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Geology of Akiyoshi*

By

Ryuzo TORIYAMA

ABSTRACT—Part I of this paper is divided into three chapters. Chapter 1 concerns the fusulinid zones of the Akiyoshi limestone group. Six major fusulinid zones are described as *Profusulinella* zone, *Fusulinella* zone, *Pseudoschwagerina* zone, *Parafusulina* zone, *Neoschwagerina* zone and *Yabeina* zone. *Fusulina* Zone of upper Middle and *Triticites* Zone of Upper Pennsylvanian age are missing in the Akiyoshi limestone group.

Chapter 2 considers the correlation of the fusulinid zones of the Akiyoshi limestone group with Pennsylvanian and Permian formations of not only other parts of Japan but also of Tethys Sea Region and North America. Stratigraphic relationships among fusulinid zones are also discussed in some detail.

Chapter 3 concerns the stratigraphy of the Akiyoshi limestone group. To determine the stratigraphic order of succession twenty-seven sections are chosen and described. The geologic structure of the Akiyoshi limestone group derived from the distribution of fusulinid zones and the tectonic relationships between the Akiyoshi limestone group and non-calcareous Upper Paleozoic groups are also discussed in detail. Based on the distribution of fusulinid zones, lithology of limestones and mode of occurences of fusulinid fossils, Permian epeirogenic movements in the Akiyoshi region are discussed.

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* Dedicated to the late Doctor Yoshiaki OZAWA.

Introduction

Sudies of the Upper Paleozoic stratigraphy of the Akiyoshi district, Yamaguchi Prefecture (Nagato Province*), Southwestern Japan were started by Y. OZAWA and T. OGURA in 1923. OZAWA was also the first who studied the Upper Paleozoic faunas of the Akiyoshi limestone and published a paper titled "Palaeontological and stratigraphical Studies on the Permo-Carboniferous Limestone of Nagato, Part II, Palaeontology" in 1925. To our regret, however, OZAWA's lamentable death came before the publication of Part I, Stratigraphy in English, although he published in Japanese "Stratigraphical Studies of Chichibu System including the Akiyoshi Limestone" in 1923.

In 1934 T. KOBAYASHI, who succeeded OZAWA at Tokyo University, began a comprehensive study on the stratigraphy of Southwest Japan with the cooperation of his students. Summarizing his works, he published the voluminous paper, "Sakawa Orogenic Cycle, and its bearing on the Origin of the Japanese Islands" in 1941, in which he considered that the Akiyoshi limestone is a large Klippe lying on the contemporaneous but heterogeneous Paleozoic formations. Meanwhile, S. HANZAWA of Tohoku University expressed his opinion, which will be mentioned later, on the fusulinid zones of the Akiyoshi limestone in 1941.

Although OZAWA's paleontologic study on the Akiyoshi fusulinids was one of the most prominent at that time, it has been a quarter of century since his paper was published, and there is a need for a restudy of the Akiyoshi fusulinids under the light of knowledge gained in this decade.

Upon the suggestion by Prof. KOBAYASHI I began biostratigraphical and paleontological studies of the Paleozoic formations in Southwest Japan in 1940, and I have published several papers on fusulinids contained in the Yasuba Conglomerates and its allies. After I changed my position from Himeji Junior College (Kotogakko) to Kyushu University in 1941, I began to study all Upper Paleozoic rocks developed in Akiyoshi area and collected numerous specimens of fusulinids not only from the Akiyoshi limestone but also from the Tsunemori, Beppu, Gampi and Ota groups which are largely non-calcareous and are exposed around the Akiyoshi limestone.

Fortunately enough, I** had a chance to visit the United States of America and to study with Dr. THOMPSON of the University of Wisconsin my collection from the Akiyoshi limestone and compare them with his numerous collections from the Pacific coast of North America.

This paper is the result of that study. Although much still remains to be done, it seems appropriate to publish these results at this time because the Paleozoic rocks of Akiyoshi district are very important, being considered to be the standard

* Nagato is an old provincial name for the western part of Yamaguchi Prefecture.

** Research associate of the Graduate School at the University of Wisconsin in 1950-1951.

of the Upper Paleozoic stratigraphy of Southwest Japan.

This paper deals only with Part I. Part II and Part III (Systematic Paleontology) will be published separately in the near future.

Acknowledgments

I wish to acknowledge the help given to me by many persons and institutes in the preparation of this study. First of all, I wish to express my most sincere thanks to Prof. T. KOBAYASHI of Tokyo University under whose suggestion and special guidance I undertook the investigation. Prof. M. L. THOMPSON of University of Wisconsin gave me valuable criticisms and technical advices in preparation of numerous microphotographs while I was in Madison, Wisconsin in 1950–1951. Prof. T. TOMITA, Prof. H. MATSUSHITA, Prof. T. MATSUMOTO and Assist. Prof. K. KANMERA, all of Kyusyu University, and Prof. I. TATEIWA of Tokyo University, and Prof. E. KONNO of Tohoku University, gave me valuable criticisms and encouragements. Prof. S. MATSUSHITA of Kyoto University and Prof. S. HANZAWA of Tohoku University kindly permitted free use of the library of their Department.

I wish, further, to express my hearty thanks to many persons who gave me kind assistances in carrying out the field works: namely, Messers. I. ETO, S. OBA, M. FUJIMURA and T. KITAMURA, all of Akiyoshi-mura, Mr. G. OKAFUJI of Omine High School, Mr. K. NAKAMOTO of Kyowa-mura, Mr. C. OSHIMA of Akago-mura, and Mr. N. YAMANE of Hagi-shi.

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Brief Summary of the Earlier Works

In his biostratigraphic study of the Akiyoshi area OZAWA determined the stratigraphic succession of the Chichibu System, including the Akiyoshi limestone, in 1923 as tabulated below. (More recent generic and specific references are given in parenthes).

Ozawa was of the opinion that the oolitic limestone lenses containing *Nagatophyllum* in the lower and *Lonsdaleia floriformis* in upper horizons may be Viséan in age. He divided the main limestone and superjacent limestone lenses into the Moscovian *Fusulinella*, Uralian *Schwagerina*, and Permian *Neoschwagerina* zones.

C. Alternation of the lenticular limestone bearing shale, hornstone and sandstone, 300 to 400 m thick			P_3 *Sumatrina annae* subzone	*Neoschwagerina* zone
B. Akiyoshi limestone, 400-450 m thick	(3) Limestone conglomerate and limestone breccia		P_2 *Fusulina* (*Pseudofusulina*) *ambigua* subzone	*Neoschwagerina* zone
	(2) Fusulinid limestone		P_1 *Fusulina* (*Pseudofusulina*) *japonica* subzone	*Neoschwagerina* zone
			CPg *Fusulina* (*Parafusulina*) *lutugini* subzone	*Neoschwagerina* zone
			C_3^2 *Schwagerina princeps* (*Pseudoschwagerina glomerosa*) or *Fusulina* (*Pseudofusulina*) *vulgaris* subzone	*Schwagerina* (*Pseudoschwagerina*) zone
			C_3^1 *Schwagerina* (*Pseudoschwagerina*) *moungthensis* subzone	*Schwagerina* (*Pseudoschwagerina*) zone
			C_2 *Fusulinella bocki* subzone	*Fusulinella* zone
	(1) Oolitic limestone lenses interbedded with schalstein		C_1^2 *Lonsdaleia floriformis* subzone	*Lonsdaleia* zone
			C_1^1 *Nagtophyllum satoi* subzone	*Lonsdaleia* zone
A. Thick non-fossiliferous formation, 3000 m thick	(2) Radiolarian chert interbedded with slate, graywacke, sandstone and schalstein			
	(1) Graywacke sandstone interbedded with shale and chert. A few limestone lenses in lower part			

At that time he considered that the Akiyoshi limestone lies conformably on the thick non-fossiliferous formation or the division A in the table and that it is overlain conformably by the fossiliferous formation or the division C. Furthermore, he thought that the Akiyoshi limestone reveals an anticline completely overturned towards the north; and seeing that the fossil zones are reverse in order at Kaerimizu doline and other places, he concluded that the only lower wing of the overturned anticline now remains (Fig. 1a).

Having observed the fusulinid zones at the eastern slope of Kaerimizu doline the late SUGIYAMA (1939) also divided the Permian section of the Akiyoshi limestone into the following fusulinid zones:

5. *Schwagerina* (*Pseudofusulina*) *vulgaris* var. *globosa* zone
4. *Doliolina* (*Misellina*) *claudiae* zone
3. *Parafusulina* (*Pseudofusulina*) *japonica* zone
2. *Neoschwagerina craticulifera* zone
1. *Verbeekina verbeeki* zone

At the same time SUGIYAMA found fusulinid fossils in several horizons which were referred by OZAWA to the thick non-fossiliferous formation; and he thought

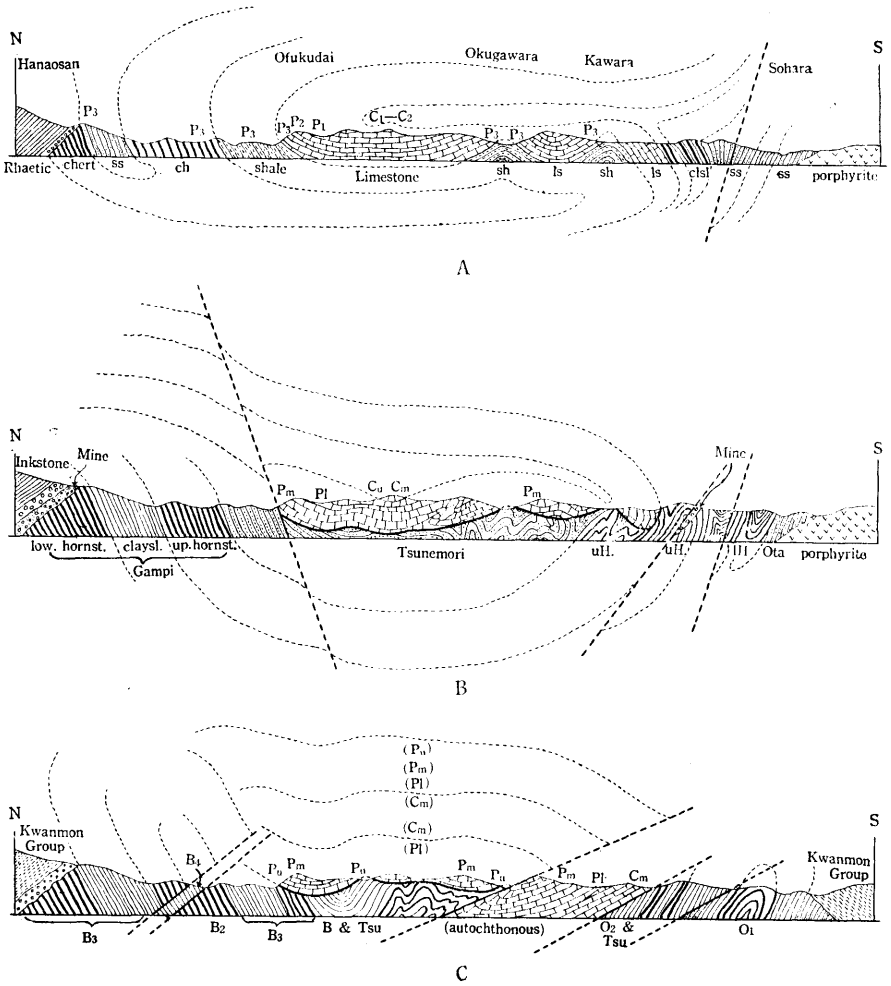

Fig. 1. Profiles of the Akiyoshi limestone plateau drawn on the basis of three different explanations.

A. OZAWA's interpretation of the limestone plateau as an autochthonous recumbent fold.

B. KOBAYSHI's interpretation of the limestone plateau as a Klippe of the Oga Decke.

A and B after T. KOBAYASHI (1941, p. 258, fig. 10)

C. The present interpretation (somewhat idealized)

Left half (northern part) of the limestone is the erosion remnants of the lower wing of thd overturned anticline: right half (southern part) is autochthonous, being in normal order. The left half thrust up the right one.

Tsu = Tsunemori group, B = Beppu group, O = Ota group

that OZAWA's division A, B and C are not in the stratigraphical order of succession, but all of them are Upper Paleozoic formations ranging in age from Carboniferous to Permian. He also pointed out that the division A and C are in normal order, and concluded that OZAWA's well known interpretation of the geologic structure of the

Akiyoshi district seems to need certain modification by the several facts he had found.

Having surveyed the Akiyoshi district under field guidance of his student, M. KOONO, S. HANZAWA (1941, 1944) expressed the opinion that the Akiyoshi limestone are divisible into the following three fusulinid zones:

3. Upper zone—characterized by species of *Sumatrina, Yabeina, Neoschwagerina, Verbeekina, Misellina, Parafusulina* and *Paraschwagerina.*

   The Upper zone can be divided into

   Upper subzone—characterized by species of *Yabeina, Sumatrina, Neoschwagerina, Verbeekina, Misellina* and *Paraschwagerina,* but lacking the species of *Pseudoschwagerina.*

   Lower subzone—characterized by species of *Parafusulina* and *Paraschwagerina,* but lacking the species of *Yabeina, Sumatrina, Neoschwagerina, Verbeekina* and *Misellina.*

2. Middle zone—characterized by species of *Pseudoschwagerina, Paraschwagerina, Schwagerina, Quasifusulina* and *Triticites.*

   ……faunal break……

1. Lower zone—characterized by species of *Fusulinella.*

HANZAWA was of the opinion that his Lower zone is not younger than the Moscovian stage; the Middle zone is safely assignable to the Sakmarian stage, and the Upper zone may be referred to the Artinskian stage. He endeavored to make a more detail subdivision of the limestone, but he found that it is impracticable.

Analysing the facies of the Paleozoic rocks in Japan, KOBAYASHI (1941) classified the Paleozoic Chichibu Supergroup of Southwest Japan into the following facies from the inner to the outer side of Southwest Japan:

Akiyoshi and Para-Akiyoshi facies
Yamaguchi and Para-Yamaguchi facies
Para-Kitakami facies
Chichibu facies

Of these the first one is, of course, represented by the Akiyoshi limestone and the second by his Ota, Gampi and Tsunemori series in this district. KOBAYASHI considered that the Akiyoshi limestone is completely overturned, or is in normal order, or else forms intraformational folds, the order varying in different places, and that the Gampi and Tsunemori series are in normal order, dipping toward the Akiyoshi limestone. Due to the remarkable differences in facies and tectonic relation he expressed the opinion that the Akiyoshi limestone is a large Klippe lying on the structural basin of the autochthonous Ota, Gampi and Tsunemori series (Fig. 1b).

Part I. Study of the Akiyoshi Limestone Group

General Remarks

Surrounded by the Ota, Gampi, Beppu and Tsunemori groups of non-calcareous facies, the **Akiyoshi limestone group** * is in the central part of the Miné-gun **, Yamaguchi Prefecture, occupying the areas of nine towns and villages—Ota-machi, Isa-machi, Omine-machi, Ofuku-mura, Beppu-mura, Kyowa-mura, Akago-mura, Akiyoshi-mura, and Iwanaga-mura. It extends 17 km from the northeast to the southwest, and 7.5 km from the northwest to the southeast, occupying an total area of about 130 square kilometers.

Physiographically speaking, the Akiyoshi limestone plateau is divided by the River Koto into two plateaux—the Akiyoshi plateau of the northeast and the Ofuku plateau of the southwest. (In this paper the Akiyoshi plateau is used in the strict sense, namly, for the north-east plateau). The heights above sea level ranges from 100 m to 400 m in both plateaux, many of the marginal slopes of which are steep.

The rocks of the Akiyoshi limestone group consist mostly of limestone, interbedded with very few amount of chert. Not only the crystalline limestones which were altered by later igneous intrusions, but also almost all other limestones of this group are greyish-white to white in color and are completely massive, having no stratification. Accordingly, it is almost impossible to determine the stratigraphic succession in the field, and a detailed study of fusulinids is the only key for determining stratigraphic order and overall geologic structure of the limestone mass.

To determine the stratigraphic order or succession of the massive limestone, I chose steep slopes around the limestone plateaux and collected numerous fusulinids along these slopes. Of course, I collected many fusulinids from other numerous localities on the plateaux other than those of the slopes mentioned above. Thus, I have determined the following fusulinid zones and clarified the geologic structure of the Akiyoshi limestone group through the study on about 2000 slides made of the limestones collected.

Chapter 1. Fusulinid zones of the Akiyoshi Limestone Group

As already stated at some length, OZAWA divided the Akiyoshi limestone group into four fossil zones, which were, in turn, subdivided into nine subzones. Later HANZAWA expressed the opinion that the Akiyoshi limestone group is divisible into three zones, the upper zone of which is divided into two subzones.

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* KOBAYASHI designated the Akiyoshi group for the Paleozoic rocks which have his Akiyoshi facies; to avoid future confusion I designate the limestone formation in this district as **Akiyoshi limestone group.**

** From the geographical point of view, the limestone group of this district should be named "Miné group," but the "Miné series" was pre-occupied by the Triassic formation.

So far as the fusulinid fauna is concerned, I have come to the conclusion that the Akiyoshi limestone group is divisible into the following six zones,* three of which are each, in turn, divisible into two or three subzones:

Yabeina zone	:	*Yabeina shiraiwensis* zone	Pu α	
Neoschwagerina zone	:	*Neoschwagerina douvillei* subzone *Verbeekina verbeeki* subzone *Neoschwagerina craticulifera* subzone	Pm	δ γ β α
Parafusulina zone	:	*Parafusulina kaerimizensis* subzone *Pseudofusulina ambigua* subzone	Pl	γ β α
Pseudoschwagerina zone	:	*Pseudofusulina vulgaris* subzone *Triticites simplex* subzone		
Fusulinella zone	:	*Fusulinella biconica* zone	Cm	β
Profusulinella zone	:	*Profusulinella beppensis* zone		α

1. *Profusulinella* zone: *Profusulinella beppensis* zone Cmα

The lowermost fusulinid zone of the Akiyoshi limestone group is the *Profusulinella beppensis* zone, which is found in the eastern and southeastern parts of the Akiyoshi plateau. The *Nagatophyllum satoi* zone, which underlies the *Fusulinella biconica* zone, is developed along the southern margins of both the Akiyoshi and Ofuku plateaux and is presumed to correspond with the *Profusulinella beppensis* subzone. The relation between them will be discussed later.

The *Profusulinella beppensis* subzone also occurs as erosion remnants on the heights of the northern parts of both plateaux where the Akiyoshi limestone group is overturned.

Profusulinella beppensis zone is characterized by the following species:

Profusulinella beppensis n. sp.
P. *rhomboides* (LEE et CHEN)
P. sp.
Akiyoshiella ozawai TORIYAMA
A. sp.

Assoφciating species are,

Fusulinella sp. C.
Nankinella sp.

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* As already pointed out by H. YABE (1949A), fusulinid zones are used in two different senses; one is a stratigraphic unit characterized by the prevailing genus, hence, one zone does not overlap the other, whereas stratigraphic range of that genus sometimes may be up or down outside of zone. The other, which may be called a biozone, is a stratigraphic division related to the geologic range of the respective genus, hence there being cases in which two zones overlap each other, although the geologic range of the genus is confined within the zone. In this paper as well as in YABE's papers (1948, 1949A, B), a fusulinid zone is used in the sense of the first category, and "Zone" is always used for universal correlation distinguished from the fusulinid "zone" of local usage.

Staffella akagoensis n. sp.
Eoschubertella obscura (LEE et CHEN)

Profusulinella beppensis somewhat resembles *P. copiosa* THOMPSON which was described by THOMPSON (1948) from the Arreu formation of Powwow Canyon, Texas, but it is larger in size of its shell. *Profusulinella* sp. resembles *P. marblensis* THOMPSON, but I have not been able to determine the nature of this species because of insufficient material at hand. *Profusulinella* (?) *rhomboides* from the lower part of the Huanglung limestone of South China was originally described by LEE and CHEN as a species of *Fusulinella*, but their original illustration shows that the species belongs to the genus *Profusulinella*. Their illustration does not suit further discussion.

Akiyoshiella ozawai, the type species of that genus, which was described from Shishidedai of Akago-mura, northeastern part of the Akiyoshi plateau, looks like a specialized form of the genus *Fusulina*. Although the phylogenetic relation of *Akiyoshiella* to other fusulinellid genera is not clear, it is worth noting that a species of *Akiyoshiella* has been very recently reported by THOMPSON, PITRAT and SANDERSON (1953) from a part of the Cache Creek group of central British Columbia. American form of *Akiyoshiella*, *A. toriyamai* is not conspecific with the Akiyoshi form, *A. ozawai*, but they are rather closely related with each other. Further discussion upon their stratigraphic occurrence will be mentioned in Chapter 2.

