North America and the fauna of C_3^2 zone of Pamir, and the fauna equivalent to the *Rugosofusulina arctica* fauna has been reported from Northeast Greenland.

TORIYAMA (1958) described many species of *Triticites* and a few species of *Schwagerina* and *Pseudoschwagerina* from the *Triticites simplex* subzone of Akiyoshi, which is most widely distributed among the fusulinid zones and subzones of the Akiyoshi Limestone group. The species of *Triticites* which mainly occur in the *Triticites simplex* subzone are *Triticites simplex* (SCHELLWIEN), *T. ozawai* TORIYAMA, *T. noinskyi* RAUSER-CHERNOUSSOVA var. *paula* TORIYAMA, *T. isaensis* TORIYAMA, *T. obai* TORIYAMA, *T. michiae* TORIYAMA, *T. suzukii* (OZAWA), *T. tantula* TORIYAMA, *Quasifusulina longissima* var. *tenuis* (LEE), *Schwagerina satoi* (OZAWA) and *Pseudoschwagerina muongthensis* (DEPRAT). Of these, *Triticites ozawai* and *T. obai* are identical to those of Atetsu, and the shape and the size of *Triticites noinskyi paula*, and *T. isaensis* are closely similar to those of *T. kawanoboriensis*. *Quasifusulina longissima tenuis* resembles *Q. longissima ultima* in the shell-shape and some internal characters. These facts show that the *Rugosofusulina arctica* subzone is equivalent in age to the *Triticites simplex* subzone.

The lower part of the Handa Limestone in Yamaguchi Prefecture is characterized by *Triticites* and was designated as the *Triticites ozawai* zonule (KAWANO, 1961) which overlies the *Fusulinella eopulchra* zonule. From this zonule KAWANO described the following species, viz., *Triticites ozawai* TORIYAMA, *T. biconica* TORIYAMA and *Quasifusulina*? sp. As pointed out by KAWANO they are commonly found in the *Triticites simplex* subzone of Akiyoshi and *T. ozawai* and *Quasifusulina* also occur in the *Rugosofusulina arctica* subzone of Atetsu. Therefore the *Rugosofusulina arctica* subzone is perhaps correlated with the *Triticites ozawai* zonule of the Handa Limestone.

The Mizuyagadani formation (IGO, 1957) is typically developed in the Fukuji area, Gifu Prefecture and its lower part is composed mainly of the limestones containing the Lower Permian fusulinid fauna. Therefrom IGO (1957) described *Triticites* cf. *kagaharensis* HUJIMOTO, *T.* sp. B, *Quasifusulina longissima* (MÖLLER), *Rugosofusulina alpina* (SCHELLWIEN), *Schubertella kingi* DUNBAR et SKINNER and *Pseudoschwagerina morikawai* IGO. In comparison with the species which have been known from Atetsu, the *Pseudoschwagerina morikawai* zone of the Mizuyagadani formation is believed to correspond to the *Rugosofusulina arctica* subzone of Atetsu.

KANUMA (1958) studied the Okumyokata formation developed in Gifu Prefecture, the southern part of the Hida Massif, and descriminated the *Pseudoschwagerina orientalis-Triticites kawanoboriensis* subzone from the lower part of this formation. According to him, this subzone is characterized by such fusulinids as *Triticites kawanoboriensis* HUJIMOTO, *T. montiparus* (MÖLLER), *T. simplex* (SCHELLWIEN), *T. subobsoletus* (OZAWA), *T. satoi* HUJIMOTO, *Pseudofusulina* sp., and *Pseudoschwagerina orientalis* HUJIMOTO. Of these species, *Triticites kawanoboriensis* and *T. montiparus* are identical to those of Atetsu. This zone probably corresponds to the *Rugosofusulina*

arctica subzone of the Iwamoto formation.

KANMERA (1958) studied the Yayamadake Limestone in the Hikawa Valley, Kumamoto Prefecture and established the *Pseudoschwagerina* zone. The lower part of this zone is characterized by the species of *Triticites*, *Schwagerina*, *Quasifusulina* and *Pseudoschwagerina* such as *Triticites montiparus* (MÖLLER), *T. ozawai* TORIYAMA, *T.* sp. aff. *T. haydeni* (OZAWA), *T. yayamadakensis evectus* KANMERA, *Rugosofusulina prisca* ((EHRENBERG) MÖLLER), *Schwagerina* cf. *S. alpina* (SCHELLWIEN) and *Quasifusulina longissima ultima* KANMERA. The fusulinid assemblages stated above show definitely the lower part of the Yayamadake Limestone to be of early Permian age. Of the Yayamadake species, *Triticites montiparus*, *T. ozawai* and *Quasifusulina longissima ultima* are the same as those of the *Rugosofusulina arctica* subzone of Atetsu.

In South China, CHEN (1934) studied the Swine, Chihsia, Chuanshan and Maping Limestones and therefrom he described a large number of species of *Triticites*, *Pseudofusulina*, *Parafusulina*, *Quasifusulina*, etc. Judging from his descriptions, the lower parts of the Chuanshan and Maping Limestones are characterized by *Quasifusulina longissima* MÖLLER and *Q. longissima* var. *compacta* LEE in association with *Pseudofusulina alpina* (SCHELLWIEN). These species are identical or similar to those of *Rugosofusulina arctica* subzone of Atetsu.

From the *Pseudofusulina* zone (C_3^2) of Pamir MIKLUKHO-MACLAY (1949) described the following species, viz., *Pseudofusulina alpina* (SCHELLWIEN), *P. prisca* (EHRENBERG), *P. pailensis* (SCHWAGER), *Quasifusulina longissima* (MÖLLER), *Q. baloniformis* PUTRJA, *Triticites vulgaris* MIKLUKHO-MACLAY, *T. delicatus* CHEN, *T. regularis* CHEN and *Parastaffella pseudosphaeroidea* (DOUTKEVITCH). *Pseudofusulina alpina*, *Triticites regularis* and *Quasifusulina longissima* have been known from the early Permian of South China and Japan. The assemblage of the species of Pamir recalls me to the early Permian fusulinid fauna in Japan and its adjacent countries.

The upper Marine group of Northeast Greenland studied by ROSS and DUNBAR (1962) contains the prolific fauna composed mainly of *Rugosofusulina arctica* (SCHELLWIEN), *Schwagerina krotowi* (SCHELLWIEN), *Pseudofusulina amdrupensis* ROSS and DUNBAR, *Pseudoschwagerina pavlovi* RAUSER-CHERNOUSSOVA, etc. *Rugosofusulina arctica* which has been regarded as a transitional form between *Triticites* and *Pseudofusulina* is the most characteristic species in the *Rugosofusulina arctica* subzone of the Atetsu Limestone and *Schwagerina krotowi* is quite common in the Japanese Lower Permian. However, in the Atetsu Limestone *Pseudoschwagerina pavlovi* first appears in the *P. kanmerai* subzone.

In North America, the early Wolfcampian fusulinid faunas have been brought to light by many workers such as THOMPSON (1954), ROSS (1960, '62 and '63), RICH (1961), BOSTWICK (1962), etc. from various localities. THOMPSON (1954) described and illustrated a large number of species from Kansas, North Central Texas, New Mexico, Arizona, and Central Utah. The Kansas fauna found in the Admire group and the lower part of the Council Grove group is composed of *Triticites pointensis* THOMPSON, *T. confertus* THOMPSON, *T. meeki* (MÖLLER), *T. ventricosus* (MEEK & HAYDEN), *T. rockensis* THOMPSON, *Dunbarinella fivensis* THOMPSON, *D. coextenta* THOMPSON, *D.*

americana THOMPSON, *D. hughesensis* THOMPSON, *D. glenensis* THOMPSON, *Schwagerina longissimoidea* (BEEDE) and *S. campa* THOMPSON. In North Central Texas, the fauna of the lower half of the Wichita group is characterized by *Triticites confertus* THOMPSON, *T. directus* THOMPSON, *T. ventricosus* (MEEK & HAYDEN), *T. creekensis* THOMPSON, *Dunbarinella coextenta* THOMPSON, *D. extenta* THOMPSON, *D. wetherensis* THOMPSON, *Schwagerina longissimoidea* (BEEDE), *S. campensis* THOMPSON, *Oketaella waldripensis* THOMPSON, *O. campensis* THOMPSON, *Schubertella kingi* DUNBAR and SKINNER and *Ozawainella*? *inflata* THOMPSON. In New Mexico a thick limestone bed of the upper Bursum formation in Fresnal Canyon includes the prolific fusulinids indicative of the early Wolfcampian age. They are *Triticites creekensis* THOMPSON, *Schwagerina pinosensis* THOMPSON, *S. grandensis*? THOMPSON, and *Dunbarinella coextenta* THOMPSON. In Arizona the faunas have been well known from the Bwisum formation in the Oscura Mountains and Robledo Mountains and they are closely similar to those of New Mexico in the specific composition. The fusulinids described therefrom are *Triticites creekensis* THOMPSON, *T.* cf. *T. beedei* THOMPSON, *Dunbarinella hughesensis* THOMPSON, *D.* aff. *D. glenensis* THOMPSON, *Pseudofusulina robleda* THOMPSON, *Schwagerina grandensis* THOMPSON and *S.* sp. From the lower part of the Oquirrh formation in Utah, THOMPSON described the early Wolfcampian fusulinids such as *Triticites cellamagnus* THOMPSON, *T. meeki* (MÖLLER), *Pseudofusulina utahensis* THOMPSON, *P.* sp., *Schwagerina* sp., *Schubertella kingi* DUNBAR & SKINNER and *Dunbarinella hughesensis* THOMPSON. As described above, the early Wolfcampian fusulinid faunas in North America are remakably characterized by the association with *Triticites*, *Dunbarinella*, *Schubertella* and *Schwagerina*, and it is very interesting that neither *Paraschwagerina* nor *Pseudoschwagerina* is present in North American early Wolfcampian. In the Atetsu Limestone, the early Wolfcampian *Rugosofusulina arctica* subzone equivalent to the *Triticites simplex* subzone of the Akiyoshi Limestone contains *Rugosofusulina*, *Triticites*, *Quasifusulina*, and *Chusenella*, the last of which somewhat resembles *Dunbarinella* in some morphological characters, and *Pseudoschwagerina* and *Paraschwagerina* are not observable in it. These two genera occur in the stratigraphically higher position where they are associated with many species of *Pseudofusulina*. These facts suggest that the *Rugosofusulina arctica* subzone is approximately correlated with the lower part of *Pseudoschwagerina* zone of North America. RICH (1961) described the species of *Schwagerina*, *Triticites*, *Pseudoschwagerina*, etc. from the upper part of the lower half of the Bird Spring formation near Lee Canyon in Clark County, Nevada, which he called the *Schwagerina* zone. According to his stratigraphic columnar section of the lower half of the Bird Spring formation, the lowest part of the *Schwagerina* zone contains *Schwagerina* cf. *S. jewetti*, *Pseudofusulina* sp. B, *Triticites* sp. D, and *T.* cf. *T. creekensis*, and the appearance of *Pseudoschwagerina* is in slightly higher stratigraphic position. In consideration of the stratigraphic occurrence and the generic composition of this fauna shown by RICH, I am induced to believe that the lower part of the *Schwagerina* zone of the Bird Spring formation is equivalent in age to the *Rugosofusulina arctica* subzone of the Atetsu Limestone. From his closer study of the *Uddenites* zone of the

Glass Mountains, Texas, BOSTWICK (1962) listed and illustrated many species of *Triticites* and *Schwagerina* such as *Triticites* aff. *T. creekensis* THOMPSON, *T. pinguis* DUNBAR and SKINNER, *T.* spp. A and B, *T. rockensis* THOMPSON, *Schwagerina* aff. *S. pinosensis* THOMPSON, and *S.* sp. He concluded that most of the forms of *Triticites* did not seem to be critically indicative of age, but the presence of *Schwagerina* in the *Uddenites* Zone was considered as a certain indication of the Wolfcampian age. The generic composition and the stratigraphic distributions of fusulinids in the *Uddenites* Zone remind me vividly of the Japanese Lower Permian fusulinid zones including the *Rugosofusuline arctica* subzone of the Atetsu Limestone.

b) *Pseudoschwagerina kanmerai* subzone (Pl β). The *Pseudoschwagerina kanmerai* subzone is represented by the upper part of the Iwamoto formation in the Atetsu area and from this subzone the following species were identified, viz., *Pseudoschwagerina kanmerai* Sada, *P. pavlovi* (RAUSER-CHERNOUSSOVA), *P. saigusai* NOGAMI, *P. muongthensis* (DEPRAT), *Pseudofusulina vulgaris* (SCHELLWIEN), *P. vulgaris globosa* (SCHELLWIEN), *P. regularis* (SCHELLWIEN), *Chusenella* sp. aff. *C. schwagerinaeformis* SHENG, *Schwagerina primigena* NOGAMI, *S. okafujii* (TORIYAMA), and *Triticites kawanoboriensis* HUJIMOTO. A few years in advance of my paper (1964), NOGAMI (1961) adopted the names of the *Pseudoschwagerina subspherica* subzone and the *Pseudofusulina vulgaris* zone. The *Pseudoschwagerina kanmerai* subzone corresponds to the *P. subspherica* subzone plus the *Pseudofusulina vulgaris* subzone of Nogami (1961). In the Inner and Outer Zones of Japan, the *Pseudoschwagerina* zones equivalent in age to the *Pseudoschwagerina kanmerai* subzone indicating the upper part of the *Pseudoschwagerina* zone have been known in the following limestones and formations, viz., the Akiyoshi Limestone, the Handa and Zomeki Limestones, the Okumyokata formation, the Yayamadake Limestone, the Kameiwa formation, the Onji formation and the Shiraiwa Limestone. The fusulinid faunas related to the *Psudoschwagerina kanmerai* fauna can be known in China, Iraq, Montenegro, Pamir, Northeast Greenland and North America.

