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Geology of Akiyoshi Part II. : Stratigraphy of the Non-calcareous Groups developed around the Akiyoshi Limestone Group

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Geology of Akiyoshi
Part II*. Stratigraphy of the Non-calcareous Groups developed around the Akiyoshi Limestone Group

By

Ryuzo TORIYAMA

ABSTRACT—Part II of Geology of Akiyoshi is divided into four chapters. Chapter 1, 2, 3, and 4 concern the stratigraphy of the Ota, Gampi, Beppu and Tsunemori groups, respectively. In each chapter geographical distribution, lithology and fossil contents of the formations of each group are described, and correlation of them with fusulinid zones of the Akiyoshi limestone group and the geologic structure of each group are also discussed.

So far as the paleontologic evidences are concerned, the Ota group is ranging from Middle Pennsylvanian? to Upper Permian; the Gampi group is referred with question to Middle Pennsylvanian, but it may be possible that it is Permian in age; the Beppu group is ranging from Lower to Upper Permian; and the Tsunemori group is representing only Middle and Upper Permian.

All these groups of non-calcareous facies are considered to be autochthonous deposits and are assumed to take more complex geologic structures than hitherto believed.

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* Part I of Geology of Akiyoshi was published in this Memoirs, Vol. IV, No. 1 (June, 1954).

General Remarks

Occupying an extensive area around the Akiyoshi limestone group, the Ota, Gampi, Beppu and Tsunemori groups are developed, all of them referred by KOBAYASHI (1941) to his Yamaguchi facies in which only a small amount of calcareous rocks is contained. As already summarized in Part I, OZAWA (1923) thought that all these groups (his Division A and C) folded together with the Akiyoshi limestone (Division B), while KOBAYASHI was of the opinion that the Akiyoshi limestone is a large Klippe lying on the structural basin of the autochthonous non-calcareous groups. Interesting enough that both the interpretations showed so marked contrast that they have nothing in common with each other except only in one point that the Akiyoshi limestone is completely overturned.

Although calcareous rocks are exceedingly rare in these groups, fusulinid fossils are sometimes very prolific in minor limestone lenses which are interbedded with the clastic facies of different horizons. Except few brachiopods and indeterminable crinoid stems no macrofossil has been found in these groups. Accordingly fusulinids play also very important roll to determine the stratigraphic age of formations of these groups same as they do in the Akiyoshi limestone group; so the present biostratigraphic study has been carried out laying emphasis on the faunal assemblage and the occurrence of fusulinids in limestone lenses.

So far as the paleontologic evidences are concerned, it has been ascertained that the Ota, Gampi, Beppu and Tsunemori groups are contemporaneous but heteropic with the whole or at least a part of the Akiyoshi limestone group, and that their geologic structures are a little more complex than hitherto believed. Future detailed study, however, will be needed to clarify the questions introduced by the present study.

Chapter 1. Ota Group

Introductory Remarks

The Ota group developed to the southeast of the Akiyoshi plateau is a thick formation consists mainly of graywacke and chert. It was referred by OZAWA (1923) to his Division A, thick non-fossiliferous formation, and by KOBAYASHI to his Yamaguchi facies. Studied the occurrence of false beddings in sandstone SUGIYAMA (1939) ascertained that the Ota group is laid in normal order. Furthermore he clarified by the paleontologic evidences that it is synchronous but heteropic with the Akiyoshi limestone group, ranging from Middle Pennsylvanian (Moscovian) to Permian in age.

Generally speaking, the Ota group surrounds the Akiyoshi limestone group from the southeast to the south, dipping to the latter. It consists mainly of graywacke and chert, and a very small amount of clayslate,

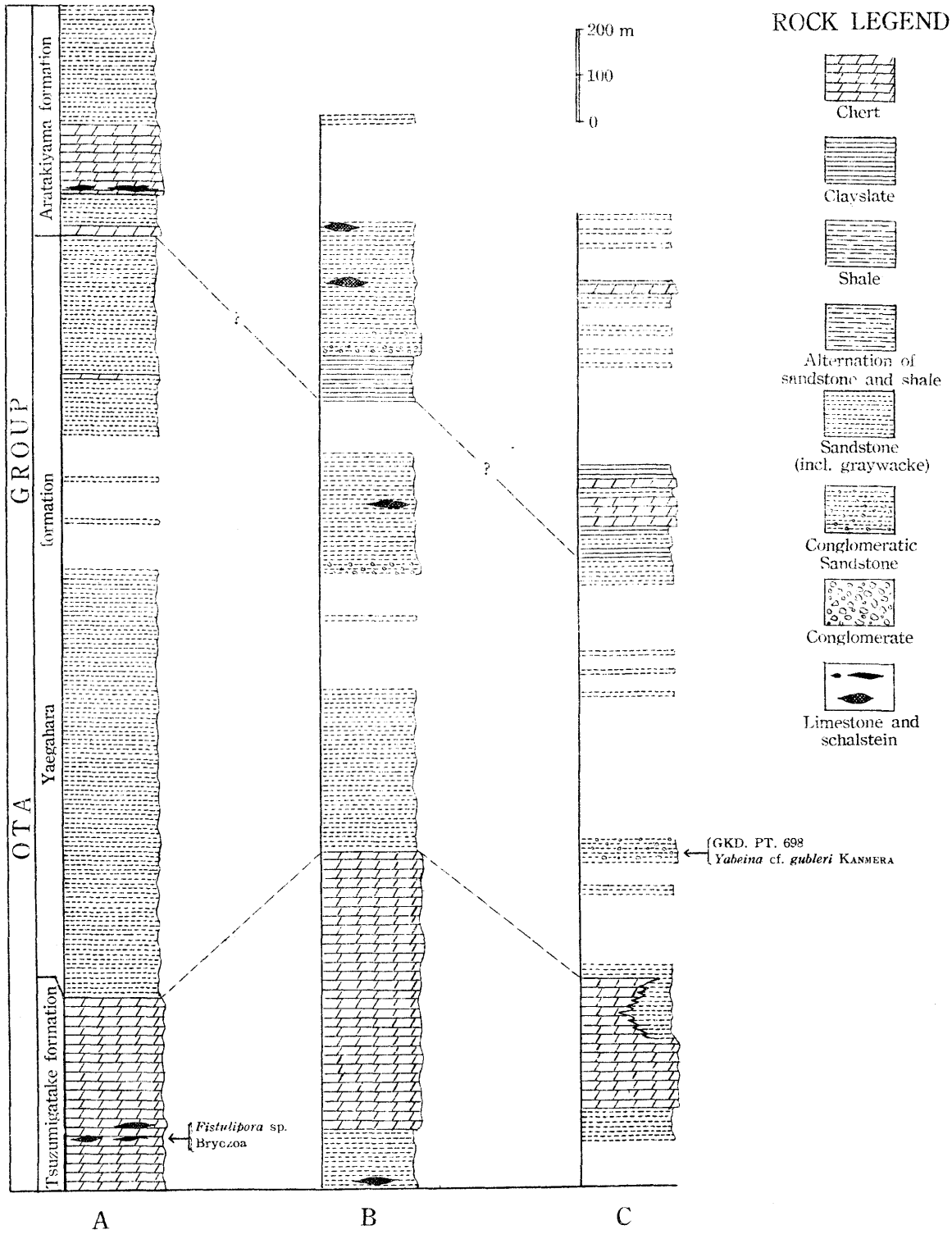

Fig. 1. Diagrammatic illustration of the southern wing of the Ota group: A, section measured from the south of Aratakiyama north-northwestward to the southwest of Asao, Iwanaga-mura; B, from Tokusaka, Managata-mura to Kurita, Iwanaga-mura through Yamada, Ayagi-mura; C, from the Saigato-pass to the top of Tsuzumigatake.
Rock legend same as used in all following diagrammatic sections.

schalstein and limestone is contained in some horizons. In general, sandy facies predominates in the eastern part and silicious one in the western part.

Although the Ota group is apparently monoclinal, dipping 40°—70° to the NNW, paleontologic evidences have revealed that it actually forms an isoclinal anticlinorium. It is marked off from the Motoyama phyllite group on the south by the Saigato tectonic line, which extends from the Saigato pass to the southwest along the River Koto, and from the Akiyoshi limestone group on the north by a thrust fault. This thrust fault is, in turn, cut by faults of N-S or NNW-SSE trends, by which the western block relatively shifted to the south against the eastern one.

Because of the extreme rarity of fossil it is difficult to divide the group from the biostratigraphic point. I have divided, therefore, the Ota group into three formations mainly based on the difference of rock facies.

Table 1

Formation name		Thickness im m	Rack facies Western part←→Eastern part		
Aratakiyama formation	O_3	300+	[absent]	ch	ch
		500–700	gw (ch, ls)	gw (cs)	gw (cs, ch)
Yaegahara formation	O_2	800–1100	ch (sch, ls)	gw (ch, sch)	gw
		1600– 900	gw (ch)	gw	gw
Tsuzumigatake formation	O_1	500	ch (gw, sch, ls)	ch, gw (sch)	gw (ch)

ch=chert, gw=graywacke, cs=clayslate, sch=schalstein, ls=limestone. Upper and lower columns in the upper two formations mean the northern and southern wings of the anticlinorium, respectively. Abbreviations will be also used in the Tables 2-4.

1. Tsuzumigatake formation, O_1

Distribution

The lower formation of the Ota group is here named the Tsuzumigatake formation which distributes in the middle belt of the area of NE-SW direction, extending from Nakamura and Katsurazaka of Akago-mura southwestward to Yaguchi and Ueno of Isa-machi; small patches exposed on the northwestern flank of Sakurayama and on the way from Kobayashi to Hase, Isa-machi may also be referred to this formation.

General strike of the Tsuzumigatake formation is in a direction of NE-SW, which turns to NNE-SSW in the northeastern part, and to NEE-SWW in the southwestern one. Although small folding with an

axis of folding of NE-SW trend can be observed in the central part of the terrain, the formation is, as a whole, dipping 40°—70° to the NNW; accordingly it is apparently monoclinal in the field, but is, in fact, forming a large scale of isoclinal folding which is ascertained by the paleontologic evidences in the middle Yaegahara formation. The axis of isoclinal folding is presumed to be running from Amagoi-yama, east of Ota-machi to Tsuzumigatake and further to the southwest.

Rock facies

The main rock facies of the Tsuzumigatake formation is graywacke and chert. Graywacke predominates in the northeastern part in which very small amount of chert is intervening, while chert prevails in the southeastern part in which few beds of graywacke and small lenses of schalstein and limestone are contained. Graywacke is very hard and is usually fine-grained, but sometimes changes to coarse and even to conglomeratic. Blue is predominating color, which sometimes changes to greenish or purplish blue, and to brown if weathered. Chert is quite massive, having no stratification, and is milky-white, yellowish to blueish green in color.

The central part is intermediate in the rock facies between those of the northeastern and southwestern parts, namely, graywacke and chert are about equal in the amount.

In some part of the central and northeastern parts chert of chocolate to pink color is contained which was referred by OZAWA to Radiolarian chert. Although chert of this kind sometimes alternates with other kinds of rock, lenticular occurrence in graywacke or in chert of another color is common. Good displays of chert of this kind are found at the north of Yamada, northwestern valley of Miyama, and Shiroyama (a low hill of 217.0m in height) of Gomigahara, all in Ayagi-mura.

Schalstein occurs in graywacke or chert as small lenses at the southern riverside of the River Ota, viz., the southwest of Nukuyu, Ota-machi and in the southwestern valley of Asao, Iwanaga-mura. It seems that the occurrence of schalstein is not necessarily restricted to the definite horizon.

Small limestone lenses are known to be found at Asao, Iwanaga-mura, and Futagami and Shiroyama, both in Isa-machi. All of them are interbedded with massive chert which is seemingly the lower member of the formation. SUGIYAMA (1939) once reported the occurrence of *Fistulipora* and bryozoa of indefinite affinity from the limestone lense at Asao. Because the species of *Fistulipora* is identified with that from the Kuwabara formation of the Gampi group which occurs associated with *Fusulinella bocki* MÖLLER and *Chaetetes* sp., he considered that the limestone lense at Asao is Moscovian in age. Unfortunatly, however, I have not been able to find any species other than crinoid stems at Asao, because the the limestone there has been almost exhausted.