Fusulinella sp. C, which is very small for a species of *Fusulinella*, seems to be a species of *Profusulinella*, but its spirothecal structure shows that it does not belong to the latter.

On the *Nagatophyllum satoi* zone.

OZAWA (1923) divided the lowermost fossil zone, *Lonsdaleia* zone (C_1) of the Akiyoshi limestone group into (C_1^1) *Nagatophyllum satoi* and (C_1^2) *Lonsdaleia floriformis* subzones.

MINATO (1949, 1952), who studed the coral specimens collected by OZAWA, FUJIMOTO, SEKI and me, divided the Middle Carboniferous Nagaiwa Series of Japan into *Nagatophyllum* zone of Nagato stage and *Fusulinella* zone of Taishaku stage. He insisted that the *Nagatophyllum* zone is not Lower Carboniferous in age but is Bashikirian in age.

Although my knowledge of coral faunas is too meager for discussion of them, it is evident that the *Fusulinella* zone of Taishaku stage is represented in the Akiyoshi limestone group by the *Fusulinella biconica* zone which is overlying a horizon referred to the *Nagatophyllum* zone by OZAWA. Coral fossils occur at Tobinosu and Okubo of Ota-machi and at many localities belonging to this horizon, while the *Profusulinella* zone is underlying *Fusulinella biconica* zone in Shishidedai and in low hills around Ueyama, both in Akago-mura, northeastern part of the Akiyoshi plateau. Therefore, a question is raised whether the *Profusulinella beppensis* and *Nagatophyllum* zones

are the same horizon or not. Because of the fact that both of these show almost the same pattern of distribution, developing along the eastern, southeastern and southern margins of the Akiyoshi and Ofuku plateaux and are underlying the *Fusulinella biconica* zone, I am of the opinion that both zones may be of the same stratigraphic age. However, future study will be needed for final determination.

It must be noted that considerable amounts of schalstein occur in the lowest part of the *Profusulinella* zone and of the *Nagatophyllum* zone. Corals are obtained not only in limestones but also in schalstein, while in some part of the *Nagatophyllum* zone oolitic limestone barren of fossil predominates.

2. *Fusulinella* zone : *Fusulinella biconica* zone Cmβ

The uppermost fusulinid zone of the Pennsylvanian part of the Akiyoshi limestone group is designated *Fusulinella biconica* zone. It is present in a wide belt that extends from the northeastern part of the Akiyoshi plateau to the southern parts of the Akiyoshi and Ofuku plateaux. In the overturned part of the Akiyoshi limestone group, the *Fusulinella biconica* zone is present as erosion remnant on the high places of both plateaux.

The *Fusulinella* zone has hitherto been recognized as the *F. bocki* zone which corresponds to OZAWA's C_2 zone* and HANZAWA's Lower Zone. There is, however, some doubt about the specific identification of that species in earlier works, because most fusulinellids having large shell were identified with *F. bocki*** due to the insufficiency of MÖLLER's original description and illustration. Therefore, species of earlier reports of this species should be restudied to verify the identifications of *F. bocki* MÖLLER.

The lower part of *Fusulinella biconica* zone is characterized by such primitive species of *Fusulinella* as *F. simplicata* n. sp, while the middle and upper parts of the zone are yielding following species:

Fusulinella biconica (HAYASAKA)
F. itoi OZAWA***
F. cf. *bocki* MÖLLER

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* OZAWA (1923) wanted to designate his C_2 as *Fusulinella biconica* zone, but he adopted *Fusulinella bocki* zone, because the stratigraphic range of the former was uncertain.

** Because of the importance of the type species of the genus *Fusulinella*, THOMPSON (1945) redescribed topotype specimens of the species at length. His figure (pl. I fig. 15) well agrees with MÖLLER's original specimens.

*** OZAWA's report of *Fusulinella itoi* from Shiraiwa, Omine-machi, associating with Upper Permian species of *Yabeina* and *Sumatrina* caused the attention of students of fusulinid foraminifera. THOMPSON referred (1946) that species to *Yangchienia* with question, and later (1948) to *Neofusulinella*; while HANZAWA (1938) believed *F. itoi* may have been derived from brecciated boulders brought up from below by faulting of Moscovian rocks. It is unfortunate that OZAWA's type specimen of *F. itoi* was lost from his collection. Having studied his syntype specimens I have found that *F. itoi* is not found in the same limestone mass with species of *Yabeina*, but is only contained in limestone pebbles of limestone conglomerate which is a member of the Upper Permian Shiraiwa formation of the Tsunemori group (See Part II, Chapter 4).

F. cf. *pseudobocki* (LEE et CHEN)
F. *subspherica* n. sp.
F. spp. A, B and C
Fusulina akiyoshiensis n. sp.
Fusiella cf. *typica* LEE et CHEN

Beside these, long-ranging species of *Staffella akagoensis* n. sp., *S. mollerana* THOMPSON, *Eoschubertella obscura* (LEE et CHEN), *E.* spp. A and B are often associating throughout the *Fusulinella biconica* zone, although some of them are restricted in occurrence in the upper part.

3. *Pseudoschwagerina* zone

A. *Triticites simplex* subzone Plα

The basal part of the Permian section of the Akiyoshi limestone group contains prolific *Triticites* faunas. As the Uralian series of Russia and the Kawvian (Missourian and Virgilian) series of North America are designated *Triticites* Zone, establishment of *Triticites* subzone, if not zone, in the basal Permian rock may not be appropriate because it may cause future confusion. Notwithstanding, the *Triticites* fauna is so prolific in the basal Permian part of the Akiyoshi limestone group that I cannot help but designated a *Triticites simplex* subzone after the name of a representative species.

The *Triticites* simplex subzone is most widely distributed among fusulinid zones and subzones of the Akiyoshi limestone group. Except for the heights of both plateaux and the bottoms of deep dolines and uvales, it presents widely in the northern half of the Akiyoshi plateau probably because of accordance of the inclination of the strata and the surface of the plateau. It is also present in considerably wide belts in the southern part of the Akiyoshi and Ofuku plateaux, overlying the *Fusulinella biconica* zone.

I have identified twenty species of *Triticites*, including ten new species, among the Akiyoshi fusulinids. Almost all of them range continuously up to the upper *Pseudofusulina vulgaris* subzone, and a few of them extend more into the *Pseudofusulina ambigua* subzone. Careful observation shows that there are three groups of *Triticites* faunas; one comprises species which mainly occur in the *Triticites simplex* subzone, the other is rather characteristic of the *Pseudofusulina vulgaris* subzone although it appears already in the *Triticites simplex* subzone, and the third is common to both subzones.*

Species of *Triticites* of the first group is, generally speaking, smaller in size of shell and more weak in septal fluting than those of the second group.

* These differences are shown by thick and thin lines in the fossil list which will be attached in Part III.

Species of *Triticites* which mainly occur in the *Triticites simplex* subzone are as follows:

Triticites simplex (SCHELLWIEN)
T. ozawai n. sp. (A part of *T. montipora* OZAWA)
T. noinskeyi RAUSER-CERNOUSSOVA, var. n. var.
T. isaensis n. sp.
T. obai n. sp.
T. michiae n. sp.
T. suzukii (OZAWA)
T. tantula n. sp.

Besides, the following species, though rare, are characteristic in this subzone.*

Pseudoschwagerina muongthensis (DEPRAT)
Schwagerina satoi (OZAWA)
Quasifusilina longissima var. *tenuis* (LEE)

Pseudoschwagerina muongthensis (DEPRAT) is a well-known species which is characteristic of the basal Permian of the Tethys region, while *Schwagerina satoi* (OZAWA) is an intermediate form between *Triticites* and *Pseudoschwagerina*. It should be noted that *Pseudoschwagerina muongthensis* appears first in a horizon a little above the base (about 5m above the base of Section IV and XXI), but not at the lowermost part of the *Triticites simplex* subzone. The basal part of this subzone contains in abundance only the species of *Triticites* listed above.

Minute species of *Ozawainella akiyoshiensis* n. sp., *O.* sp. A, *Nankinella nagatoensis* n. sp. and *Schubertella japonica* n. sp. are scarse in the *Triticites simplex* subzone, but some of them are not restricted to this subzone, but extend into the overlying subzones.

In short, it has been ascertained that the lowest part of Permian rocks of the Akiyoshi limestone group is characterized by prolific *Triticites* faunas, and especially that the most basal part yields only species of that genus.

B. *Pseudofusulina vulgaris* subzone P1β

The upper subzone of the *Pseudoschwagerina* zone in the Akiyoshi limestone group is designated the *Pseudofusulina vulgaris* subzone. Like the lower subzone, it is widely distributed in the eastern and southern parts of the Akiyoshi and in the southern part of Ofuku plateaux, overlying the *Triticites simplex* subzone. It is

* As indiuiduals of *Pseudoschwagerina* are very few in number in the Akiyoshi limestone group, it is sometimes impossible to find them unless we collect a large quantity of limestone. On the other hand, individuls of accompanying species of *Triticites* are so large in number that the ratio of individuals of *Pseudoschwageerina* to *Triticites* may be more than 1: 100. Accordingly, the possibility of finding species of *Pseudoschwagerina* is related to the amount of material collected and the number of slides studied. According to the personal information from Mr. KANMERA, the same is the case with *Pseudoschwagerina* zone of southern Kyushu.

also present in the northern overturned part of the Ofuku plateau.

Among fusulinid zones and subzones of the Akiyoshi limestone group, the *Pseudofusulina vulgaris* subzone is the most prolific in fusulinid fossils, and contains more than fifty species.

(1) The following species of *Pseudofusulina* appear almost simultaneously in this subzone.

Pseudofusulina vulgaris (SCHELLWIEN)
P. *vulgaris* var. *globosa* (SCHELLWIEN)
P. *vulgaris* var. *megaspherica* n. var.
P. *watanabei* (OZAWA)
P. *globosa* var. *exilis* n. var.
P. *isaensis* n. sp.
P. *ambigua* (DEPRAT)
P. *yobarensis* (OZAWA)
P. *kraffti* var. *magna* n. var.

Of these, some species range up into the upper *Pseudofusulina ambigua* subzone and others further into the upper *Parafusulina kaerimizensis* subzone and even into the *Neoschwagerina craticulifera* subzone.

(2) As already stated, species of *Triticites* are considerably abundant in this subzone. Most of them, however, had already appeared in the lower *Triticites simplex* subzone, and some become more abundant in this subzone. Few species of *Triticites* appear for the first time in this subzone.

Rather characteristic species of *Triticites* to this subzone are as follows:

Triticites ellipsoidalis n. sp.
T. *haydeni* (OZAWA)
T. *kawanoboriensis* HUZIMOTO
T. *kuroiwaensis* n. sp.
T. *densa* n. sp.

Of these, *T. ellipsoidalis*, which is a small, ellipsoidal to subcylindrical species, is a good indicator for this subzone, as well as *Acervoschwagerina akiyoshiensis* which will be mentioned later.

Species of *Triticites* which continuously occur from the lower subzone are as follows:

Triticites suzukii (OZAWA)
T. *tantula* n. sp.
T. *biconica* n. sp.
T. *noinskeyi* RAUSER-CERNOUSSOVA, var. n. var.
T. *simplex* (SCHELLWIEN)
T. *isaensis* n. sp.
T. *obai* n. sp.

T. *arctica* (SCHELLWIEN)
T. spp. A, and C

(3) *Schwagerina* is also abundant in the *Pseudofusulina vulgaris* subzone, most of the species are rather small in size and primitive and are considered to be transitional forms from *Triticites* to *Schwagerina*. It is sometimes difficult to determine to which genus they belong.

Species of *Schwagerina* restricted to this subzone are as follows:

Schwagerina okafujii n. sp.
S. *tschernyschewi* (SCHELLWIEN)
S. *etoi* n. sp.
S. cf. *alpina* var. *rossica* (SCHELLWIEN)
S. cf. *otukai* HUZIMOTO
S. spp. B and C

Species of *Schwagerina* which mainly occur in this subzone, but extend into upper subzones include the following:

Schwagerina kueichihensis (CHEN)
S. *regularis* (SCHELLWIEN)
S. *kyowaensis* n. sp.
S. *krotowi* (SCHELLWIEN)
S. cf. *royandersoni* THOMPSON, WHEELER and DANNER

(4) Representatives of *Dunbarinella* and *Nagatoella* also occur in this subzone, though they are very scarse. The stratigraphic range of the former genus is almost restricted within this subzone, whereas that of the latter is very long, extending even into the *Neoschwagerina craticulifera* subzone.

Species of *Dunbarinella* and *Nagatoella* are as follow:

Dunbarinella cervicalis (CHEN)
D. n. sp. A
Nagatoella kobayashii THOMPSON
N. sp. A

(5) As well as *Triticites ellipsoidalis* n. sp., *Acervoschwagerina akiyoshiensis* n. sp. is one of the best index species for this subzone. The said subgenus was established by HANZAWA (1949) for a form from the Sakmarian Gonbo formation of Gifu Prefecturc, Central Japan, in which *Parafusulina* sp. and *Schwagerina* sp. were also reported.

(6) Few species of *Parafusulina* appear in this subzone, of which *P. lutugini* (SCHELLWIEN) is restricted to this subzone, while *P. gigantea* (DEPRAT) extends far into the upper subzones.

(7) Long-ranging minute species of *Ozawainella*, *Nankinella*, *Staffella*, and *Schubertella* are associating with species listed above. They are as follows:

Ozawainella akiyoshiensis n. sp.

Nankinella nagatoensis n. sp.
Staffella cf. *mollerana* THOMPSON
S. *yobarensis* OZAWA
S. spp. A and B
Schubertella japonica n. sp.
S. *kingi* DUNBAR and SKINNER

It should be noted that *Schubertella kingi* DUNBAR and SKINNER, reported from the ~~Upper Guadalupian~~ Wolfcampian rocks of North America, is found in this subzone.

4. *Parafusulina* zone

A. *Pseudofusulina ambigua* subzone P1α

The lower subzone of the *Parafusulina* zone in the Akiyoshi limestone group is here designated *Pseudofusulina ambigua* subzone. Comparing with the two subzones below, this subzone is considerably limited in its geographic distribution. In the Akiyoshi plateau, it occurs on the top and middle of the eastern slope of the Kaerimizu doline, where the order of succession is normal and reverse, respectively. It is also present at the central part (in normal order) and the western slope (in reverse order) of the plateau. In the Ofuku plateau, it is present in the heights of southeastern and southwestern parts (both in normal order), and in south central part and northern slope (in reverse order). The *Pseudofusulina ambigua* subzone of normal order is distributed in a belt with a northeast by east direction, always bordering with the lower *Pseudofusulina vulgaris* subzone.

Among the fusulinid zones and subzones of the Akiyoshi limestone group, the *Pseudofusulina vulgaris* subzone is, as mentioned already, most prolific, while number of species decreases in the present subzone.

(1) Species of *Pseudofusulina* are still common in this subzone. The following species are obtained in it:

Pseudofusulina ambigua (DEPRAT)
P. *yobarensis* (OZAWA)
P. *kraffti* (SCHELLWIEN) var. *magna* n. var.
P. *vulgaris* (SCHELLWIEN)
P. *vulgaris* var. *globosa* (SCHELLWIEN)
P. *vulgaris* var. *megaspherica* n. var.
P. *watanabei* (OZAWA)

Of these species, the first two are characteristic of this subzone, and the others are, as already stated, present in the lower *Pseudofusulina vulgaris* subzone but are incidental to this one.

(2) Species of *Triticites*, which are the last representatives of that genus, and species of *Schwagerina*, which succeed from the subzone below or have long duration, are present in this subzone. They are as follows:

Triticites haydeni (OZAWA)
T. *biconica* n. sp.
Schwagerina kueichihensis (CHEN)
S. *regularis* (SCHELLWIEN)
S. *kyowaensis* n. sp.
S. *krotowi* (SCHELLWIEN)
S. cf. *royandersoni* THOMPSON, WHEELER and DANNER

(3) *Parafusulina gigantea* (DEPRAT) appeared first in the lower *Pseudofusulina vulgaris* subzone but also occurs in this subzone, while *Parafusulina pseudojaponica* n. sp.* appcars first in the upper part of this subzone.

(4) In addition, long-ranging species of *Nagatoella* and minute fusulinids occuring with the species listed above include the following:

Nagatoella kobayashii THOMPSON
N. sp. A
Nankinella nagatoensis n. sp.
Staffella spp. A and B
Schubertella japonica n. sp.
S. *kingi* DUNBAR and SKINNER

B. ***Parafusulina kaerimizensis* subzone Pmα**

The upper subzone of the *Parafusulina* zone is here designated the *Parafusulina kaerimizensis* subzone. Compared with the lower three subzones, this subzone is very limited in geographic distribution, covering only the following areas; the lower part of the eastern slope of the Kaerimizu doline (between the levels of 35m to 100m above the bottom of the doline), and the northwestern part (in reverse order) in the Ofuku plateau.

The faunal assemblage in this subzone is in considerable contrast to the *Pseudofusulina ambigua* subzone, though species of *Parafusulina* are common to both.

In this subzone no species of *Triticites* is present, while species of *Parafusulina kaerimizensis* and its allies and long-ranging species of *Schwagerina, Nagatoella,* and *Pseudofusulina* are associated. They are as follows:

Parafusulina kaerimizensis (OZAWA)
P. *edoensis* (OZAWA)
P. *pseudojaponica* n. sp.

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* I distinguished *Parafusulina pseudojaponica* as a new species of *Parafusulina* from *Pseudofusulina japanica* (GÜMBEL) because it has considerably large proloculus, heavy axial fillings, and clear cuniculi. GÜMBEL's oaiginal illustration shows that *Fusulina japonica* has very few axial filling if any. The presence of cuniculi and phrenotheca can not be ascertained. THOMPSON (1948) referred this species to *Pseudofusulina* with question. *Schellwienia japonica* described by OZAWA from Akasaka limestone has also very few axial filling. Because their being has been often reported as representatives of the *Parafusulina* zone, as well as *Parafusulina kaerimizensis* OZAWA, it seems that they should be restudied in more detail.

P. *gigantea* (DEPRAT)
P. spp. A and B
Schwagerina kyowaensis n. sp.
S. cf. *royandersoni* THOMPSON, WHEELER and DANNER
S. cf. *douvillei* (COLANI)
Nagatoella kobayashii THOMPSON
N. sp. A
Pseudofusulina yobarensis (OZAWA)
P. *kraffti* var. *magna* n. var.

It should be pointed out that species of verbeekinids and neoschwagerinids first appear in this subzone. They are, however, incidental in their occurrences, being considered to be forerunners of the overlying *Neoschwagerina craticulifera* subzone in which they are prolific. Also it must be noted that they occur not necessarily throughout the whole range of this subzone. For example, *Neoschwagerina craticulifera* (SCHWAGER) begins to appear sporadically in the horizon 20m above the base of Section I at Kaerimizu. The following species are determined:

Misellina ? sp.
Pseudodoliolina ozawai YABE and HANZAWA
Neoschwagerina craticulifera (SCHWAGER)
N. *craticulifera* var. *haydeni* DOUTKEVITCH
N. spp. A and B
Afghanella schencki THOMPSON

In addition, long-raning minute fusulinids are in this subzone.

Nankinella nagatoensis n. sp.
Staffella spp. A and B
Schubertella japonica n. sp.

5. *Neoschwagerina* zone

A. *Neoschwagerina craticulifera* subzone Pmβ

"*Neoschwagerina craticulifera* zone" is well known in the Permian rocks of Japan, except in the Kitakami massif. In the Akiyoshi limestone group the *Neoschwagerina craticulifera* subzone is also well ascertained, though its distribution is limited. It is present in the lower part of the eastern slope of the Kaerimizu doline, composing a fossil zone of about 25m in thickness. In the Ofuku plateau it occurs in the lowest part of northwestern margin (in reverse order).

Neoschwagerinids and verbeekinids predominate in this subzone. They include the following species:

Neoschwagerina craticulifera (SCHWAGER)
N. *craticulifera* var. *haydeni* DOUTKEVITCH

N. spp. A and B
Afghanella schencki THOMPSON
A. sp. A
Pseudodoliolina pseudolepida (DEPRAT)
P. *ozawai* YABE and HANZAWA

Of these, some are, as stated above, already present sporadically at least in the upper part of the *Parafusulina kaerimizensis* subzone, associated with *Parafusulina kaerimizensis* and its allies. In the present subzone *Neoschwagerina craticulifera* and *N. craticulifera* var. *haydeni*, as well as *Afghanella schencki*, are very prolific, forming a well-defined fossil zone.

The accompanying species to this subzone are such long-ranging species of *Schwagerina*, *Nagatoella*, *Pseudofusulina* and *Parafusulina* as the following:

Schwagerina cf. *royandersoni* THOMPSON, WHEELER and DANNER
S. cf. *douvillei* (COLANI)
S. sp. A
Nagatoella kobayashii THOMPSON
Pseudofusulina kraffti var. *magna* n. var.
Parafusulina gigantea (DEPRAT)
P. *kaerimizensis* (OZAWA)
P. *edoensis* (OZAWA)
P. *pseudojaponica* n. sp.
P. spp. A and B

Parafusulina kaerimizensis and *P. edoensis* do not occur in the upper part of this subzone.