In Japan, TORIYAMA (1958) described many species from the *Pseudofusulina vulgaris* subzone of the Akiyoshi Limestone. The representative species of this subzone are *Paraschwagerina akiyoshiensis* TORIYAMA, *Pseudoschwagerina muongthensis* (DEPRAT), *Pseudofusulina vulgaris* (SCHELLWIEN), *P. vulgaris* var. *globosa* (SCHELLWIEN), *P. watanabei* (OZAWA), *P. ambigua* (DEPRAT), *P. yobarensis* (OZAWA), *P. kraffti magna* TORIYAMA, *Triticites ellipsoidalis* TORIYAMA, *T. haydeni* (OZAWA), *T. kawanoboriensis* HUJIMOTO, *T. kuroiwaensis* TORIYAMA, *T. densa* TORIYAMA, etc. *Pseudoschwagerina muongthensis* (DEPRAT) and *Pseudofusulina vulgaris* (SCHELLWIEN), which are characteristic of the Lower Permian in the Tethys region, occur most widely in the *Pseudofusulina vulgaris* subzone, and in the Atetsu area these two species are restricted to the *Pseudoschwagerina kanmerai* subzone. *Pseudofusulina vulgaris globosa* (SCHELLWIEN), *P. vulgaris megaspherica* TORIYAMA and *P. vulgaris watanabei* (OZAWA em. LEE) resemble *Pseudofusulina vulgaris* (SCHELLWIEN) in the general shell-characters and they are seemingly the same as *P. vulgaris* (SCHELLWIEN) in the general stage of evolution. The faunal similarity between the *Pseudofusulina vulgaris* subzone of the Akiyoshi Limestone and the

Pseudoschwagerina kanmerai subzone of the Atetsu Limestone supports the correlation that both subzones are of the same age.

From the *Pseudofusulina vulgaris* zone of the Handa Limestone in Yamaguchi Prefecture, KAWANO (1961) described *Pseudofusulina vulgaris* (SCHELLWIEN), *P. vulgaris globosa* (SCHELLWIEN), *P. vulgaris megaspherica* TORIYAMA, *Paraschwagerina akiyoshiensis* TORIYAMA and several species of *Triticites* and *Schwagerina*. As stated above, *Pseudofusulina vulgaris* is quite common in the *Pseudoschwagerina kanmerai* subzone of the Atetsu Limestone and its subspecies have the resemblance to each other in the general shell-characters. In the Akiyoshi Limestone, furthermore, *Paraschwagerina akiyoshiensis* first appears in the *Pseudofusulina vulgaris* subzone in association with *Pseudoschwagerina muongthensis* (DEPRAT). Taking all these facts into account, I am inclined to think that the *Pseudofusulina vulgaris* zone of the Handa Limestone and the *Pseudoschwagerina kanmerai* subzone of the Atetsu Limestone are of the same age.

The upper part of the *Paraschwagerina* (*Acervoschwagerina*) zone of the Ibukiyama Limestone of Shiga Prefecture (KOBAYASHI, 1957) contains *Pseudofusulina vulgaris* (SCHELLWIEN), *Schwagerina hawkinsi* DUNBAR and SKINNER and *Paraschwagerina* (*Acervoschwagerina*) sp. A. *Pseudofusulina vulgaris* is identical with the specimens obtained from the *Pseudoschwagerina kanmerai* subzone and the species (KOBAYASHI, 1957, p. 268, pl. 2, fig. 14) of *Paraschwagerina* (*Acervoschwagerina*) is closely similar in many features to *Paraschwagerina kanmerai* (NOGAMI, 1961, pp. 185–187, pl. 4, figs. 4–7) of the Atetsu Limestone. These similarities suggest that the upper part of the *Paraschwagerina* (*Acervoschwagerina*) zone of the Ibukiyama Limestone is equivalent in age to the *Pseudoschwagerina kanmerai* subzone of Atetsu.

From the Akuda Limestone in Gifu Prefecture KANUMA (1958) described the following fusulinids: *Pseudoschwagerina uddeni* (BEEDE and KNIKER), *Paraschwagerina* (*Acervoschwagerina*) *fujimotoi* KANUMA, *Pseudofusulina nelsoni* (DUNBAR and SKINNER), *P. kraffti* (SCHELLWIEN), *P. vulgaris fusiformis* (SCHELLWIEN), *P.* cf. *crassiseptata* (DEPRAT), *P. ambigua* (DEPRAT) and *Minojaponella elongata* FUJIMOTO and KANUMA. The fusulinids described by KANUMA have several related species, if not identical, to those in the *Pseudoschwagerina kanmerai* subzone of the Atetsu Limestone. *Pseudoschwagerina uddeni* (BEEDE and KNIKER), which has been well known in the Wolfcampian in North America, is somewhat similar to *P. morikawai* IGO and *P. saigusai* NOGAMI, and *Pseudofusulina vulgaris fusiformis* (SCHELLWIEN) is allied in the essential biocharacters of the shell to *P. vulgaris* (SCHELLWIEN).

IGO (1959) described the following fusulinids from the *Pseudofusulina vulgaris* zone of the Hirayu group in the southern part of the Hida Massif, viz., *Pseudofusulina vulgaris* (SCHELLWIEN), *P. vulgaris globosa* (SCHELLWIEN), *Paraschwagerina* sp., *Pseudoschwagerina* sp., etc. The first two have also been found in the *Pseudoschwagerina kanmerai* subzone and *Pseudoschwagerina* sp. of IGO (p. 252, pl. 1, fig. 9) is somewhat similar to *Pseudoschwagerina kanmerai* from Atetsu. These faunal similarities indicate that the *Pseudofusulina vulgaris* zone of the Hirayu group is intimately related with the *Pseudoschwagerina kanmerai* subzone of Atetsu.

SAKAGAMI and OMATA (1957) described the species of *Schubertella*, *Kwantoella*, *Triticites*, *Schwagerina*, *Pseudoschwagerina*, etc. from the Shiraiwa Limestone in Nishitama-gun, Tokyo-To and they considered this fauna to be of the middle to the later Wolfcampian age. The species of *Triticites*, *Chusenella*, *Schwagerina* and *Pseudoschwagerina* are as follows: *Triticites simplex* (SCHELLWIEN), *T. kawanoboriensis* FUJIMOTO, *T. fujimotoi* SAKAGAMI and OMATA, *T. intermedia* SAKAGAMI and OMATA, *Chusenella guembeli pseudoregularis* (DUNBAR and SKINNER), *C. guembeli compacta* (SAKAGAMI and OMATA), *Schwagerina modica* THOMPSON and HAZZARD and *Pseudoschwagerina* cf. *orientale* FUJIMOTO. *Triticites simplex* has been known in the lower and the upper part of the *Pseudoschwagerina* zone in Japan and *T. kawanoboriensis* has been recognized in both *Rugosofusulina arctica* and *Pseudoschwagerina kanmerai* subzones of Atetsu. *Pseudoschwagerina orientale* FUJIMOTO is similar in the general development of the shell to *P. kanmerai* and *Chusenella guembeli compacta* (SAKAGAMI) and *C. guembeli pseudoregularis* (DUNBAR and SKINNER resemble in the essential biocharacters *Chusenella* aff. *C. schwagerinoides* CHEN from the Atetsu Limestone. The occurrence of these spcies in the *Pseudoschwagerina orientale* fauna of Shiraiwa and the *Pseudoschwagerina kanmerai* fauna of Atetsu precludes the possibility of the faunal correlation stated above.

Fusulinids from the upper part of the *Pseudoschwagerina* zone of the Yayamadake Limestone in the Hikawa Valley, Kumamoto Prefecture (KANMERA, 1958) are *Pseudoschwagerina minatoi* KANMERA, *Paraschwagerina shimodakensis* KANMERA, *Triticites samaricus* RAUSER-CHERNOUSSOVA, *T.* aff. *T. pusillus* (SCHELLWIEN), *Rugosofusulina pristina* KANMERA, *R. serrata* RAUSER-CHERNOUSSOVA, *Pseudofusulina santyuensis* HUZIMOTO, *P. regularis* (SCHELLWIEN), *P. sokensis* RAUSER-CHERNOUSSOVA, *P. horrida* KANMERA, etc. Of these, the identical species to those of the Atetsu fauna is only *Pseudofusulina regularis* (SCHELLWIEN). However, *Pseudoschwagerina saigusai* of Atetsu is similar in the general stage of evolution to *P. minatoi* KANMERA. These facts indicate that the upper part of the *Pseudoschwagerina* zone of the Yayamadake Limestone is probably contemporaneous with the *Pseudoschwagerina kanmerai* zone of the Atetsu Limestone.

The *Pseudoschwagerina* fauna of the Kusune formation described by SUYARI (1961) from the east of Kusune of Anan City, Tokushima Prefecture, is nearly allied in the specific composition to the *Pseudoschwagerina kanmerai* fauna of the Atetsu Limestone. Both *Pseudofusulina regularis* (SCHELLWIEN) and *Triticites kawanoboriensis* HUZIMOTO of the Kusune formation are identical with those of Atetsu, and *Pseudoschwagerina geyeri* Kahler and Kahler described by SUYARI shows a general resemblance to *Pseudoschwagerina saigusai* NOGAMI but differs from it in having slightly larger proloculus and slightly rapider expansion of the shell in the outer volutions.

Many species of *Schwagerininae* and *Fusulininae* have been described by CHEN (1934) from the Chuanshan Limestone of South China. Among them, *Pseudoschwagerina princeps* EHRENBERG (1964, pl. 15, figs. 1–4) somewhat resembles *Pseudoschwagerina pavlovi* (RAUSER-CHERNOUSSOVA) in its shell-shape and its internal characteristics, and *Schwagerina* sp. (1934, pl. 15, figs. 6–7) is closely allied to *Pseudofusulina regularis*

(SCHELLWIEN) in the size, the shell-shape, the proloculus diameter, the number of volutions and the septal fluting. *Pseudoschwagerina fusulinoides* (SCHELLWIEN) of CHEN (1934, pl. 14, figs. 1–4) is similar in the general stage of evolution to *Pseudoschwagerina saigusai* of Atetsu. *Pseudoschwagerina princeps*, *P. fusulinoides* and *Schwagerina* sp., as described above, seem to be of the same age as the species of the *Pseudoschwagerina kanmerai* subzone.

MIKLUKHO-MACLAY (1949) described a number of species of fusulinids from the *Schwagerina* zone (C_3^3) in Pamir, which have been generally thought to indicate the Lower Permian in Japan. The representative species of this zone are as follows: *Pseudoschwagerina sphaerica* (RAUSER et SCHERBOVITCH), *P. moelleri* (RAUSER), *P. fusiformis* (KROTOW), *P. amedaei* RAUSER et SCHERBOVITCH, *Paraschwagerina primaeva* RAUSER et SCHERBOVITCH, *P.? fusulinoides* (SCHELLWIEN), *P. complicata* (SCHELLWIEN), *P. moelleri* (SCHELLWIEN), *Pseudofusulina complicata* (SCHELLWIEN), *P. pailensis* (SCHWAGER), *Quasifusulina longissima pseudoelongata* MIKLUKHO-MACLAY, etc. Of these species, *Pseudoschwagerina sphaerica* (RAUSER et SCHERBOVITCH) and *P. moelleri* (RAUSER) (MIKLUKHO-MACLAY, 1949, pl. 6, figs. 1–2; pl. 5, figs. 1–2) were originally described under the generic name of "*Schwagerina.*" However, they are relatively large and subglobular in the shape. The inner three to four volutions are tightly coiled and beyond the fifth volution the shells expand rapidly. The chomata are low and narrow in the inner volutions. The septa are so widely spaced and weakly fluted in the outer volutions. From these characteristics of the shell, I have considered that these two species should be referred to genus "*Pseudoschwagerina.*" *Pseudoschwagerina sphaerica* (RAUSER et SCHERBOVITCH) is nearly allied to *Pseudoschwagerina pavlovi* (RAUSER-CHERNOUSSOVA) in the general stage of evolution. They may be of the same age. *Pseudofusulina complicata* (SCHELLWIEN) and *P. pailensis* (SCHWAGER) (MIKLUKHO-MACLAY, 1949, pl. 10, figs. 1–3; pl. 12, fig. 6) are similar in the general development of the shell to *Pseudofusulina regularis* (SCHELLWIEN). Judging from these species stated above, it may be probable that the *Schwagerina* zone of Pamir is referable to the *Pseudoschwagerina kanmerai* subzone.