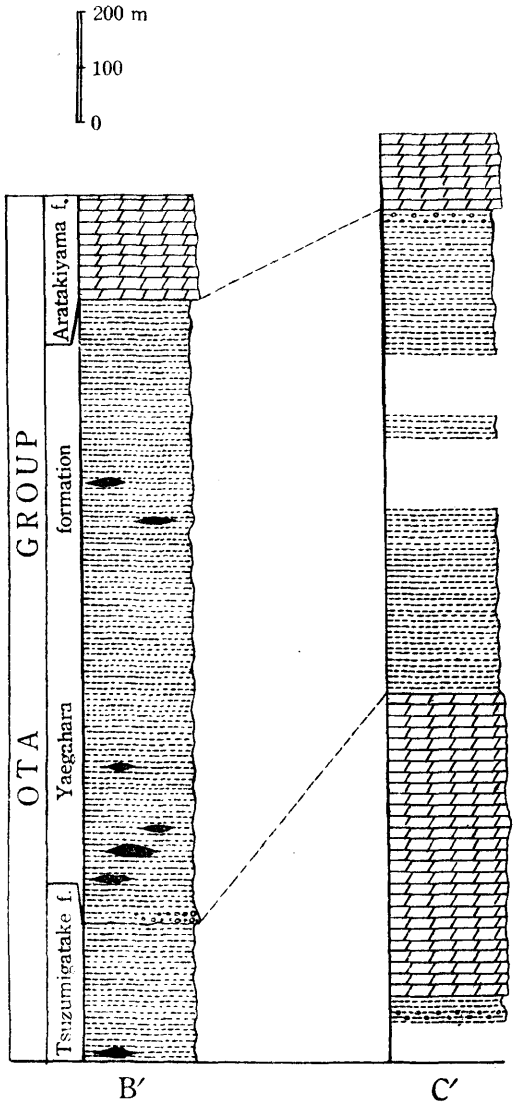

Fig. 2. Diagrammatic illustration of the northern wing of the Ota group. B′ and C′ are the north-northwestern extensions of B and C of Fig. 1, respectively: B′, measured from Kurita, Iwanaga-mura to Zuitoku, Akiyoshi-mura; C′ from the top of Tsuzumigatake to the northwest of Hirabara, Ota-machi.

2. Yaegahara formation, O_2

The middle formation of the Ota group is designated the Yaegahara formation. Yaegahara is in the central part* of Akiyoshi-mura. As well as the Lower Tsuzumigatake formation the Yaegahara formation takes the general trend of NE–SW, which turns to NNE–SSW in the northeastern and to NEE–SWW in the southwestern parts, and dips to NNW with considerable degrees. The formation consists mainly of graywacke, associating with chert, clayslate, and limestone of small amount. As the Ota group is, as a whole, forming a large scale of isoclinal folding, it is divided into the northern and southern wings, intervening the Tsuzumigatake formation between them; accordingly I describe each of them separately for convenience' sake.

(A) Northern wing

Distribution

The northern wing of the Yaegahara formation distributes in a narrow belt of NE–SW direction, extending from Iwanami and Shimoyama of Akago-mura to Maruyama, Isa-machi. Good displays of the formation are observed along the recently constructed prefectural highway between Edo and Ota-machi through Shimoyama, Okotsu and Ono, and farther southwestwardly to Akiyoshi, Akiyoshi-mura. The formation becomes gradually narrow in distribution toward the southwest where it merges into the rocks probably equivalent to the Shiraiwa formation of the Tsunemori group.

Rock facies

The Yaegahara formation of the northern wing is composed exclusively of massive coarse grained graywacke of greenish blue to blueish grey in color in the northeastern part, and the lithology changes to chert, clayslate and very small amount of schalstein in the central part. No limestone is known in these parts. In the central part of the wing, chert predominates in the middle and upper parts, while clayslate in the lower one, associating minor lenses of schalstein and limestone.

It is noteworthy that conglomeratic sandstone and conglomerate of the Yaegahara formation is overlying the upper part of the Tsuzumigatake formation unconformably at Sakobata, Akiyoshi-mura (Loc. 420). The conglomerate is very thin, attaining a thickness of less than 0.5m, in which pebbles of sandstone is exclusively abundant. (Diameter of pebbles is 2–3cm and less than 10cm at the greatest).

Except for the above one, no unconformable relationship between the Tsuzumigatake and Yaegahara formations has been ascertained in

* In the topographic map of scale of 1 : 50,000 only locality names of Kamiyae and Shimoyae are printed, but this neighbourhood is called Yaegahara.

any place, but they are seemingly conformable each other in the field. Especially in the northeast of Ota-machi, it is difficult even to distinguish the formation with a naked eye, because both are composed of similar graywacke.

The Yaegahara formation of the northern wing is esteemed to have a thickness of ranging from 800 to 1000m.

In the southwestern part the Yaegahara formation is composed mainly of chert and sandy clayslate. Minor lenses of schalstein and limestone are interbedded in different horizons. Chert is massive, and is milky white, pale to dark green, greenish blue or variegated in color. Due to the later displacements caused by faulting of NNE-SSW and NNW-SSE directions, alignment of the formation is considerably disturbed in this part. Although much still remains to be studied it has been ascertained that the rocks of the Yaegahara formation of this part merges into those of the Tsunemori group which have long been regarded as Triassic in age, because thin coal seams are known to occur.

Lithologically speaking the southwestern part of the Yaegahara formation is rather referable to the Upper Aratakiyama formation, but it is correlated with the Yaegahara formation of the southern wing from the paleontologic points of view.

SUGIYAMA (1939) once reported the occurrence of fusulinids from the south of Shohoji, Isa-machi. He stated as follows—"At the south of Shohoji prolific limestone occurs on a trail between Sohara and Shohoji. The limestone is clearly situated to the south of the Akiyoshi limestone, separated from which by intervening graywacke of considerable thickness. Adjacent to the limestone occur schalstein, hornstone and shale successively. Strike of the formation measured on shale is NE 40°—60°, dipping to the north with an angle of 50°—70°, and rarely of 40°. They apparently seem to be underlying the Akiyoshi limestone. Graywacke of southern side which is contacting with schalstein is much disturbed and it is impossible to measure its strike and dip precisely." He reported the following fusulinids from the limestone:

Yabeina shiraiwensis OZAWA
Verbeekina verbeeki GEINITZ
Schwagerina sp.

Unfortunately, however, I have not been able to find the limestone although I surveyed the area several times.

At the southern foot of a small low hill of Maruyama, Isa-machi (Loc. 590) small limestone lenses of irregular shape are interbedded with dark grey clayslate. They are clearly limestone conglomerate and yield the following species:

Nankinella sp.
Fusulinella sp.
Schwagerina sp.

Nagatoella cf. *orientis* (OZAWA)
Parafusulina cf. *pseudojaponica* n. sp.
Parafusulina gigantea (DEPRAT)
Verbeekina sp.
Neoschwagerina douvillei OZAWA
Yabeina shiraiwensis OZAWA

Of these *Yabeina shiraiwensis* is found only in the matrix, while all other species are in the pebbles of limestone conglomerate, hence these limestone lenses are clearly correlated with the *Yabeina shiraiwensis* zone of the Akiyoshi limestone group. It is unfortunate, however, that it is not possible to ascertain the stratigraphic relation of the limestone lenses under consideration to the rocks of the Akiyoshi limestone group which exposed 300m north of the formers.

(B) Southern wing

Distribution

Overlying the Lower Tsuzumigatake formation, the southern wing of the Yaegahara formation distributes in a belt of NE–SW trend. The northeastern part exposes from Katsurazaka and Katsurazaka pass of Akago-mura southwestwardly to Yakuoji and Suhojin of Ayagi-mura; the central part develops near Kuzegahara and Sesegawa of Ayagi-mura; and the southwestern part occurs around Hinotake (458.6m) which is on the border between Isa-machi, Mine-gun and Kibe-mura, Asa-gun.

Rock facies

Similar with that of the northeastern and central parts of the northern wing the rock facies of the southern wing is exclusively massive, coarse to medium grained graywacke. When fresh it is greenish to greyish blue and sometimes purplish blue in color, and changes into brown if weathered. Sometimes it becomes coarse, or even turns to conglomeratic in which irregular small pieces of clayslate of 2—3mm in diameter are contained.

At Takayama of Ayagi-mura (Loc. 698) I have found the following species in the clayslate-bearing conglomeratic calcareous sandstone, which is in the middle part of the southern wing:

Yabeina cf. *gubleri* KANMERA

The coarse sandstone which is presumed to be the equivalent of the above is exposed at the roadside of Sesegawa, Ayagi-mura, in which stems of crinoid have been found. No other fossil has been found in the southern wing of the Yaegahara formation.

The Yaegahara formation of the southern wing is most thick in the southwestern part where it attains a thickness of about 1600m, but is 900m in the northeastern one.

3. Aratakiyama formation, O_3

The Upper formation of the Ota group is the Aratakiyama formation named after Arataki-yama (455,9m in height) in Kibe-mura, Asa-gun. In the Lower Tsuzumigatake and Middle Yaegahara formations main rock facies is generally almost the same in both wings, except in the western part of the northern wing of the Yaegahara formation, while in the Aratakiyama formation it shows not only considerable differences between both the wings but also lateral changes even in one wing.

(A) Northern wing

Distribution

The northern wing of the Aratakiyama formation develops in a narrow belt extending from Shiromae-yama (449m) of Akago-mura to the south-southwest, but turns to the southwest in the central part of the wing. Probably due to the later displacements the northern wing does not expose from the southwest of Yamazuyu.

Rock facies

The northern wing consists mainly of massive chert of milky white, pale to yellowish green and variegated in color. Small amounts of graywacke and clayslate are also contained.

Marked off from the lowest part of the Akiyoshi limestone group in the tectonic relation it is assumed that some of the upper part of the formation is not exposed in the northern wing.

The thickness of the Aratakiyama formation of the northern wing is less than 300m so far as exposed.

(B) Southern wing

Distribution

Overlying the Lower Yaegahara formation, the southern wing of the Aratakiyama formation is developed from Choegoe, Ayagi-mura southwestward to the environs of Arataki-yama where it is fairly widely developed, because it repeats minor folding with the folding axis of NE–SW direction. On the south the southern wing is marked off from the phyllite group by the Saigato tectonic line which also runs in NE–SW direction. Rocks in which graywacke predominates are known to be found in the environs of Iwaseto, Sasanami-mura, Abu-gun. They are presumed to be the northeastern extension of the southern wing, but I have not yet surveyed the area.

Rock facies

Showing considerable contrast to the cherty facies of the northern wing, the southern one is composed mainly of graywacke, and clayslate,

chert and minor lense of limestone are also contained. As a whole, lateral facies change is rather remarkable.

The northeastern part of the southern wing consists of medium to coarse graywacke of blue or blueish green in color, interbedded with compact black slate and massive chert of milky white, greenish yellow, or chocolate to pink in color. It dips to the NW with high angles.

Comparing with the northeastern part, cherty facies is rather predominating in the southwestern one. Graywacke is also silicious, and is medium to coarse grained, blue to blueish green in color, and becomes fine where it merges into chert. Chert is massive, milky white, yellowish-green, or variegated. No chert of chocolate or pinkish color has been found. At the west of Imaono and the southwest of Arataki, both in Kibe-mura, small limestone lenses are intercalated in the dark blueish chert which belongs to the upper horizon of the Aratakiyama formation. Both of them are crystalline, yielding no fossil.

The southern wing is delimited by the Saigato tectonic line on the south, hence the upper limit is unknown as well as in the northern one.

Thickness of the southern wing of the Aratakiyama formation is, so far as exposed, ranging from 500m to 700m.

4. Geologic structure and stratigraphic age of the Ota group

The Ota group is most widely distributed among the non-calcareous groups which surround the Akiyoshi limestone group. Broadly speaking it forms an anticlinorium with an axis of folding of NE–SW direction, dipping to NW with considerably high angles. As already stated, the Ota group is delimited from the Akiyoshi limestone group of the north by a thrust and from the Motoyama phyllite group of the south by the Saigato tectonic line. Both of the tectonic lines are running almost parallel in the direction of NE–SW. The alignment of the former, however, is disturbed by later faults, most of which are running in the direction of NW–SE, cutting not only the rocks of the Ota group but also those of the Akiyoshi limestone group at the same time. As pointed out by MATSUMOTO (1951) the western block of a fault relatively shifted to the south against the eastern one. Especially in the southwestern part of the northern wing, where the rocks of the Ota and Tsunemori groups seemingly interfinger each other, later tectonic displacements, caused not only by the faults above stated but also by the other one which runs almost east-west through Yamazuyu and Onbo, Akiyoshi-mura, make geologic structure further complex. It will be needed further study to clarify the geologic structure of this part.

There is some difficulty for correlation of the Ota group with other Upper Paleozoic rocks, because fossil is exceedingly rare in the group. Therefore much still remains to be studied.

Here, the following correlation will be discussed:

(1) *Fistulipora* and bryozoa of indefinite affinity reported by SUGIYAMA (1939) from the limestone lense at Asao, Iwanaga-mura are only available paleontologic evidence for correlation of the Tsuzumigatake formation. SUGIYAMA considered that the limestone lense at Asao is the Middle Pennsylvanian in age, because species of bryozoa is identified to that from the Kuwabara formation of the Gampi group with which *Fusulinella bocki* MÖLLER is associated. As will be discussed in detail, however, there is a little doubt about specific identification of the said species. Therefore I am still hesitating to regard limestone lense at Asao as Pennsylvanian in age. However, I am referring the Tsuzumigatake formation to Middle Pennsylvanian age with question, because the existence of an unconformity, though it is very local, has been ascertained at the base of Yaegahara formation which is clearly Permian in age.