As in the lower subzones are minute fusulinids present which have long ranges. They are as follows:

Ozawainella sp. B*
Nankinella nagatoensis n. sp.
Staffella spp. A and B
Schubertella japonica n. sp.

B. *Verbeekina verbeeki* subzone Pmγ

So far as the fusulinids are concerned, the *Verbeekina verbeeki* subzone is the highest one in the Akiyoshi plateau. This subzone occurs in the lowest part (level of 15m to 25m above the ponor) of the eastern slope of the Kaerimizu doline, forming a fossil zone of about 10m in thickness in which *Verbeekina verbeeki* is exclusively contained. In the very lowest part of the eastern slope, that is to say, from the ponor of doline up to the level of 15m above, neither species of verbeek-

* Stratigraphic range is limited to this subzone.

inid nor of neoschwagerinid occurs, but *Parafusulina pseudojaponica* and *P.* spp. A and B are found just around the ponor. It is not known if this part is contained in the *Verbeekina verbeeki* subzone.

C. *Neoschwagerina douvillei* subzone Pmδ

The highest subzone of the *Neoschwagerina* zone in the Akiyoshi limestone group is here designated *Neoschwagerina douvillei* subzone. It is extremely narrow in its distribution. This subzone only occurs in the lower part of the western slope of the Yobara doline (Section XXVI), comprising a fossil zone of about 20m in thickness. So far as surveyed it has not been detected in the Akiyoshi plateau.

The *Neoschwagerina douvillei* subzone is very prolific in species of *Neoschwagerina*, but no species of *Yabeina* is associated with them.

The following species have been determined in the *Neoschwagerina douvillei* subzone of Section XXVI:

Neoschwagerina douvillei OZAWA
N. *megaspherica* DEPRAT
N. *tobleri* LANGE
N. *craticulifera* var. *haydeni* DOUTKEVITCH

The *Neoschwagerina douvillei* subzone of Section XXVI consists of white to dark blue limestone, which is more or less brecciated in the upper part of the subzone.

6. *Yabeina* zone: *Yabeina shiraiwensis* zone Puα

The uppermost fusulinid zone of the Akiyoshi limestone group is the *Yabeina shiraiwensis* zone, which does not occur in the Akiyoshi plateau but is rather widely distributed in the Ofuku plateau. This zone occurs in the following localities in the Ofuku plateau:

i. The central part of the northern margin—near Serita along the road between Serita and Yobara, Beppu-mura.

ii. The southern area of the community of Yobara—along the road between Yobara and Irimi.

iii. The lower part of the northern slope of Amagoi-yama, the eastern end of which is seen at the entrance to Okugawara.

iv. Remain of the limestone quarry to the northeast of the Shigeyasu station.

Fusulinids of the *Yabeina shiraiwensis* zone are characterized by the association of specialized *Yabeina* and *Sumatrina*. They include the following species:

Yabeina shiraiwensis OZAWA
Y. *pinguis* n. sp.
Y. spp. A and B
Sumatrina longissima (DEPRAT)

Schwagerina sp. A, which is highly specialized form of that genus, is often associating with species of *Yabeina* or *Sumatrina.*

The *Yabeina shiraiwensis* zone is found only in the overturned part of the Akiyoshi limestone group, and no representative of this zone is seen in the normal part. Hence the upper limit of this zone is unknown.

Chapter 2. Correlation of the Fusulinid zones

General Considerations

It is well accepted among the students of the Upper Paleozoic stratigraphy that the fusulinid foraminifers play a great roll in the study of Pennsylvanian and Permian stratigraphy. Most larger groups of fusulinids developed along closely similar phylogenetic trends and in approximately the same stratigraphic order in Europe, America and Asia including Japan. It is also well recognized that the stratigraphic ranges of genera are very useful for interregional as well as intercontinental correlations, while species have been found very serviceable as index fossils for stratigraphic correlations in local areas.

Since OZAWA's studies (1925, 1927) to THOMPSON's study of American Fusulinids (1948), many papers regarding fusulinid zones have been published. In this country YABE (1948, 1949A, B), FUJIMOTO (1951, 1952), KANMERA (1952A, B, 1953) and others expressed their opinions concerning the matter very recently.

In this chapter, correlations of fusulinid zones of the Akiyoshi limestone group, which have been described in detail in the foregoing chapter, with those of other Pennsylvanian and Permian rocks of not only Japan but also of other parts of the world will be discussed.

In Japan it has been ascertained that the following fusulinid zones exist in rocks ranging in age from the Upper Mississippian to the Upper Permian.* They are in descending order:

10. *Lepidolina* zone
9. *Yabeina* zone
8. *Neoschwagerina* zone
7. *Parafusulina* zone
6. *Pseudoschwagerina* zone
5. *Triticites* zone

* From paleogeographic point of view Japan is a part of the Tethys region of the eastern Hemisphere, hence it is natural to use such European divisions of Period or System as Moscovian, Uralian, Sakmarian, Artinskian, etc. However, correlation of fusulinid zones with them has not yet been satisfactorily established in Europe, although GERTH (1950) has recently classified Permian rocks based on ammonoid faunal zones; while it is very precisely determined in North America. In this paper, therefore, American usage of divisions of Pennsylvanian and Permaian Periods and Systems will be applied to avoid future confusion and for the completeness' sake.

4. *Fusulina* zone
3. *Fusulinella* zone
2. *Profusulinella* zone
1. *Millerella* zone

The zones 3, 6, 7, 8, and 9 have been widely recognized in Japan, and it has been either recognized or assumed that a stratigraphic hiatus exists below Wolfcompian (or Sakmarian) rocks not only in Japan but also widely separated area, including Manchuria, Korea, and North and South China. Very recently, however, the zone of *Triticites* has been found at several places in Japan by KANMERA (1952A), KAWADA and FUJIMOTO (1952), KANUMA (1952) and MORIKAWA (1953). The first mentioned author also reported the existence of the *Millerella* zone at the lowest part and of the *Fusulina* zone between the *Fusulinella* zone and the *Triticites* zone in Upper Paleozoic rocks of southern Kyushu. At the same time, he proposed to establish the *Lepidolina* zone from stratigraphic and paleontologic points of view. I (1952) have also suggested that the uppermost fusulinid zone in the Kitakami massif, northeast Japan should be designated the *Lepidolina* zone.

As already mentiond, typical *Triticites* and *Fusulina* zones are lacking in the Akiyoshi limestone group, notwithstanding the fact that there is no visible trace of a stratigraphic break between rocks of the *Pseudoschwagerina* and *Fusulinella* zones. Although the *Millerella* zone has not yet been found in the Akiyoshi limestone group, it may not be impossible to expect the existence of *Millerella* zone in the lowest part of the group, especially in the eastern part of Akiyoshi and southern parts of both Akiyoshi and Ofuku plateaux, where the group is laid in normal order. Actually I have found a species of *Millerella* ? in the limestone pebble contained in the limestone conglomerate of the Beppu group which might have been derived from the Akiyoshi limestone group.

1. *Profusulinella* zone Cmα

Profusulinella occurs in the lower part of the Atokan series (Lower Middle Pennsylvanian) in North America and in rocks of lower Moscovian age of northern Urals and Samara Bend of Russia. In North America several species of *Millerella*, *Ozawainella*, *Nankinella*, *Eoschubertella*, *Pseudostaffella* and *Staffella* occur associated in the *Profusulinella* zone. As already pointed out by THOMPSON (1948) and MOORE and THOMPSON (1949) genera of *Profusulinella* and *Fusulinella* do not overlap each other in the Mid-Continent of North America. While in Asia, the lower part of the Huanglung limestone of China, which contains species of both *Profusulinella* and *Fusulinella*, seemingly ranges in age from *Profusulinella* zone to the *Fusulinella* zone.

In the Akiyoshi limestone group, representatives of *Millerella* and *Pseudostaffella* have not been found yet, it is noteworthy that primitive representatives of *Fusu-*

linella and species of *Akiyoshiella* already appear in the rocks referred to the *Profusulinella* zone. At Shishidedai, Akago-mura, *Akiyoshiella ozawai*, the type species of the genus, and *A.* sp. A occur associated with *Profusulinella* sp., while at the north of Taisho-cave, Akago-mura, *Profusulinella beppensis* n. sp. is associated with *Fusulinella* sp. C which is referred to the genus with question.

It is of interest that THOMPSON, PITRAT and SANDERSON (1953) have very recently described *Akiyoshiella toriyamai* from a part of the Cache Creek group of central British Columbia, where it is associated with *Fusulinella jamesensis* and species of *Millerella*?, *Nankinella* and *Staffella*. Fusiform type of *Fusulinella jamesensis*, including the holotype specimen, is very closely allied, if not conspecific, with *F. simplicata* n. sp. which occurs in the lower part of the *Fusulinella biconica* zone of the Akiyoshi limestone group. It seems, therefore, that the genus *Akiyoshiella* occurs in slightly different horizon in the opposite sides of the Pacific Ocean, and that the genus may be ranging in age from the *Profusulinella* zone to the *Fusulinella* zone, although the phylogenetic relation of *Akiyoshiella* to other genera is not understood.

As mentioned above, it is beyond doubt that species of *Profusulinella* occurs with primitive form of *Fusulinella* in the Akiyoshi limestone group, and there is no evidence to show that shells of *Profusulinella* had been derived from the underlying beds. Therefore, I am of the opinion that primitive form of *Fusulinella* had been coexisted with species of *Profusulinella* which is, in turn, associated with species of *Akiyoshiella*. However, I have no positive evidence to determine whether *Profusulinella* and *Akiyoshiella* range upward into the lower part of the *Fusulinella* zone or *Fusulinella* ranges down into the upper part of the *Profusulinella* zone. *Fusulinella* sp. C which occurs with *Profusulinella beppensis* n. sp. is considered to be one of the most primitive form of *Fusulinella*, while *Profusulinella beppensis* n. sp. is in no way specialized but is a rather primitive form of that genus. Accordingly, the latter alternative is seemingly more appropriate.

In short, the fact that characteristic species of the *Profusulinella* zone in the Akiyoshi limestone group, viz., *Profusulinella beppensis* and *P.* sp. resemble *P. copiosa* and *P. marblensis*, respectively, which are known in the lower part of the *Profusulinella* zone of North America, and that the occurrence of *P.* (?) *rhomboides* which was described from the lower part of the Huanglung limestone, lead me to the conclusion that the *Profusulinella beppensis* zone of the Akiyoshi limestone group is certainly to be correlated with the *Profusulinella* zone of North America.

Although the *Profusulinella* zone has not yet been reported in other part of Japan, it may be possible that more detailed future study on fusulinids contained in the *Fusulinella* zone will demonstrate the existence of *Profusulinella* zone in the so-called "*Fusulinella* zone," especially in the lower part of it.

2. ***Fusulinella biconica* zone Cmβ**

Species of *Fusulinella* are widespread in the Moscovian series of the Tethys region. The genus dominates the fusulinid fauna of the upper Atokan series but ranges upward into the lower part of *Fusulina* zone in North America. The part of the section in which advanced *Fusulinella* is associated with primitive *Fusulina* is considered to belong to the Desmoinesian stage. The *Fusulinella* zone is also widespread in Asia, to which the Taiyuan seris of South Manchuria and North China and the upper part of the Huanglung limestone have been identified.

In the Akiyoshi limestone group, OZAWA's C_2 *Fusulinella bocki* zone and HANZAWA's Lower Zone are unquestionably referred to the *Fusulinella biconica* zone, in which rather large species of "*Fusulinella bocki*" and its allies are dominating. They have massive chomata and almost plane septa. Faunally they show a close resemblance to those of the Taiyuan series of South Manchuria and North China and to those of the Huanglung limestone of South China, displaying characteristic of the Tethys fusulinids.

As listed already, the upper part of the *Fusulinella* zone is characterized by the association of such advanced forms of *Fusulinella* as *F. biconica* (HAYASAKA) and its allies and by such primitive one of *Fusulina* as *F. akiyoshiensis* n. sp. It is interesting enough that almost exactly the same kind of faunal association has been reported by THOMPSON (1948) from the Pennsylvanian rocks of New Mexico in North America, where *Fusulina* n. sp. occurs associating with *Fusulinella* cf. *iowensis* THOMPSON. The former has much resemblance with *Fusulina akiyoshiensis* n. sp., showing close relationship, if not conspecific, while *Fusulinella* cf. *iowensis* THOMPSON resembles *F. biconica* (HAYASAWA) and its allies, having massive chomata and almost plane septa. As pointed out by THOMPSON, these primitive forms of *Fusulina* are considered to be gradational in nature between some form of *Fusulinella* in the lower Middle Pennsylvanian (lower Oklan) and forms of *Fusulina* in the upper Middle Pennsylvanian (upper Oklan).

In short, the fact that the *Fusulinella biconica* zone of the Akiyoshi limestone group contains primitive form such as *F. simplicata* n. sp. in the lower part and advanced forms of *Fusulinella* with *Fusulina akiyoshiensis* n. sp. in the upper part, shows that the *Fusulinella biconica* zone is of about the same age as the whole of the *Fusulinella* zone and the basal part of the *Fusulina* zone of North America. In another words, rocks of the *Fusulinella biconica* zone are correlated with the Atokan stage and the basal Desmoinsian stage. In North America, however, a stratigraphic break is generally recognized between Atokan and Desmoinesian rocks, and paleontological discontinuity at this hiatus is said to be of considerable magnitude.

In the Akiyoshi limestone group, there is no evidence to show any kind of stratigraphic break or paleontologic discontinuity between the upper and lower parts

which may correspond to those in North America. While the *Fusulinella biconica* zone will be certainly identified to the middle part of Moscovian rocks in Russia.

3. *Pseudoschwagerina* zone

A. *Triticites simplex* subzone P1α

The Carboniferous-Permian boundary problem, which attracted the worldwide attenion of students of Upper Paleozoic stratigraphy for many years, was also fully discussed in Japan. It has been either recognized or assumed that the so-called "Uralian" series is lacking even where no stratigraphic break is observable beween the overlying rocks of Wolfcampian (or Sakmarian) age and the undyling rocks of Oklan (or Moscovian) ages. Very recently, however, the existences of Uralian rocks have been reported by KANMERA (1952), KAWADA and FUJIMOTO (1952), and KANUMA (1952) from southern Kyushu and central Honshu. Accordingly, the "Uralian" problem has been brought up again to Japanese geologists.

As already discussed, it has ascertained that the *Fusulina* zone and the *Triticites* zone are lacking in the Akiyoshi limestone group, in spite of the fact that there being no visible evidence of a stratigraphic break between the *Pseudoschwagerina* zone and the *Fusulinella* zone.

The *Triticites simplex* subzone which is, as defined, the lower subzone of the *Pseudoschwagerina* zone, contains abundant species of *Triticites*, of which species hitherto described, as well as new ones, show characteristics of the so-called "Tethyian fauna" of the Moscow Basin, Samara Bend and China, etc.

There is almost no doubt that the *Triticites simplex* subzone is identified with rocks of Lower Permian age in other parts of the world, namely, for example, the rocks of early Sakmarian age in Russia and of early Wolfcampian age in north America. Although characteristic species of this subzone, such as *Triticites simplex*, *T. arctica* and *T. montipara*, are known from the Uralian series, they are also characteristic species of the Sakmarian series of Russia. So far as known in Japan, both *Triticites simplex* and *T. ozawai** have been reported from Sakmarian rocks with species of *Pseudoschwagerina* and from recently found "Uralian" rocks in Central Honshu. With their allied forms, these species are clearly distinguishable from *Triticites matsumotoi* (MS) and *T. yayamadakensis* (MS), which were reported by KANMERA (1952A) from the Uralian Yayamadake subgroup of southern Kyushu.

As already stated in Chapter 1, there is a horizon composed exclusively of species of *Triticites* at the base of the *Triticites simplex* subzone of the Akiyoshi limestone group. As pointed out by THOMPSON and others (1946), it is of interest to note

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* As OZAWA's *Triticites montipara* is not conspecific with SCHELLWIEN's type specimen, I distinguished species referable to *T. montipara* OZAWA from *Fusulina montipara* SCHELLWIEN as a new species *T. ozawai*.

that the same relationship exists in the basal Wolfcampian rocks of Kansas, north-central Texas and the Glass Mountain of Texas in North America where the lowest fusulinid fauna consists of only species of *Triticites*.

On the other hand, it should be noted that KANMERA (1952A) reported the existence of a horizon of 20–30m in thickness which contains only species of *Triticites* above the horizon in which species of *Pseudoschwagerina* first appear in the basal part of the *Pseudoschwagerina* zone of the Yayamadake subgroup. At the same time, KANMERA reported the stratigraphic hiatus between the *Pseudoschwagerina* and underlying *Triticites* zones; accordingly, it is assumed that some horizon which should be correlated with the upper part of Kawvian *Triticites* zone of North America is still lacking in the Yayamadake subgroup.

From a paleontologic point of view it seems that a more critical discussions on *Triticites* zone recently found in central Honshu should be made to determine if it really is "Uralian" in age or is referable to some horizon which should be included in the lower part of the *Pseudoschwagerina* zone.

The *Triticites simplex* subzone of the Akiyoshi limestone group is safely correlated with OZAWA's *Pseudoschwagerina moungthensis* subzone (C_3^1) and the lower part of HANZAWA's Middle zone.

B. *Pseudofusulina vulgaris* subzone P1β

The *Pseudofusulina vulgaris* subzone of the Akiyoshi limestone group is clearly of the same age as OZAWA's *Schwagerina princeps* subzone (C_3^2) and HANZAWA's Middle zone, and perhaps a part of the Lower subzone of the Upper zone, because the fusulinid fauna of this subzone is characterized by *Pseudofusulina vulgaris* and its allies and *Pseudoschwagerina* sp., though the latter species is very rare.

As stated in Chapter 1, the *Pseudofusulina vulgaris* subzone is the most prolific of the fusulinid faunas, containing many of the Lower Permian species of *Pseudofusulina, Schwagerina* and *Triticites*. Faunistically speaking, the faunal assemblage of this subzone shows a close relationship to the Tethys fusulinids of the C_3^2 and C_3^3 of the Moscow Basin, Samara Bend, Darwas, etc.

Pseudofusulina vulgaris (SCHELLWIEN), the index species of this subzone, has often been reported with species of *Pseudoschwagerina* in the Lower Permian rocks of Japan. In the Akiyoshi limestone group, *Acervoschwagerina* akiyoshiensis* n. sp. and *Triticites ellipsoidalis* n. sp. are also good horizon indicator, the stratigraphic

* *Acervoschwagerina* was established as a subgenus of *Paraschwagerina* by HANZAWA who once discussed at some length on stratigraphic occurrences of the said genus. He (1941) considered that the genus *Paraschwagerina* is ranging from Sakmarian (*Pseudoschwagerina* zone) into Artinskian (*Parafusulina* zone). However species of *Parafusulina* already appear in the upper part of *Pseudofusulina vulgaris* subzone; therefore, coexistence with species of *Parafusulina* not necessarily show the Artinskian age. In North America stratigraphic occurrence of *Paraschwagerina* is restricted to the *Psuedoschwagerina* zone, and no species of that genus is known in the *Parafusulina* zone.

occurrences of which are restricted to this subzone.

In short, *Pseudofusulina vulgaris* subzone is correlated with the upper part of the Wolfcampian or Sakmarian series.

4. ***Parafusulina* zone**

The Leonardian series and a lower part of the Guadalupian series of North America and the Artinskian series of Ural are referred to the *Parafusulina* zone. In Japan, the *Parafusulina* zone is sometimes rather hard to recognize faunally, an example of which is seen in the Upper Paleozoic rocks of the Kitakami massif where the Shishiori stage of the Kanokura series is considered to be *Parafusulina* zone.* In the Kwanto massif, the lower part of HUZIMOTO's III, zone of *Neoschwagerina craticulifera* or *Schwagerina* (*Pseudofusulina*) *ambigua*, is perhaps referable to the *Parafusulina* zone. It is well known that a good display of the *Parafusulina* zone is present in Nabeyama, Ashio massif, but paleontologic study of it has not yet been published. In the Akiyoshi area OZAWA's CPg, *Fusulina* (*Parafusulina*) *lutugini* subzone, is at least contained in the *Parafusulina* zone.

I subdivided the *Parafusulina* zone of the Akiyoshi limestone group into two subzones, the lower *Pseudofusulina ambigua* and upper *Parafusulina kaerimizensis* subzones.