In Iraq, many fusulinids have been described from the Lower Permian rocks. LLOYD (1963) described two species of *Pseudoschwagerina* from the Zinnar formation in the Kurdistan region of Northern Iraq. The species of *Pseudoschwagerina* are *P. fusiformis* (KROTOW), *P. contorta* LLOYD and *P.* sp., and *Pseudoschwagerina fusiformis* has a great resemblance to *P. pavlovi* (RAUSER-CHERNOUSSOVA) in its general stage of evolution and *P. contorta* appears to be of the primitive form among the species of *Pseudoschwagerina.* These suggest that the lower part of the Zinnar formation containing pseudoschwagerinids may be of the early Wolfcampian age and both the Kurdistan and Atetsu faunas may be of the same age.

From the Tara region in Central Crna Gora, Montenegro, KOCHANSKY-DEVIDÉ described *Dunbarinella? taraensis* KOCHANSKY-DEVIDÉ, *Rugosofusulina intermedia* SULEJMANOV, *Pseudofusulina vulgaris* (SCHELLWIEN), *P. vulgaris rhombica* KOCHANSKY-DEVIDÉ, *P. gallowayi* CHEN, *P. valida exiqua* (SCHELLWIEN em. LEE), etc. Among them *Pseudo-*

fusulina vulgaris (SCHELLWIEN) is also very common in the Atetsu Limestone and *P. vulgaris rhombica* is somewhat similar to *P. vulgaris globosa* SCHELLWIEN in some shell-chracters. Taking the identical or the related species into consideration, I am of the opinion that the Tara fauna can be correlated with the Atetsu fauna.

ROSS and DUNBAR (1962) described *Pseudoschwagerina pavlovi* (RAUSER-CHERNOUSSOVA) from Northeast Greenland, where it was associated with *Schwagerina krotowi* (SCHELLWIEN) and *Rugosofusulina arctica* (SCHELLWIEN). In the Atetsu Limestone, as already mentioned before, *Pseudoschwagerina pavlovi* is the characteristic species among the species of the *Pseudoschwagerina kanmerai* subzone and its occurrence suggests that the *Pseudoschwagerina kanmerai* fauna and the *Pseudoschwagerina pavlovi* fauna of Northeast Greenland may be of the same age.

In North America it has been known that the Upper Wolfcampian *Pseudoschwagerina* faunas occur in Kansas, North-Central Texas, Arizona and Central Utah (THOMPSON, 1954), Nevada (RICH, 1961), Texas (BOSTWICK, 1962), etc. THOMPSON (1954) described many species of fusulinids from the upper part of the Council Grove group and the Chase group in Kansas. Fusulinids therefrom are *Pseudoschwagerina texana* DUNBAR and SKINNER, *Paraschwagerina kansasensis* (BEEDE and KNIKER), *Dunbarinella tumida* (SKINNER), *D. obesa* (BEEDE), *Pseudofusulina? moranensis* THOMPSON, *Schwagerina longissimoidea* (BEEDE), *S. jewetti* THOMPSON, *S. emaciata* (BEEDE), *S. vervillei* THOMPSON, etc. Fusulinid fauna described by THOMPSON (1954) from the Upper Wolfcampian rocks, the upper part of the Wichita group of North-Central Texas is composed mainly of *Pseudoschwagerina texana* DUNBAR and SKINNER, *Pseudofusulina? moranensis* THOMPSON, *Schwagerina complexa* THOMPSON, etc. In the Hueco Mountains of Arizona, the Upper Wolfcampian Hueco Limestone from which the *Pseudoschwagerina* fauna was described by THOMPSON (1954) rests on the Powwow conglomerate member and the Burusum formation unconformably overlying the Virgilian rocks. The Hueco fauna is generally characterized by *Pseudoschwagerina uddeni* (BEEDE and KNIKER), *P. texana* DUNBAR and SKINNER, *P. needhami* THOMPSON, *P. morsei* NEEDHAM, *P. beedei* DUNBAR and SKINNER, *P. convexa* THOMPSON, *P. gerontica* DUNBAR and SKINNER, *Pseudofusulina nelsoni nelsoni* (DUNBAR and SKINNER), *P. nelsoni opima* THOMPSON, *P. huecoensis* DUNBAR and SKINNER, *Schwagerina diversiformis* DUNBAR and SKINNER, *S. eolata* THOMPSON, *S. fax* THOMPSON, etc. In Central Utah, the upper part of the Oquirrh formation which is typically developed in the Wasatch Mountains contains abundant fusulinids which are closely similar to those of Kansas, North-Central Taxas and Arizona. The species described and illustrated by THOMPSON (1954) from the upper part of this formation are as follows: *Pseudoschwagerina uddeni?* (BEEDE and KNIKER), *Schwagerina elkoensis* THOMPSON and *Schwagerina* sp. The North American *Pseudoschwagerina* fauna occurring in the Upper Wolfcampian strata is composed mainly of *Pseudoschwagerina*, *Paraschwagerina*, *Pseudofusulina* and *Schwagerina*, and it is very interesting that the genus *Triticites* which is flourishing in the early Wolfcampian cannot be observed in the *Pseudoschwagerina* fauna except for the fauna described from the Earp formation in Arizona (SABINS and ROSS, 1963). Many species of

Pseudoschwagerina described by THOMPSON from the above-stated districts seem to be of the typical forms in general, and of these forms, several species are somewhat similar in the morphological character or the general stage of evolution to the species from the *Pseudoschwagerina* zone of Atetsu and its adjacent areas. *Pseudoschwagerina beedei* DUNBAR and SKINNER from Arizona resembles somewhat *P. saigusai* NOGAMI in the shell-shape, the number of volutions, the proloculus diameter and the septal fluting, and the former appears to be equivalent to the latter in the stage of evolution. *Pseudoschwagerina rhodesi* THOMPSON from New Mexico is slightly smaller than *P. pavlovi* (RAUSER-CHERNOUSSOVA) in its shell-size. The former species, however, is similar to the latter in the essential biocharacters and the general stage of evolution. *Pseudoschwagerina needhami* THOMPSON obtained from Arizona resembles closely *P. nakazawai* NOGAMI in the shell-shape, the number of volutions, the proloculus diameter and the mode of the chomata, *Pseudoschwagerina morsei* NEEDHAM from Arizona is similar to *P. morikawai* IGO and *P. saigusai* NOGAMI in the general stage of evolution. In Lee Canyon area of Nevada, RICH (1961) described *Pseudoschwagerina texana* DUNBAR and SKINNER, *Schwagerina elkoensis* THOMPSON and HANSEN, *S. eolata* THOMPSON, *S. wellsensis* THOMPSON and HANSEN, *S. crassitectoria* DUNBAR and SKINNER, *S. gumbeli* DUNBAR and SKINNER and a species of *Parafusulina* from the uppermost part of the lower half of the Bird Spring formation and the upper half of the same formation overlying the older strata comprising the lowest Permian *Triticites* fauna. Of these species, *Pseudoschwagerina texana* DUNBAR and SKINNER is a good index species of the later Wolfcampian age in North America and this species is generally associated with *Pseudoschwagerina beedei* DUNBAR and SKINNER and *P. needhami* THOMPSON in Nevada and Arizona which resemble somewhat *Pseudoschwagerina saigusai* NOGAMI and *P. nakazawai* NOGAMI from the Atetsu Limestone, respectively. *Schwagerina gumbeli* DUNBAR and SKINNER has also been described from the Ibukiyama Limestone and the Kameiwa formation in Shikoku, and *Schwagerina wellsensis* THOMPSON is nearly allied in the general stage of evolution to *S. regularis* (SCHELLWIEN) commonly found in the *Pseudofusulina vulgaris* zone of Akiyoshi which is equivalent to the *Pseudoschwagerina kanmerai* subzone as stated before. SABINS and ROSS (1963) presented the assemblage zone of *Pseudoschwagerina-Schwagerina-Triticites* from the Earp formation of the Naco group in Arizona and they pointed out that the species from this zone showed a close similarity to those from the Council Grove group of Kansas, the lower part of the Lower Division of the Hueco Limestone in Texas, the Neal Ranch formation of Glass Mountain in Texas, and the upper part of the Bird Springs Limestone in Southern California. The species of *Pseudoschwagerina* described by SABINS and ROSS are *Pseudoschwagerina uddeni* (BEEDE and KNIKER), *P. portalensis* SABINS and ROSS, and *P.* sp. A. The first one is the most typical of the genus and very common in the Wolfcampian rocks of North America, while the last two appear to be of the primitive type among the species of this genus and somewhat resemble *Pseudoschwagerina nakazawai* NOGAMI in some shell-characters. Therefore they may be considered to be of the same degree in the stage of evolution.

The species of *Schwagerina* described by them are *S. emaciata* (BEEDE), *S. silverensis* SABINS and ROSS, *S. grandensis* THOMPSON, *S. compacta* (WHITE), *S. providens* THOMPSON and HAZZARD and *S. loringi* (THOMPSON). The first two species have been generally thought to be of the primitive form and the last four to be of the intermediate form in the shell-development. Of these species, *Schwagerina compacta* (WHITE) somewhat resembles *S. stabilis* (RAUSER-CHERNOUSSOVA) from the Yayamadake Limestone (KANMERA, 1958) in its morphological character, and also *S. grandensis* which were referred to the original specimens illustrated by THOMPSON from New Mexico and Arizona (1954, pl. 24, figs. 1–5, 16–24; pl. 29, figs. 15–16; pl. 32, figs. 10–18; pl. 33, fig. 15?), may be referable to the specimens (KANMERA, 1958, pl. 31, figs. 1–12) described from the upper part of the *Pseudoschwagerina* zone of the Yayamadake Limestone. Moreover, from the Earp formation SABINS and ROSS described the only one species of *Triticites*, *T. creekensis* THOMPSON, which was originally described from the Lower Permian of the Bursum and Pueblo formation of New Mexico, Arizona and Texas. It has a larger shell, more numbers of volutions, strongly fluted septa in the median portion of the shell and fairly massive chomata. Judging from these morphological characteristics, *Triticites creekensis* should be considered to be of the highly advanced form among the species of *Triticites* and it is very interesting that this species has a higher stratigraphic horizon in this formation than *Pseudoschwagerina uddeni* (BEEDE and KNIKER) which is indicative of the Upper Wolfcampian. This fusulinid zone stated above indicates distinctly the upper part of the Wolfcampian *Pseudoschwagerina* zone and may be approximately equivalent in age to the *Pseudoschwagerina kanmerai* subzone of Atetsu.

6. *Parafusulina Zone (Pm)*

The presence of the *Pseudofusulina* zone equivalent in age to the *Parafusulina kaerimizensis* zone of the Akiyoshi Limestone was amply proved by IMAMURA (1959) in his comprehended study of the Permian of the Atetsu Limestone. In 1961, NOGAMI investigated this zone and he gave it the name of *Parafusulina* zone. Moreover, it was subdivided into two subzones, the lower *Pseudofusulina kraffti magna* and the upper *Parafusulina kaerimizensis*. Those will be certified and adopted in my present paper.

a) *Pseudofusulina kraffti magna* subzone (Pm α). The *Pseudofusulina kraffti magna* subzone is typified by the lower part of the Shoyama formation in the Atetsu district and comprises the following fusulinids, viz., *Pseudofusulina kraffti magna* TORIYAMA, *P. fusiformis* SCHELLWIEN, *P. uralika sphaerica* BELJAEV, *Parafusulina semilucera* (NOGAMI) and *P. semilucera granda* (NOGAMI). The *Pseudofusulina kraffti magna* subzone of the Atetsu Limestone may be correlative with the following fusulinid zones and the formations in the Inner and Outer Zones of Japan: the *Pseudofusulina ambigua* subzone of the Akiyoshi Limestone (TORIYAMA, 1958), the *Pseudofusulina ambigua* subzone of the Ibukiyama Limestone (KOBAYASHI, 1957), the lower part of the Hirayu formation (IGO, 1959), the lower part of the *Parafusulina* zone of the Akasaka Limestone

(OZAWA, 1927), and the *Misellina claudiae* zone of the Kozaki formation (KANMERA, 1963). Furthermore, several fusulinid zones or faunas which seem to be of the same age as the *Pseudofusulina kraffti magna* subzone of Atetsu have been known in Yugoslavia, Pamir and North America.

From his study of the Akiyoshi Limestone, TORIYAMA (1958) established the *Pseudofusulina ambigua* subzone which is rather limited in its geographical distribution. He described the following species from this subzone, viz., *Pseudofusulina ambigua* (DEPRAT), *P. yobarensis* (OZAWA), *P. kraffti magna* TORIYAMA and *P. vulgaris* (SCHELLWIEN), in addition to the species of *Triticites*, *Schwagerina* and *Nagatoella* of long duration. *Pseudofusulina ambigua* which is the most characteristic species in this subzone, is nearly allied to *P. fusiformis* (SCHELLWIEN) in its morphological characters and in the general development of the shell. *Pseudofusulina kraffti magna* TORIYAMA and *P. vulgaris* (SCHELLWIEN) are quite identical with the species of the Atetsu Limestone. These suggest that the *Pseudofusulina kraffti magna* subzone corresponds to the *Pseudofusulina ambigua* subzone of the Akiyoshi Limestone.