(2) Emphasis is placed on the horizons in the Yaegahara formation of the northern wing in which fusulinids occur. As *Yabeina shiraiwensis* OZAWA and other fusulinid species have been reported from the limestone lenses at the south of Shohoji and Maruyama of Isa-machi by SUGIYAMA and me, respectively, it is beyond doubt that the limestone lenses are correlated with the *Yabeina shiraiwensis* zone of the Akiyoshi limestone group. From the lithologic and tectonic points of view the rocks in which the limestone lenses under consideration are intervening are presumed to be the southwestern extension of the Aratakiyama formation of the northern wing which is aligned almost parallel to the lowest zone of the Akiyoshi limestone group. As already stated, however, a species of *Yabeina* has been obtained in the coarse graywacke of the Yaegahara formation of the southern wing, and that species is most closely allied, if not conspecific, with *Yabeina gubleri* KANMERA which has been reported by KANMERA (1954) from the Kuma formation of Southern Kyushu. It is evident, therefore, that the *Yabeina*-bearing horizon of the northern wing is the same with, or at least not upper than the *Yabeina*-bearing horizon of the southern wing in spite of the fact that the former is apparently the uppermost part of the northern wing of the Ota group. Laying stress on the paleontologic evidences, I am here referring the *Yabeina*-bearing formation of the northern wing to the Yaegahara formation of the southern one. If this is the alternative, the absence of the Aratakiyama formation in the southeastern part of the northern wing comes into question. It may be due to that the Aratakiyama formation is thinning out toward the southwest or to that it is not exposed, displaced by later tectonic movements in which the Yamazuyu-Onbo tectonic line and strike faults of almost E–W direction may be included.

(3) Supposing that the Tsuzumigatake formation is Middle Pennsylvanian in age and that both *Yabeina*-bearing formations of the northern and southern wings are referred to the *Yabeina shiraiwensis* zone of the

Akiyoshi limestone group, the thickness of Permian part of the Ota group is brought up to a question, namely, known Permian section in the Ota group is represented by only the lower half of the Yaegahara formation which is very thin, attaining a thickness of less than 300m.

Attention must be payed to the existence of unconformity at the base of the Yaegahara formation though it is very local, and to that of conglomerate or conglomeratic sandstone at the horizon from which species of *Yabeina* obtained. These facts have lead me to assume that it may be not impossible that the Yaegahara formation is representing only a part of Permian rocks, in other words, some part of Lower and Middle Permian formations had not been deposited there or denudation had taken place before the *Yabeina*-bearing horizon was deposited.

(4) Although much still remains to be studied, it must be noted that there are still unfossiliferous rocks of 1300m in thickness above the *Yabeina*-bearing horizon in the Ota group. This unfossiliferous part may be Permian in age as a whole, but it may be not impossible that some part of the Aratakiyama formation is not Permian but Triassic in age.

Chapter 2. Gampi group

Introductory Remarks

"Gampi series" which develops to the northwest of the Akiyoshi limestone group was named by KOBAYASHI (1940) for the thick formation consists of hornstone, clayslate and sandstone. He (1941) thought that the "Gampi series" is ranging from Middle Pennsylvanian to Lower Permian in age, because the "Tsunemori series" is overlying the "Gampi series" conformably, and the Middle Pennsylvanian fauna comprising *Fusulinella* cf. *bocki* MÖLLER occurs at Kuwabara, Ofuku-mura.

The "Gampi series" is developed to the north and the northwest of the Ofuku plateau. Although rock facies is almost the same, the northern and northwestern parts are different in stratigraphic age and are divided by the Ofuku-Yoshinori tectonic line into different structural units. Therefore I (1948) limited the Gampi group for rocks west of the Ofuku-Yoshinori line and proposed to name the Beppu group for rocks developed east of the line, because it mainly distributes around Beppu-mura, Mine-gun.

As thus defined, the Gampi group is widely developed around Gampi-san, Ofuku-mura, and is marked off from the Tsunemori group on the south by a fault of almost E-W direction, from the Beppu group on the east by the Ofuku-Yoshinori line, and from the Triassic Mine series on the north and east by the Gampi thrust.

From the lithologic standpoint the Gampi group is divided into two formations, the lower Kuwabara and upper Nishihata formations.

Table 2

Formation name		Thickneas in m	Main rock facies SW←→NE
Nishihata formation	G_2	900	ch cs
Kuwabara formation	G_1	800	cs ch

Abbreviations in rock facies are the same as in Table 1.

1. Kuwabara formation, G_1

Distribution

The Kuwabara formation develops in a belt of NNE–SSW direction around Gampi-san as its center. Crossing the Mine railroad line the northeastern extension occurs to the north of Manko, Ofuku-mura, and rocks probably referred to the formation expose around Kamitashiro, Ofuku-mura. Best displays of the Kuwabara formation are seen along the road from Kuwabara to Nishihata and also from Nishihata to Kamitashiro, all in Ofuku-mura.

Rock-facies

Generally speaking, the Kuwabara formation consists of chert in the lower two-thirds and black clayslate in the upper one-third. Minor limestone lense occurs at the base and in the upper part. General strike is apparently NE 20°–30°, dipping 50°–80° to SE. Thickness is more than 800m if it is monoclinal.

Lower chert is massive, having no stratification. Color is milky dark grey, milky blue or green, or white. Upper clayslate is considerably hard, most of which is black in color, though sometimes turns to blue-black. Clayslate sometimes becomes silicious, intervening thin chert lenses.

Dark to light grey limestone lenses are interbedded with chert or clayslate. Three of them are known to occur at or near the base of the Kuwabara formation; namely, one (Loc. 133) is at the level of 300m on the northern slope of Gampi-san and the other two are 300m east and 1100m northeast of the first one. Unfortunately all of them are more or less crystalline, yielding no fossil other than stems of crinoid.

Two limestone lenses also occur at Kuwabara, Ofuku-mura, both of them interbedded in the black clayslate of the upper part of the Kuwabara formation. One (Loc. 80) is located at the southeastern riverside about 600m northeast of the junction to Nishihata from Kuwabara, and the other (Loc. 81) is at the roadside about 50m northeast of the former. They might have been continous, because they are aligned parallel to the strike of the formation. Because of being only fossil locality, they are

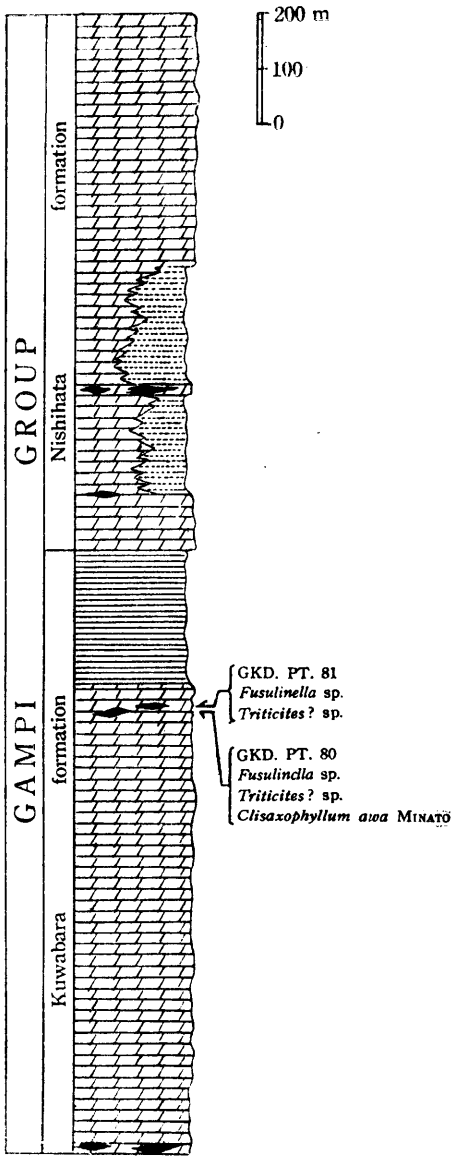

Fig. 3. Diagrammatic illustration of the Gampi group (more or less schematized). The lower half of the section measured from about 700m north of Kuwabara southeast-eastwardly; and the upper half from the 100m south of the top of a hill (521m in height) to Ofuku, all in Ofuku-mura.

very important to discuss the stratigraphic age of not only the Kuwabara formation but also of the whole Gampi group.

Stratigraphic age

There is almost no doubt that the limestone lenses at Kuwabara are the same as that described by SUGIYAMA (1939) as limestone lense of Kuwabara from which he reported the following species as:

Fusulinella cf. *bocki* MÖLLER
Chaetetes sp.
Tetracoral gen. et sp. indet.
Fistulipora sp.

He considered that the limestone of Kuwabara is Middle Pennsylvanian in age, because *Fistulipora* is the same species as that from Asao, Iwanaga-mura, and *Chaetetes* sp. is identified to those from Toriyama, Isamachi, Shishidedai, Akago-mura, Shikanode, Kyowa-mura, and the lower part of the Akiyoshi limestone group.

I have also found the following species in the limestone lense of Loc. 80:

Fusulinella sp.
Triticites? sp.
Clisaxophyllum awa MINATO *

And in the limestone lense of Loc. 81:

Fusulinella sp.
Triticites? sp.

Both the limestone lenses are conglomeratic limestone, comprising irregular or subangular, white, greyish white or blackish grey limestone pebbles of usually 2–3mm, and rarely of 20–30mm in diameter, cemented by blackish grey calcareous matrix. As a whole limestone is grey in color, and is somewhat crystalline. Being crushed, pebbles are sometimes hard to be distinguished from matrix.

According to MINATO *Clisaxophyllum awa* MINATO is abundant in the Carboniferous rocks, but not necessarily restricted to that age but ranging up to Permian. Here species of *Triticites?* comes into question. Specimens under consideration seemingly have keriothecal structure in the spirotheca, although it has not been ascertained with certainty because of the poor state of preservation. Furthermore, they have rather large shell, having a diameter of more than 3mm, and are larger than any species of *Fusulinella* hitherto known.

If mode of occurrence of these fusulinids are clear, the answer will be much easier, but it is almost hard to determine whether they are contained in pebbles of limestone conglomerate or in matrix, because they occur mixed with minute pieces of semi-crystalline limestone of few

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* Determined by Dr. M. MINATO of Hokkaido University to whom I express my sincere thank.

milimeters. As already clarified in Part I, no species of "Uralian" *Triticites* is known in the Akiyoshi limestone group and species of the said genus occur abundantly in the *Triticites simplex* and *Pseudofusulina vulgaris* subzones. Accordingly, if fusulinid specimens under consideration are certainly referred to *Triticites* it is highly possible to regard the limestone lenses at Kuwabara as Permian rather than Pennsylvanian in age whichever the specimens may be contained in pebbles or in matrix of limestone conglomerate.

Although limestone lenses at Kuwabara are very important for age determination of the Gampi group, much still remains to be studied on generic affinity and occurrence of fusulinids found there.

2. Nishihata formation, G_2

The upper division of the Gampi group is the Nishihata formation named after Nishihata, Ofuku-mura. It is overlying the Kuwabara formation comformably, except at Nishihata where they are in tectonic contact. General strike of the formation is in a direction of NE 10°–30°, dipping 50°–80° to the SE. It is apparently monoclinal in the field, attaining a thickness of more than 900m.

Distribution

As well as the lower division the Nishihata formation distributes in a belt of NE–SW direction. It is delimited from the Tsunemori group by a fault of almost E–W direction which runs through the south of Kuwabara and Hirakunigi, Ofuku-mura, and by the Ofuku-Yoshinori tectonic line on the northeast. Good displays of the Nishihata formation are observed along a new road from Nishihata to Nozako and Sunaji, and also along a valley from Nishihata to the top of a hill of 521m in height, all in Ofuku-mura.

Rock facies

The Nishihata formation consists mainly of chert, with intercalating sandstone, clayslate and minor lenses of limestone. Chert is massive, milky white, milky green or greenish blue in color, and is hardly distinguishable from that of the Kuwabara formation. Sandstone is hard, medium grained, dark blue in color, being somewhat hornfelsic. Clayslate is also hard and blueish black in color. Limestone lenses* are known to occur in several places, but all of them are not pure and more or less crystalline, yielding no fossil.

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* According to the geologic section in the report by Ogura (1921), limestone lense is shown to be intercalated in thick chert formation in the Ofuku mine, east of Sunaji, Ofuku-mura, which is not worked at present. The limestone cannot be observed on the surface.

Stratigraphic age

The stratigraphic age of the Nishihata formation is unknown, because no fossil has been found in the formation. Supposing that the lower Kuwabara formation is the Middle Pennsylvanian in age, the Nishihata formation may be also Middle Pennsylvanian or so-called "Uralian", or even Permian in age. If the Kuwabara formation is Permian, the Nishihata formation is probably the same in age.

In short, there is no positive evidence to dertermine the stratigraphic age of the Nishihata formation, except for the fact that it is stratigraphically upper than the Kuwabara formation in the field.