A. ***Pseudofusulina ambigua* subzone P1γ**

Fusulina ambigua was described with *F. subcylindrica* from French-Indochina by DEPRAT who considered that they are Upper Permian in age. OZAWA established the *Fusulina ambigua* subzone (P_2) in the *Neoschwagerina* zone. In his collection, however, only two thin sections are found which are labeled as *F. ambigua*, both of them are not well oriented; he described the same spcies in the lowest Benijima limestone of Akasaka. Although there are some discrepancies between the faunal contents of the Benijima limestone determined by OZAWA and those of the lowest horizon which DEPRAT (1914) considered Uralian in age, MINATO (1952) regards both of them as Lower Permian elements.

In the Akiyoshi limestone group, the *Pseudofusulina ambigua* subzone is considered to be of the upper part of the Lower Permian, because associated species with the index species of *P. ambigua* (DEPRAT) include species of *Pseudofusulina vulgaris* and its varieties. The latters continuously occur from the lower subzone with species of *Triticites*, though very few in number; while species of *Pseudoschwagerina* are absent in this subzone, but species of *Parafusulina* already appear. Therefore, the *Pseudofusulina ambigua* subzone is regarded as the lower subzone of the *Parafusulina* zone.

* Because of the extreme poor state of preservation the fusulinids of Kitakami massif are not appropriate for a critical paleontologic study, although I (1952) have described some of them very recently.

Laying special emphasis on faunal assemblages, I placed the boundary between the Lower and Middle Permian on the top of the *Pseudofusulina ambigua* subzone, although it lies between the lower and upper subzones of the *Parafusulina* zone. Namely, the lower subzone of the *Parafusulina* zone (*Pseudofusulina ambigua* subzone) still contains species of *Triticites* and faunal aspects in general common to that of the *Pseudoschwagerina* zone. On the other hand, the upper subzone (*Parafusulina kaerimizensis* subzone) contains no species of *Triticites*, but contains already many representatives of Verbeekininae and Neoschwagerininae. Species of *Parafusulina* are common through both subzones.

B. ***Parafusulina kaerimizensis* subzone Pmα**

As index species for *Parafusulina* zone, *P. kaerimizensis* (OZAWA) has often been reported in Permian rocks of Japan. As OZAWA's type is not a perfect specimen, it might be a case that many species have been referred to *P. kaerimizensis* which should be referred to other species. OZAWA regarded *P. kaerimizensis* as a member of *Parafusulina lutugini* subzone (CPg), the lowest subzone of *Neoschwagerina* zone in the Akiyoshi limestone. FUJIMOTO (1936, 1944) reported the species from the lower Permian P_1 (Artinskian) in the Kwanto massif and from the lowest Permian (Sakmarian) in the Taishaku plateau, Hiroshima Pref. It is known that *P. kaerimizensis* occurs abundantly in Nabeyama, Tochigi Pref., but the exact stratigraphic position of it has not yet been determined with certainty.

Parafusulina kaerimizensis shows a rather long range in the Akiyoshi limestone group of the Section I at the Kaerimizu doline, the type locality of the species. However, it is most abundant near the bottom of doline, that is to say, in the upper horizon of Section I. In the Section XVI on the northern margin of the Ofuku plateau, it is also prolific in the upper part of the section.

As pointed out already, there is a rather marked contrast between the faunal assemblages of the *Parafusulina kaerimizensis* and *Pseudofusulina ambigua* subzones, although both belong to the *Parafusulina* zone. Comprising many representatives of primitive verbeekinids and neoschwagerinids as forerunner but no species of *Triticites* and primitive *Schwagerina*, the *Parafusulina kaerimizensis* subzone is assumed to be Middle Permian in age. It is correlated with the upper part of the *Parafusulina* zone, viz., to the lower Guadalupian in North America.

In the Kitakami massif, the Shishiori stage is considered to be referable to the *Parafusulina* zone, the faunal assemblage of which seems to represent, however, only the upper subzone of the *Parafusulina* zone. Accordingly, it may be possible that the lower subzone—the *Pseudofusulina ambigua* subzone in the Akiyoshi limestone group—is lacking in the Kitakami massif.

5. *Neoschwagerina* zone

Representatives of Neoschwagerininae and Verbeekininae* have been regarded as the characteristics of Middle and Upper Permian fusulinids of Tethys Sea region. In North America the occurrences of both subfamilies are restricted to the northern part of the Pacific Coast, including British Columbia, Washington and Oregon, from where THOMPSON, WHEELER and DANNER (1950) have described many species of neoschwagerinids and verbeekinids designating them as American Tethys faunas, because they are closely related to the Middle and Upper Permian faunas of the Orient, including Japan, China and French-Indochina.

Because neither species of neoschwagerinid nor verbeekinid has been found in the Permian rocks of Mid-Continent region of North America, the relationship between the *Neoschwagerina-Verbeekina* zone of the Tethys region and the *Polydiexodina* zone of North America is still not clearly known. THOMPSON (1946) suggested that the latter is at least partly equivalent in age to the former, because *Polydiexodina* is associated with *Verbeekina* and *Neoschwagerina* in Afghanistan and because *Verbeekina* occurs stratigraphically above typical *Parafusulina* faunas in South China.

In Japan one of the best displays of Middle and Upper (?) Permian rocks is found in Akasaka, Gifu Prefecture which was studied by OZAWA (1927). His zoning of the Akasaka limestone through the phylogenetic relation of *Neoschwagerina* is still useful. In the Akiyoshi limestone group the *Neoschwagerina* zone is much restricted in its distribution as described in the foregoing chapter, hence it is not suitable for the study of Middle Permian fusulinids.

A. *Neoschwagerina craticulifera* subzone Pmβ

Neoschwagerina craticulifera (SCHWAGER), the index species of this subzone, is common and easily distinguishable. The *Neoschwagerina craticulifera* zone is well recognized in most Middle Permian rocks of Japan, except in the Kitakami massif. FUJIMOTO's III, zone of *Neoschwagerina craticulifera* or *Schwagerina* (*Pseudofusulina*) *ambigua* in the Kwanto massif, OZAWA's Nc zone in the Akasaka limestone, the lower part of OZAWA's P_2 or the lower part of the upper subzone of HANZAWA's Upper zone in the Akiyoshi limestone are all correlated with the *N. craticulifera* subzone. A part of the *Polydiexodina* zone in North America, perhaps the lower part of it, will be correlated with the *Neoschwagerina craticulifera* subzone. However, it must be noted that the index species of this subzone has a rather long range. It ranges from the upper part of Nn zone to the lower part of Nm zone in the Akasaka limestone, from P_1 to P_3 in the Kwanto massif, and according to OZAWA, from CPg to P_3** in the Akiyoshi limestone.

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* Combining both subfamilies DUNBAR (1948) established a new fusulinid family *Neoschwagerinidae*.

** In his fossil list OZAWA (1925) regarded the range of this species as being from the CPg to the P_3, but he put a question mark on the P_2.

Although the *Neoschwagerina craticulifera* subzone of the Akiyoshi limestone group is much limited in distribution, it forms a good fossil zone in Section I at Kaerimizu, where the species first appears in the *Parafusulina kaerimizensis* subzone as accompanying species with its varieties, and becomes the main component in the subzone under consideration. It is associated with species of *Parafusulina, Pseudofusulina* and *Schwagerina.*

In short, *Neoschwagerina craticulifera* has a rather long stratigraphic range in Middle Permian rocks, but the *N. craticulifera* subzone can be accepted as a fusulinid zone if faunal assemblages are to be taken into account.

B. *Verbeekina verbeeki* subzone Pmγ

As well as the next one the *Verbeekina verbeeki* subzone is most narrowly restricted in distribution among the fusulinid zones of the Akiyoshi limestone group, and its upper limit is unkown in Section I in the Akiyoshi plateau.

So far as known *Verbeekina verbeeki* has been reported from the following horizons; IV zone of *Neoschwagerina margaritae* in the Kwanto massif, from Nc to Nm zones of the Akasaka limestone, P_2 and P_3 in the Akiyoshi limestone, and in the Middle-Upper Permian rocks of the Tethys belt, including the Chihsia limestone of South China, Indochina, and Sicily. The horizon in which *Verbeekina verbeeki* occurs abundantly in Japan has been designated the *Neoschwagerina margaritae* zone, because it usually is associated with *N. margaritae.*

As mentioned in the foregoing chapter data at my disposal show that *V. verbeeki* occurs only associated with species of *Parafusulina* and *Schwagerina* but with no species of *Neoschwagerina.* Accordingly, the direct correlation of the *Verbeekina verbeeki* subzone with *Neoschwagerina margaritae* zone* is not discussed in detail here. However, I am tentatively referring the *V. verbeeki* subzone to the *N. margaritae* zone of other parts of Japan, because the horizon in which *V. verbeeki* is abundant is clearly above the *Neoschwagerina craticulifera* subzone.

C. *Neoschwagerina douvillei* subzone Pmδ

Showing rather marked contrast to the overlying *Yabeina shiraiwensis* zone, the *Neoschwagerina douvillei* subzone is much restricted in its distribution.

As will be discussed in the following pages, the Permian rocks which have hitherto been referred to the uppermost fusulinid zone are divisible into the lower *Yabeina* subzone and the upper *Lepidolina* zone. Of these, the former is considered to be the uppermost subzone of the *Neoschwagerina* zone, because it contains highly

* Although OZAWA (1923) divided the *Neoschwagerina* zone of the Akiyoshi limestone group into four subzones, he stated that the faunal relations of them are so intimate that it is hard to determine them with certainty, and he only named subzone but did not list species of each subzone, except for the *Sumatrina annae* subzone (P_3).

advanced representatives of *Neoschwagerina* and primitive members of *Yabeina*. A typical example is the Ng zone of the Akasaka limestone in the central Japan, comprising the following species:

Neoschwagerina minoensis OZAWA
Yabeina globosa (YABE)
Y. katoi OZAWA

Another example is the *Yabeina globosa* subzone of Southern Kyushu which is now studied by KANMERA. A part of the *Yabeina globosa* zone of the Kwanto massif and of the *Sumatrina* and *Yabeina* zone of the Taishaku limestone is considered to be also referred to the uppermost subzone of the *Neoschwagerina* zone.

Neoschwagerina douvillei was originally established by OZAWA for the forms described as *Neoschwagerina globosa* by DEPRAT and DOUVILLE; and it is common in this country that *N. douvillei* associates with *Yabeina globosa* and *Y. katoi*, although it sometimes ranges down to the underlying subzones.

No species of *Yabeina* has been found in the *Neoschwagerina douvillei* subzone of the Akiyoshi limestone group; therefore, it is not certain if this subzone is referable to the *Yabeina globosa* subzone of the Akasaka limestone or Southern Kyushu. Accordingly, I am tentatively referring the *Neoschwagerina douvillei* subzone to the *Yabeina globosa* subzone of *Neoschwagerina* zone.

6. *Yabeina* zone

The Permian rocks, comprising most advanced species of *Yabeina*, are generally regarded as the uppermost fusulinid zone. It should be noted, however, that KANMERA (1952A) and I (1952) separately pointed out that there is a horizon in which species of *Lepidolina* and highly advanced froms of *Yabeina* are the main components with no associated species of *Neoschwagerina*. Accordingly, we proposed separately to designate the horizon as the *Lepidolina* zone. According to KANMERA, the rocks of the *Lepidolina* zone of Southern Kyushu are remarkably different in facies and in the condition of deformation with the rocks which contain primitive species of *Yabeina* —*Y. globosa*, *Y. katoi*, etc.—and highly advanced forms of *Neoschwagerina*—*N. margaritae*, *N. douvillei* and others. These rocks are designated *Yabeina globosa* subzone s. str. by KANMERA. It is unfortunate that the stratigraphical relationship between the *Lepidolina* zone and *Yabeina globosa* subzone is not known in Southern Kyushu because they occur in dfferent tectonic belts.

In this country the upper part of the Kanokura series in the Kitakami massif, FUJIMOTO's V zone of *Yabeina globosa* in the Kwanto massif, the Ng zone of the Akasaka limestone, the *Yabeina* and *Sumatrina* zone of the Taishaku limestone, the Yasuba type of conglomerates of the Southwestern Japan (TORIYAMA, 1947–1951) and others have hitherto been referred to the *Yabeina* zone. However, critical studies on

these *Yabeina*-bearing rocks show that some of them are not referable to the *Yabeina globosa* subzone, but are undoubtedly correlated with the *Lepidolina* zone.

***Yabeina shiraiwensis* zone Puα**

According to KANMERA, *Yabeina shiraiwensis* is one of the characteristic species of the *Lepidolina* zone in Southern Kyushu, while in the Akiyoshi limestone group no species of *Lepidolina* has been found in the horizon in which *Y. shiraiwensis* occurs abundantly.* As will be stated later, rocks of this horizon is distinguished from those of the underlying subzones from the stratigraphic standpoint. I am, therefore, referring the highest fusulinid zone of the Akiyoshi limestone group to the *Lepidolina* zone, designating the *Yabeina shiraiwensis* zone.

THOMPSON, WHEELER and DANNER (1950) have recently described several species of *Yabeina* from the Middle and Upper Permian rocks of Washington and British Columbia. Of these, *Yabeina cascadensis* (ANDERSON) is almost the same with Y. *globosa* and its allies in the assumed relative degree of evolutionary development within the genus *Yabeina*, although no species of highly advanced representative of *Neoschwagerina* has been reported with them. On the other hand, *Y. columbiana* (DAWSON), *Y. minuta* THOMPSON and WHEELER, and *Y.*? n. sp., which were considered by them to be more advanced representatives of *Yabeina* than *Y. cascadensis*, show close relationships in many respects with *Y. shiraiwensis* and its allies. In fact, *Y.*? n. sp. is seemingly an intermediate form from *Yabeina* to *Lepidolina*, although their descriptions and illustrations are not sufficient for the critical discussion. In short, it is highly possible that the Granite Fall limestone of British Columbia with *Y. cascadensis* is correlated with the *Yabeina globosa* subzone, and that the Marble Canyon limestone with *Y. columbiana*, *Y. minuta* and *Y.*? n. sp. is assumed to be at least not older than the *Lepidolina* zone of Japan including the *Yabeina shiraiwensis* zone of the Akiyoshi limestone group.

Although it is clear that the *Yabeina shiraiwensis* zone is stratigraphically the uppermost horizon in the Akiyoshi limestone group, there still remain problems to be studied; first, is it definitely correlated with the *Lepidolina* zone of the Kuma

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**Yabeina shiraiwensis* was described by OZAWA from the Shiraiwa formation of the Tsunemori group which was referred by OZAWA to his division C, alternation of lenticular limestone-bearing shale, hornstone and sandstone. He listed the following forms as accompanying species as *Fusulinella itoi* OZAWA, *Schwagerina exilis* (SCHWAGER), *Pseudofusulina kraffti* (SCHELLWIEN), *P. crassiseptata* (DEPRAT), *Parafusulina granum-avenae* (ROEMER). *Verbeekina verbeeki* GEINITZ, *Neoschwagerina craticulifera* (SCHWAGER), *N. margaritae* DEPRAT, and *Afghanella schenki* THOMPSON. As will be mentioned later, however, the limestone lenses which crop out at Shiraiwa are all limestone conglomerate, and all species listed above except *Y. shiraiwensis* are contained not in the matrix, but in pebles of limestone conglomerate. Therefore, they are regarded as derived fossils. *Y. shiraiwensis* usually occurs in matrix, being crushed, and rarely in pebles of limestone conglomerate. However, no species is associated in the latter case that is regarded as contemporaneous with the limestone conglomerates (See Part II, Chapter 4).

formation in Southern Kyushu in spite of there being no species of *Lepidolina* contained in it; second, is the stratigraphic range of *Yabeina shiraiwensis* restricted only to the Upper Permian *Lepidolina* zone, namely, is there any possibility that the species under consideration ranges down into the lower fusulinid zones. Much more detailed stratigraphic and paleontologic studies on the Permian rocks seem to be needed to clarify these questions in which species of *Yabeina* occur not only in the Akiyoshi area but also in other parts of this conntry.

As pointed out by many previous workers, it must be noted that rocks of considerable thickness believed to be Permian in age overlie the highest fusulinid zone. Representatives of them in Japan are the most part of the Toyoma series in the Kitakami massif, the Kamiyoshida series in the Kwanto massif, the Taki series to the west of Kyoto, the Uji and Terauchi series of the Oga and Atetsu plateaux, the upper parts of the Shiraiwa formation of the Tsunemori group and of the Ota group in the Akiyoshi area, and the upper part of the Kuma formation in Southern Kyushu.

Stratigraphic and paleontologic studies of world-wide scale on Upper Permian rocks and fusulinids will clarify the questions as to which of the two- or three-fold division is more suitable for the Permian stratigraphy and as to which horizon of the Permian is to be correlated with the highest fusulinid-bearing rocks.

Stratigraphic relationships among fusulinid zones

As emphasized already, it is almost impossible to determine the stratigraphic order of successive fusulinid zones in the field in the Akiyoshi area because whole limestone mass has no stratification. Moreover, it is true that the distribution of fusulinid zone and even the stratigraphic order of succession of limestone have not been determined until the laboratory works were finished. Therefore, I here mention stratigraphic relationships between fusulinid zones based on the distribution of fusulinid zones, the characters of the limestones, and the occurrences of fossils.

1. Relation of *Triticites simplex* subzone to *Profusulinella beppensis* and *Fusulinella biconica* zones.

So far as the paleontologic evidences show, Pennsylvanian fusulinid zones are represented only by the *Profusulinella beppensis* and *Fusulinella biconica* zones, and rocks referred to *Fusulina* and *Triticites* Zones are lacking. Namely, there is a large faunal break between the *Triticites simplex* subzone and underlying fusulinid zones in spite of the fact that there is no evidence to show a physical hiatus between them. Limestone conglomerates sometimes occur in what is regarded as the boundary between the *Triticites* subzone and the underlying zones. However, conglomerates occur also even within one fusulinid zone. Therefore, the occurrence of limestone conglomerates does not necessarily indicate a stratigraphic break.

Although the *Triticites simplex* subzone generally overlies the *Fusulinella biconica* zone, and shows almost the same trend of distribution as that of the latter, the former directly overlies the *Profusulinella beppensis* subzone at Ueyama, Akago-mura in the eastern part of the Akiyoshi plateau. Accordingly, the *Triticites simplex* subzone overlies either the *Fusulinella biconica* or *Profusulinella beppensis* zones. An unconformable relation is assumed between the lower Wolfcampian (or Sakmarian) *Triticites simplex* zone and the underlying zones.

2. Relation between the *Yabeina shiraiwensis* zone and the underlying fusulinid zones.

I have already pointed out that there still remains a problem to be discussed as to whether the *Yabeina shiraiwensis* zone, the uppermost fusulinid zone in the Akiyoshi limestone group, is the correlative of the *Lepidolina* zone of Southern Kyushu, and attention must be given to the distribution of the *Y. shiraiwensis* zone and its relation to the underlying fusulinid zones.

The *Yabeina shiraiwensis* zone does not occur in the most nearly normal part of the Akiyoshi limestone group, but occurs in the overturned part, occupying a rather considerably wide area, while the underlying *Neoschwagerina douvillei, Verbeekina verbeeki* and *Neoschwagerina craticulifera* subzones are much more limited in their distribution. The differences in their distribution are rather remarkable.

The *Yabeina shiraiwensis* subzone overlies either the *Noschwagerina douvillei* or lower subzones. A physical hitatus is, therefore, assumed to occur between the *Yabeina shiraiwensis* and underlying zones, notwithstanding the fact that no positive evidence has been observed. However, it must be noted that limestone referred to the *Yabeina shiraiwensis* zone is usually limestone conglomerate, the pebbles of which contain fusulinids referred to different zones.

Limestones referable to the Lower and Middle Permian fusulinid zones, comprising those from the lower *Triticites simplex* to the upper *Noschwagerina douvillei* subzones, seem in successive order. Future study may clarify the differences of lithic characters between the limestones of each zone.

Summary

The following summarizes Chapter 2.

The Akiyoshi limestone group is divided into the following fusulinid zones and subzones in descending order:

Yabeina zone	:	*Yabeina shiraiwensis* zone	Pu	α
Neoschwagerina zone	:	*Neoschwagerina douvillei* subzone	Pm	δ
		Verbeekina verbeeki subzone		γ
		Neoschwagerina craticulifera subzone		β
Parafusulina zone	:	*Parafusulina kaerimizensis* subzone		α
Pseudoschwagerina zone	:	*Pseudofusulina ambigua* subzone	Pl	γ
		Pseudofusulina vulgaris subzone		β
		Triticites simplex subzone		α
Fusulinella zone	:	*Fusulinella biconica* zone	Cm	β
Profusulinella zone	:	*Profusulinella beppensis* zone		α

1. The *Profusulinella beppensis* zone is correlated with the upper part of the lower Atokan series of North America or with the lower Moscovian series of Russia.