KOBAYASHI (1957) described *Pseudofusulina sekii* KOBAYASHI, *P. ambigua* (DEPRAT), *P. uenoensis* KOBAYASHI, *P. crassitectoria* DUNBAR and SKINNER, *P. gümbeli* (DUNBAR and SKINNER) and several species of the other genera from the *Pseudofusulina ambigua* subzone of the Ibukiyama Limestone. Of these species, *Pseudofusulina sekii* KOBAYASHI (1957, pp. 280–281, pl. 5, figs. 3–8) resembles *P. kraffti magna* TORIYAMA in the shell-shape, the number of volutions and the internal mode. *Pseudofusulina ambigua* (KOBAYASHI, 1957, pp. 271–272, pl. 5, figs. 9–10, pl. 6, figs. 1–2), *P. uenoensis* KOBAYASHI (1957, pp. 282–283, pl. 4, figs. 1–8), *P. crassitectoria* (KOBAYASHI, 1957, pp. 273–275, pl. 3, figs. 8–9) and *P. gümbeli* (KOBAYASHI, 1957, pp. 277–278, pl. 3, figs. 1–4) are similar to *Pseudofusulina fusiformis* (SCHELLWIEN) of the Atetsu Limestone in the general development of the shell. These facts indicate that the *Pseudofusulina ambigua* subzone is probably contemporaneous with the *P. kraffti magna* subzone of Atetsu.

The middle division of the Hirayu group, which was studied by IGO (1959) and distributed in the Hirayu district, Southeastern Part of the Hida Massif, contains the *Parafusulina yabei* fauna which consists of *Parafusulina yabei* (HANZAWA), *Pseudofusulina* sp B. and *Misellina minor* (DEPRAT). Judging from the morphological characters, *Parafusulina yabei* (1959, p. 248, pl. 2, fig. 8) may be considered to be of the primitive form for the genus. *Pseudofusulina* sp. B (1959, p. 247, pl. 3, fig. 7) is similar to *P. fusiformis* (SCHELLWIEN) in the general development of the shell. These suggest that the *Parafusulina yabei* subzone is approximately equivalent to the *P. kraffti magna* subzone of Atetsu.

OZAWA (1927) described *Pseudofusulina ambigua* (DEPRAT), *P. granum-avenae* (RÖEMER), *P. kraffti* (SCHELLWIEN) and *Parafusulina japonica* GÜMBEL from Nn zone of the Akasaka Limestone. Of these, *Pseudofusulina ambigua* (OZAWA, 1927, pp. 145–146, pl. 35, fig. 7; pl. 36, figs. 2, 4; pl. 38, fig. 1 a; pl. 39, fig. 10; pl. 45, figs. 7, 8), as mentioned before, is similar to *P. fusiformis* (SCHELLWIEN) of the Atetsu Limestone

in the general stage of evolution. *Pseudofusulina kraffti* (OZAWA, 1927, p. 147, fig. 5) resembles somewhat *P. kraffti magna* TORIYAMA in some internal biocharacters of the shell.

The Kozaki formation (KANMERA, 1963) which is distributed in Kuma Massif, Southern Kyushu, contains prolific fusulinid faunas at four horizons in it, the lowest horizon of which is composed mainly of such fusulinids as *Misellina claudiae* (DEPRAT), *Parafusulina gruperaensis* THOMPSON and MILLER, *P. figueroi* (THOMPSON and MILLER), *P. nakamigawai* MORIKAWA and HORIGUCHI, *Monodiexodina kumensis* KANMERA, etc. Of these species *Parafusulina figueroi* (KANMERA, 1963, pp. 96–98, pl. 16, figs. 1–5), as already pointed out by KANMERA, closely resembles *P. semilucera granda* described by NOGAMI from the Atetsu Limestone and *P. gruperaensis* has a smaller shell, fewer volutions, and weaker septal fluting than those of the species-group of *P. kaerimizensis* which is generally considered to be of the advanced form among the species of the genus. *Misellina claudiae* (DEPRAT) has been known from various localities. Recently, KANMERA (1963) fully discussed the stratigraphic range of this species and concluded that *M. claudiae* defined a restricted stratigraphic zone just below the *Parafusulina kaerimizensis* zone or the *Neoschwagerina simplex* zone. From these, it would seem that both the *Misellina claudiae* fauna of the Kozaki formation and the *Pseudofusulina kraffti magna* fauna are of the same age.

MIKLUKHO-MACLAY (1949) described *Pseudofusulina kraffti* (SCHELLWIEN), *P. parakraffti* MIKLUKHO-MACLAY, *P. fusiformis* (SCHELLWIEN), *Parafusulina complicata* (SCHELLWIEN) etc. from the *Parafusulina-Paraschwagerina-Pseudoschwagerina* zone (P_1^1) of Pamir. *Pseudofusulina kraffti* and *P. parakraffti* have a strong resemblance to *P. kraffti magna* TORIYAMA in the essential biocharacters of the shell and *P. fusiformis* has been described from the *Pseudofusulina kraffti magna* zone of the Atetsu Limestone. *Parafusulina complicata* resembles *P. semilucera* (NOGAMI) in general shell-shape and the internal characters and both the species may be regarded to be of the same degree in the stage of the development of the shell. The stratigraphical occurrence of the Pamir fauna has not been shown in detail, but it is possibly of the same age as the *Pseudofusulina kraffti magna* fauna of Atetsu.

From the algal limestone of Crna Gora of Montenegro in Yugoslavia, KOCHANSKY-DEVIDÉ (1962) described a number of species of fusulinids such as *Nankinella*, *Staffella*, *Schubertella*, *Biwaella*, *Oketaella*, *Rugosofusulina*, *Schwagerina* and *Pseudofusulina* and this fauna was considered by her to indicate the lower Leonardian. The fauna is somewhat unique in the species-assemblage. The species which are identical or similar to those of the Atetsu Limestone are very rare. The species of *Pseudofusulina* important for the correlation with the Atetsu fauna is only *P. fusiformis* (SCHELLWIEN) which has a fairly thicker spirotheca, fewer numbers of volutions and weaker septal fluting.

In Central America, the stratigraphical and palcontological knowledge of the late Palcozoic strata of Southern Chiapas, Mexico, was gained by THOMPSON and MILLER (1944), and they described *Parafusulina gruperaensis* (THOMPSON and MILLER) and

Schwagerina chiapasensis THOMPSON and MILLER from the Grupera formation; *Schwagerina figueroi* THOMPSON and MILLER from the lower part of the La Vainilla Limestone of Chiapas. In Guatemala, KLING (1960) described *Parafusulina gruperaensis* together with *Eoverbeekina americana* THOMPSON and MILLER from the lower part of the Chochal formation overlying the Santa Rosa formation which extends eastward from Chiapas, Mexico. In Japan the specimens assigned to *Parafusulina gruperaensis* were described by KANMERA (1963) from the *Misellina claudiae* zone just below the *Neoschwagerina simplex* zone of the Kozaki formation and it is noteworthy that *Parafusulina gruperaensis* is associated with *Schwagerina figueroi* THOMPSON and MILLER in that zone. As already pointed out by KANMERA (1963), *Schwagerina figueroi* shows striking resemblances in the general features to *Parafusulina semilucera granda* (NOGAMI) from the *Pseudofusulina kraffti magna* subzone of Atetsu.

b) *Parafusulina kaerimizensis* subzone (Pm β). The *Parafusulina kaerimizensis* subzone is symbolized by the upper part of the Shoyama formation which is quite limited in geographic distribution in the Atetsu area and comprehends several species of fusulinids such as *Parafusulina kaerimizensis* (OZAWA), *P. edoensis* (OZAWA), *P. armstrongi* THOMPSON, *Nagatoella kobayashii* THOMPSON, *Misellina* sp., *Verbeekina* sp., *Pseudodoliolina ozawai* YABE and HANZAWA and *Neoschwagerina craticulifera* (SCHWAGER). Among them *Parafusulina kaerimizensis* is the most characteristic species and *Neoschwagerina craticulifera* is very rare in this subzone. The *Parafusulina kaerimizensis* subzone of this area corresponds with the following fusulinid zones or formations described from the Inner and Outer Zones of Japan, viz., the *Parafusulina kaerimizensis* subzone of the Akiyoshi Limestone (TORIYAMA, 1958), the *Parafusulina kaerimizensis* zone of the Ikadaba formation (KAWANO, 1961), the *Parafusulina sapperi* subzone of the Ibukiyama Limestone (KOBAYASHI, 1957), the Nc zone of the Akasaka Limestone (OZAWA, 1927; MORIKAWA, 1958), the *Parafusulina hirayuensis* subzone (IGO, 1959), the Kuchibora formation in Gifu Prefecture (KANUMA, 1958), the *Schwagerina* zone of Kanto (=Kwanto) Mountainland (MORIKAWA, 1955), and the *Neoschwagerina simplex* zone of the Kozaki formation (KANMERA, 1963). The faunas equivalent in age to the Atetsu fauna have also been widely recognized in the Tethys region, e.g. China, Pamir, Jugoslavia, Central and North America.

In the Akiyoshi Limestone, the *Parafusulina kaerimizensis* subzone which was designated by TORIYAMA (1958) as the upper part of the *Parafusulina* zone comprises four species of *Parafusulina*, one of *Nagatoella*, *Pseudodoliolina*, *Neoschwagerina* and *Afghanella*, respectively, two of *Pseudofusulina* and several of the other genera. The species of *Parafusulina* are *P. kaerimizensis* (OZAWA), *P. edoensis* (OZAWA), *P. pseudojaponica* TORIYAMA and *P. gigantea* (DEPRAT), and the most characteristic species among them are the first two. There are specimens referred to *P. kaerimizensis* and *P. edoensis* have also in the *Parafusulina kaerimizensis* subzone of Atetsu. The described species of *Nagatoella*, *Pseudodoliolina*, and *Neoschwagerina* are *Nagatoella kobayashii* THOMPSON, *Pseudodoliolina ozawai* YABE and HANZAWA, and *Neoschwagerina craticulifera* (SCHWAGER), all of which occur in association with *Parafusulina kaerimizensis* in the

Atetsu Limestone. *Neoschwagerina craticulifera* is, however, very rare in this subzone. As stated above the faunal assemblage of the *Parafusulina kaerimizensis* subzone of the Akiyoshi Limestone is similar to that of the *P. kaerimizensis* subzone of Atetsu.

KAWANO (1961) reported the *Parafusulina kaerimizensis* fauna composed of *Parafusulina kaerimizensis* (OZAWA), *P. edoensis* (OZAWA), *Pseudofusulina tschernyschewi* (SCHELLWIEN), *Staffella yobarensis* OZAWA and *Schubertella* sp. from the lower part of the Ikadaba formation in Yamaguchi Prefecture. The mutually related species between the Ikadaba fauna and the Atetsu fauna are *Parafusulina kaerimizensis* and *P. edoensis* which are the most characteristic species in the *Parafusulina kaerimizensis* fauna. *Pseudofusulina tschernyschewi* (SCHELLWIEN) in Japan has been described by TORIYAMA (1958) from the *Pseudofusulina vulgaris* and *P. ambigua* subzones just below the *Parafusulina kaerimizensis* subzone of the Akiyoshi Limestone and described by FUJIMOTO (1936) from the Kwanto Mountainland. As judged from these facts, *Pseudofusulina tschernyschewi* may be regarded as the species of long duration. *Staffella yobarensis* which had been originally described by OZAWA (1925) from the Akiyoshi Limestone, was recently redescribed by TORIYAMA (1958) in detail from the same limestone and it was clarified that this species was of the upper Lower Permian in age. However, the fact that *S. yobarensis* is associated with *Parafusulina kaerimizensis* in the Ikadaba formation shows that this species ranges over the *Parafusulina kaerimizensis* subzone, if it is not a derived fossil. Taking all these facts into consideration, I consider that both the Ikadaba and Atetsu faunas are equivalent in age.