3. Geologic structure of the Gampi group

The Gampi group is maked off by faults from all the surrounding rocks——the Permian Beppu and Tsunemori groups and Triassic Mine series. Most conspicuous one of these faults is the Gampi thrust which was named by KAWAI (formerly FUKUI, 1944). Delimiting the Gampi group off from the Mine series the thrust line runs from the south of Kuwabara around the northwest of Gampi-san northeastward to Manko. Although there is no place where the thrust plane itself can be observed in the field, limestone of the Gampi group is almost horizontally overlying the alternation of sandstone and shale of the Mine series at the northern foot of Gampi-san; and furthermore, chert of the Gampi group is lying as a small Klippe on the Mine series at the Ofuku coal mine, northeast of Manko, Ofuku-mura. Rocks of the latter are much disturbed, forming a sheared zone.

It is assumed that the Gampi thrust was caused by the same orogenic movement which caused the Akiyoshi thrust in the Akiyoshi limestone group.

Chapter 3. Beppu Group

Introductory Remarks

Permian rocks exposed to the north of the Akiyoshi limestone group is the Beppu group named after Beppu-mura, Mine-gun, which were once referred by OZAWA (1923) to his Division C, alternation of lenticular limestone-bearing shale, hornstone and sandstone, and later by KOBAYASHI (1941, 1948) to the northeastern extension of his "Gampi" and Tsunemori series.

The Beppu group is hardly distinguishable from the Gampi group from a lithologic point of view, but it differs from the latter in stratigraphic age so far as the paleontologic evidences are concerned, and is in a different structural unit, marked off by the Ofuku-Yoshinori tectonic line.

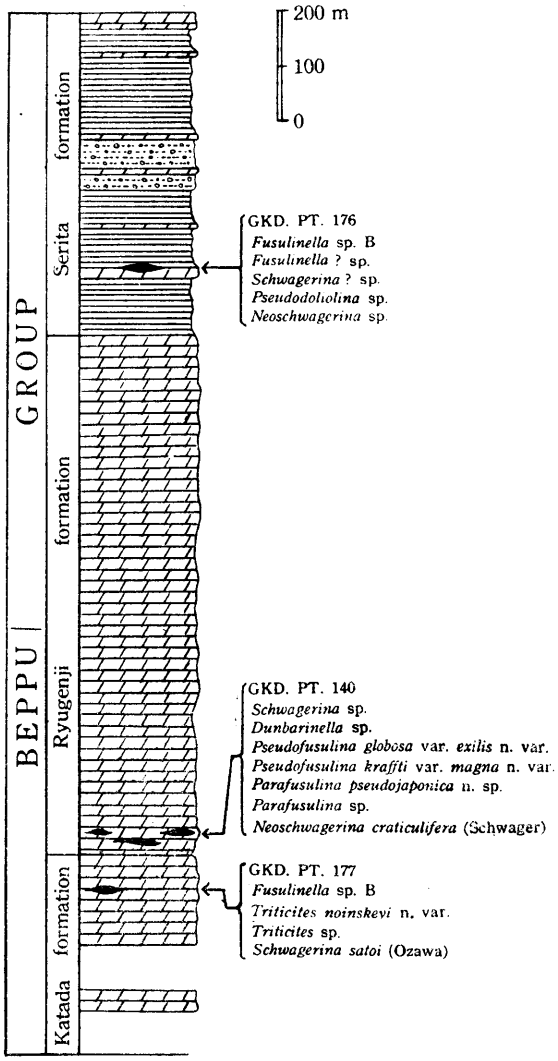

Fig. 4. Diagrammatic illustration of the Beppu group. Section measured along the east side of the valley of Kawarakami, Beppu-mura.

On the other hand the Beppu group is synchronous but heteropic with the Permian section of the Akiyoshi limestone group and the Ota group, and partly with the Tsunemori group.

The general trend of the Beppu group is in NEE-SWW direction in the western part, which turns to NE-SW in the eastern part. It is seemingly monoclinal in the field, dipping to the south, viz., to the Ofuku

plateau, but it has been ascertained that it reveals much more complex structures than hitherto assumed.

Although I (1948) once divided tentatively the Beppu group into three formations, the lower Kawarakami, middle Sanbonmatsu and upper Serita formations, later field investigation and paleontologic study on fusulinids collected from several horizons of the Beppu group have lead me to the conclusion that the following division is more appropriate:

Table 3

Formation name		Thickness in m	Rock facies
Sanbonmatsu formation	B_4	100+	cs (ls)
Serita formation	B_3	550	cs (ls)
Ryugenji formation	B_2	1000+	ch cs ss (ls)
Katada formation	B_1	360+	ch (ls)

Abbreviations in rock facies are the same as in Table 1.

1. Katada formation, B_1

Distribution

As well as the uppermost Sanbonmatsu formation the Katada formation is most limited in the distribution, occupying only small area to the northwest of Katada, Beppu-mura. It exposes on the low hill which is located to the northern side of the prefectural highway between Hagiwara and Katada, and at the east side of the mouth of a long valley of Kawarakami, and along small valleys of "Sebato" and "Komizu".

Rock facies

The Katada formation consists exclusively of chert, except for minor limestone lense which is interbedded in the upper part of the formation. Chert is massive, milky white, blue to green in color. The limestone lense (Loc. 177) of about 20m in thickness is interbedded with chert which is about 100m below the top of the formation. It apparently seems to be massive, but careful observation shows that it is a limestone conglomerate, comprising of irregular limestone pebbles which have a diameter of several to over ten centimeters. Matrix is also calcareous substances.

The base of the Katada formation is unknown, being delimited by a

fault of almost E-W direction. Thickness of the formation is more than 360m so far as exposed.

Stratigraphic age

The stratigraphic age of the Katada formation is determined by the fusulinids collected from the limestone lense above stated. They are,

Fusulinella sp. B
Triticites noinskyi var. n. var.
Triticites sp.
Schwagerina satoi (OZAWA)

Fusulinids which are contained in pebbles of considerable size are preserved in good condition, but those in matrix with minute pieces of limestone are sometimes hard to distinguish, outer part of shell being crushed out.

Of species above listed, *Fusulinella* sp. B is found only in the pebbles of limestone conglomerate, associating with no species, while the others are both in pebbles and matrix. Accordingly, *Fusulinella* sp. B, which is an element of Cmβ* of the Akiyoshi limestone group, is regarded as derived fossil. As all other species are known to occur in Plα, the lower subzone of the *Pseudoschwagerina* zone, the limestone lense of Loc. 177 is certainly correlated with Plα of the Akiyoshi limestone group.

As already stated, there is still considerable thickness of rocks referred to the Katada formation below the limestone lense discussed above. It is not known whether this section of the Katada formation is also included in the basal Permian or is referred to a part of Pennsylvanian. In the field no physical break has been ascertained below the limestone lense, although exposure of rocks is not good, covered by thick surface soils.

2. Ryugenji formation, B_2

Distribution

The Ryugenji formation is most widely developed, occupying the middle part of belt of the Beppu terrain, which begins to appear at the western cliff of "Iwayama" (348.2m in height) of Ryugenji, Ofuku-mura, extending toward the northeast-east to the valley of Kawarakami where it turns the direction to the northeast. The northeastern extremity of the formation is seen at Handa, Kyowa-mura. Rocks exposed along the valleys of Tateishi of Ofuku-mura, "Mizunashi" and Kawarakami of Beppu-mura, and Fumoto and Yakegakochi of Kyowa-mura are referred to the Ryugenji formation. The best diplay of the formation is observed

* Instead of giving each fusulinid zone or subzone, the abbreviations used in Part I will be used hereafter for the sake of simplicity. It should be noted that each abbreviation is used either for time-stratigraphic term or time term.

at "Iwayama" of Ryugenji and along the valley of Kawarakami from the mouth to the village of Kawarakami.

Rock facies

Generally speaking, the Ryugenji formation consists mainly of chert, with intervening silicious clayslate, sandstone and minor limestone lenses in the southwestern part, while sandy facies predominates in the northeastern one.

In the southwestern part chert is massive, having almost no stratification, and is milky blueish green, green or milky white in color. Sandstone and clayslate are hard, being more or less silicious.

It is noteworthy that chert of chocolate color, which is known to be found in the Tsuzumigatake formation of the Ota group, is interbedded with milky white chert in the northeastern small tributary of valley of Kawarakami. Some part of which is conglomeratic, comprising of angular chert pieces of few to scores of centimeter.

In the northeastern part main facies changes from silicious to arenaceous. Good display of this part is seen along a trail from Fumoto, Kyowa-mura toward the top of Hanao-san. Sandstone is medium to coarse, considerably hard, being more or less hornfelsic and is blueish black or greyish blue. It sometimes becomes tuffaceous or conglomeratic. In the environs of Yakegakochi and Sakamizu of Kyowa-mura, tuffaceous clayslate predominates instead of sandstone.

Limestone lenses are found at several localities—the mouth of valley of Kawarakami (Loc. 140), "Sebato" and "Komizu", both are northwestern small valleys of Katada, Beppu-mura (Loc. 249 and 250), the south of Sakamizu, Kyowa-mura (Loc. 245), near the border of villages on the way from Hagiwara, Ofuku-mura to the north of Serita, Beppu-mura (Loc. 139), and the south of Hagiwara, Ofuku-mura (Loc. 192). Some of them are, however, barren in fossil.

Thickness of the formation is more than 970m in the eastern side of valley of Kawarakami if it is monoclinal.

Stratigraphic age

The stratigraphic position of the Ryugenji formation is determined by fusulinids occur in some of the limestone lenses above stated.

In the limestone lense at the mouth of valley of Kawarakami (Loc. 140) the following species are identified:

Schwagerina sp.
Dunbarinella ? sp.
Pseudofusulina globosa var. *exilis* n. var.
Pseudofusulina cf. *kraffti* var. *magna* n. var.
Parafusulina pseudojaponica n. sp.
Parafusulina sp.
Neoschwagerina craticulifera (SCHWAGER)

The limestone conglomerate of Loc. 140 consists of minute pieces of limestone of 1.0 to 1.5mm in diameter, up to 2 to 3mm even at the largest; furthermore almost all of specimens contained are more or less destroyed. It is, therefore, almost hard to distinguish whether each specimen is found in pebble or in matrix. Species of fusulinid listed above are all known in the Akiyoshi limestone group, although they occur in different fusulinid subzones.* Of these species *Dunbarinella?* sp. and *Pseudofusulina globosa* var. *exilis* n. var. are assumed to regard at least as derived fossils, and it seems most probable that the limestone lense of Loc. 140 is Pmα–Pmβ in age.

Limestone lense occurs at "Sebato", Beppu-mura, but no fusulinid has been found there. Only *Parafusulina* sp., *Schwagerina* sp. and *Neoschwagerina* sp. have been found in the limestone lenses at "Komizu" (Loc. 249 and Loc. 250), a small valley situated to the north of Katada, Beppu-mura. Accordingly, the stratigraphic age of these limestones is not certain, but it may be the same in age as that of limestone lense of Loc. 140, because they are seemingly in almost the same horizon.

In the Ryugenji formation exposed south of the prefectural highway between Hagiwara and Katada, two limestone lenses are known. Of which one is unfossiliferous, but the other (Loc. 139) yields the following species:

Triticites biconica n. sp.
Triticites sp. A
Triticites sp.
Schwagerina sp.
Parafusulina sp.
Pseudodoliolina sp.
Neoschwagerina sp.

Among those, *Pseudodoliolina* sp. may possibly be referred to *P. ozawai* YABE and HANZAWA, and *Neoschwagerina* sp. is a primitive form for the genus. Species of *Triticites* and *Schwagerina* are clearly derived fossil, being contained in the pebbles in good condition of preservation. The stratigraphic age of this limestone lense is, therefore, presumed to be the same as that of Loc. 140, namely, Pmα–Pmβ and it is more likely to be Pmα.

In short, the stratigraphic age of limestone lenses found in the Ryugenji formation is either Pmα or Pmβ. As the lower part of the Serita formation is, as will be stated, regarded as Pmγ in age, the Ryugenji formation is presumed to be ranging from Pmα to Pmβ, and it may be not impossible that the lowest part of the formation is ranging down to Plγ or even to Plβ, because the Katada formation is only representing Plα.

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* As for the stratigraphic range of each species, the reader should refer the Table 5.

3. Serita formation, B_3

Distribution

Overlying the Ryugenji formation conformably, the Serita formation is also widely developed in two areas. The southern one distributes widely in the environs of Serita, Beppu-mura, marked off from the Akiyoshi limestone group by the sheared zone, and the northern one is exposed along the upstream of valleys of Tateishi of Ofuku-mura, "Mizunashi" and Kawarakami of Beppu-mura, and Yakegakochi of Kyowa-mura, delimited on the northern margin by thick covering of the Cretaceous Kwanmon (Inkstone) group.