2. The *Fusulinella biconica* zone is correlated with the upper half of the Atokan series and possibly with the lowest part of Desmoinesian series, or with middle Moscovian age of Russia.

3. Rocks referable to almost the whole Desmoinesian (*Fusulina* Zone) and all of Missourian—Virgilian series (*Triticites* Zone) are lacking.

4. The *Triticites simplex* and *Pseudofusulina vulgaris* subzones are correlated with lower and upper halves of the Wolfcampian series of North America or the Sakmarian series of Russia, respectively.

5. The *Pseudofusulina ambigua* and *Parafusulina kaerimizensis* subzones, representing the lower and upper parts of the *Parafusulina* zone, are correlated with the lower Leonardian and upper Leonardian to lower Guadalupian series of North America, respectively. They are also correlated with the lower and upper halves of the Artinskian series in Russia, respectively.

6. The *Neoschwagerina craticulifera, Verbeekina verbeeki* and *Neoschwagerina douvillei* subzones are representing the lower, middle and upper parts of *Neoschwagerina* zone. The last named subzone is considered to be correlated with *Yabeina globosa* subzone of the Akasaka limestone and Southern Kyushu. As a whole, the *Neoschwagerina* zone is probably to be correlated with the middle and upper Guadalupian series of North America.*

7. The *Yabeina shiraiwensis* zone, the highest fusulinid zone in the Akiyoshi limestone group, is most possibly correlated with the Kuma formation of Southern Kyushu and with the lowest part of the Toyoma series of Kitakami massif and is seemingly almost the same in age with the *Yabeina* zone of American Tethys area.

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* In the type locality of the Permian rocks in Ural, no fusulinid has been reported in the rocks above the Kungurian series. Opinion is, therefore, divided as to what fusulinid zone the Kungurian, Kazanian and Tartarian series correlate with. MOORE, LALICKER and FISCHER (1952) correlated the Kungurian and Kazanian with the Guadalupian series, and the Chideruan with the Ochoan series.

Chapter 3. Stratigraphy of the Akiyoshi Limestone Group

General Remark

Since OZAWA discovered the "liegende Falten" first in Japan, his interpretation of the geologic structure of the Akiyoshi limestone group, as well as his study on the fusulinid zones, have attracted stratigraphers' and paleontologists' attention. Some of those who have had special interest in the Upper Paleozoic stratigraphy of Japan have expressed opinions different from OZAWA's.

Among them, KOBAYASHI's explanation (1939, 1941) was most antipodal against OZAWA's. The two ideas were quite different, except for the one point that both considered the whole limestone mass as being completely overturned. I have made an attempt to clarify the geologic structure of the Akiyoshi limestone group, without necessary favor to either explanation.

I have already emphasized that the only key of determing the stratigraphic succession and areal distribution of fossil zones of the Akiyoshi limestone group is the fusulinid fossils. The whole imestone mass of the group, comprising no other facies than limestone, except small amounts of chert, is so massive that it is impossible to determine the stratigraphic order of the limestone in the field. I chose the topographically steep slopes, and collected fusulinids along these slopes in the following twenty-seven sections.*

Assuming that the Akiyoshi limestone group is almost horizontal as hitherto presumed, the approximate thickness of a fossil zone in the section is determined by the differences in elevation of the lower and upper limits of zone. The thickness of a fossil zone thus obtained does not show much difference among the following twenty-seven sections, except in few cases. The difference in the thickness of a fossil zone of the same age in different sections usually corresponds within a presumable change of thickness of that zone. It is assumed, therefore, that the Akiyoshi limestone group was laid almost horizontally as a whole, except in the southern marginal parts of both plateaux where the limestone is assumed to dip northward.

1. Description of Sections

Section I. Eastern slope of the Kaerimizu doline (Western slope of Managatake)

Section I is the classical locality where OZAWA found reverse order of fossil zones of the Akiyoshi limestone group. One can observe good display of overturned

* In each section, species of fusulinids are shown. It seems not appropriate to use the term "bed" in each section, because it is impossible to discriminate a "bed" in the thick limestone which has no stratification and is almost uniform in lithologic character. I used, therefore, only the term "number" for locality whence the fusulinids were collected. The "number" of each section is numbered in ascending order, regardless of whether the limestone is in a normal or reverse order. Height above sea level at each locality is shown at the left side of the columnar section. Original field locality numbers are indicated in the explanations of figures.

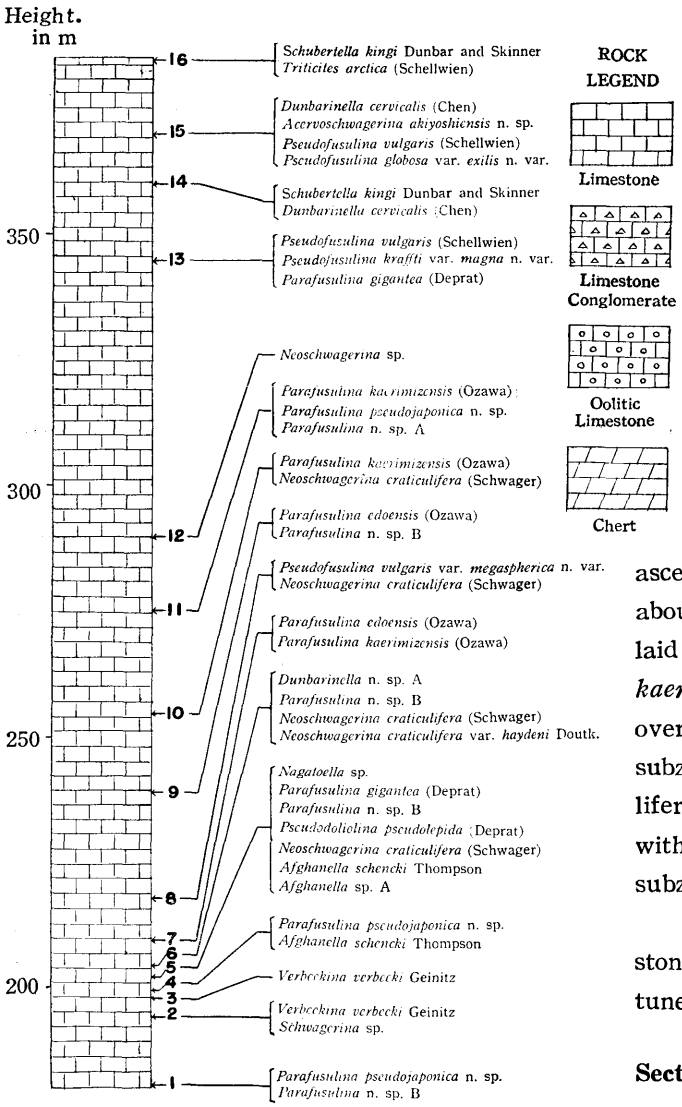

Fig. 2. Section I. Kaerimizu: 1=285A, 2=285, 3=286A, 4=286, 5=287, 6=287A, B, 7=288A, 8=289, 9=290, 10=291, 11=292, 12=293, 13=295, 14=296, 15=297, 16=298

Numbers to left of column are *height above the sea level*. Arabic figures in gothics to right of column and in the explanations of figures are "*Number*" in Section, corresponding *field locality number* of which is indicated by arabic figures in the explanation of Figures 2-28. Abbreviation GKD-PT for field locality number is omitted for briefness' sake.

fusulinid zones along the slope from the ponor of the doline up to near the top of Managatake. SUGIYAMA once mentioned the fululined zones there which I already stated.

Commencing at the ponor of the doline the *Verbeekina verbeeki* subzone (25m), *Neoschwagerina craticulifera* subzone (25m) and *Parafusulina kaerimizensis* subzone occur successively in ascending order. Limestone of about 65m in thickness which is laid between the *Parafusulina kaerimizensis* subzone and the overlying *Pseudofusulina vulgaris* subzone (40m) is almost unfossiliferous, but may be correlated with the *Pseudofusulina ambigua* subzone in other sections.

In short, the Akiyoshi limestone group is completely overtuned in the Section I.

Section II. Shishidedai

Section II at the western flank of Shishidedai is comprising only the lower two fusulinid zones—the *Profusulinella beppensis* zone in the lower and the *Fusulinella biconica* zone in upper parts. No species has been found in the limestone exposed at the top of Shishidedai, but *Akiyoshiella ozawai* TORIYAMA first appears at the level 35m below the top of Shishidedai, which again occurs at the level 60 m more below, associated with *Profusulinella* sp.

Limestone of 30m in thickness further below is unfossiliferous, and the upper part of the *Fusulinella biconica* zone occurs at the north of the entrance to Kagekiyo-cave. The unfossiliferous limestone of 30 m in thickness, there-

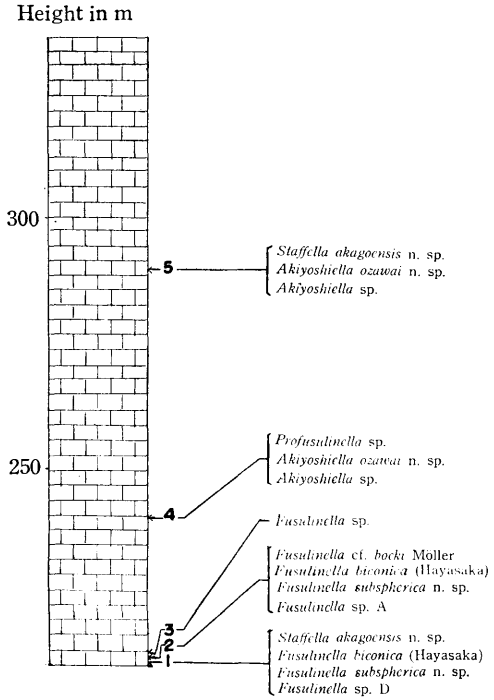

Fig. 3. Section II. Shishidedai: 1=355, 2=354, 3=353, 4=352, 5=351

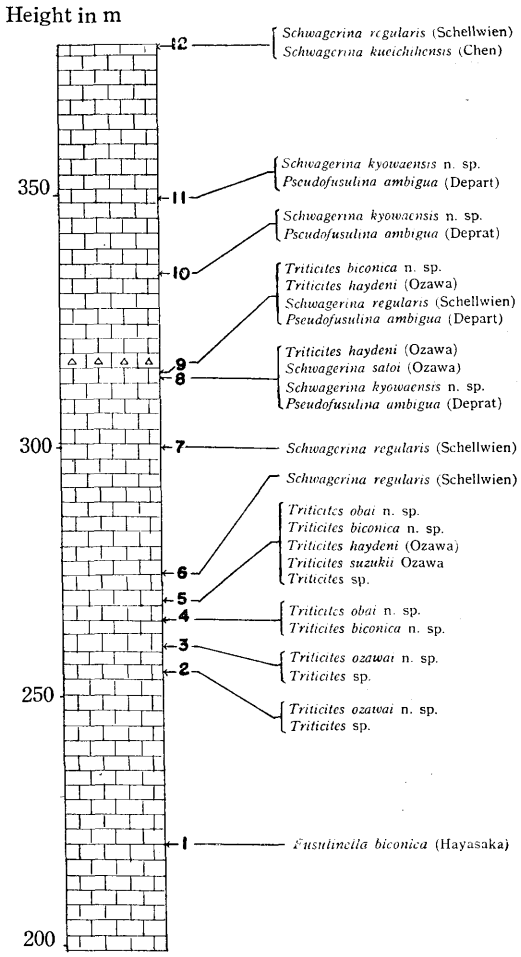

Fig. 4. Section III. Eastern flank of Managatake: 1=538, 2=539, 3=539A, 4=540A, 5=540, 6=541, 7=542, 8=543, 9=543A, 10=544, 11=545, 12=546

fore, may be referable to the lower part of the *Fusulinella biconica* zone.

In Section II fossil zone apparently seems to be in reverse order, but it may be true that the lower fossil zone is present at topographically higher places on account of that the Akiyoshi limestone group of Shishidedai is dipping to the southwest-west with gentle angles. The same relation is seen in the southern part of the Akiyoshi and Ofuku plateaux.

No fossil has been found in the eastern flank of Shishidedai.

Section III. Eastern flank of Managatake

Section III is developed along the trail from Sayama, Akago-mura to the top of Managatake, namely, it is the opposite facing the Section I, but is in almost the same

trend as the latter. In this section the *Fusulinella biconica* zone (50m+), the *Triticites simplex* subzone (20m) and the *Pseudofusulina vulgaris* subzone (65 m?) occur in ascending order. Of which the first one is very rare in fusulinid, and the upper (30m) and lower (20 m) parts of it are barren. It may be possible that the lower part of the *Fusulinella biconica* zone in this section is referred to the *Profusulinella beppensis* zone, although it needs much more future study.

As shown by the order of succession, the fusulinid zones of Section III are in normal order in spite of being Section I and III form the western and eastern flanks of Managatake, respectively.

Section IV. Ueyama

Section IV is along the road from Ueyama, Akago-mura to Kaerimizu, and is almost parallel to Section III. In this section the *Profusulinella beppensis* zone is directly overlaid by the *Triticites simplex* subzone (20m) which is, in turn, overlaid by the *Pseudofusulina vulgaris* subzone. The *Fusulinella biconica* zone is, therefore, missing in this section. Limestome occurs at the boundary between the *Profusulinella beppensis* zone and the *Triticites simplex* subzone is conglomeratic.

Section V. "Benkei-yama"

"Benkei-yama" is a low hill located 600 m north of "Minami-yama" (a high hill of 321.4 m in height) which is near the boundary between Akiyoshi-mura and Ota-machi in the southern part of the Akiyoshi plateau. Section V is along the northern slope of "Benkei-yama," in which only the *Pseudofusulina vulgaris* subzone

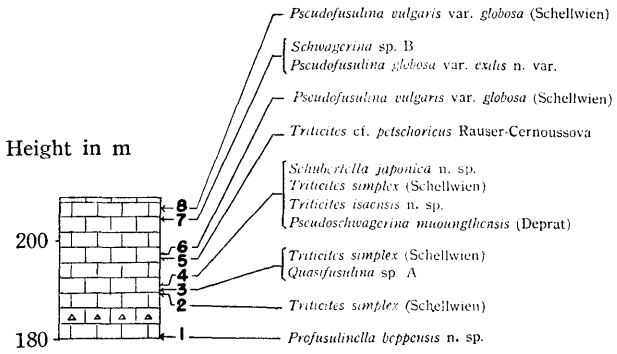

Fig. 5. Section IV. Ueyama: 1=712, 2=716, 3 = 716A, 4=717, 5=718, 6=719, 7=720, 8=720A

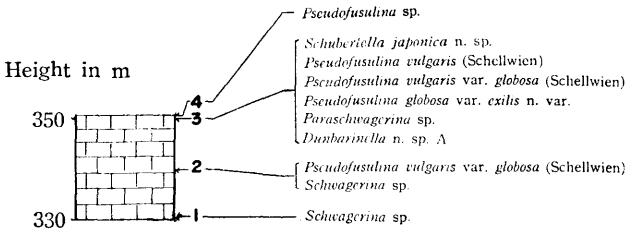

Fig. 6. Section V. "Benkei-yama": 1=461, 2=462, 3=463, 4=464

developed, consisting of fossiliferous limestone of 20 m in thickness. Good displays of the *Fusulinella biconica* zone can be observed at and around the top of "Minami-yama" stated above.

Section VI. "Tanaiwa"

All over the area of the small hill of 302. 1m in height is called "Tanaiwa," which is situated northeast of the Oniana-doline. Limestones crop out on the southern (Section VIA) and western (VIB) slopes of "Tanaiwa" are prolific in fusulinids, all of which are referred to the *Pseudofusulina vulgaris* subzone. In the southern slope, however, the difference of height between the top and the base of the section exceeds 90 m. This may be explained by an assumption that the limestone is not laid horizontally, but is dipping gently in accordance with the inclination of the surface slope, or that the same horizon appears repeatedly by intraformational folding.

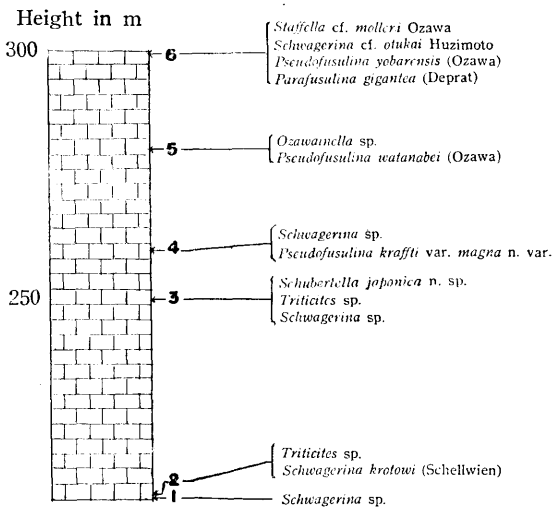

Fig. 7. Section VIA. "Tanaiwa": 1=447, 2=448. 3=449, 4=450, 5=451, 6=452

Section VII. "Ryugoho"

"Ryugoho" which is in the southwestern part of the Akiyoshi plateau is the highest hill on that plateau, attaining a height of 425.5m above the sea level. Along the southern slope of the hill, namely, the road from Seto, Akiyoshi-mura to the top of "Ryugoho," fusulinid zones occur in somewhat complex way. Around Seto and Akiyoshi, crystalline limestone is widely distributed, which might have been formed by the granodioritic intrusion at Kyozuka. The *Fusulinella biconica* zone first appears at the level of 170m, which is overlaid by the *Triticites simplex* and *Pseudofusulina vulgaris* subzones (20m and 20m+, respectively) in ascending order. Overlying the latter, the *Fusulinella biconica* zone (15 m?) and then the *Triticites simplex* subzone (30 m) expose again, and, lastly, the *Fusulinella biconica* zone appears three times near the top of "Ryugoho." Accordingly, it is presumed that the *Fusulinella biconica* zone and a part of *Triticites simplex* subzone are repeated by strike fault in the middle part of the section, and that the rest of the *Triticites simplex* subzone and the *Fusulinella biconica* zone, which are exposed near the top of "Ryugoho," are erosion remnant of the overturned anticline. Eventually, limestone conglomerates occur in the *Triticites simplex* subzone of the middle part.

Section VIII. Southwestern slope of "Ryugoho"

Section VIII is along the trail from Hirano-bashi (a bridge between Hosoono and Yobiiwa), Beppu-mura to "Ryugoho," in which the *Triticites simplex* and *Pseudofusulina vulgaris* subzones are developed bounded by the level of about 100m. Limestone overlying the latter is completely crystalline, in which no fossil can be found. Just the southeast of the highest point of "Ryugoho" (425.5 m) is exposed the *Fusulinella biconica* zone which belongs to the overturned part.

Section IX. Mizuta

Section IX is along the road from Mizuta, Iwanaga-mura southwest-westwardly to the Ofuku plateau. The *Fusulinella biconica* zone (30 m+) in the lower part of section is overlaid by non-fossiliferous limestone of about 120 m thick, which is, in turn, overlaid by the *Triticites simplex* subzone.

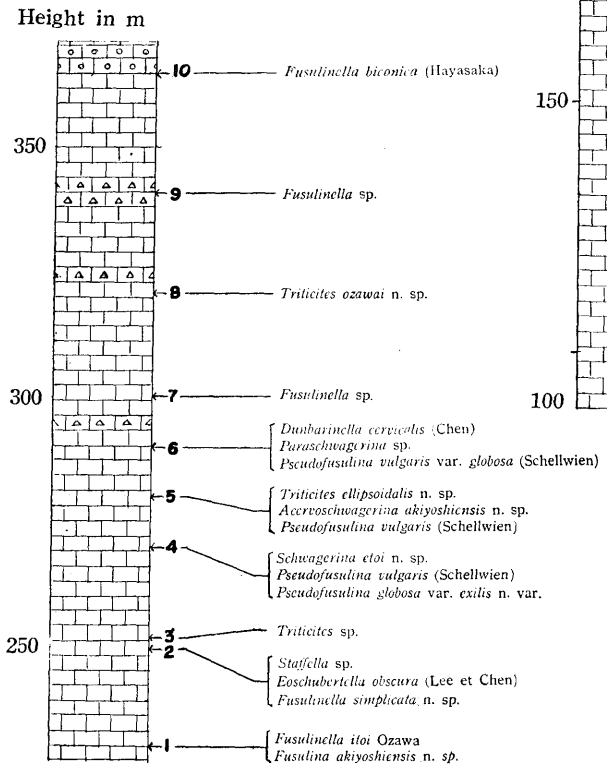

Fig. 8. Section VII. Southern flank of "Ryugoho": 1=327, 2=433, 3=434, 4=435, 5=436, 6=437, 7=438, 8=441, 9=440, 10=439

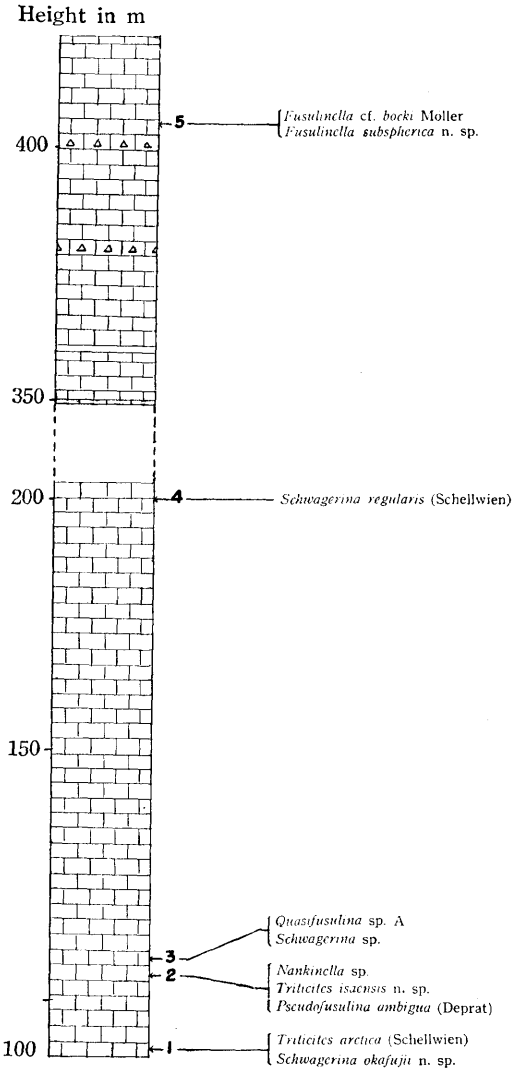

Fig. 9. Section VIII. Southwestern slope of "Ryugoho": 1=318, 2=319, 3=320, 4=322, 5=325

To which subzone the middle non-fossiliferous part belongs, or if some fusulinid zone is repeated by fault as in Section VII, is not able to determine in this section.