In the Ibuki area of Shiga Prefecture, the fauna equivalent in age to the *Parafusulina kaerimizensis* fauna of the Atetsu Limestone is represented by the *Parafusulina sapperi* fauna of the Ibukiyama Limestone (KOBAYASHI, 1957). This fauna is composed of the following species, viz., *Parafusulina kaerimizensis* (OZAWA), *P. sapperi* (STAFF), *Parafusulina japonica* (GÜMBEL), *P. gigantojaponica* (KOBAYASHI), *Pseudofusulina sekii* KOBAYASHI, *Cancellina* cf. *nipponica* (OZAWA) and *Neoschwagerina* sp. Of these, *Parafusulina kaerimizensis* described by KOBAYASHI (p. 291, pl. 7, fig. 1) does not agree with the holotype and the paratype from the Akiyoshi Limestone. Kobayashi's specimen takes the highly advanced form for the genus, having a larger shell, thicker spirotheca, stronger septal fluting and rapider expansion of the shell than those of the holotype. *Parafusulina sapperi* which has a rather thick fusiform shell with six to seven volutions and has moderate thick spirotheca and regularly and strongly folded septa, resembles somewhat *P. kaerimizensis* in its general shell-characters. Both *P. sapperi* and *P. kaerimizensis* may be considered to be approximately of the same age from their close similarities in the general development of the shell. *Parafusulina japonica* of KOBAYASHI (p. 285, pl. 6, figs. 3, 4, 5) quite resembles *P. edoensis* from the Akiyoshi Limestone and the Atetsu Limestone in the shell-shape, the proloculus diameter, the expansion of the shell, the spirothecal thickness, the septal fluting and the axial filling. These two forms may be one and the same species. *Parafusulina gigantojaponica* (KOBAYASHI) (p. 287, pl. 6, fig. 8)

resembles *P. edoensis* (OZAWA) in the essential biocharacters of the shell but the former species has a slightly larger shell and slightly rapider expansion of the shell. *P. gigantojaponica*, from the general shell-shape and the internal modes, seems to be of the species-group of *P. edoensis*. In the *Parafusulina sapperi* subzone of this area it is very interesting to find the primitive species of *Neoschwagerina*, such as *N. craticulifera* or its allies identical with those of the Atetsu and Akiyoshi Limestones. MORIKAWA and ISOMI (1961) described the new species under the name of *Parafusulina takeyamai* from the southern part of the Ibukiyama Limestone. Judging from the illustrations, this species is more or less deformed and somewhat resembles in the shell-shape and the internal modes *Parafusulina erratoseptata* KLING, *P. biturbinata* KLING and *P. sapperi* (STAFF) from the *Parafusulina* fauna of Guatemala which may be equivalent in age to the Atetsu fauna.

In the Akasaka Limestone, *Parafusulina japonica* (GÜMBEL) and its variant form, *Verbeekina verbeeki* (GEINITZ), *Pseudodoliolina ozawai* YABE and HANZAWA and *Neoschwagerina craticulifera* (SCHWAGER) were described by OZAWA (1927) from the upper part of Nc zone. From the same limestone MORIKAWA (1958) described many new and known species of *Parafusulina* and *Schwagerina*, and a few of *Pseudodoliolina* and *Neoschwagerina*, but most of them are identical or similar to those of the *Parafusulina kaerimizensis* subzones of the Atetsu and the Akiyoshi Limestone. The examination of the species and the faunal assemblage of the OZAWA's Nc zone and the MORIKAWA's *Parafusulina japonica* and the *Pseudodoliolina ozawai* zone stated above shows that these zones have a mutual relation to the *Parafusulina kaerimizensis* subzone of Atetsu.

MORIKAWA (1955) described *Parafusulina kaerimizensis* (OZAWA) and *Parafusulina japonica* (GÜMBEL) from the Shomaru pass, eastern part of the Kwanto (=Kanto) Massif. However, the former is different from *P. kaerimizensis* in having thicker spirotheca for corresponding volutions, more weakly fluted septa and less extensive axial fillings in the inner volutions, and the latter also can be separated from *Parafusulina japonica* because of the smaller shell, the fewer volutions, the slower expansion of the shell, the smaller proloculus and the weaker septal fluting.

The *Parafusulina hirayuensis* zone of the Hirayu district in the southern part of the Hida Massif is correlated with the *Parafusulina kaerimizensis* subzone of the Atetsu Limestone by the occurrence of the typical *Parafusulina* and *Pseudodoliolina*. The faunal assemblage of this zone consists of *Parafusulina japonica* (GÜMBEL), *P.* sp. aff. *P. japonica* var. *cincta* (REICHEL), *P. hirayuensis* IGO, *P. hayashii* IGO and *Pseudodoliolina ozawai* YABE and HANZAWA. *Parafusulina japonica* and its varieties are similar in the general stage of evolution to *P. edoensis* (OZAWA). *Parafusulina hayashii* and *P. hirayuensis*, both of which have the highly elongate, fusiform shells, the relatively thin spirotheca, and the regularly and complicatedly fluted septa, closely resemble *P. guatemalaensis* described by DUNBAR (1939) and KLING (1960) from the Chochal limestone at Purulha, Guatemala rather than any other known species, and it is worthy of note that in this zone *Pseudodoliolina ozawai* which is quite common in the

Parafusulina kaerimizensis subzone of Atetsu is accompanied with *Parafusulina japonica*, *P. hirayuensis* and *P. hayashii*.

The fusulinids described by KANMERA (1963) from the Kozaki formation in Kuma Massif, Kyushu, have some identical or closely related species to those of the *Parafusulina kaerimizensis* subzone of Atetsu. The Kozaki fauna is composed of the following fusulinids, viz., *Parafusulina kaerimizensis* (OZAWA), *P.* cf. *sapperi* (STAFF), *Verbeekina sphaera* OZAWA, *Cancellina tenuitesta* KANMERA, *Neoschwagerina simplex* (OZAWA) and *Yangchienia compressa* OZAWA. The Kozaki specimens referred to *Parafusulina kaerimizensis* (OZAWA) quite agree with the Atetsu specimens. *Parafusulina sapperi* (STAFF), as stated before, is similar to *P. kaerimizensis* in the general stage of evolution. Such primitive forms of *Cancellina* and *Neoschwagerina* as *C. tenuitesta* and *N. simplex* do not occur in the Atetsu Limestone. *Verbeekina* sp. listed from the *Parafusulina kaerimizensis* subzone of Atetsu is small in size and resembles *V. sphaera* in some shell-characters. The occurrences of the typical species of *Parafusulina* and the primitive *Verbeekina* in the Kozaki and the Atetsu fauna indicate that both faunas are of the same age.

In China, the *Parafusulina* fauna has been well known from the Chihsia Limestone studied by CHEN (1934). The species of *Parafusulina* described and illustrated from this limestone are *P. multiseptata* (SCHELLWIEN), *P. undulata* CHEN, *P. constricta* CHEN, *P. subextensa* CHEN, *P. lungtanensis* CHEN, *P. chekiangensis* CHEN and *P. gracilis* CHEN, and most of them are regarded to be of the typical form for the genus. Of these forms, *Parafusulina multiseptata* (p. 86, pl. 11, figs. 2–4; pl. 12, figs. 2–4; pl. 13, figs. 1–6) and *P. undulata* (p. 82, pl. 12, fig. 5) are similar in the general stage of evolution to the species group of *P. subrectangularis* (KLING, 1960, p. 654, pl. 82, figs. 2–5), and *P. sapperi* (DUNBAR, 1939, p. 334, pl. 35, figs. 1–6) from Central America and *P. nakamigawensis* (MORIKAWA and HORIGUCHI, 1956, p. 261, pl. 35, figs. 1–7) from Japan. *P. constricta* CHEN (1934, p. 88, pl. 11, fig. 1) and *P. gracilis* CHEN (1934, p. 89, pl. 12, fig. 1) are similar in the general development of the shell to the specimens of MORIKAWA (1955, p. 107, pl. 15, figs. 11–13) which were described under the name of *Parafusulina kaerimizensis* (OZAWA) from the Shimokuzu conglomerate in the eastern part of Kwanto Mountainland. In the shell-shape and the internal characters *Parafusulina subextensa* CHEN (1934, p. 90, pl. 12, fig. 8) resembles closely *P. guatemalaensis* (DUNBAR, 1939, p. 347, pl. 36, figs. 1–10) from the Middle Permian Limestone of Purula in Guatemala and the same species described by KLING (1960, p. 649, pl. 81, figs. 1–3, 6) from the Chochal Limestone in Guatemala. The paleontological evidence stated above maintains the correlation of the *Parafusulina multiseptata* zone of the Chihsia Limestone with the upper part of the *Parafusulina* zone of Japan including the *P. kaerimizensis* subzone of Atetsu.

MIKLUKHO-MACLAY (1949) described many fusulinids from the *Misellina* zone (P_1^2) of Pamir. The listed and described species are *Misellina claudiae* (DEPRAT), *M. termieri* (DEPRAT), *M. parvicostata* (DEPRAT), *M. dyhrenfurthi* (DOUTKEVITCH), *Parafusulina japonica* (GÜMBEL), *Pseudofusulina chihsiaensis* LEE, *P. pseudochihsiaensis* CHEN, *P.*

darvasica MIKLUKHO-MACLAY, *Cancellina primigena* (HAYDEN) and *Neoschwagerina craticulifera* (SCHWAGER). Among them, there are some species identical or similar to those of the *Parafusulina kaerimizensis* subzone of Atetsu. For instance, *Misellina claudiae* (DEPRAT) is closely similar to *M.* sp. from the Atetsu Limestone in the general shell-shape and the internal characters of the shell, and *Parafusulina japonica* is, as already pointed out by TORIYAMA (1958), similar in the shell-shape and some internal modes of the shell to *P. edoensis* (OZAWA) commonly associated with *P. kaerimizensis*. *Neoschwagerina craticulifera* is identical with the Atetsu specimens.

In Central America, the *Parafusulina* faunas have been reported by DUNBAR (1939) and KLING (1960) from Guatemala, and by THOMPSON and MILLER (1944) from Southernmost Mexico. DUNBAR described two species of *Parafusulina*, that is, *P. sapperi* (STAFF) and *P. guatemalaensis* DUNBAR from Trece and Panzal of Guatemala. The former species, as already mentioned before, somewhat resembles *P. kaerimizensis* in some shell-characters and both species may be considered to be approximately of the same age. The latter species resembles *Parafusulina hayashii* IGO and *P. hirayuensis* IGO in the shell-shape and some internal characters of the shell, which come from the *Parafusulina* zone of the Hirayu Limestone equivalent in age to the *Parafusulina kaerimizensis* zone of Atetsu. In 1960, KLING described several species of *Parafusulina* from Chiantla and Purulha of Guatemala and British Honduras. The described species of *Parafusulina* are as follows, viz., *Parafusulina gruperaensis* THOMPSON and MILLER, *P. australis* THOMPSON and MILLER, *P. erratoseptata* KLING, *P. guatemalaensis*, *P. biturbinata* KLING and *P. subrectangularis* KLING. All are of the advanced forms among the species of the genus. Of these, *Parafusulina guatemalaensis* is similar to *P. kaerimizensis* (OZAWA) and *P. erratoseptata* and *P. biturbinata* are similar in the general stage of evolution to *P. takeyamai* MORIKAWA and ISOMI from the *Parafusulina sapperi* zone of the southern part of the Ibukiyama Limestone which is equivalent in age to the *Parafusulina kaerimizensis* zone of Atetsu.

7. *Neoschwagerina douvillei* Zone (*Pm* γ)

The *Neoschwagerina douvillei* zone (IMAMURA, 1959; SADA, 1960, '61 and '63) is represented by the Maki formation of the lower part of the Yukawa group and characterized by such fusulinids as *Neoschwagerina douvillei* OZAWA, *N. toriyamai* SADA, *N. megaspherica* DEPRAT, *N. margaritae* DEPRAT, *N. minoensis* DEPRAT, *N. craticulifera* (SCHWAGER), *Yabeina katoi* (OZAWA), *Afghanella* sp., *Sumatrina annae* VOLZ, *S. longissima* DEPRAT, *Verbeekina verbeeki* (GEINITZ), *Pseudodoliolina pseudolepida* (DEPRAT), and *Parafusulina armstrongi* THOMPSON. Of these species, *Neoschwagerina douvillei* OZAWA is the most prolific species and it is very interesting that *Sumatrina longissima* first appears in this zone. IMAMURA (1959) instituted the *Verbeekina verbeeki* zone in the Middle Permian of the Atetsu Limestone and placed it under the *Neoschwagerina douvillei* zone. The examination of the *Verbeekina verbeeki* zone by me, however, shows that the present zone is composed of *Verbeekina verbeeki* (GEINITZ), *Neoschwagerina douvillei*

OZAWA, *N. margaritae* DEPRAT, *N. megaspherica* DEPRAT, etc. and has the same faunal assemblage as that of *N. douvillei* zone. Accordingly, I am inclined to think that the *Verbeekina verbeeki* zone of IMAMURA should be referred to the *Neoschwagerina douvillei* zone. NOGAMI (1961) discriminated the *Neoschwagerina craticulifera* subzone from the *N. douvillei-N. margaritae* subzone in this limestone. The *Neoschwagerina craticulifera* subzone characterized by *N. craticulifera* and its allies, however, has never been found from any outcrops in this plateau. *N. craticulifera* (SCHWAGER) occurs commonly in the *N. douvillei* zone and very rarely in the *Parafusulina kaerimizensis* subzone of the upper part of the *Parafusulina* zone. In the Inner and Outer Zones of Japan, the *Neoschwagerina* zones corresponding to the *Neoschwagerina douvillei* zone have been known from the following limestones and formations, viz., the *Neoschwagerina douvillei* zone of the Akiyoshi Limestone (TORIYAMA, 1958), the *Neoschwagerina megaspherica* zone of the Zomeki Limestone (KAWANO, 1961), the *Neoschwagerina margaritae* zone of the Akasaka Limestone (OZAWA, 1927, MORIKAWA et al., 1956), the *Neoschwagerina margaritae* zone of the Ibukiyama Limestone (KOBAYASHI, 1957), the *Neoschwagerina* zone of the Ishiyama Limestone (ISOMI, 1954), the Okuzumi formation and the Kayugawa formation of the Southern part of the Hida Massif (KANUMA, 1958), the *Neoschwagerina margaritae* zone of the Tsukumi Limestone (FUJII, 1954), and the *Neoschwagerina margaritae* zone of the Kozaki formation (KANMERA, 1963). Furthermore, the fusulinid faunas closely related to the *Neoschwagerina douvillei* fauna of Atetsu have been found in South China, Pamir, Jugoslavia, and North America.