Rock facies

Main rock facies of the Serita formation is black clayslate, associating with small amount of chert, sandstone and limestone. The southern block of the Serita formation which develops around Serita is composed mainly of black to brownish black clayslate or slaty shale, with intercalating thin calcareous sandstone and minor limestone lenses. Chert or silicious rock does not occur in this part.

The northern block, which distributes along upstream valleys of Tateishi, "Mizunashi", Kawarakami and Yakegakochi, consists of clayslate and sandstone, with intervening chert and limestone. Sandstone is hard, medium to coarse grained, and is blue in color (becomes brownish black if weathered). It sometimes becomes calcareous or conglomeratic, comprising small pieces of black clayslate. Clayslate is black to brownish black in color, and is more or less sandy. Slaty shale is found to be interbedded with clayslate at the north of Kawarakami. Chert is massive, milky white, milky yellow or milky green in color. Limestone lenses are found in the lower part of the northern block and in the middle and lower parts of the southern one, all of them are limestone conglomerate.

Stratigraphic age

In the northern block several limestone lenses are known to be found, all of them are seemingly aligned in the lowermost horizon of the Serita formation.

(1) In the limestone lense of Loc. 144 at the western side of valley of "Mizunashi," the following species have been obtained:

Parafusulina sp.
Pseudodoliolina sp.
Verbeekina sp.
Neoschwagerina sp.

The limestone lense of Loc. 144 is unquestionably limestone conglomerate, consisting of almost white, greyish white or blackish grey limestone pebbles of 1—2 to 20mm in diameter, cemented by impure calcareous matrix. Almost all of the specimens, which are more or less destroyed or crushed, are contained not in pebbles but in matrix. Although

it is rather difficult to identify the species with certainty, *Parafusulina* sp. is presumed to be conspecific with *P. kaerimizensis* (Ozawa) and *Verbeekina* sp. with *V. verbeeki* Geinitz, hence the limestone lense of Loc. 144 is probably correlated with Pmγ of the Akiyoshi limestone group.

(2) Limestone lense of Loc. 145 is exposed about 500m east of that of Loc. 144. It is more or less arenaceous in lithologic character and greenish in color, consisting of minute pieces of limestone and arenaceous substances, in which only *Parafusulina* sp. and *Schwagerina* sp. have been detected. Although it is not possible to determine the age of this limestone it may probably be the same as that of the limestone conglomerate of Loc. 144, both of them are seemingly in the same horizon of the Serita formation.

(3) Two limestone lenses are exposed upstream of Kawarakami valley, which are also in almost the same horizon as limestone lenses in the valley of "Mizunashi" (Loc. 144 and Loc. 145). One (Loc. 143) which occurs at the west of village of Kawarakami yields the following species as:

Millerella? sp.
Schubertella sp.
Fusulinella biconica (Hayasaka)
Fusulinella sp.
Triticites sp.
Schwagerina cf. *regularis* (Schellwien)
Schwagerina sp.
Parafusulina gigantea (Deprat)
Neoschwagerina sp.

Except for the last one which is unquestionably contained in matrix, all these species are found in limestone pebbles of angular or subangular in shape. It is of interest that specimen of the genus *Millerella?*, though only one in number, has been found there in spite of the fact that none of the representative of the said genus has yet been found in the Akiyoshi limestone group. As *Neoschwagerina* sp. is presumably referred with *N. douvillei* Ozawa the limestone lense of Loc. 143 is assumed to be Pmγ–Pmδ in age.

(4) The other limestone lense (Loc. 176) of Kawarakami valley is also comprising of irregular to subangular limestone pebbles of white, greyish white, or blackish grey in color, and yields the following species:

Fusulinella sp. B
Fusulinella (?) sp.
Schwagerina (?) sp.
Pseudodoliolina sp.
Neoschwagerina sp.

Of these *Fusulinella* (?) sp. is so primitive that it may be rather referable to the genus *Profusulinella*, but it has not been determined with certainty because of insufficiency of material and poor condition of preser-

vation. *Pseudodoliolina* sp., having large shell, may be referred with *P. lepida* (SCHWAGER) and *Neoschwagerina* sp. is an advanced form for the genus. Specimens of *Fusulinella* and *Schwagerina?* are clearly derived fossils, being found only in limestone pebbles. The age of the limestone lense of Loc. 176 is, therefore, presumed to be Pmβ–Pmδ.

In the southern block the limestone lenses are found in the black clayslate of the lower and middle parts of the Serita formation which develops along the road through the village of Serita. Fusulinid fossils occur in the limestone lenses of the middle part (Loc. 9 and Loc. 10), and not in that of the lower one (Loc. 8).

(5) The limestone lense of Loc. 9, which is situated about 200m west of the farm-house of the western extremity in Serita, is a typical limestone conglomerate, consisting of 2 to 20cm subangular limestone pebbles of pale to dark grey in color, in which the following species have been determined:

Schubertella sp.
Schwagerina etoi n. sp.
Schwagerina sp.
Parafusulina cf. *gigantea* (DEPRAT)
Neoschwagerina craticulifera (SCHWAGER)
Neoschwagerina sp.

Among the species listed above, *Neoschwagerina* sp., which is an advanced representative for the genus, is closely allied to *N. margaritae* (DEPRAT) and is found only in matrix, being more or less destroyed. As species of *Schwagerina* and *Parafusulina* occur in limestone pebbles they are regarded as derived fossils. The age of the limestone lense of Loc. 9 is, therefore, correlated with Pmβ–Pmδ.

(6) The limestone lense of Loc. 10 is located about 30m east of Loc. 9 separated from the former by intervening thin black clayslate. It is also typical limestone conglomerate, consisting of rather large size of pebbles, diameter of which is sometimes up to 10cm. The following species have been collected:

Pseudofusulina kraffti (SCHELLWIEN)
Pseudofusulina vulgaris (SCHELLWIEN)
Pseudofusulina sp.
Neoschwagerina sp.

All of these species are found only in limestone pebbles, and sometimes a pebble is comprising exclusively of numerous specimens of *Pseudofusulina kraffti* (SCHELLWIEN). As no species has been found in matrix of limestone conglomerate, it is difficult to determine the age of limestone lense of Loc. 10, although it is clearly younger than Pmα. However, it may probably be the same in age as that of the limestone lense of Loc. 9, because they are presumed to be situated in almost the same horizon, locating so closely each other.

In short, the stratigraphic age of the Serita formation is considered to be Pmγ-Pmδ, although some part of it may be ranging down Pmβ.

4. Sanbonmatsu formation, B_4

The uppermost formation of the Beppu group is the Sanbonmatsu formation, named after "Sanbonmatsu" where is just east of the pass between Hagiwara, Ofuku-mura and Katada, Beppu-mura on the prefectural highway.

Distribution

Among the formation of the Beppu group the Sanbonmatsu formation is most narrowly distributed, exposing in a very narrow belt along the highway above mentioned. Tectonically speaking, it is presumed that it is wedged into the middle Ryugenji formation, marked off from the latter by faults of NEE-SWW direction. Much is still unknown for the Sanbonmatsu formation because of its poor exposure covered by thick surface soils.

Rock facies and Stratigraphic age

So far as observed, the Sanbonmatsu formation consists of black silicious clayslate and minor limestone lenses. The latters are exposed at the roadside 600m east of the pass between Hagiwara and Katada (Loc. 178), and at the point 200m east of the former (Loc. 284). Both the limestone lenses are composed of minute limestone pieces of 0.5-1.0mm to 4-5mm in diameter, cemented by hard silicious substances.

The following species have been obtained in the limestone lense of Loc. 178:

Nankinella? sp.
Fusulinella biconica (HAYASAKA)
Triticites sp.
Schwagerina cf. *deprati* (OZAWA)
Schwagerina tschernyschewi (SCHELLWIEN)
Schwagerina sp.
Pseudofusulina globosa var. *exilis* n. var.
Parafusulina sp.
Pseudodoliolina sp.
Neoschwagerina sp.
Yabeina sp.
Sumatrina sp.

The limestone conglomerate of Loc. 178 consists of very minute irregular pieces of limestone, and outer portion of pebbles in which derived fusulinids contained is crushed or destroyed. Accordingly, all of specimens apparently seem to be found in matrix; in other words, it is almost impossible to distinguish which is the derived fossil among them. Judging

from the faunal assemblage above listed, however, it is impossible to regard that all the species were existed at the same time.

Because *Yabeina* sp. is closely allied to *Y. shiraiwensis* OZAWA, the limestone lense of Loc. 178 is assumed to be correlated with Puα of the Akiyoshi limestone group.

No fusulinid has been detected in the limestone lense of Loc. 284.

Rocks which are exposed along the incline from the south of Hagiwara to the limestone quarry of Loc. 765 have been referred to the upper part of the Serita formation, in some part of which, however, coarse sandstone or even conglomeratic one develops. The rocks above that horizon may be referable to the Sanbonmatsu formation, but there is no positive evidence to support that contention.

5. Geologic structure of the Beppu group

The lower three formations of the Beppu group, namely, the Katada, Ryugenji and Serita formations are in conformable relation with one another, while the relation of the uppermost Sanbonmatsu formation to the Serita formation is unknown, because there is no place where both are in contact with each other. Although exceedingly narrow distribution and poor outcropping of the Sanbonmatsu formation make it much difficult to ascertain the tectonic relation with others in the field, it is presamed that the Sanbonmatsu formation was wedged into the Ryugenji formation by thrusts.

As mentioned already, the Beppu group is divided by the Kawarakami tectonic line into the western and northeastern parts, the former of which is subdivided by the intervening Sanbonmatsu formation into the northern and southern blocks.

Generally speaking, strike of the Beppu group is NEE-SWW in the western part which turns to NE-SW in the northeastern one and further to N by E in the northeastern extremity. Dip is toward SSE in the western and SE to SEE in northeastern parts. Judging from these facts it is presumed that the Beppu group is apparently laid in reverse order in the northeastern part and in the southern block of the western one; while it is in normal order in the northern block of the western part.

By what tectonic movement the geologic structure mentioned above was caused? Interesting enough that two tectonic movements of the opposite direction and of different age are enough to answer the question. That is to say, as well as in the Akiyoshi limestone group, the isoclinal fold with the axial plane of NE-SW direction dipping to the southeast was first formed, and then thrust movement took place later toward the south from the north by which the Sanbonmatsu formation was wedged into the Ryugenji formation.

In short I am of the opinion that the tectonic movement by which the folding was formed should be distinguished from the other which

caused the thrusting toward the south from the north, and it is presumed that the former was caused by the Akiyoshi orogenic movement and the latter by the Oga orogenic movement as well as the two movements assumed in the Akiyoshi limestone group.

Brief note on the rocks referred to the Beppu group but of indeterminable age

In the bottom of large doline of Yobara, Beppu-mura, much disturbed black clayslate is exposed under the rocks of the Akiyoshi limestone group, marked off from the latter by sheared zone. It is presumed to be referred to the Beppu group, but it cannot be determined to which formation of the group it belong, because it is barren in fossil. However, it may probably be referable to the Serita or Sanbonmatsu formation from the lithologic points of view.

Chapter 4. Tsunemori Group

Introductory Remarks

The Permian rocks now referred to the Tsunemori group had long been believed to be Mesozoic in age (OGURA, 1922), until KATAYAMA (1939) clarified that they are Paleozoic in age and proposed to name "Tsunemori series" after Tsunemori where is about 1.5km east of the Omine station. Compiling studies by KATAYAMA, SUGIYAMA and himself, KOBAYASHI (1940, 1941, 1950, 1951) classified the non-calcareous Paleozoic formations of this district to his Yamaguchi facies, and he thought that the "Tsunemori series" is the uppermost member among the rocks of the Yamaguchi facies and synchronous but heteropic with at least some part of the Akiyoshi limestone.

Generally speaking the Tsunemori group consists mainly of shale (or slaty shale) and sandstone, or alternation of both, with association of small amount of conglomerate and limestone. It is characteristic that chert or silicious rock is quite absent in the group.

Distribution in general

The Tsunemori group mainly develops to the west of Mine railroad line, occupying an area of 3.5km from the north to the south and 3km from the east to the west. Tsunemori is about in the center of the area. It develops also in the bottom of large dolines at Irimi and Okugawara, underlying the Akiyoshi limestone group from which it is marked off by sheared zone. Furthermore, a part of rocks exposing to the south of the Ofuku plateau, which has hitherto been considered to be Mesozoic in age, is probably referable to the Tsunemori group. Accordingly distribution area of the group is considerably wide.