Section X. "Iwanaga-dai"

The southeastern part of the Ofuku plateau is called "Iwanaga-dai." Section X is along the southern gentle slope of a high hill, about 3 km north of the prefectural stad-farm, which is located in the middle between "Tsuguneno-atama" (the highest point on the Ofuku plateau) and a hill (319.0 m), about 2 km north of the prefectural stad-farm.

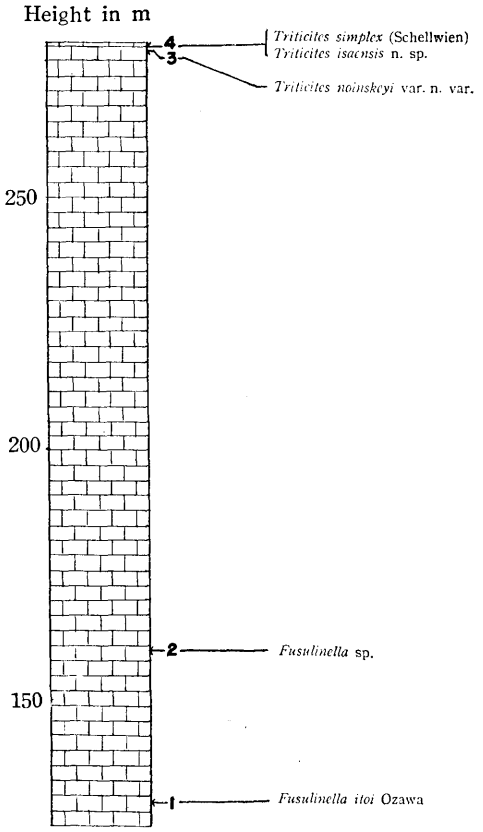

Fig. 10. Section IX. Mizuta: 1=516, 2=518, 3=519, 4=520

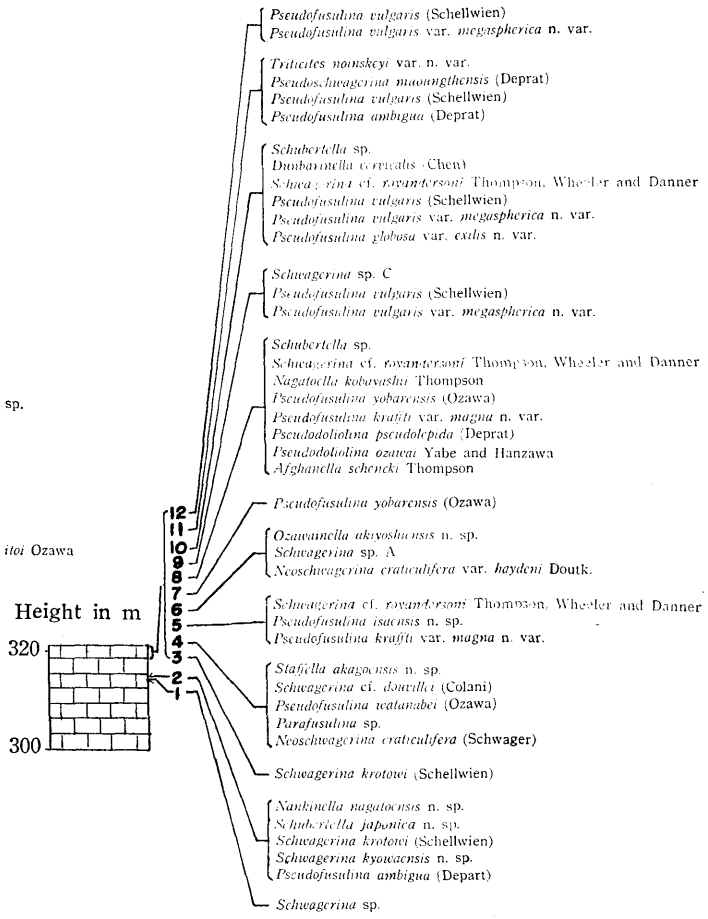

Fig. 11. Section X. "Iwanaga-dai": 1=491, 2=492, 3=493, 4=521, 5=522, 6=523, 7=566, 8=567, 9=568, 10=568A, 11=568B, 12=568C

This is the only section in which upper fusulinid subzones of the Akiyoshi limestone group occur in normal order, and "Iwanaga-dai" is the only place where stratigraphically higher *Neoschwagerina craticulifera* subzone is present at the topographically higher position.

Around the hill (319.0m) above stated, the *Pseudofusulina vulgaris* subzone is widely distributed in the lower part of Section X, overlying which the *Pseudofusulina ambigua* subzone is developed in the upper part of Section X. The *Parafusulina kaerimizensis* and *Neoschwagerina craticulifera* subzones occur at the top of section in exceedingly narrow area. They are very thin, less than 5m in thickness, probably because a large part of them might have been eroded away.

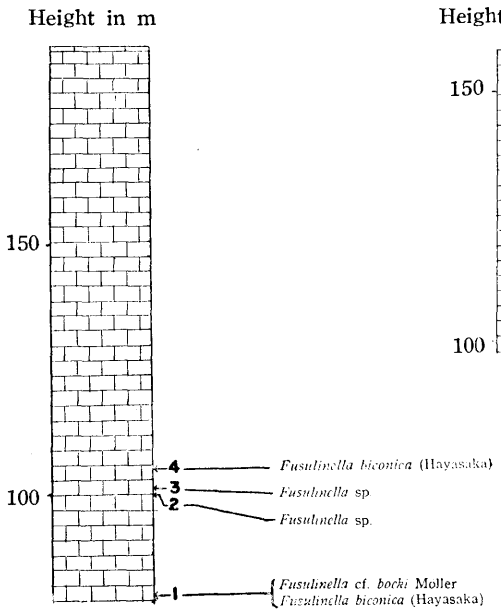

Fig. 12. Section XIA. Iwanaga-hongo: 1 = 500, 2 = 501, 3 = 502, 4 = 502A

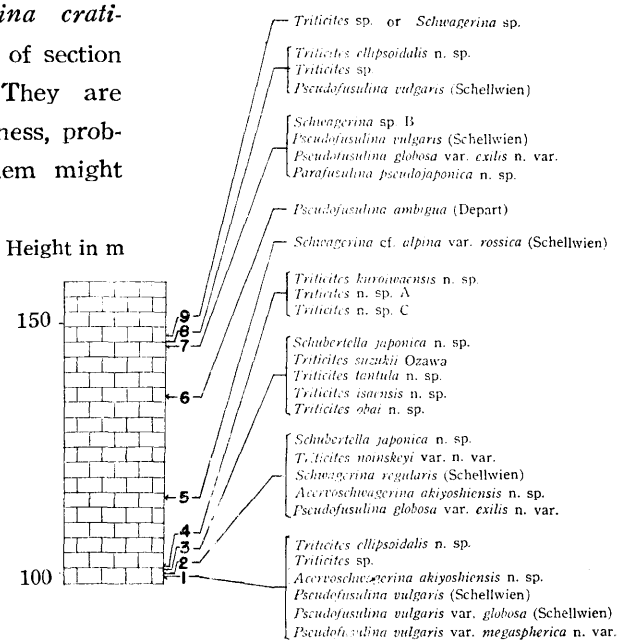

Fig. 13. Section XII. No. 3 quarry at Isa-machi: 1 = 606, 2 = 606A, 3 = 607, 4 = 607A, 5 = 608, 6 = 609, 7 = 610, 8 = 611, 9 = 612

Section XI. Iwanaga-hongo

Section XIA is along the road from the north of Iwanaga-hongo to the Ofuku plateau, and XIB is from the west of Iwanaga-hongo over the southern margin of the Ofuku plateau to the prefectural stad-farm, Isa-machi. The *Fusulinella biconica* zone (25m) occurs in the lower part of XIA and XIB. Overlying limestone is more or less crystalline, yielding no fossil except stems of crinoid. Order of succession of limestone, therefore, can not be determined in this section.

Section XII. No. 3 quarry at Isa-machi

There are several limestone quarries along the southern foot of Konokami-yama

(233.0 m) which is in the southwestern part of the Ofuku plateau. Among them No. 3 quarry is most prolific in fusulinids. Section XII is exposed along the trail from No. 3 quarry to halfway up the top of Konokami-yama, in which the *Triticites simplex, Pseudofusulina vulgaris* and *P. ambigua* subzones occur in ascending order. However, the first subzone, only 10 m in thickness, is again interbedded into the second one. It is presumed, therefore, that the *Triticites simplex* subzone is interbedded into the *Pseudofuulina vulgaris* subzone by fault or the former is repeated by intraformational folding.

Section XIII. Southwestern flank of Konokami-yama

Section XIII is along the southwestern flank of Kanokami-yama (233.0 m). The order of the fusulinid zone is almost the same as in Section XII, namely, the *Pseudofusulina vulgaris* subzone is interbedded with the *Triticites simplex* subzone of about 10m in thickness. The tectonic relation between them is, therefore, considered to be the same as in Section XII.

Section XIV. Shigeyasu quarry

Around the Shigeyasu station of the Mine railroad line are there several limestone quarries, most of them are prolific in fusulinids.

Section XIV is along the western cliff of a small hill (253,9m) which is located southeast of the Shigeyasu station. In the lowest part of the section the *Yabeina shiraiwensis* zone occurs exceedingly limited in the distribution. Overlying fusulinid zones

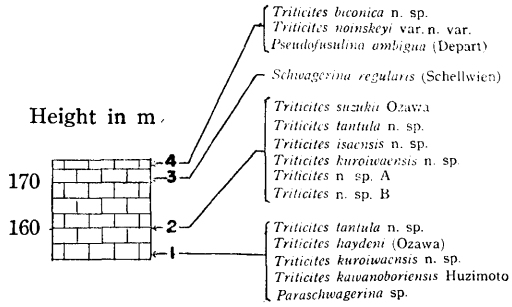

Fig. 14. Section XIII. Southwestern flank of Konokami-yama, Isa-machi: 1 = 570, 2 = 570A, 3 = 571, 4 = 571A

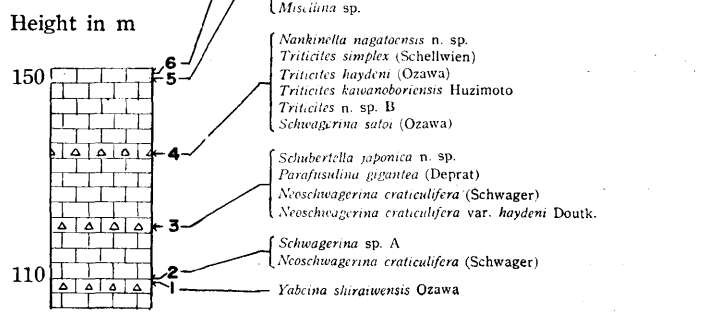

Fig. 15. Section XIV. Shigeyasu quarry: 1 = 97, 2 = 98, 3 = 100, 4 = 103, 5 = 101, 6 = 102

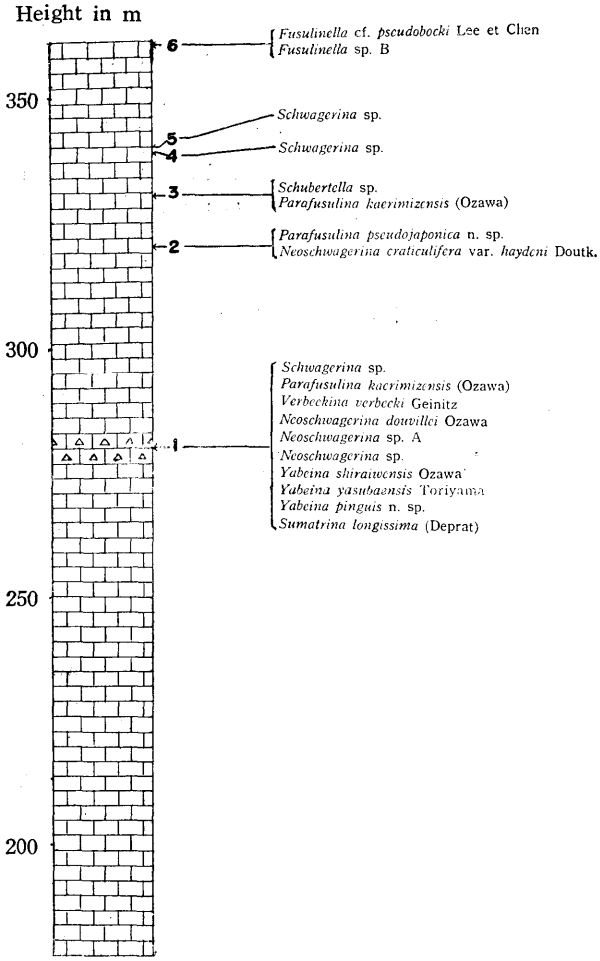

Fig. 16. Section XV. "Ofuku-daiyama": 1=765, 2=184, 3=183, 4=185, 5=186, 6=776

are the *Neoschwagerina craticulifera* (15m), *Triticites simplex* and *Pseudofusulina vulgaris* subzones in ascending order. Accordingly, the Akiyoshi limestone group is clearly in reverse order in the lower part of Section XIV, but it is assumed that a part of limestone is in normal order due to fault or interaformational folding.

Section XV. "Ofuku-daiyama"

The northwestern part of the Ofuku plateau is locally called "Ofuku-daiyama," southern part of which is quite barren in fossil, because limestone became beautiful marble, effected by granodiorite which is widely distributed around Sunaji, Ofuku-mura. However, the northern part of "Ofuku-daiyama" is very prolific, and is probably one of the best locality for studying the Akiyoshi fusulinids.

Section XV is along the road from the northeast of the Ofuku station to "Ofuku-daiyama." Basement of the section consists of thick clayslate of the Serita formation of the Beppu group, overlying which, with the tectonic relation, crystalline limestone is developed, which may be correlated to a part of the uppermost fusulinid zone. Section XV, beginning at the level of 280 m, is comprising the *Yabeina shiraiwensis* zone, *Neoschwagerina craticulifera*, *Parafusulina kaerimizensis* subzones and the *Fusulinella biconica* zone in ascending order. Between the last two is there unfossiliferous limestone of 20 m thick which is presumed to be correlated with the *Pseudofusulina ambigua* and *P. vulgaris* subzones, although it has not yet been ascertained.

Section XVI. Northeastern flank of "Akanta-yama"

The highest hill (409.4 m) in the northern part of the Ofuku plateau is called

"Akanta-yama," along the northeastern slope of which we can observe a fairly good display of Permian fusulinid zones in reverse order. Section begins at the south of Serita (160 m in height) where the *Yabeina shiraiwensis* zone (10 m+) occurs. Due to the thick covering of surface soil no limestone exposes until at the level of 210 m, where *Verbeekina verbeeki* subzone crops out. At an interval of unfossiliferous limestone of 30 m in thickness, the *Parafusulina kaerimizensis* (70 m?), *Pseudofusulina ambigua* (40 m?), *P. vulgaris* (30 m?) and *Triticites simplex* (10m+) subzones are present in ascending order. Although the Pennsylvanian fusulinid zone has not been ascertained around the top of "Akanta-yama," the *Fusulinella biconica* zone occurs (Loc. 187) at 300 m northwest-west of the top, where is topographically 50 m lower than the top of "Akanta-yama." Accordingly it is presumed that the Akiyoshi limestone group is slightly dipping to the west or the southwest.

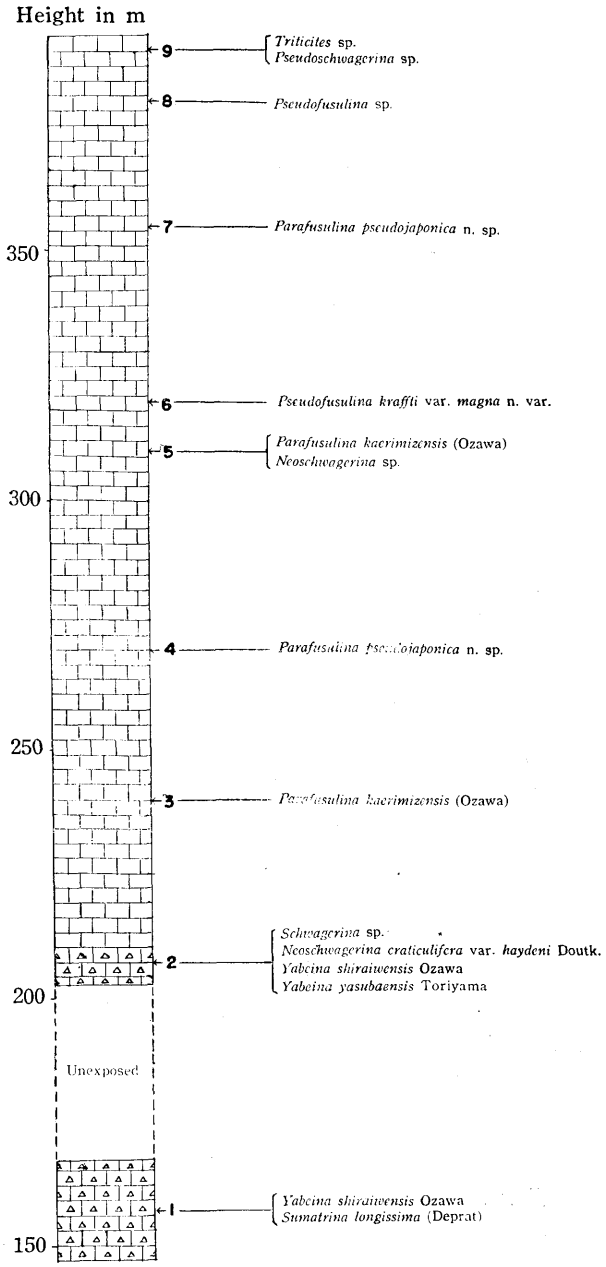

Fig. 17. Section XVI. Northeastern flank of "Akanta-yama": 1=370, 2=742, 3=191, 4=190, 5=189, 6=188, 7=744, 8=745, 9=746

Section XVII. East of Narutaki

Along the west side of the pass between Narutaki, Kyowa-mura and "Tanaiwa," Akiyoshi-mura Section XVII is developed, which is located north of Section VII. The *Fusulinella biconica* (35 m) and *Profusulinella beppensis* (10 m+) zones occur in ascending order at the west side of the pass. Same as in the

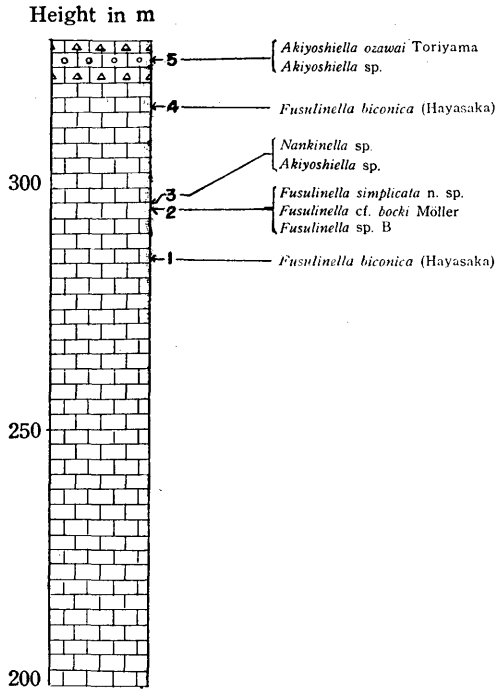

Fig. 18. Section XVII. East of Narutaki: 1=303, 2=304, 3=305, 4=310, 5=311

uppert part of Section VII, these zones are presumed to be erosion remnant of the overturned anticline.