In the Akiyoshi area, the *Neoschwagerina douvillei* subzone designated by TORIYAMA (1958) underlies the *Parafusulina kaerimizensis* subzone in the reversed order in the west of Yobara (Section 26) and this subzone contains *Neoschwagerina douvillei* Ozawa, *N. megaspherica* DEPRAT, *N. craticulifera* (SCHWAGER) including *N. craticulifera haydeni* DOUTKEVITCH and *Neoschwagerina tobleri* LANGE. Of these species, *Neoschwagerina douvillei*, *N. megaspherica*, *N. craticulifera* are identical with those of Atetsu. *Neoschwagerina tobleri* has not been found in the Atetsu Limestone. However, this species is closely related with *N. douvillei* in the shell-shape and the internal biocharacters of the shell. The presence of the identical and the closely related species of neoschwagerinids strongly suggests that both the *Neoschwagerina douvillei* subzone of the Akiyoshi Limestone and the *N. douvillei* zone of the Atetsu Limestone are of the same age.

The *Neoschwagerina megaspherica* zonule which was defined by KAWANO (1961) from the Zomeki Limestone in Yamaguchi Prefecture is characterized by *Neoschwagerina megaspherica* DEPRAT, *N.* sp. and *Schwagerina* sp., and this zonule overlies the *Parafusulina* sp. zonule corresponding with the *Parafusulina kaerimizensis* subzones of the Akiyoshi and Atetsu Limestones. The species identical with those of the Atetsu fauna are rather few, but the occurrences of *Neoschwagerina megaspherica* as well as the stratigraphic position of it show that both the *N. megaspherica* zonule of the Zomeki Limestone and the *N. douvillei* zone of Atetsu are of the same age. In 1953,

KAWANO studied the limestone bed of the upper part of the Ikadaba formation in the northern part of Yamaguchi Prefecture and from this limestone bed he reported the following species, viz., *Neoschwagerina douvillei* OZAWA, *N. megaspherica* DEPRAT, *N. margaritae* DEPRAT, *N. craticulifera* (SCHWAGER), *N. simplex* OZAWA, *Afghanella* sp., *Sumatrina annae* DEPRAT, *Verbeekina verbeeki* (GEINITZ), and some species of *Parafusulina* and *Pseudofusulina*. The first four species of *Neoschwagerina* and the two species of *Verbeekina* and *Sumatrina* are identical with those of the *N. douvillei* zone of Atetsu. Accordingly, it is no doubt that the *Neoschwagerina* faunas of the Ikadaba formation and the Atetsu Limestone are of the same age.

SADA (1963) described *Neoschwagerina margaritae* DEPRAT and listed *N. douvillei* OZAWA and *N. craticulifera* (SCHWAGER) from the *Neoschwagerina margaritae* fauna of the Joé Limestone in Jinseki-Gun, Hiroshima Prefecture. These three species are identical with those of the *Neoschwagerina douvillei* fauna of Atetsu. From these facts, I considered that the *Neoschwagerina margaritae* fauna of the Joé Limestone is equivalent in age to the *N. douvillei* fauna of Atetsu.

OZAWA (1927) described *Neoschwagerina margaritae* DEPRAT, *N. multicircumvoluta* DEPRAT, *N. craticulifera* (SCHWAGER), *Verbeekina verbeeki* (GEINITZ) from the *Neoschwagerina margaritae* zone (Nm) of the Akasaka Limestone in Gifu Prefecture. Recently, from the same limestone MORIKAWA (1961) described some new species of *Neoschwagerina*, that is, *N. muratai* MORIKAWA, *N. okuboi* MORIKAWA, *N. larga* MORIKAWA and *N. hanaokensis* MORIKAWA, all of which seem to belong to the species-group of *N. douvillei* in the shell-shape and the internal characters of the shell. These species of *Neoschwagerina* and *Verbeekina* which are similar to those of the Atetsu Limestone strongly suggest that the *Neoschwagerina margaritae* zone of the Akasaka Limestone are equivalent in age to the *Neoschwagerina douvillei* zone of Atetsu.

KOBAYASHI (1957) described *Neoschwagerina margaritae* DEPRAT, *N. craticulifera* (SCHWAGER), *Cancellina* cf. *nipponica* OZAWA, *Pseudodoliolina ozawai* YABE and HANZAWA, *Schwagerina japonica* (GÜMBEL), and *Verbeekina verbeeki* (GEINITZ) from the *Neoschwagerina margaritae* zone underlying the *Yabeina* cf. *katoi* zone of the Ibukiyama Limestone in Shiga Prefecture. Of these species, *Neoschwagerina margaritae*, *N. craticulifera* and *Verbeekina verbeeki* are identical with the specimens of the Atetsu Limestone. These abundantly demonstrate that the *Neoschwagerina margaritae* zone of the Ibukiyama Limestone is equivalent in age to the *N. douvillei* zone of Atetsu.

The fusulinids from the Ishiyama Limestone in the Ogaki district, Gifu Prefecture, which were studied by ISOMI (1954), are the same as those of the *Neoschwagerina douvillei* zone of the Atetsu Limestone. They are *Neoschwagerina margaritae* DEPRAT, *N. craticulifera* (SCHWAGER) and *Yabeina katoi* (OZAWA) and these three species are quite common in the *N. douvillei* zone of Atetsu. Therefore, it is no doubt that the faunas of the Ishiyama and the Atetsu Limestone are of the same age.

The Okuzumi and Kayugawa formations in Gifu Prefecture which were studied by KANUMA (1958) in detail, contain *Neoschwagerina margaritae* DEPRAT, *N. douvillei*

OZAWA and *Verbeekina verbeeki* (GEINITZ). These three species are exactly the same as those of the *N. douvillei* zone and these similarities suggest that the Okuzumi and Kayugawa formations are equivalent in age to the *N. douvillei* zone of the Atetsu Limestone.

Some species of fusulinids reported by FUJII (1954) from the *Neoschwagerina* zone which is underlying the *Yabeina globosa* zone of the Tsukumi Limestone in Oita Prefecture are identical with the species of the *Neoschwagerina douvillei* zone of the Atetsu Limestone. The former zone is characterized by *Neoschwagerina craticulifera* (SCHWAGER), *N. minoensis* DEPRAT, *N. margaritae* DEPRAT, *Verbeekina* sp., *Pseudodoliolina* sp. and *Schwagerina* sp. The occurrence of the first three species and also the stratigraphic position strongly suggest that both the Tsukumi and Atetsu faunas are of the same age.

The fusulinids from the Tosayama in Kochi Prefecture (TORIYAMA, 1947) resemble most closely those from the *Neoschwagerina douvillei* fauna of Atetsu. The Tosayama fauna is composed of *Neoschwagerina douvillei* OZAWA, *N. margaritae* DEPRAT and *N. craticulifera* SCHWAGER, which are the most characteristic species in the Atetsu fauna. The occurrence of these three species indicates that both faunas are of the same age.

CHEN (1956) described several species of *Neoschwagerina* from the Maok'ou Limestone in South China. Neoschwagerinids found in this limestone are *Neoschwagerina craticulifera* SCHWAGER, *N. douvillei* OZAWA, *N. margaritae* DEPRAT, *N. megaspherica* DEPRAT, *N. leei* CHEN and *N. multicircumvoluta* DEPRAT. The first four of these species are conspecific with those of the *Neoschwagerina douvillei* fauna of the Atetsu Limestone. The paleontological evidence stated above appears to support the correlation of the *Neoschwagerina* fauna of the Maok'ou Limestone with the *Neoschwagerina douvillei* fauna of Atetsu.

8. *Yabeina shiraiwensis Zone* (*Pm δ*)

It was not until IMAMURA's study (1959) came out that the Paleozoic students learned the occurrence of *Yabeina* in the Terauchi formation. Afterwards, this formation was studied in detail by me (1960, '61) and both the *Yabeina shiraiwensis* fauna (formerly called *Yabeina globosa* fauna) and the *Lepidolina imamurai* fauna were brought out. The significance of these faunas and their correlation were fully mentioned in my preceding paper (1960). The *Yabeina shiraiwensis* zone represented by the basal part of the Terauchi formation contains many fusulinids, viz., *Yabeina shiraiwensis* OZAWA, *Y. globosa* (YABE), *Y. katoi* (OZAWA), *Y. columbiana* (DAWSON), *Neoschwagerina douvillei* OZAWA, *N. megaspherica* DEPRAT, *N. toriyamai* SADA, *N. margaritae* DEPRAT, *N. minoensis* DEPRAT, *N. craticulifera* (SCHWAGER), *Sumatrina annae* VOLZ, *S. longissima* DEPRAT, *Verbeekina verbeeki* (GEINITZ) and *Pseudodoliolina pseudolepida* (DEPRAT), *P. ozawai* YABE and HANZAWA. All of them were listed before. NOGAMI (1961) described most of them and he was of the opinion that this fauna was of the middle Middle Permian. The fauna is, however, very similar to the Akasakan *Yabeina*

globosa fauna and the North American *Yabeina cascadensis* fauna which have been regarded as the typical fusulinid faunas in the upper Middle Permian. The discussion on the faunal assemblage and its correlation will be given in the following article. In the Atetsu fauna, *Yabeina shiraiwensis* is the most diagnostic species and moreover it should be noted that the species of neoschwagerinids and verbeekinids occur in association with *Yabeina shiraiwensis*. In Japan, *Yabeina* zones which correspond to the *Yabeina shiraiwensis* zone of Atetsu have been found out in the following limestones and formations, viz., the *Yabeina* zone of the Kyodoko formation (KAWANO, 1961), the *Yabeina shiraiwensis* zone of the Maedani formation (YOKOYAMA, 1959), the *Yabeina shiraiwensis* subzone of the Uji formation (YOSHIMURA, 1961), the *Yabeina* cf. *katoi* zone of the Ibukiyama Limestone (KOBAYASHI, 1957), the *Yabeina globosa* zone of the Akasaka Limestone (OZAWA, 1927; MORIKAWA, 1961), the *Yabeina globosa* zone of the Kwanto (=Kanto) Mountainland (FUJIMOTO (=HUJIMOTO), 1936), the *Yabeina shiraiwensis* zone of the Iwaizaki Limestone (MORIKAWA, 1960), the *Yabeina globosa* zone of the Tsukumi Limestone (FUJII, 1954), and the *Yabeina* subzone in the Tosa Structural Zone of Kochi and Tokushima Prefectures (SUYARI, 1961). In the outside of the Japanese Islands, the *Yabeina* faunas which seem to be connected with the *Yabeina shiraiwensis* zone of the Terauchi formation in the Atetsu district in the specific composition have been reported from South China, Indochina and North America.

In Yamaguchi Prefecture, KAWANO (1961) described many species of fusulinids from the *Yabeina* zone of the Kyodoko formation of the upper part of the Gampi group developed in the vicinities of Aihara and Ikadaba along the lower course of the Abu River. The species given the descriptions are *Schubertella* cf. *mullerieai* THOMPSON and MILLER, *Schwagerina* cf. *hutiensis* (CHEN), *Schwagerina* aff. *acris* THOMPSON and WHEELER, *Pseudofusulina vulgaris megaspherica* TORIYAMA, *Verbeekina* sp., *Neoschwagerina* cf. *douvillei* OZAWA, *Yabeina shiraiwensis* OZAWA, and *Sumatrina* sp. Of these, *Yabeina shiraiwensis* and *Neoschwagerina* cf. *douvillei* are the most important for the determination of the geologic age and the correlation and they have been commonly found in the *Yabeina shiraiwensis* zone of the Terauchi formation. Therefore, I cannot escape the conclusion that the *Yabeina* zone of the Kyodoko formation by KAWANO may correspond to the *Yabeina shiraiwensis* zone of the Terauchi formation.

From the limestone lenses of the Maedani formation of the Taishaku district in Hiroshima Prefecture, YOKOYAMA (1959) reported the following fusulinids, viz., *Yabeina shiraiwensis* OZAWA, *Neoschwagerina margaritae* DEPRAT, *Sumatrina annae* VOLZ, *Pseudodoliolina* sp., *Schwagerina* sp., and *Pseudofusulina* sp. The first three of these species are the same as those from the *Yabeina shiraiwensis* zone of the Terauchi formation. Lithologically, the Maedani formation is composed of black shale, with small limestone lenses in its basal part which contain the *Yabeina shiraiwensis* fauna now under consideration. The extraordinary similarities in the faunal assemblage and the sequence of rocks between the Maedani formation and the lower part of the Terauchi formation show that both are contemporaneous in the time of the

deposition.