Type section and division of the group

The best display of the Tsunemori group is seen along the road from the Omine station to Kamiryo, Higashibun, through Tsunemori. Although somewhat disturbed by minor strike faults of NNE-SSW direction, fairly well continuous order of succession of the Tsunemori group is observed along the section mentioned above. It was, therefore, designated the type section of the group. It is unfortunate, however, that the type section does not comprise any fossil-bearing limestone lenses which occur in other

Lithology of the type section

Bed	Thickness in m	Lithology
10	50±	Sandstone, conglomeratic, thin sandy shale interbedded in the lower part.
9	3	Conglomerate, containing round pebbles of porphyrite, chert, clayslate and sandstone; matrix coarse sand.
8	60	Sandstone, conglomeratic, thin shale bed interbedded in the lower part.
7	5	Lithology the same as that of 9.
6	60	Sandstone, massive and coarse.
5	30	Alternation of sandstone and shale; sandstone medium grained, shale more or less sandy.
4	110	Shale, sandy; fine sandstone bed is interbedded in some part, in which crinoid stems are contained.
3	150	Sandstone, fine, greyish to brownish.
2	35	Conglomerate; hard, medium grained sandstone interbedded in the base; thin sandy shale in the middle part; pebbles of conglomerate become smaller in size toward the top.
1	250±	Alternation of hard fine sandstone and sandy shale; well stratified; sandstone is of from 20 to 100cm, shale from 3 to 10cm.

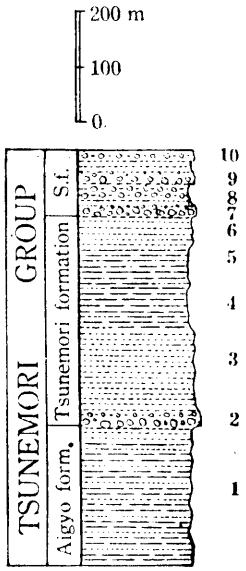

Fig. 5. Diagrammatic illustration of the type section of the Tsunemori group. Numbers to the right of column refer to beds of the described section.

Table 4

Formation name		Thickness in m	Rock facies
Shiraiwa formation	T_3	150+	ss cgl sh (ls)
Tsunemori formation	T_2	350	ss sh (cgl ls)
Aigyo formation	T_1	250+	ss sh

Abbreviations in the rock facies are the same as in Table 1.

parts. The type section is, accordingly, correlated with limestone-bearing rocks by similarity in rock facies and tectonic relation. The division of the Tsunemori group is tabulated in Table 4.

1. Aigyo formation, T_1

Distribution

The Aigyo formation develops in a belt of NE–SW direction extending from the southeast of the Omine station to Maki through Tsunemori in which the type section is contained. It also develops to the west of the Omine railroad line, extending from the south of Aigyo to the east of Takiguchi.

Rock facies

The Aigyo formation consists mainly of alternation of sandstone and shale, of which the former more or less predominates. The alternation is usually composed of sandstone of thickness ranging 20cm to 100cm and shale of 3cm to 10cm. Sandstone is hard, fine-grained, and blue in color when it is fresh. Shale is sometimes sandy. In the type section rocks of the Aigyo formation are well stratified, being NE 50°—70° in strike, dipping 40° to 60° toward NW. Toward the east shale is gradually increasing in relative amount, but stratification of bed becomes to be disarranged. In the block west of the Omine railroad line alternation of sandstone and shale is predominating in the northern part, and slaty shale in the southern one.

The thickness of the Aigyo formation in the type section is estimated to be more than 250m.

Stratigraphic age

The stratigraphic age of the Aigyo formation is not determined with certainty, because no fossil has been found not only in the type section but also in all the rocks referred to the formation. However, it is clear that the Aigyo formation is older than $Pm\gamma$ of the Akiyoshi limestone group to which the overlying Tsunemori formation is correlated.

2. Tsunemori formation, T_2

Distribution

Because the underlying Aigyo formation forms an anticline with the axial plane of NE–SW direction in the type section, the rocks of the Tsunemori formation also develop in the belts of the same direction on both the wings of the anticline, of which the southwestern one widely develops in the low land from the northwest of Yoshinori to Higashishibukura, displaying minor foldings of low angles (here referred to the Yoshinori-Higashishibukura block). The northeastern extension of the southwestern wing is also considerably widely distributed along the northern side of deep valley from Shigeyasu to Irimi, Omine-machi.

The rocks of the Tsunemori formation are also found around the low hill of Ojigase, north-northwest of the Minami-omine station (Ojigase block), and also on the low hill of Nishishibukura (Nishishibukura block), northeast of the station around which the River Asa is meandering.

Rock facies

Main rock facies of the Tsunemori formation is sandstone and shale; besides, small amount of conglomerate and limestone occurs in some part. In the type section of the group the Tsunemori formation begins with conglomerate. As a whole it has a thickness of more than 40m, but medium hard sandstone is intervening in the lower, sandy shale in the middle, and conglomeratic sandstone in the upper parts. Conglomerate is comprising round pebbles of sandstone, clayslate, chert, limestone and granitic rocks*, most of them are less than 5cm in diameter, but pebble size becomes gradually smaller toward the upper part. Overlying the conglomerate, fine grey sandstone of more than 150m in thickness occur, which is, in turn, overlaid by sandy shale of about 100m in thickness, interbedded with thin fine sandstone layers. Stems of crinoid are sporadically found in sandy shale. The upper part of the Tsunemori formation consists of alternation of medium grey sandstone and shale, and the uppermost one of coarse sandstone.

In the belt of NE-SW direction located to the south of Shiraiwa, the Tsunemori formation is, as a whole, predominating in shale, although conglomeratic sandstone occurs at the base. Detailed order of succession is unknown because of the poor state of outcropping.

The Tsunemori formation of the Nishishibukura block consists of fine sandstone and slaty shale in which limestone lenses of Loc. 204 and Loc. 206 are interbedded. Little is known about the Tsunemori formation of the Yoshinori-Higashishibukura block because of poor outcropping, but limestone lenses of Loc. 385 and Loc. 104 are interbedded in slaty shale of small hill of Higashishibukura. Coally shale is also known to occur in this block.

In the Ojigase block chert mass presumed to be referred to the Akiyoshi limestone group is lying on the top of hill as a Klippe, underlying which rocks of the Tsunemori formation composed of alternation of sandstone and shale is developed, but the stratigraphic succession is hard to determine because rocks are much disturbed. In the western margin of the Ojigase block limestone lense of Loc. 64 occurs about 500m north of the Minami-omine station.

Stratigraphic age

Although no limestone lense is known to be found in the type section of the Tsunemori formation, several ones occur in the Yoshinori-Higashi-

* It is noteworthy that Dr. TOMITA (1954) of Kyushu University has recently determined the age of these granitic rocks to be pre-Cambrian by his "Zircon method".

shibukura, Nishishibukura and Ojigase blocks, in some of which fusulinids are prolific.

In the Ojigase block limestone lense of Loc. 64 yields the following species:

Nankinella sp.
Pseudofusulina cf. *vulgaris* (SCHELLWIEN)
Pseudofusulina vulgaris var. *megaspherica* n. var.
Pseudofusulina yobarensis (OZAWA)
Parafusulina pseudojaponica n. sp.
Parafusulina kaerimizensis (OZAWA)
Parafusulina sp.
Neoschwagerina sp.

The limestone of Loc. 64 apparently seems to be massive, but polished surface reveals that it is unquestionably limestone conglomerate, pebbles of which are greyish white in color, ranging from 1cm to 10cm in size. All the species listed above are found in pebbles, except for *Neoschwagerina* sp. which occurs only in the matrix. *Pseudofusulina* cf. *vulgaris* (SCHELLWIEN) and *P. vulgaris* var. *megaspherica* n. var. are sometimes crowded in pebbles. *Neoschwagerina* sp. is an advanced form for the genus, but specific identification is almost hard to be done because almost all of the specimens are not preserved in good condition, outer portion of some of them being crushed out, while considerable part of the others is destroyed.

The stratigraphic age of limestone lense of Loc. 64 is presumed to be correlated with Pmβ—Pmγ of the Akiyoshi limestone group.

In the western part of the low hill of the Nishishibukura block, a limestone lense of more than 100m in length is outcropping along the eastern riverside of the River Asa, most parts of which are, however, barren in fossil, except for the middle part (Loc. 204) from where the following species have been obtained:

Staffella sp.
Schubertella sp.
Parafusulina sp.
Pseudodoliolina sp.
Neoschwagerina sp.

Of these, *Pseudodoliolina* sp. is presumably referable to *P. ozawai* YABE and HANZAWA, and *Neoschwagerina* sp. is a more or less advanced form.

At the southeastern end of the low hill, limestone lense of Loc. 206 is exposed in which the species listed below have been determined:

Schwagerina sp.
Parafusulina sp.
Verbeekina sp.
Pseudodoliolina sp.
Neoschwagerina sp.

Pseudodoliolina sp. is also presumed to be referred to *P. ozawai* YABE and HANZAWA.

Both the limestone lenses of Loc. 204 and Loc. 206 are limestone conglomerate though they are not clear in lithic character. As some part of the latter is comprising minute fragmentary pieces of limestone, it is rather difficult to distinguish whether fusulinid specimen is contained in matrix or in pebble. So far as determined, however, *Neoschwagerina* sp. which is specialized for the genus is found only in matrix of the limestone conglomerate of Loc. 206, and both in matrix and pebbles of Loc. 204. It is presumed that both the limestone lenses are the same in age, and correlated with Pmγ—Pmδ.

In the Yoshinori-Higashishibukura block two limestone lenses are known to occur, one (Loc. 385) is at the central southern margin of small low hill of Higashishibukura, and the other (Loc. 104) at a cutting along the railroad track between the Minami-omine and Yoshinori stations.

The following species have been obtained in the limestone lense of Loc. 385:

Nankinella sp.
Schubertella japonica n. sp.
Pseudofusulina crassiseptata (DEPRAT)
Neoschwagerina douvillei OZAWA
Neoschwagerina sp.

The limestone is a typical limestone conglomerate, consisting of subangular pebbles of 1—2mm to 30mm in diameter, some of which are exclusively prolific in *Pseudofusulina crassiseptata* (DEPRAT). *Neoschwagerina douvillei* OZAWA is found both in pebbles and matrix, but more abundant in the latter. It is safely concluded that the age of limestone is Pmγ—Pmδ.

In the limestone lense of Loc. 104 species listed below have been collected:

Staffella sp.
Schwagerina sp.
Parafusulina n. sp. A
Parafusulina gigantea (DEPRAT)
Parafusulina sp.

The limestone is also limestone conglomerate, composed of limestone pebbles of 1—4mm to over 20mm in diameter. As all the species listed above occur only in pebbles and no species has been detected in matrix, the age of the limestone is not exactly known. However, it may be the same in age as that of Loc. 385, because both the limestone lenses are almost continuous in the field.

In short, the Tsunemori formation is rather prolific in fusulinid fossils, especially in the limestone lenses of the southeastern part, and almost all of them are correlated with Pmγ–Pmδ of the Akiyoshi limestone

group. Accordingly, it is presumably concluded that the Tsunemori formation is, as a whole, referable to Pmγ—Pmδ, although some of the lower part of the formation may be ranging down to Pmβ of the Akiyoshi limestone group.

3. Shiraiwa formation, T_3

The upper formation of the Tsunemori group is the Shiraiwa formation, named after Shiraiwa, Omine-machi, the type locality of *Yabeina shiraiwensis* OZAWA.

Distribution

The Shiraiwa formation is developed in the environs of Shiraiwa, and along the eastern side of valley which runs from Shiraiwa to the north, viz., on the southwestern flank of "Miyama" (472.7m in height). It is also exposed in the eastern part of the type section; namely, along the road from Tsunemori to Kamiryo, Higashibun, Omine-machi, where it occurs in belts of NE-SW direction, repeated by faults of the same direction. Rocks develop along the southeastern side of valley runs from Shigeyasu to Irimi, and those widely occur to the south of the Ofuku plateau which merge into the rocks of the Ota group may probably be referable to the Shiraiwa formation, although it has not been ascertained by the paleontologic evidence.

Rock facies

In the type section of the Tsunemori group, namely, along the road from Tsunemori to Kamiryo, the Shiraiwa formation consists mainly of conglomerate and coarse to conglomeratic sandstone, with intervening thin shale. Conglomerate occurs in several horizons, showing a tendency that pebbles of which are increasing in size upward. Pebbles are almost the same in kind as those of the Tsunemori formation. As lateral changes in facies are rather outstanding in the Shiraiwa formation, conglomerate is hardly to be traced laterally. At any rate, the fact that local unconformity or sedimentary anomaly is observed, is considered to suggest the unstable condition of sedimentation.