Section XVIII. East of Ono

About 700 m north of Section XVII, Section XVIII is developed along the road from Ono, Kyowa-mura eastward-

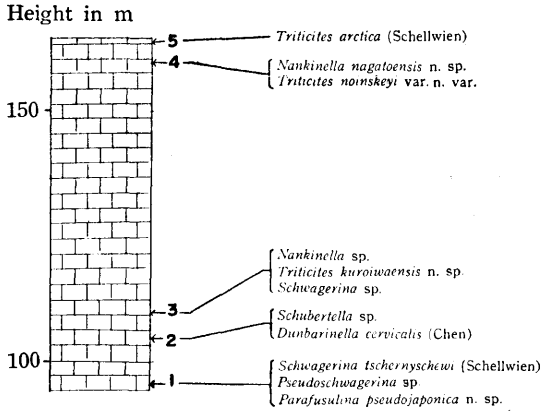

Fig. 19. Section XVIII. East of Ono: 1=317, 2=316, 3=315, 4=314, 5=313

ly up to the Akiyoshi plateau.

At the level of 90 m the *Pseudofusulina ambigua* subzone (10 m+) begins to apper, but limestone soon becomes non-fossiliferous which has a thickness of about 150 m, followed by the *Triticites simplex* subzone (10+). It is not known that to what fusulinid subzone the unfossiliferous part belongs, or that if some fusulinid zone is repeated.

Section XIX. Southeast of Kajiya

Section XIX is located about 600 m north of Section XVIII, which is along the road from the southeast of Kajiya, Kyowa-mura eastward to a small hill of Loc. 376. Although some part is barren in fusulinid, it is beyond doubt that the fusulinid zones are in reverse order in this section, namely, the *Parafusulina kaerimizensis* subzone occurs at the level of 95 m, overlaid by unfossiliferous limestone (25 m) which is presumed to be the *Pseudofusulina ambigua* subzone, overlying which the *Pseudofusulina vulgaris* subzone exposes. At an interval of unfossiliferous limestone of 95m in thickness above the *P. vulgaris* subzone, occurs the *Fusulinella biconica* zone at the top of a small hill (210 m in height).

Section XX. "Takayama"

Isolated from the Akiyoshi plateau proper by a tributary of the River Koto, a

small hill (228.0 m) called "Takayama" is in Minamikochi, Kyowa-mura. "Takayama" block is also isolated tectonically from the Akiyoshi plateau by a fault. Along the southwestern slope of "Takayama" Section XX is developed, comprising the *Pseudofusulina ambigua*, *P. vulgaris* subzones and the *Fusulinella biconica* zone in ascending order, but considerable thickness of unfossiliferous limestone occurs above and below the second subzone.

Section XXI. South of Kuroiwa

Section XXI is along the trail from Kuroiwa, Kyowa-mura to Chojagamori, famous place for sightseeing of karst topography on the Akiyoshi plateau. Although some part is barren in fossil, all the horizons up to the level of 310 m in this section are referable to the *Triticites simplex* subzone. It is most probable to assume, therefore, that the same horizon develops along the section because of being the inclination of strata and that of slope almost the same or very similar. It should be noted that some part of the section is conglomeratic.

Section XXII. "Kirigadai"

A high hill located southwest-west of the Kaerimizu doline is called "Kirigadai," along the northwestern slope of which Section XXII is developed. It begins from the *Pseudofusulina vulgaris* subzone, overlying which *Triticites simplex* subzone

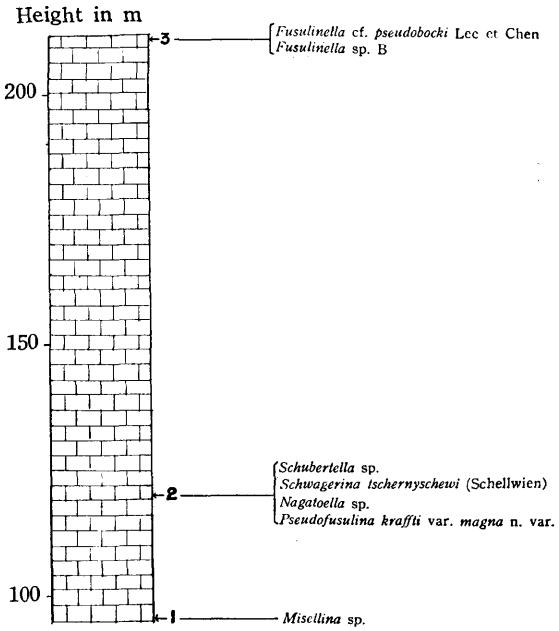

Fig. 20. Section XIX. Southeast of Kajiya: 1=374, 2=375, 3=376

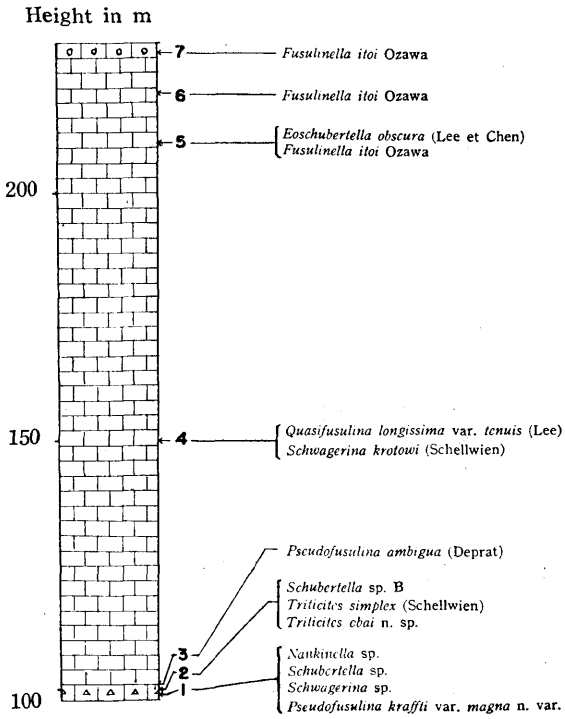

Fig. 21. Section XX. "Takayama": 1=265, 2=343, 3=342, 4=338, 5=339, 6=340, 7=341

(40 m+) occurs, followed then by unfossiliferous limestone of 60 m in thickness, and the *Fusulinella biconica* zone occurs at the top of the hill.

The *Pseudofusulina ambigua* and *P. vulgaris* subzones are exposed in ascending order along the steep slepe of a deep doline, which is located southwest of Section XXII. It is clear, therefore, that the Akiyoshi limestone group is in reverse order around Section XXII.

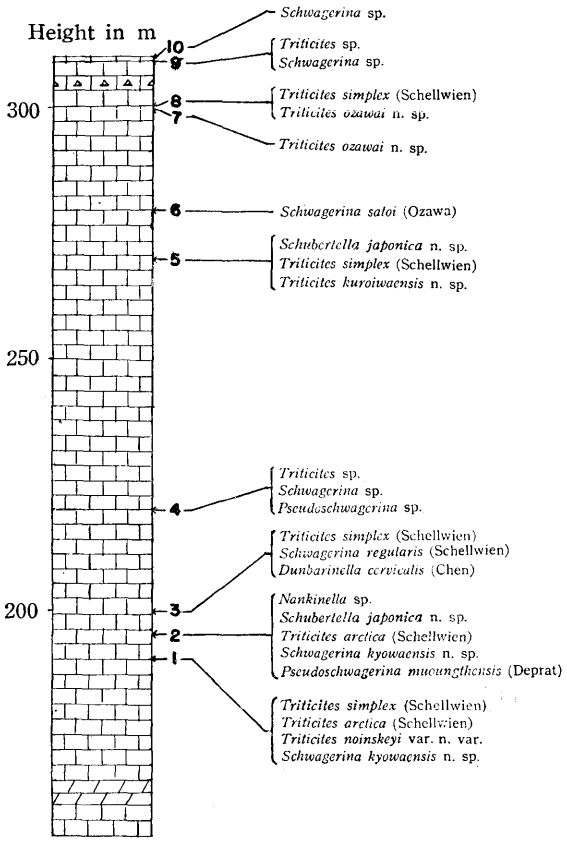

Fig. 22. Section XXI. South of Kuroiwa: 1=257, 2=258, 3=259, 4=260, 5=262, 6=337, 7=264, 8=263, 9=476, 10=477

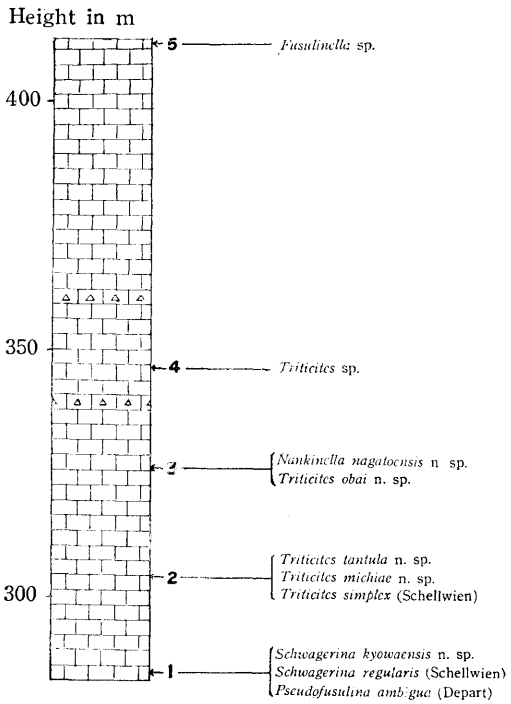

Fig. 23. Section XXII. "Kirigadai": 1=329, 2=330, 3=331, 4=332, 5=333

Section XXIII. Small hill of 394.5 m, west of Kaerimizu

There is a small hill of 394.5 m in height to the north of "Kirigadai," along the southern slope of which Section XXIII is developed. The section is comprising the *Pseudofusulina vulgaris* subzone in the lower and upper parts and the *P. ambigua* subzone in the middle. Therefore, it is presumed that the former is repeated by fault or intraformational folding.

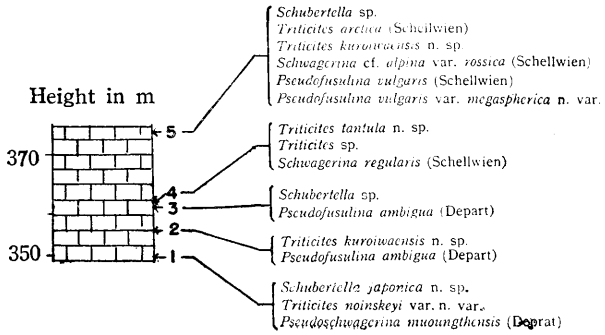

Fig. 24. Section XXIII. Southern slope of a hill of of 394.5 m in height: 1=269, 2=270, 3 = 271, 4=272, 5=273

Section XXIV. Jigokudai

The area northwest of Chojagamori is called Jigokudai where the typical displays of karst topography can be seen. Although the northeastern extension of this section is in the western slope of the Kaerimizu doline, no fusulinid has been found there. Beginning at the level of 300 m Section XXIV is comprising the *Pseudofusulina vulgaris*, *Triticites simplex* subzones and the *Fusulinella biconica* zone in ascending order, the last one is exposing at the level of about 340 m.

Section XXV. Shikanode

A small hill situated north-northwest of the Kaerimizu doline is called Shikanode. Section XXV is developing along the northern slope of the hill. The lower part of the section is the *Fusulinella biconica* zone (80 m), in which unfossiliferous limestone of about 50 m in thickness is contained. Overlying the unfossiliferous middle part (50 m), which is probably referred to the *Triticites simplex* subzone, the *Pseudofusulina vulgaris* subzone is developing in the upper part of the section. The fossil bed at Shikanode, which was considered by SUGIYAMA (1939) to be the proof that the Akiyoshi limestone group being not overturned, is clearly referred to this section which is undoubtedly in normal order.

Section XXVI. West of Yobara

Section XXVI is developed along the road from Yobara, Beppu-mura

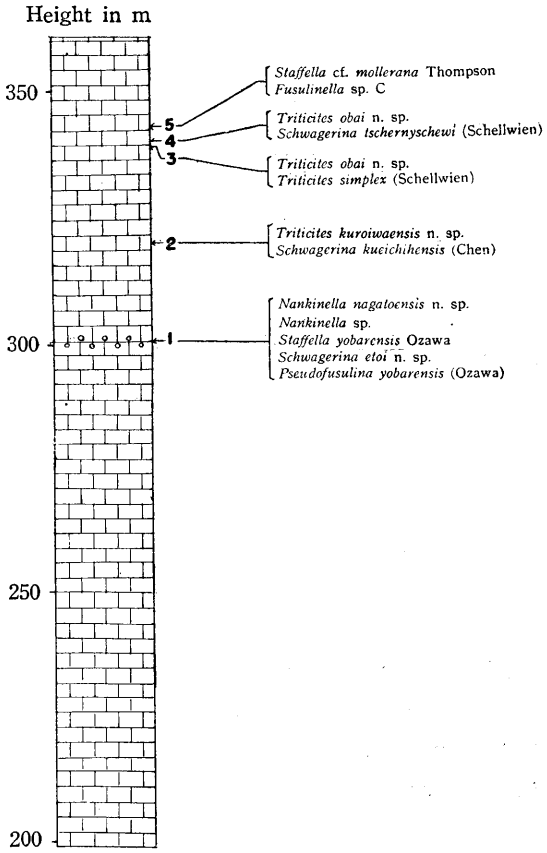

Fig. 25. Section XXIV. Jigokudai: 1=552, 2=551, 3=550A, 4=550, 5=549

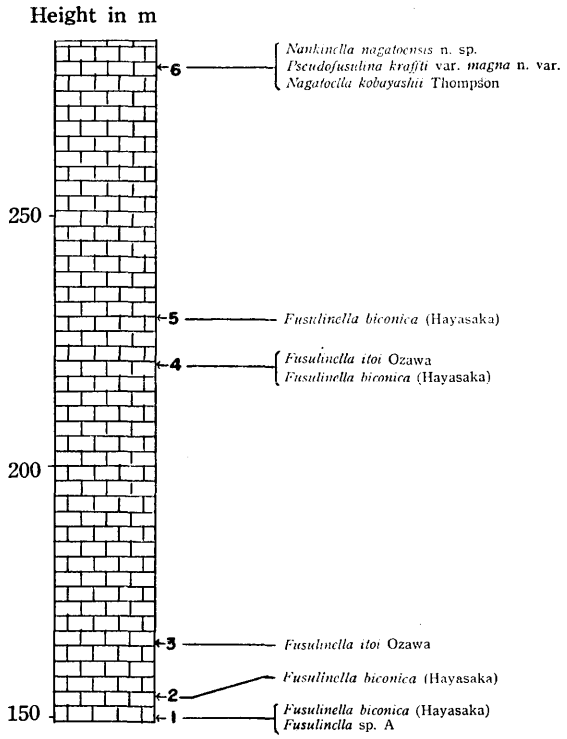

Fig. 26. Section XXV. Shikanode: 1=279, 2=278, 3=277, 4=276, 5=275, 6=300

XXVI may probably be referable to the *Verbeekina verbeeki*, *Neoschwagerina craticulifera* and *Parafusulina kaerimizensis* subzones in asceding order. At the level of 245 m *Pseudofusulina ambigua* subzone (20 m +) begins to appear. The uppermost part of Section XXVI is referable to the *Pseudofusulina vulgaris* subzone (10 m +) which appears from the level of about 260 m upward, but soon merges into the crystalline limestone.

As clearly understood by the above description the Akiyoshi limestone group is reverse in westward to the gentle hills which are situated almost the midst of the Ofuku plateau.

With a presumable tectonic relation to the underlying rocks of the Beppu group, the *Yabeina shiraiwensis* zone (10 m+) first appears near the junction of road from Yobara to Irimi and the gentle hills mentioned above. Overlying limestone of about 20 m in thickness is referred to the *Neoschwagerina douvillei* subzone. The is the only display of *N. douvillei* subzone in both Ofuku and Akiyoshi plateaux. The superjacent limestone of about 40 m thick is difficult to refer to any fusulinid zone with certainty, because fusulinid fossils occur rather sporadically. However, this part of Section

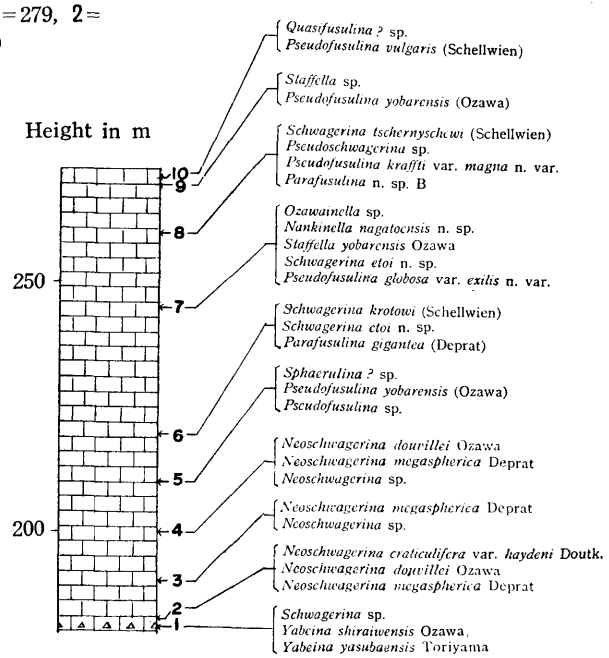

Fig. 27. Section XXVI. West of Yobara: 1=750, 2=751, 3=752, 4=753, 5=754, 6=755, 7=757, 8=758, 9=759, 10=760

order around Section XXVI.

Section XXVII. Northeastern slope of Amagoi-yama

Amagoi-yama is a fairly steep mountain located in the southern central part of the Ofuku plateau, along the northeastern slope of which Section XXVII is present. This section may certainly coincide with the fossil zones which were considered by SUGIYAMA (1939) to be the Lower Permian in age.

Section XXVII begins near the western end of the irrigation reservoir at Okugawara upward to the top of Amagoi-yama. The lowest part (30m+) is referable with certainty to the *Yabeina shiraiwensis* zone. The fossils contained in the overlying limestone of more than 150 m in thickness are not enough to refer to any fusulinid zone, but this part of the section may probably be referred to the Lower Permian three fusulinid subzones. The upper part of the section is at least referable to the *Triticites simplex* subzone. No limestone exposes around the top of Amagoi-yama.

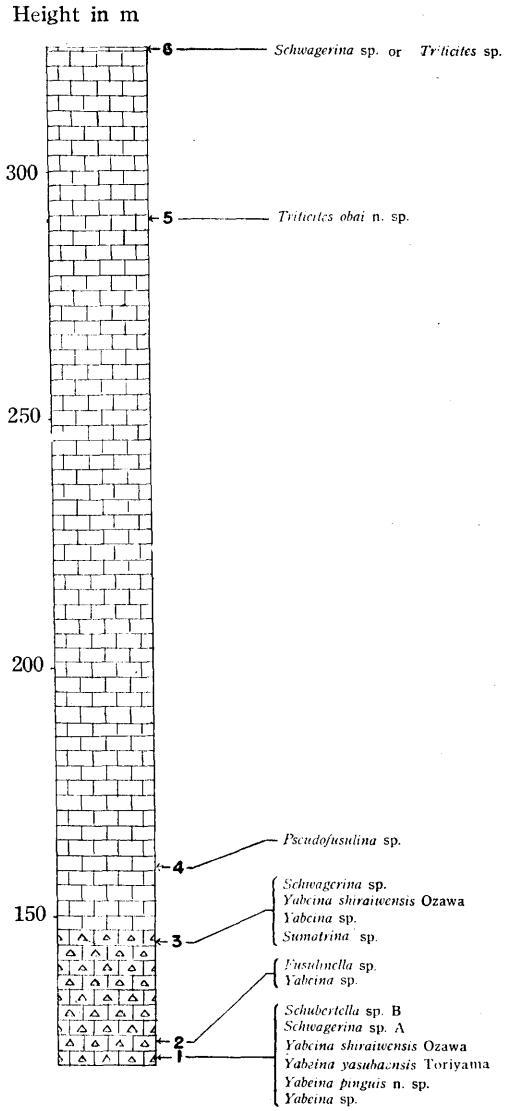

Fig. 28. Section XXVII. Northeastern slope of Amagoi-yama: 1=1, 2=782, 3=785, 4=783, 5=791, 6=792

2. Geologic structure of the Akiyoshi limestone group derived from the distribution of fusulinid zones.

I have derived the geologic structure of the Akiyoshi limestone group from age determination made of the limestones in the twenty-seven sections described above and at many localities sporadically situated over both plateaux but not in any of the sections.