In the Oga district of Okayama Prefecture, YOSHIMURA (1961) reported *Yabeina shiraiwensis* OZAWA from his unit A of the lower part of the Uji formation consisting mainly of shale with interbedded limestone lenses. The occurrence of *Yabeina shiraiwensis* and its stratigraphic position strongly suggest that the unit A of the Uji formation may correspond to the *Yabeina shiraiwensis* zone of the Terauchi formation.

KOBAYASHI (1957) described *Yabeina* cf. *katoi* (OZAWA), *Y.* cf. *cascadensis* (ANDERSON), *Y.* sp., *Neoschwagerina margaritae* DEPRAT and *N. craticulifera* (SCHWAGER) from the *Yabeina* cf. *katoi* zone of the Ibukiyama Limestone in Shiga Prefecture. All of them except *Y.* cf. *cascadensis* are quite identical with those of the Terauchi formation, as already pointed out by me (1960). On the basis of these facts I consider that the *Yabeina* cf. *katoi* zone of the Ibukiyama Limestone can safely be correlated with the *Y. shiraiwensis* zone of the Terauchi formation.

The faunal comparison between the *Yabeina globosa* zone (Ng) of the Akasaka Limestone and the *Y. shiraiwensis* zone of the Terauchi formation was already discussed by me (1960). In 1927, OZAWA described *Yabeina globosa* (YABE), *Y. katoi* (OZAWA), *Sumatrina annae* VOLZ and *Neoschwagerina minoensis* DEPRAT from the Ng zone of the Akasaka Limestone, and recently MORIKAWA (1961) described *Yabeina igoi* MORIKAWA from the same limestone. Of these species, the first four are the same as those of the Terauchi formation. This paleontological evidence steadfastly supports the correlation of the *Yabeina shiraiwensis* zone of the Terauchi formation with the *Y. globosa* zone of the Akasaka Limestone.

In Miyagi Prefecture of Northeast Japan, MORIKAWA (1960) described *Yabeina shiraiwensis* (OZAWA), *Verbeekina verbeeki* (GEINITZ), some species of *Codonofusiella* and *Rauserella*, and several species of *Pseudofusulina* from the *Yabeina shiraiwensis* zone of the Iwaizaki Limestone. Of these, *Verbeekina verbeeki* and most of the species of *Pseudofusulina* are generally common in the *Neoschwagerina* and *Parafusulina* zones of Japan, respectively. According to him, *Verbeekina verbeeki* and some *Pseudofusulina* are prolific among the species of fusulinids of this limestone. On the basis of the occurrence of *Y. shiraiwensis* and *V. verbeeki* I am inclined to think that the *Yabeina shiraiwensis* zone of the Iwaizaki Limestone may be equivalent in age to the *Yabeina shiraiwensis* zone of the Terauchi formation.

FUJII (1954), in his study of the Tsukumi Limestone of Oita Prefecture, reported *Yabeina globosa* (YABE), *Y. katoi* (OZAWA) and *Y.* sp. without descriptions from the upper part of this limestone. Judging from the specific composition cited above, both the *Yabeina globosa* fauna of the Tsukumi Limestone and the *Y. shiraiwensis* fauna of the Terauchi formation may be considered to be of the same age.

SUYARI (1961) described *Neoschwagerina* cf. *douvillei* OZAWA, *Yabeina omurensis* YAMAGIWA and ISHII, *Y. globosa* (YABE), *Pseudodoliolina pseudolepida* (DEPRAT) and *Reichellina* sp. from the *Yabeina* subzones of the Hisone formation and the Wakasugi group in the Chichibu Terrain of Shikoku. The species described under the name of *Yabeina globosa*, *Neoschwagerina douvillei* and *Pseudodoliolina pseudolepida* are also

commonly found in the *Yabeina shiraiwensis* zone of the Terauchi formation. The occurrence of the three species cited above supports the justifiability of the correlation.

In South China, CHEN (1957) described a large number of the species of *Neoschwagerina*, *Yabeina* and *Sumatrina* from the upper part of the Maok'ou Limestone. The species given the descriptions are *Neoschwagerina margaritae* DEPRAT, *N. megaspherica* DEPRAT, *N. craticulifera* (SCHWAGER), *N. douvillei* OZAWA, *N. leei* CHEN, *Yabeina inouyei* DEPRAT (=*Y. globosa* (YABE)), *Y. shiraiwensis* OZAWA, *Y. proboscis* CHEN, *Sumatrina annae* VOLZ and *S. longissima* DEPRAT. As already discussed by me (1960), all of them are closely similar to the species which came from the *Yabeina shiraiwensis* zone of the Terauchi formation. The first four species of *Neoschwagerina*, two of *Yabeina*, that is, *Y. inouyei* (=*Y. globosa*) and *Y. shiraiwensis*, two of *Sumatrina* are identical with those of the Terauchi formation, and in the general shell-shape and the internal modes, *Neoschwagerina leei* CHEN is closely allied to *Yabeina katoi* (OZAWA) from the Akasaka Limestone and some other districts in Japan. In the faunal assemblage of the species, the extraordinary similarity between the *Yabeina* zone of the Maok'ou Limestone and the *Yabeina shiraiwensis* zone of the Terauchi formation strongly suggests that the both faunas are of the same age.

In North America, THOMPSON and WHEELER (1942) described *Yabeina packardi* THOMPSON and WHEELER from a cobble of limestone collected from the base of Gray Butte formation, Jafferson County, near Madras, Oregon. Several years later, THOMPSON, WHEELER and DANNER (1950) described *Yabeina cascadensis* (ANDERSON), *Schwagerina andersoni* THOMPSON, WHEELER and DANNER, and *Codonofusiella duffelli* THOMPSON, WHEELER and DANNER from the Canyon Creek limestone quarry, three and one-half miles northeast of Granite Falls, and at the same time they described *Yabeina cascadensis* and *Schwagerina andersoni* from the Old Granite Falls limestone quarry, four miles northeast of Granite Falls, Snohomish County in Washington. *Yabeina packardi* resembles *Y. globosa* (YABE) (=*Y. inouyei* DEPRAT) in the general development of the shell, the development of the primary septula in the outer volutions of the mature specimens, the number of the secondary axial and spiral septula, and the stage of their first appearance. *Yabeina cascadensis* is typical for the genus, but it takes a less advanced form in the general development of the shell, compared with *Y. columbiana* from the Upper Permian of Marble Canyon of British Columbia which has been considered to be of the quite advanced form among the species of *Yabeina*. Furthermore, in the general stage of evolution and the internal biocharacters of the shell *Yabeina cascadensis* somewhat resembles *Y. igoi* MORIKAWA (1961, pp. 64–65, pl. 9, fig. 3; pl. 20, figs. 1–9) from the *Yabeina globosa* zone of the Akasaka Limestone. Therefore, I have reached the conclusion that the *Yabeina* faunas of the Gray Butte formation of Oregon and the Old Granite Falls Limestone of Washington and the *Yabeina shiraiwensis* fauna of the Terauchi formation (equivalent in age to the *Yabeina globosa* fauna of the Akasaka Limestone) may probably be of the same age.

9. *Lepidolina imamurai Zone* (*Pu α*)

The upper part of the Terauchi formation was tentatively named the *Lepidolina* zone (IMAMURA, 1959) and the stratigraphical and paleontological studies of this zone has been succeeded by me. As a result of my studies, I have reported the following fusulinids from the IMAMURA's *Lepidolina* zone, viz., *Lepidolina imamurai* SADA, *Yabeina yasubaensis* TORIYAMA, *Y. shiraiwensis* OZAWA, *Y. columbiana* (DAWSON), *Y. globosa* (YABE), *Y. katoi* (OZAWA), *Neoschwagerina douvillei* OZAWA, *N. megaspherica* DEPRAT, *N. margaritae* DEPRAT, *N. minoensis* DEPRAT, *N. craticulifera* (SCHWAGER), *Sumatrina annae* VOLZ, *S. longissima* DEPRAT, *Pseudodoliolina pseudolepida* (DEPRAT), *Codonofusiella* sp. and *Schwagerina* sp. Taking the stratigraphic horizon and the faunal assemblage into the consideration, the *Lepidolina* zone of this formation was designated by me (1960, '61) as the *Lepidolina imamurai* zone. On the other hand, NOGAMI (1961) called the same zone the *Yabeina shiraiwensis* subzone and concluded that this zone was of the Middle Permian in age. However, of the above-listed species, the first three are the most characteristic and they clearly show that this fauna overlying the *Yabeina shiraiwensis* fauna is of the Upper Permian in age. The *Lepidolina imamurai* zone is correlated to the following fusulinid zones, viz., the *Yabeina shiraiwensis* zones of the Akiyoshi Limestone and its surrounding areas (TORIYAMA, 1954; MURATA, 1961), the *Lepidolina* zone of the Taishaku Limestone (YOKOYAMA, 1959), the *Lepidolina* zonule of the Dodo conglomerate (KONISHI, 1952), the *Lepidolina toriyamai* zone of the Maizuru Terrain (NOGAMI, 1958), the *Lepidolina* zone of the Takagami conglomerate (CHISAKA, 1960), the *Yabeina* zone of the Kitakami Mountainland (HANZAWA, 1963), the *Lepidolina toriyamai* zone of the Kuma formation (KANMERA, 1953), and the *Yabeina* zone of the Yasuba conglomerate (TORIYAMA 1942). On the other hand, when correlated with foreign countries, the *Lepidolina imamurai* zone of the Terauchi formation is closely related to the Upper Permian fauna of Cambodge in Indochina described by GUBLER (1935) and to the *Yabeina columbiana* fauna of Marble Canyon in British Columbia described by THOMPSON, WHEELER and DANNER (1950).

TORIYAMA (1954) described *Yabeina shiraiwensis* OZAWA, *Y. yasubaensis* TORIYAMA, *Sumatrina annae* DEPRAT and *S. longissima* DEPRAT from the *Yabeina shiraiwensis* zones of the Akiyoshi Limestone and its adjacent Shiraiwa formation. Recently, MURATA (1961) reported *Yabeina shiraiwensis* OZAWA, *Y. yasubaensis* TORIYAMA, *Neoschwagerina douvillei* OZAWA and *Sumatrina annae* DEPRAT from the Tsutsumi, the Yaegahara and the Kawarakami formation in the Akiyoshi area. To take a gneral view of the specific composition of these faunas, they are mainly characterized by *Yabeina shiraiwensis* and *Y. yasubaensis*. This available evidence suggests that the *Yabeina shiraiwensis* zones of the Akiyoshi Limestone and its surrounding area are equivalent in age to the *Lepidolina imamurai* zone of the Terauchi formation.

YOKOYAMA (1959) reported *Lepidolina* sp., *Yabeina shiraiwensis* OZAWA, *Neoschwagerina* sp., *Codonofusiella* sp. etc. from the Yasumoto formation of the Taishaku Limestone plateau in Hiroshima Prefecture. Among them, *Lepidolina* sp. illustrated as fig. 2 and 3 on pl. 12 is typical for the genus and has the large and elongated shell with

the fairly large form ratio, the slower expansion of the shell, the very thin spirotheca in the inner and outer volutions, the thin primary spiral septula, the thin and short secondary spiral septula and the numerous and circular foramina. In these respects this species should be referred to *Lepidolina elongata* GUBLER (1935) from the Upper Permian of Cambodge in Indochina, where *L. elongata* has been commonly found in association with *L. multiseptata* DEPRAT as the type species of the genus. *Lepidolina* sp. of YOKOYAMA (1959) resembles somewhat *L. imamurai* from the Terauchi formation in the general shell-shape and some internal characters such as the spirothecal thickness, the expansion of the shell, and the modes of the primary and the secondary spiral septula. Therefore, I arrived at the conclusion that the *Lepidolina* zone of the Yasumoto formation was correlative with the *Lepidolina imamurai* zone of the Terauchi formation.

In the Oga Limestone of Okayama Prefecture, YOSHIMURA (1961) reported *Lepidolina multiseptata* DEPRAT and *Yabeina yasubaensis* TORIYAMA from the upper part of the Uji formation. The occurrence of these two species shows that the *Lepidolina* zone of the Uji formation is of the Upper Permian age and corresponds possibly to the *Lepidolina imamurai* zone of the Terauchi formation.

KONISHI (1952) reported and described the species of *Neoschwagerina*, *Yabeina* and *Sumatrina* together with some species of Permian algae from the Dodo conglomerate in Okayama Prefecture and he concluded this fauna was of the same age as that of the Yasuba limestone conglomerates studied by TORIYAMA (1942). On examining the specimens illustrated as fig. 4 and fig. 2 on pl. 14 which were described under the name of *Sumatrina annae*, the former has a quite elongated shell, thin spirotheca, thin primary spiral septula and slower expansion of the shell and the latter possesses a large proloculus, thin spirotheca and secondary spiral septula from the second volution. Founded on these shell-characters, KONISHI's fig. 4 may be considered to belong to *Lepidolina kumaensis* KANMERA which was originally described by KANMERA (1953) from the Kuma formation and fig. 2 to *Yabeina yasubaensis* TORIYAMA from the Yasuba limestone conglomerate of Shikoku. These paleontological evidences stated above show that the Dodo and Terauchi faunas are of the same age.