In the environs of Hinaga where is the southwestern extension of the type section, conglomerate changes into alternation of coarse sandstone and shale, the latter of which is often bearing pebbles of clayslate or shale. Numerous cavities of irregular shape are sometimes observable in shale which might have been filled with limestone pebbles. The diameter of these cavities are ranging from 2—3mm to 10mm or more. Accidentally I have found a limestone pebble which has been remained in shale at Loc. 68 in Hinaga, in which, fortunately enough, I have been able to detect a specimen of *Afghanella* which is presumably identified to *A. schenki* THOMPSON. Along with pebbles numerous stems of crinoid and

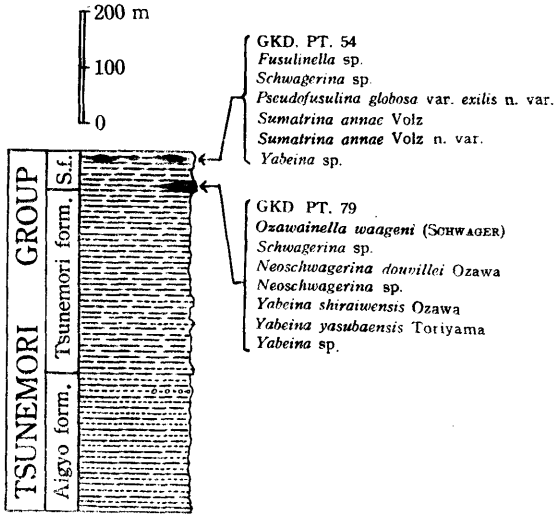

Fig. 6. Diagrammatic illustration of the Tsunemori group. Section measured from the north of Tsunemori northwestward to the south of Shiraiwa, all in Omine-machi.

brachiopods of indeterminable affinity occur, although the latters are exceedingly rare in number.

At the Loc. 127, about 300m southeast of Loc. 68, a limestone lense occurs which is interbedded with shale.

No conglomerate occurs in the Shiraiwa formation in the environs of Shiraiwa and along the southwestern flank of "Miyama," where the formation consists of alternation of sandstone and shale, intercalated with limestone lenses. In the upstream of the valley of Shiraiwa clayslate is rather predominating.

Stratigraphic age

The facies change is so remarkable in the Shiraiwa formation that the correlation of rocks in separate blocks with one another is almost impossible otherwise than by fusulinids occur in limestone lenses.

(1) In the limestone lense at Hinaga (Loc. 127), which is in the southwestern extension of the type section, prolific fusulinids occur*:

Ozawainella waageni (SCHWAGER)

* *Gemmellaroia* (*Gemmellaroiella*) *ozawai* MABUCHI described by MABUCHI (1937) might have been collected from this limestone lense. He only described "the limestone lense at Yoshinori" as the type locality, but did not describe the very point in detail. Although several limestone lenses are known to occur in the environs of Yoshinori, species of *Sumatrina* which was reported by MABUCHI as an associating species, occurs only in the limestone lense of Loc. 127.

Schubertella sp.
Schwagerina deprati (OZAWA)
Schwagerina sp.
Parafusulina pseudojaponica n. sp.
Pseudodoliolina sp.
Neoschwagerina douvillei OZAWA
Yabeina sp.
Sumatrina annae VOLZ
Sumatrina annae var. *stricta* DEPRAT
Sumatrina annae var. n. var.

Although the limestone is apparently massive, careful observation reveals that it is conglomeratic, pebbles of which are, however, sometimes hard to be distinguished from the matrix, because both are the same in color. Some of pebbles are comprising exclusively of one species such as *Parafusulina pseudojaponica* n. sp. or *Pseudodoliolina* sp. On the other hand, it has been observed that species of *Sumatrina annae* and its varieties occur associating with *Schwagerina deprati* (OZAWA), and *Yabeina* sp., though very few in numer, may probably be referable to *Y. yasubaensis* TORIYAMA.

The limestone lense of Loc. 127 is presumably correlated with Puα of the Akiyoshi limestone group.

(2) In the environs of Shiraiwa and along the valley runs from Shiraiwa to the north are several fusulinid-bearing limestone lenses found, intercalating with shale. Although Shiraiwa is the type locality of *Yabeina shiraiwensis* OZAWA and *Fusulinella itoi* OZAWA, it has not been ascertained that from which limestone lense OZAWA had collected these species. In the environs of Shiraiwa two limestone lenses (Loc. 54 and Loc. 79) are exposed at both sides of the road from Shiraiwa to Mugikawa.

In the limestone lense of Loc. 54 the following species are known:

Fusulinella sp.
Schwagerina sp.
Pseudofusulina globosa var. *exilis* n. var.
Sumatrina annae VOLZ
Samatrina annae var. n. var.
Yabeina sp.

The limestone is typically conglomeratic, consisting of pebbles of 20 to 30mm in diameter. A part of limestone is sometimes much crushed. Numerous specimens belonging to one species often occur crowded in one pebble. *Yabeina* sp. is found only in matrix.

(3) Species listed below have been obtained from the limestone lense of Loc. 79.

Ozawainella waageni (SCHWAGER)
Schwagerina sp.
Neoschwagerina douvillei OZAWA

Neoschwagerina sp.
Yabeina shiraiwensis OZAWA
Yabeina yasubaensis TORIYAMA
Yabeina sp.

The limestone is similar in character to that of Loc. 54, but species of *Yabeina* are found both in matrix and pebbles, hence the limestone is contemporaneous limestone conglomerate.

(4) Along the valley runs from Shiraiwa northward to the south-western flank of "Miyama", serveral limestone lenses occur in the uppermost horizon of the Shiraiwa formation, aligned in almost the same direction of N-S, though shifted each other by later minor faults of E-W direction. They are Loc. 73, 61, 76, and 202 from the south to the north.

In the limestone of Loc. 73 the following species have been collected:

Ozawainella sp.
Schubertella sp.
Schwagerina sp.
Parafusulina kaerimizensis (OZAWA)
Parafusulina sp.
Pseudodoliolina cf. *pseudolepida* (SCHWAGER)
Yabeina yasubaensis TORIYAMA

The limestone seemingly is blackish grey in color and is massive, but the polished surface shows that it is unquestionably a limestone conglomerate, consisting of angular to subangular pebbles ranging from 1—2 mm to 10—20mm in size. All the species listed above are found to be crowded in greyish white pebbles, except for the last named species which is closely allied to *Y. shiraiwensis* OZAWA and is found only in matrix.

(5) About 200m north of Loc. 73 the limestone lense of Loc. 61 is exposed in which occur the following species:

Schubertella sp.
Schwagerina sp.
Pseudofusulina kraffti (SCHELLWIEN)
Pseudofusulina sp.
Parafusulina kaerimizensis (OZAWA)
Parafusulina sp.
Neoschwagerina douvillei OZAWA
Neoschwagerina sp.
Yabeina shiraiwensis OZAWA
Yabeina yasubaensis TORIYAMA
Yabeina sp.

The limestone which clearly merges into slaty shale is also a typical limestone conglomerate, comprising of limestone pebbles of less than 30 mm in diameter. Fusulinid fossils are more common in greyish white pebbles. All the species listed above are found only in pebbles, except for species of *Yabeina* which occur both in matrix and pebbles. Even when

species of *Yabeina* exist in limestone pebbles, no species other than *Schwagerina* sp. is associated with them.

(6) About 500m further north of Loc. 61 the limestone lense of Loc. 76 is exposing at the westside of the valley, marked off from the southern block by minor fault of E-W direction. The following species are known:

Schwagerina sp.
Sumatrina sp.
Yabeina shiraiwensis OZAWA
Yabeina sp.

The limestone lense is a typical limestone conglomerate which consists of angular to subangular pebbles of greyish white to blackish grey in color, cemented by blackish grey calcareous matrix. Dimension of pebbles is ranging from 1—2mm to 20—25mm in diameter. Species of *Yabeina* are found both in pebbles and matrix, although more common in the formers.

(7) The northernmost limestone lense (Loc. 202) of the Shiraiwa formation is located about 300m north of that of Loc. 76, in which the following two species only have been found:

Fusulinella biconica (HAYASAKA)
Parafusulina cf. *gigantea* (DEPRAT)

As well as the others already described, the limestone lense of Loc. 202 is a typical limestone conglomerate which consists of angular to subangular limestone pebbles of greyish white to blackish grey in color, cemented by blackish grey calcareous substances. Pebbles are less than 40 mm in diameter and are often crushed. Both *Fusulinella biconica* (HAYASAKA) and *Parafusulina* cf. *gigantea* (DEPRAT) are found only in pebbles and no species has been obtained in the matrix. Hence the stratigraphic age of the limestone lense of Loc. 202 is not exactly known, but it may probably be the same in age as those exposed in the valley of Shiraiwa.

As described above both *Yabeina shiraiwensis* OZAWA and *Y. yasubaensis* TORIYAMA, which are most closely allied with each other, are so common in the limestone lenses exposed in the valley of Shiraiwa. These *Yabeina*-bearing limestones are unquestionably correlated with Puα of the Akiyoshi limestone group which is, as stated, characterized by the same species. In the environs of Shiraiwa fusulinid-bearing limestone lenses occur in almost the uppermost horizon of the Shiraiwa formation, but it is not known that with which horizon in the type section are they correlated. The upper part of the Shiraiwa formation in the type section may comprise higher horizon than Puα. Even if such being the case, it will not so far higher than Puα, because the Shiraiwa formation in the type section is very thin in thickness, assumed to be less than 130m. In short, paleontologic evidences show that the Shiraiwa formation is at least Puα in age, although it is possible that the uppermost horizon of the formation may be slightly younger than Puα in age.

Underlying the Akiyoshi limestone group rocks consisting of slaty shale or clayslate and somewhat hornfelsic sandstone are widely exposed along the southern side of a long valley runs from Shigeyasu to Irimi and also along a valley of Okugawara, Isa-machi. In addition to the barrenness of fossil the rocks are so much disturbed that it has not been ascertained to which formation of the Tsunemori group are they referable. Due to the similarity in facies, however, I am referring them to the Shiraiwa formation with question.

To the south of Isa-machi and in the environs of Sohara, Isa-machi rocks consisting of sandstone and shale are rather widely distributed, the eastern extension of which is exposing far to the south of Yamazuyu, Iwanaga-mura. Because thin coal seams or coally shale are often known to be found, they have long been regarded as Mesozoic formation. It has been clarified however, that they are in fact a member of the Tsunemori group, and are probably referred to the Shiraiwa formation because pebble-bearing shale is often interbedded and stems of crinoid are found in shale. The Shiraiwa formation in this part is marked off from the Tsuzumigatake formation of the Ota group in tectonic relation but it merges into the Yaegahara formation at one place, while at another it is in tectonic contact with the same formation. Much still remains to be studied on the Shiraiwa formation in this part.

4. Geologic structure of the Tsunemori group

The general strike of the Tsunemori group including the type section is in a direction of NNE–SSW, displaying gentle foldings with the axial planes of the same direction. Rocks of the Tsunemori group are modified by several minor strike faults, which are, in turn, cut by faults of almost E–W direction. The latters also cut the rocks of the Mine series, and the northern block is relatively shifting 100m to 300m toward the west. (The evidence of the shifting is observed in the Takiguchi and Fujigakochi coal mines.)

At any rate, NNE–SSW direction is prevailing in the tectonic features of the Tsunemori group exposed to the west of the Ofuku-Yoshinori tectonic line as well as in the Gampi group, while in the area to the east of the line NEE–SWW or almost E–W direction is dominating, which changes to NE–SW in the western part of the Ota and Beppu terrains and at last to NNE–SSW in the eastern part.

In general rock-aspect facies changes upwards from fine to coarse, and the upper division, the Shiraiwa formation, is characterized by the predominance of conglomeratic facies including limestone conglomerate and pebble-bearing shale. It is also characterized by the occurrences of thin coal seams or coally shale and drifts in shale beds. These facts suggest that the sedimentary basin of the Tsunemori group was gradually

elevating while the deposition was still going on; in other words, the basin became gradually shallower until some part of it became estuary or even emerged above the sea. However, the occurrence of fusulinids suggests that the sedimentary basin was, as a whole, still connected with the open sea. Furthermore, frequent changes of facies in the Shiraiwa formation assume that the sedimentary basin had been in very unstable condition in the Late Permian time.

These assumptions were presumed also in the Akiyoshi limestone group. It is interest that almost the same conclusion has been led separately through the studies of quite different groups in which facies show marked contrast each other.

Brief note on the Dai formation

In the northwestern extremity of the Akiyoshi district the Paleozoic rocks called the Dai formation are developed. The upper part of the Dai formation is composed mainly of clayslate and sandy shale, while the lower one is of metamorphics, the latter of which has been referred to the Sangun metamorphic group and is presumed to be the northeastern extension of the Toyogatake phyllitic group which develops between the Jurassic and Triassic terrains of Toyora-gun. (Kobayashi, 1941; Kanao, 1942; Kawai, 1944). Covered by thick Diluvium deposits the upper part of the formation develops in a narrow belt along the road from Dai, Nishiichi-machi, Toyora-gun to Hirano (formerly Byodare) through Hisage. In the environs of Dai and Hisage, it is comprising mainly clayslate and sandy shale in which a minor limestone lense is interbedded at Hisage. General trend of the formation is in a direction of NNE–SSW, dipping 40° toward SEE. In the vicinity of Hirano the lower part of the formation consists of phyllitic rocks in which serpentine is considerably widely developed. Small patches of gneissic rocks occur in narrow belts of NEE–SWW direction. As I have not studied these metamorphics, much still remains to be studied.