As shown by the distribution of fusulinid zones, the Akiyoshi limestone group is, generally speaking, overturned in the northern part of both the Akiyoshi and

Ofuku plateaux, where the stratigraphically lower fusulinid zones occur at the topographically higher positions. In the southern part* the limestone has a normal attitude where the stratigraphically higher fusulinid zones occur at the topographically higher places**. Of course, at some places, fusulinid zones are repeated or are missed by faulting or by intraformational folding. As already pointed out by MATSUMOTO (1951), the western block is cut by a fault of NNW or NW trend which relatively shifted southward against the eastern block. Excluding these later displacements from consideration, it will be concluded that the Akiyoshi limestone group is in reverse order in the northern part as hitherto accepted but in normal order in the southern part.

Two possible answers present themselves as to how such geologic structure was derived.

A. The northern part of the Akiyoshi limestone group formed a recumbent fold trending south-north, with the upper part thrust up the lower part of the fold. That is to say, the northern limb formed a typical *Faltenüberschiebung* toward the south from the north upon a part of southern limb, and the lower wing of the overturned anticline and the rest of southern limb remain as they are.

B. The northern part of the Akiyoshi limestone group first formed "*liegende Falte*" toward the north from the south, which later thrust up the southern part of normal order by the tectonic movement toward the south from the north. Since the upper wing of "*liegende Falte*" and the upper part of southern part have been eroded away, the lower wing of the former and the lower part of the latter now remain.

Explanation A and B are quite the same in the following two points; first, the nortnern part, which was in reverse order, was thrust up a part of the southern part which was in normal order; and second, the lower wing of northern part and some—mostly lower part—of southern part still remain. However, A and B are thoroughly different in the direction and the process of tectonic movements by which the present geologic structure of the Adiyoshi limestone group was formed. In explanation A one tectonic movement—the Akiyoshi orogenic movement in the concrete—would have been enough to form the major structure now existing; namely, it is a typical "*Faltenüberschiebung*" toward the south from the north. In the explanation B, however, two tectonic movements at different time must be assumed; the first one caused the "*liegende Falte*" toward the north from the south in the northern part of the Akiyoshi limestone group, and the other, which happened later, was toward the south from the north by which the northern part was thrust up the southern part.

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* Strictly speaking they are north-northwestern and south-southeastern parts, respectively, but I am designating them northern and southern parts, respectively, for briefness' sake.

** Where the limestone bed is assumed to have a dip of considerable degrees, this relation is not kept, as seen in Section II and others.

Based on the following facts, I am of the opinion that the explanation B is more probable than A.

(1) Assuming that A is the alternative, limestones in normal order must be present under the overturned part. If so, they should be exposed somewhere in the northern part. However, no limestone of normal order has been found in the northern part where all limestones observed are completely in reverse order. Moreover, if there is limestone of normal order under the overtuned limestones, the total thickness of the Akiyoshi limestone group in the northern part must be the sum of thickness of the lower normal and upper overturned parts. As a matter of fact, however, the thickness estimated by the distribution of the fusulinid zones is too thin to regard it as the sum of the thickness of both parts. As seen in the bottom of such large dolines as Yobara and Irimi in Ofuku plateau, non-calcareous rocks are exposed and the thickness of the overlying Akiyoshi limestone group is thin.

(2) If B is the alternative, there is no need of assuming the existence of limestone of normal order under the overturned northern wing, except in a belt which is near the thrust plane. Accordingly, the thickness of the limestone in the northern part is presumed to represent only that part of the remaining lower wing.

According to the reasons above stated, I have come to a conclusion that the major structure of the Akiyoshi limestone group was formed by two tectonic movements of almost opposite directions and at different times. It seems to me most probable that the earlier movement is referable to the Akiyoshi orogenic movement by which the "*liegende Falte*" of the Akiyoshi limestone group was formed, and the later movement is referable to the Oga orogenic movement by which northern part was thrust up the southern part.

Whether one takes the explanation A or B, it is beyond doubt that the northern part of Akiyoshi limestone group was thrust up the southern one. I designate this thrust the "***Akiyoshi thrust***", the existence of which has been assumed from the distribution of fusulinid zones. Although it has not been ascertained in the field, it should be noted that dolines and uvales are considerably abundant along a zone where the thrust plane is assumed. Future detailed study may clarify the thrust plane in the field (see Fig. 1 C).

3. Is the Akiyoshi limestone group *Klippe* or autochthonous?

OZAWA (1923) considered that the whole Paleozoic formations developed in the Akiyoshi area, including not only the Akiyoshi limestone group but also under- and over-lying non-calcareous groups, represent an anticline that is completely overturned toward the north, while KOBAYASHI (1940, 1941) concluded that the Akiyoshi limestone is a large Klippe lying on the structural basin of the non-calcareous autochthonous groups, including the Ota, Gampi, Beppu and Tsunemori groups. Although the field evidence does not give a decisive answer to this question, I have come to

a conclusion that the Akiyoshi limestone group is not so large Klippe as KOBAYASHI once considered but is autochthonous, or para-autochthonous if not autochthonous in the strict sense. The reasons are as follows:

(1) The major structure of the Akiyoshi limestone group is in accord with the structures of the Beppu group of the northern side and of the Ota group of the southern side. In spite of the marked differences in facies, they show almost the same general trend from the north-northeast to the south-southwest, which gradually changes to a northeast-southwest direction as we go eastward, and finally to almost a north-south direction. If the Akiyoshi limestone group is a large Klippe from the north, the consistency of the tectonic trend between the *Deckenstirn* of the Klippe and the basement complex is too much of a coincidence.

(2) Of the non-calcareous groups around the Akiyoshi limestone group, the Beppu and Tsunemori groups comprise a considerable number of limestone lense, almost all of which are limestone conglomerate, containing species of fusulinid of various ages in the pebles. Assuming that the Akiyoshi limestope group is a Klippe, namely, if it was not in the present position in the Late Permian time, the *Heimat* from which the limestone pebles containing the fusulinids were derived becomes a subject problem. Assuming that, on the other hand, the Akiyoshi limestone group is autochthonous the answer will be very easy. In the latter alternative, it is not necessarily autochthonous in the strict sense, but can be explained as para-autochthonous; that is to say, the Akiyoshi limestone group was formed not far from its present position.

(3) If the Akiyoshi limestone group is a Klippe, the southern part which is in normal order also must be regarded as a part of the Klippe. If so, many more complexly folded structures should be present. As a matter of fact, however, the arrangement of fusulinid zones is too simple to presume complex folding.

The reasons above mentioned lead me to consider it is most highly probable that the Akiyoshi limestone group is autochthonous, or para-autochthonous if not strictly autochthonous. As will be stated in Part II, the Ota group is synchronous but heteropic with the Akiyoshi limestone group, and ranges in age from the Middle Pennsylvanian to the Upper Permian. As it is dipping rather steeply to the north, its uppermost formation (Upper Permian in age) is in contact with the southernmost part of the Akiyoshi limestone group which is referred to the lowest fossil zone of Atokan age. Accordingly, it is clear that both groups cannot be in conformable relation but are in tectonic contact. Although the thrust plane itself has not been ascertained in the field, it is noteworthy that the rocks of the Ota group are greatly disturbed along the boundary. Therefore, it is highly probable that the Akiyoshi limestone group was thrust up the Ota group from the north to the south.

Putting aside consideration of later displacements, the original stratigraphic relation between the Akiyoshi limestone group and the non-calcareous groups in the sedimentary basin should be considered. Is it possible that the sedimentary basin in which two facies of striking contrast were formed had existed continuously over such a long period of time ranging in age from the Middle Pennsylvanian to the Upper Permian? As discussed in detail by DUNBAR (1940, 1942), marked contrast between contemporaneous limestone and detrital facies is observed in the southern Urals of Russia, the type locality of Permian System, where the Artinskian detrital facies of Sim Works ranging in age from Sakmarian to Kungurian is heteropic with the limestone facies of Samara Bend. This sedimentary basin in Russia, however, extends more than 1,000 km, while that of the Akiyoshi limestone group is less than 20 km, even if we restore it to its original position. Therefore, direct comparison between the two is not appropriate to this case.

In the Inner side of Southwestern Japan, however, the Omi and Taishaku limestones, ranging in age from the Carboniferous to the Permian, are not different from the Akiyoshi limestone group so far as their areal distributions are concerned. Although its stratigraphic age has not been ascertained because of a lack of fossils, the Hirao limestone of Northern Kyushu conformably overlying the non-calcareous Paleozoic rocks, is about the same in areal distribution as that of the Akiyoshi, Omi, and Taishaku limestones. In the Inner side of Southwestern Japan, therefore, it is assumed that a rather constant paleogeographic condition existed continuously during the period of time from the Pennsylvanian to the Permian, in spite of the fact that some epirogenic movement occured in the Late Pennsylvanian time as indicated by the unconformity at the base of the Permian rocks.

4. Permian epeirogenic movement in the Akiyoshi district.

As will be mentioned later many species belonging to different fusulinid zones occur in pebbles contained in the limestone conglomerates interbedded in the Upper Permian formations of non-calcareous groups around the Akiyoshi limestone group.

Supposing that these limestone pebbles were derived from the autochthonous or para-autochthonous Akiyoshi limestone group, it is assumed that at least some part of the Akiyoshi limestone, if not all, might had been in such a condition that it was suffering denudation already when the limestone referred to the *Yabeina shiraiwensis* zone was depositing. This assumption is confirmed by the facts that the uppermost horizon of the Akiyoshi limestone group referred to the *Yabeina shiraiwensis* zone always consists of limestone conglomerate in which fusulinids of different ages often contained, although it is sometimes contemporaneous limestone conglomerate which contains the same fusulinid species in both pebbles and matrix.

On the other hand, it is worthy to note that the successive fusulinid zones except the *Yabeina shiraiwensis* zone are getting more and more narrow in distribution;

while the last named zone is rather widely distributed, lying not necessarily over the subjacent *Neoschwagerina douvillei* subzone but directly on much lower ones. Of course, those facts may be explained partially by a consideration that upper subzones had been suffered denudation more strongly than lower ones had. However, the following consideration seems much more probable that the sedimentary basin of the Akiyoshi limestone group had been gradually elevating while the deposition was still going on; in other words, it is assumed that some epirogenic movement had been taken place before the *Yabeina shiraiwensis* zone was deposited, resulting partial denudation, and that the sedimentary area were widened again when the *Y. shiraiwensis* zone was deposited, although some part of the Akiyoshi limestone was above the sea level at that time. (Formation of limestone conglomerate may be also explained by submarine erosion by which limestones of various ages eroded under the shallow sea, forming limestone conglomerate almost simultaneously. However, it is doubt that whether fusulinid foraminifers could live in such a environment as that in which so strong sea current existed that cause submarine erosion).

Conclusion

Summarizing Part I the followings are concluded:

1. The Akiyoshi limestone group consists almost of massive limestone, in some horizons of which a few amount of chert is interbedded.
2. The Akiyoshi limestone group is divisible into six fusulinid zones, three of which are, in turn, subdivided into two or three subzones. Correlation with the international fusulinid Zones is as follows:

Lepidolina-Yabeina Zone:	*Yabeina shiraiwansis* zone	Pu	α
Neoschwagerina-Verbeekina Zone:	*Neoschwagerina douvillei* subzone	Pm	δ
	Verbeekina verbeeki subzone		γ
	Neoschwagerina craticulifera subzone		β
Parafusulina Zone:	*Parafusulina kaerimizensis* subzone		α
	Parafusulina ambigua subzone	Pl	γ
Pseudoschwagerina Zone:	*Pseudofusulina vulgaris* subzone		β
	Triticites simplex subzone		α
Fusulinella Zone:	*Fusulinella biconica* zone	Cm	β
Profusulinella Zone:	*Profusulinella beppensis* zone		α

Besides, the *Nagatophyllum satoi* zone has hitherto been recognized as the lowest fossil zone in the Akiyoshi limestone group. Although the relation between the *Nagatophyllum satoi* and *Profusulinella* zones has not been studied in detail, it is probable that ~~the~~ both are the same in age.

Fusulina Zone and so-called "Uralian" *Triticites* Zone are missing.

3. Physical breaks are presumed below *Triticites simplex* subzone and *Yabeina shiraiwensis* zone, although they have not been ascertained in the field.
4. It is assumed that the Permian sea was most widely spread in this area in the

Early Permian time, and that the sedimentary basin in which the Akiyoshi limestone group deposited was gradually elevating since the Middle Permian time while the deposition was going on, and at the same time at least some part of the Akiyoshi limestone group had already been suffered denudation whichever it may be aerial or submarine.

5. Although the Permian sea somewhat spread again in the early Late Permian time, it is assumed that denudation also had been taken place at the same time in some part of the area, and that the sea at that time was very shallow, in the bottom of which limestone conglomerates were formed due to the wave action or submarine current.

6. The northern half of the Akiyoshi limestone group first formed completely overturned anticline toward the north, and later, the overturned northern part thrust up the southern one which was in normal order. Later denudation took away the upper wing of the northern overturned part and some upper part of the southern one. It is highly possible that the folding of the Akiyoshi limestone group was caused by the Akiyoshi orogenic movement and the thrusting by the Oga orogenic movement.

7. The Akiyoshi limestone group is synchronous but heteropic with at least some part of non-calcareous facies of Ota, Gampi, Beppu and Tsunemori groups, and is autochthonous or para-autochthonous as well as the others.

8. Volcanic clastic rocks characteristic to the Pennsylvanian and Lower Permian rocks in the Outer zone of Japan have not been found in the Akiyoshi limestone group except for those found in the lowest part.

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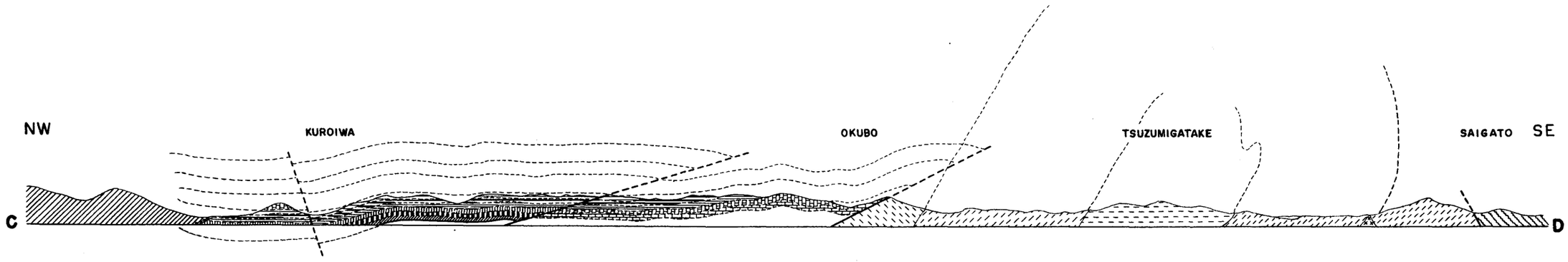
Part I completed.

Part II and Part III to be continued.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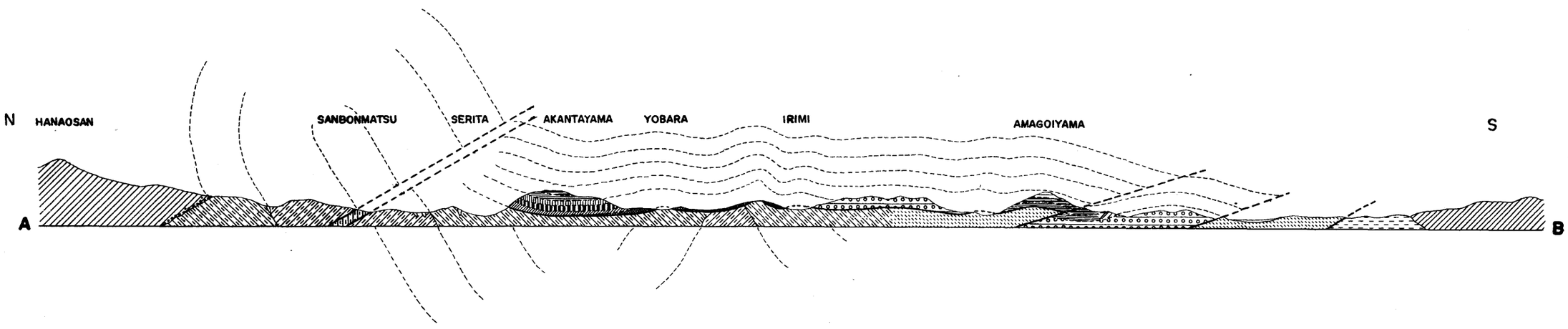
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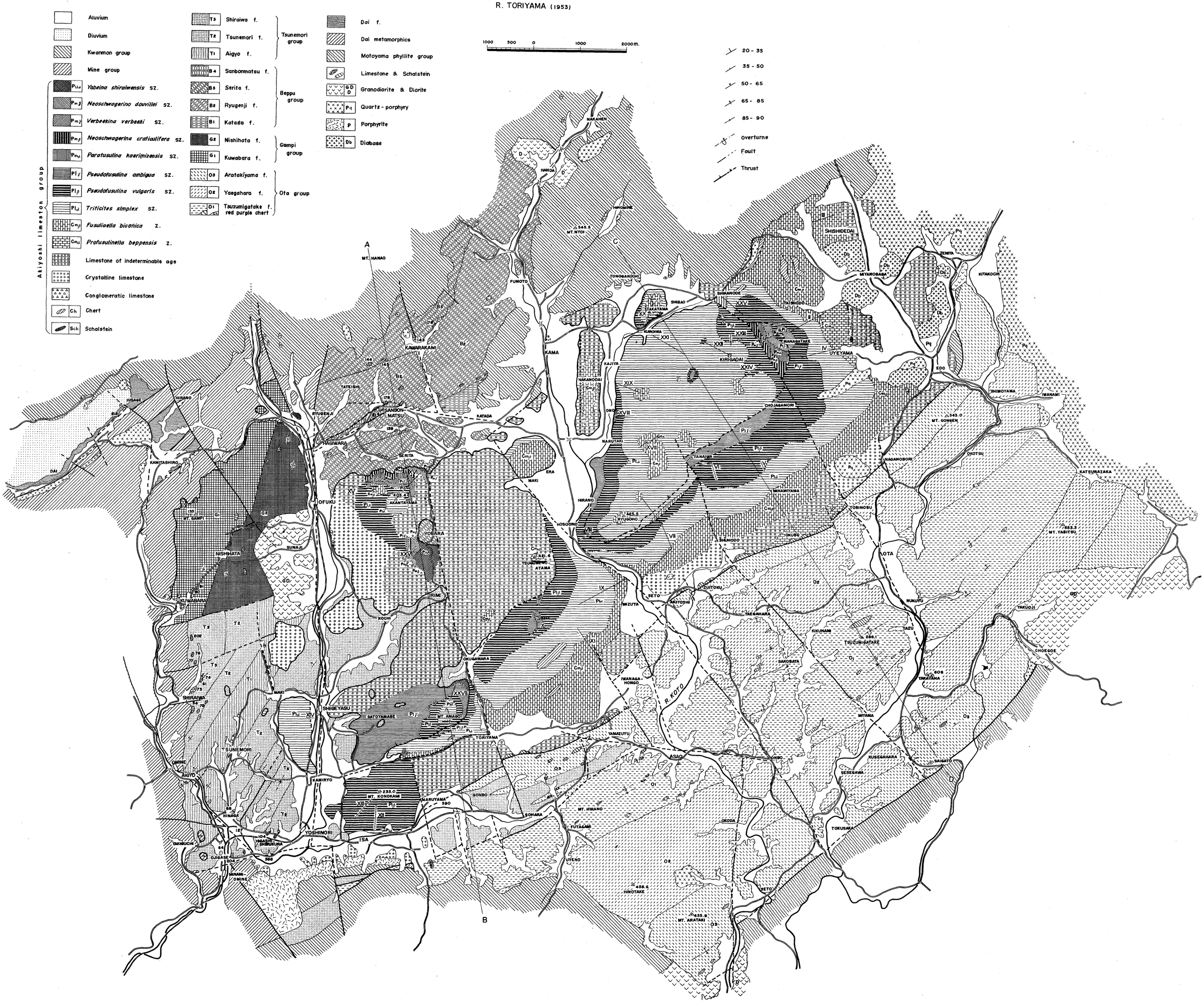
GEOLOGIC MAP OF AKIYOSHI DISTRICT

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