NOGAMI (1958) described the Upper Permian fusulinids from the Maizuru Zone in West Japan. The described species important for the determination of the geologic age are *Lepidolina toriyamai maizurensis* NOGAMI, *L. toriyamai* KANMERA, *L. kumaensis* KANMERA, *Yabeina gubleri* KANMERA, *Y. yasubaensis* TORIYAMA and *Neoschwagerina* cf. *margaritae* DEPRAT. *Lepidolina toriyamai maizurensis* resembles somewhat *L. imamurai* in the general shell-shape and some internal characters, and *Yabeina yasubaensis* and *Neoschwagerina margaritae* are referable to the species of the Terauchi formation. Therefore, the faunal resemblance between the *Lepidolina toriyamai* fauna of the Maizuru Zone and *L. imamurai* fauna of the Terauchi formation readily suggests that both are equivalent in age.

From the Takagami conglomerate of Choshi Peninsula in Chiba Prefecture, CHISAKA (1960) described several species of fusulinids indicating the Upper Permian

in age. Among them, the species ascribed to *Yabeina* which play an important role in the determination of the geologic age are *Yabeina shiraiwensis* OZAWA, *Y. katoi* (OZAWA), *Y. columbiana* (DAWSON), *Y. gubleri* KANMERA and *Y. proboscis* CHEN. The first three of these species are commonly found in the *Lepidolina imamurai* zone and both *Yabeina gubleri* and *Y. proboscis* are similar in the general stage of evolution to *Y. columbiana* originally described by DAWSON (1879) from the Marble Canyon Limestone of British Columbia in North America. The paleontologic testimony stated above indicates that the Takagami and Terauchi faunas are of the same age.

TORIYAMA (1952) described several species of *Lepidolina* from the Kitakami Mountainland but their exact occurrences have not been stated clearly. According to recent informations, CHISAKA (1962) and HANZAWA and MURATA (1963) gave descriptions of *Yabeina* from the Yamazaki conglomerate and the Yukizawa formation in Kitakami Mountainland, respectively. The closer examination of their descriptions and illustrations of the species shows that they are of the highly advanced forms among the species of *Yabeina* as well as those of the *Lepidolina imamurai* zone of the Terauchi formation.

In Kyushu, the Kuma formation studied by KANMERA (1963 and '64) has been well known as the most representative of the Upper Permian *Lepidolina* zones in Japan and it contains abundant species of *Yabeina* and *Lepidolina* such as *Yabeina yasubaensis* TORIYAMA, *Y. columbiana* (DAWSON), *Lepidolina kumaensis* KANMERA, *L. toriyamai* KANMERA, *Pseudodoliolina peseudolepida* (DEPRAT), *Codonofusiella* aff. *paradoxica* DUNBAR and SKINNER, etc. When the Kuma specimens are compared with the Terauchi ones, it is really understood that *Yabeina yasubaensis* TORIYAMA, *Y. columbiana* and *Pseudodoliolina pseudolepida* of the former are the same as those of the latter, respectively. The specimens allied to *Lepidolina toriyamai* and *L. kumaensis* have not yet been described from the Terauchi formation, but *Lepidolina imamurai* may be regarded to be of the more advanced form than *L. kumaensis* in some internal characters of the shell. The faunal similarity, as stated above, between the *Lepidolina toriyamai* and the *L. imamurai* zone shows that the Kuma formation may probably corresponds to the upper half of the Terauchi formation.

In Shikoku, TORIYAMA (1942) studied the Yasuba limestone conglomerate developed in Kochi Prefecture and described *Yabeina shiraiwensis* OZAWA and *Y. yasubaensis* TORIYAMA which have generally been thought to belong to the advanced forms among the species of the genus *Yabeina* in the general development of the shell. Besides them, recently SUYARI (1961) described *Lepidolina kumaensis* KANMERA from the same limestone conglomerate. From the paleontologic point of view stated before, I have kept the opinion that the Yasuba fauna corresponds to the *Lepidolina imamurai* fauna of the Terauchi formation.

In Indochina, GUBLER (1935) brought out the Upper Permian of Cambodge from darkness into light, describing several species referable to *Yabeina* and *Lepidolina*. As already pointed out by me (1960), some of them are very similar to the specimens of the Terauchi formation in the general shell-shape and some internal mode of the

shell, and these paleontological facts remind me of the spatial and the temporal relation of both faunas in the Tethys sea.

THOMPSON, WHEELER and DANNER (1950) described *Yabeina columbiana* (DAWSON), *Y. minuta* THOMPSON and WHEELER, and *Schwagerina acris* THOMPSON illustrated as figs. 1–3, 4–7, and 11–12 on pl. 8, respectively, from the Marble Canyon limestone of British Columbia in North America and they concluded that the British Columbian *Yabeina* fauna was the youngest of North American fusulinid faunas. The examinations of the descriptions and the illustrations of *Yabeina columbiana* and *Y. minuta* show that the Marble Canyon fauna is equivalent in age to the *Lepidolina imamurai* fauna of the Terauchi formation, for the specimens quite identical to *Yabeina columbiana* of Marble Canyon are commonly obtained from the *Lepidolina imamurai* fauna and *Yabeina minuta* has generally been regarded to be of the advanced form among the species referable to the genus *Yabeina*.

VII. CONCLUSION

The major conclusions arising from this study are as follows:

1. The Atetsu Limestone can be divided into three groups which are subdivisible into six formations as tabulated in TABLE 1.

2. The Atetsu Limestone can be divided into nine zones, two of them can be subdivided into two subzones as described below and their correlations with the international fusulinid zones are shown in TABLE 4.

Yukawa g.*	Terauchi f.*	*Lepidolina imamurai* zone (Pu α)	Up. Permian
		Yabeina shiraiwensis zone (Pm δ)	Mid. Permian
	Maki f.	*Neoschwagerina douvillei* zone (Pm γ)	
	Unconf.		
Sabushi g.	Shoyama f.	*Paf.* *Parafusulina kaerimizensis* subzone (Pm β)	
		Paf. *Pseudofusulina kraffti magna* subzone (Pm α)	
	Iwamoto f.	*Ps.* *Pseudoschwagerina kanmerai* subzone (Pl β)	Low. Permian
		Ps. *Rugosofusulina arctica* subzone (Pl α)	
	Unconf.		
Mitsudo g.	Kodani f.	*Fusulinella imamurai* zone (Cu γ)	Mid. Pennsylvanian
		Profusulinella toriyamai zone (Cu β)	
		Millerella bigemmicula-Eostaffella kanmerai zone (Cu α)	Low. Pennsylvanian
	Nagoe f.	*Endothyra-Pseudoendothyra* zone (Cl α)	Mississippian
	Fault		

3. The Atetsu Limestone, the Ishiga formation and the Taniai phyllite group are bordered with faults one another as shown in TABLE 1.

4. The Ishiga formation and the Taniai phyllite group contain some endothy-

* g. and f. indicate group and formation, and *Paf.* and *Ps.* indicate *Parafusulina* and *Pseudoschwagerina* zones, respectively.

roids and *Clisiophyllum* cf. *awa* (MINATO), respectively. Therefore, the formation and the group may be considered to have the possibility of the Mississippian in age, and this suggests that the upper members of the Ishiga formation and the Taniai group may be correlated with the Nagoe formation of the Atetsu Limestone.

5. The Atetsu Limestone plateau is divided into the northern and the southern block by the reversed fault, "the Atetsu thrust," that runs parallel with the strike of the limestone beds. In the Taniai and Hanagi areas the Atetsu Limestone forms an overturned fold, whose axial plane is inclined at the low angles towards the north from the south.

6. The *Fusulinella imamurai* zone is overlain by the *Pseudoschwagerina* zone and this plateau is lacking in the *Fusulina* and *Triticites* zones. Such phenomena signify a record of the hiatus between the Carboniferous and the Permian of the Atetsu Limestone. The Pre-Maki unconformity between the *Neoschwagerina douvillei* zone and the *Parafusulina* zone or the *Pseudoschwagerina* zone is hereby certified. Furthermore, the *Parafusulina kaerimizensis* subzone may be considered to be the deposit in the time of the regression and the *Neoschwagerina douvillei* zone in the time of the transgression.

7. The comparison between the fusulinid zones established by me and those by the previous workers and their correlation with the internatioal fusulinid zones are as shown in TABLE 2.

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GEOLOGICAL MAP OF ATETSU DISTRICT

(SADA, 1964)

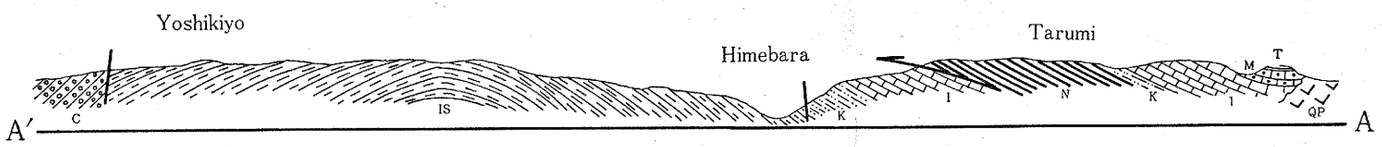
Niimi
Kanatsugi
Kuboino
Ishiga
Hirose
Osakabe River
Kuraita
Tazu
Tarumi
Niiyabara
Tateishi
Kusama
Yukawa
Kuniyori
Maki
Mitsudo
Sabushi
Morikuni
Nagoe
Terauchi
Iwamoto
Kodani
Azai
Kanikawa
Shoyama
Nakatsui
Yokouchi
Hongo
Kurakiyama
Himebara
Ikura
Mitsunaga
Yoshikiyo
Hoso
Ihara
Miyahara
Taniai
Fudodaki
Takahashi River
Ojiyaridani
Hanagi
Hogoku
114.36
A
A′
B
B′
C
C′
D
D′
E
E′

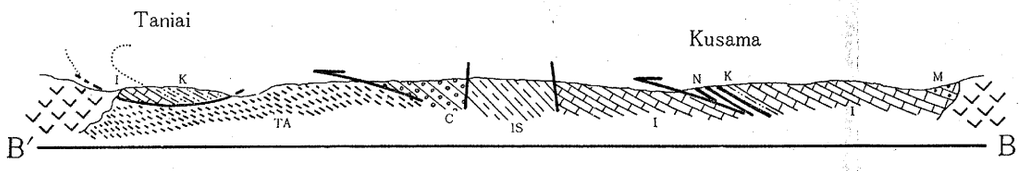
SCALE
1,000 0 1,000 2,000m.

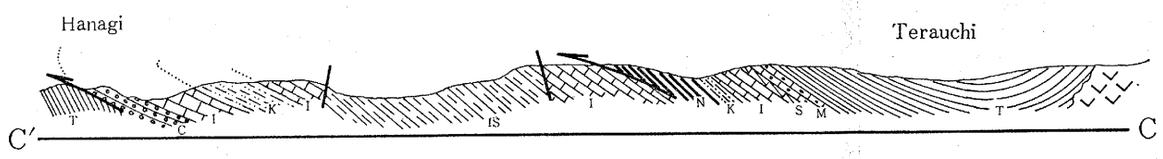
LEGEND

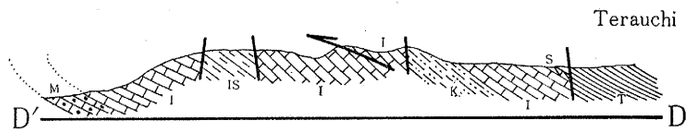
W Granite
V Quartz porphyry
U Alluvium
T Tertiary
S Ishiga formation
R Green phyllite
Q Black phyllite
P Fault
O Thrust
N Schalstein
M Limestone lens
L Terauchi formation
K Maki formation
C Yukawa group
J Shoyama formation
I Iwamoto formation
B Sabushi group
H Kodani formation
G Nagoe formation
A Mitsudo group
F Limestone of indeterminable age
E Crystalline limestone

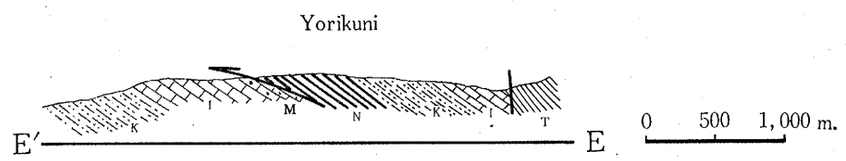
E: Crystalline limestone, F: Limestone of indeterminable age, A: Mitsudo group, G: Nagoe formation, H: Kodani formation, B: Sabushi group, I: Iwamoto formation, J: Shoyama formation, C: Yukawa group, K: Maki formation, L: Terauchi formation, M: Limestone lens, N: Schalstein, O: Thrust, P: Fault, D: Taniai phyllite group, Q: Black phyllite, R: Green phyllite, S: Ishiga formation, T: Tertiary, U: Alluvium, V: Quartz porphyry, W: Granite.











T: Terauchi formation
M: Maki formation
S: Shoyama formation
I: Iwamoto formation
K: Kodani formation
N: Nagoe formation
C: Crystalline limestone
IS: Ishiga formation
TA: Taniai phyllite group
QP: Quartz porphyry