Here I only point out the occurrence of fusulinids in the limestone lense (Loc. 218) at Hisage, in which the following species have been obtained*:

Staffella sp.
Fusulinella sp.
Triticites sp.
Schwagerina regularis (Schellwien)
Schwagerina sp.
Pseudofusulina ambigua (Deprat)

* Kanao (1942) reported *Misellina lepida* (Schwager) from Hisage. It seems, however, that he misidentified the species.

Pseudofusulina sp.
Parafusulina (?) sp.

The limestone lense of Loc. 218 is a typical limestone conglomerate, consisting of minute subangular to irregular limestone pebbles of one or two to several milimeters in diameter. Although limestone is considerably crushed, fusulinid specimens contained are fairly well preserved. Of species listed above *Staffella* sp. and *Fusulinella* sp. are found only in limestone pebbles, while the others in the matrix. *Pseudofusulina ambigua* (DEPRAT) is most abundant in number, followed by *Schwagerina regularis* (SCHELLWIEN) and S. sp. Specimens of *Triticites* and *Parafusulina* (?) are so few in number that even the generic identification has not been carried out with certainty. However, it is beyond doubt that the stratigraphic age of the limestone lense is Plβ or Plγ of the Akiyoshi limestone group.

Although future detailed study will be need on the Dai formation, the upper part of the formation is, at least, most closely allied to the Tsunemori group from lithologic and paleontologic points of view. The rocks which may probably be correlated with the Tsunemori group are also known to be found to the east of the Toyogatake phyllitic group in a narrow belt of NNE-SSW direction. The Dai formation is presumed to be the northeastern extension of this formation.

General Conclusion

The followings summarize Part I and Part II of this paper:

(1) The Paleozoic rocks widely exposed in the Akiyoshi district are classified into the Akiyoshi limestone, Ota, Gampi, Beppu and Tsunemori groups based on differences of lithologic facies and tectonic units.

The Akiyoshi limestone group is characterized by the predominance of calcareous facies, while the other groups are composed of detrital facies and extreme small amounts of calcareous materials.

(2) So far as the paleontologic evidences are concerned, the Akiyoshi limestone group and the Ota group are ranging from Pennsylvanian to Permian in age, while the Gampi group is referred to Middle Pennsylvanian with question, the Beppu group to Lower to Upper, and the Tsunemori group to Middle to Upper Permian. Accordingly, the Akiyoshi limestone group of calcareous facies and the Ota group of non-calcareous facies are almost synchronous but heteropic with each other, and the Gampi, Beppu and Tsunemori groups are also contemporaneous but heteropic with at least some part of the Akiyoshi limestone group.

(3) The Akiyoshi limestone group is divided into six fusulinid zones, three Permian zones of which are subdivided into seven subzones. The existence of the *Profusulinella* zone has been ascertained in this country

for the first time. Upper Oklan (Desmoinesian) *Fusulina* Zone and Kawvian (Uralian or Missourian-Virgilian) *Triticites* Zone are missing. Although the *Millerella* Zone, the lowest fusulinid Zone, has not yet been found, it is not improbable that the existence of it may be ascertained through future study.

A question has been left for future study as to whether the *Yabeina shiraiwensis* zone is definitely to be correlated with the *Lepidolina* zone of the Kyushu and Kitakami massifs.

(4) Upper Oklan (Desmoinesian) and Kawvian (Uralian or Missourian-Virgilian) rocks have not been found in the non-calcareous groups, in spite of the fact that there is no conspicuous physical break below the base of the Permian rocks, except for a minor local unconformity in the Ota group.

(5) All the groups are similar in the tectonic alignment. General trend of the Paleozoic terrain in this district is a NNE–SSW or NE–SW direction in the western part (area west of the Ofuku-Yoshinori line), and a NNE–SWW or almost E–W trend in the central part, which turns to a NE–SW trend toward the east until it takes a direction of NNE–SSW or even almost N–S direction.

(6) The Akiyoshi limestone group is not completely overturned as hitherto believed but is in normal order in the southern and eastern parts and in reverse order in the northern and western parts, while the Ota group forms isoclinal folds with the axial planes trending NNE, dipping to NNW. The same is in trend in the Beppu group where the axial planes dip to SSE or SE, and the northern block thrusts upon the southern block.

(7) Of course, there are many possible explanations as to how the geologic structure now seen in the Akiyoshi limestone group was derived. However, I am of the opinion that the following is the most probable. The northern half of the Akiyoshi limestone group first formed a completely overturned anticline toward the north, which later thrust upon the southern normal half. With the lower wing of the overturned anticline, the lower part of the southern half is remaining. If my assumption is correct, it is of interest that the Akiyoshi limestone group and the Ota and Beppu groups are of closely similar in later deformations.

(8) Because the Akiyoshi limestone group is marked off by thrust-fault from the surrounding non-calcareous formations, the exact stratigraphic relation of it to surrounding rocks is not determined with certainty. My contension is, however, that the Akiyoshi limestone group is autochthonous, or para-autochthonous if not autochthonous in the strictest sense. This conclusion most easily explains the occurrences of limestone conglomerates interbedded in the non-calcareous formations, including the

Table 5. List of Fusulinid Fossils of the Ota, Gampi, Beppu and Tsunemori groups and the Dai formation

Specific name \ Group	Ota group		Gampi group		Beppu group										Tsunemori group												Dai. form.
Locality	Maruyama	Takayama	Kuwabara		Entrance of Kawarakami		"Komizu"	Southeast of "Sanbonmatsu"	"Mizunashi"		Kawarakami		Serita		"Sanbonmatsu"	North of Minami-Omine station	West of Nishi-shibukura	East of Nishi-shibukura	South of Higashi-bukura	North of Higashi-bukura	Hinaga		South of Shiraiwa		North of Shiraiwa		Upper stream of Shiraiwa		Hisage
Formation	O_2	O_2	G_1	G_1	B_1	B_2	B_2	B_2	B_3	B_3	B_3	B_3	B_3	B_3	B_4	T_2	T_2	T_2	T_2	T_2	T_3	T_3	T_3	T_3	T_3	T_3	T_3	T_3	D
Collection number	590	698	80	81	177	140	249	139	144	145	143	176	9	10	178	64	204	206	385	104	68	127	79	54	73	61	76	202	218
1. *Millerella?* sp.											(×?)																		
2. *Ozawainella waageni* (Schwager)																						(×)	(×)						
3. *O.* sp.																									(×)				
4. *Nankinella* sp.	(×)														(×?)	(×)			(×)										
5. *Staffella* sp.																	(×)			(×)									(×)
6. *Schubertella japonica* n. sp.																			(◉)										
7. *S.* sp.											(×)		(×)				(×)					(×)			(×)	(×)			
8. *Fusulinella biconica* (Hayasaka)											(×)				(×)													(×)	
9. *F.* sp. B					(×)							(×)																	
10. *F.* sp.	(×)		×	×?							(×)	(×?)												(×)					(×)
11. *Triticites biconica* n. sp.								(×)																					
12. *T. noinskyi* var. n. var.					[O]																								
13. *T.* sp. A								(×)																					
14. *T.* sp.			×?	×?	[◉]			(×)			(×)				(×)														×?
15. *Dunbarinella* sp.						(×)?																							
16. *Schwagerina satoi* (Ozawa)					[×]																								
17. *S. deprati* (Ozawa)															×							◉							
18. *S.* cf. *regularis* (Schellwien)											(×)																		◉
19. *S. tschernyschewi* (Schellwien)															(×)														
20. *S. etoi* n. sp.													(×)																
21. *S.* sp.	(×)					◉	×	(×)		×	(×)	(×?)	(○)	(×)	(×)	(×)		(◉)		(×)		(×)	(×)?	(×)	(×)	(×)	[×]?		×
22. *Pseudofusulina yobarensis* (Ozawa)																(◉)													
23. *P. vulgaris* (Schellwien)														(×)		(×)													
24. *P. vulgaris* var. *megaspherica* n. var.																(×)													
25. *P. globosa* var. *exilis* n. var.						(×)?									(×)									(×)					
26. *P. kraffti* (Schellwien)														(○)												(×)			
27. *P. kraffti* var. *magna* n. var.						×																							
28. *P. crassiseptata* (Deprat)																			(◉)										
29. *P. ambigua* (Deprat)																													○
30. *P.* sp.						×								(×)		(×)										(×)			×
31. *Parafusulina gigantea* (Deprat)	(×)										(×)		(×)							(×)								(×)	
32. *P. pseudojaponica* n. sp.	(×)					×										(×)						(×)							
33. *P. kaerimizensis* (Ozawa)																(×)									(×)	(×)			
34. *P.* n. sp. A.																				(×)									
35. *P.* sp.						×	×	×	×	×					(×)	(○)	(×)	(×)		(×)					(○)	(×)			×?
36. *Nagatoella* cf. *orientis* (Ozawa)	(×)																												
37. *Pseudodoliolina* cf. *pseudolepida* (Deprat)																									(○)				
38. *P.* sp.								×	×			×			(×)		(×)?	(×)				(×)							
39. *Verbeekina* sp.	(×)								×									(×)?											
40. *Neoschwagerina craticulifera* (Schwager)						×							(×)																
41. *N. douvillei* Ozawa	(×)																		[×]			(×)				(×)			
42. *N.* sp.							◉	×	○		×	×	◉	(○)	(×)	×	[×]	○	×				(◉)			(×)			
43. *Yabeina shiraiwensis* Ozawa	×																						[○]			×	[◉]		
44. *Y. yasubaensis* Toriyama																							[×]		×	×			
45. *Y.* cf. *gubleri* Kanmera		×																											
46. *Y.* sp.															×							×	[×]	×		×	[○]		
47. *Afghanella* sp.																					(×)								
48. *Sumatrina annae* Volz																						◉		[○]					
49. *S. annae* var. *stricta* Deprat																						◉							
50. *S. annae* var. n. var.																						◉		[×]					
51. *S.* sp.															×												[×]		

Permian	Upper	*Yabeina* zone	*Yabeina shiraiwensis* zone	Puα
	Middle	*Neoschwagerina* zone	*Neoschwagerina douvillei* subzone	Pmδ
			Verbeekina verbeeki subzone	Pmγ
			Neoschwagerina craticulifera subzone	Pmβ
		Parafusulina zone	*Parafusulina kaerimizensis* subzone	Pmα
	Lower		*Pseudofusulina ambigua* subzone	Plγ
		Pseudoschwagerina zone	*Pseudofusulina vulgaris* subzone	Plβ
			Triticites simplex subzone	Plα
Pennsylvanian	Upper	*Triticites* zone*		Cu
	Middle	*Fusulina* zone*		Cmγ
		Fusulinella zone	*Fusulinella biconica* zone	Cmβ
		Profusulinella zone	*Profusulinella beppensis* zone	Cmα
	Lower	*Millerella* zone*		Cl

◉ abundant ○ common × rare

Species in ( ) are those found only in pebbles of limestone conglomerate.

Fusulinid zones with asterisk (*) are not found in the Akiyoshi limestone group.

Species in [ ] are those found both in pebbles and matrix of limestone conglomerate.

Triassic Mine series. In these limestone conglomerates are found so many species of fusulinids that might have been derived from various horizons of the Akiyoshi limestone group. If the Akiyoshi limestone group is autochthonous or para-autochthonous a question will be raised as to whether two facies of marked contrast could have been continuously existed from the Pennsylvanian to the Permian time side by side within a sedimentary basin. Much more study will be need.

(9) It is also assumed that the Permian sea was most widely spread in the Early Permian time. The basin was then gradually elevating by some epeirogenic movement until at least some part of it emerged above the sea at the end of the Middle Permian time. The Upper Permian sea again spread over the basin, although it was not so deep as in the Early Permian time, for the Upper Permian deposits suffered wave action or submarine erosion during their deposition. The epeirogenic movement in the Middle Permian time may be of the same age as the Usuginu epeirogenesis in the Kitakami massif of Northeastern Japan.

(10) The main tectonic events which occurred succesively in this district may be summarized as follows:

[1] The epeirogenic movement in the Late Pennsylvanian time.
[2] The Early Permian transgression.
[3] The epeirogenic movement in the Middle Permian time.
[4] The late Permian transgression.
[5] The Akiyoshi orogenic movement in the Middle Triassic time, by which all Paleozoic rocks in this district were strongly folded.
[6] The Oga orogenic movement in the latest Jurassic time, when strong overthrustings deformed not only the Akiyoshi limestone group but also non-calcareous facies.

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Part I and Part II completed.

Part III to be continued.

List of Locality

Locality name in quotation mark is a local name which is not printed in the topographical maps of Yamaguchi (山口), Ogori (小郡), Nishiichi (西市), and Funaki (船木) in scale 1 : 50,000.

A

Abu-gun	阿武郡
Aigyo	相行
Akago-mura	赤郷村
"Akanta-yama"	あかんた山
Akiyoshi	秋吉
Amagoi-yama	雨乞山
Arataki	荒滝
Arataki-yama	荒滝山
Asa-gun	厚狭郡
Asa, River	厚狭川
Asao	朝尾
Ayagi-mura	綾木村

B

"Benkei-yama"	弁慶山
Beppu-mura	別府村
Byodare	see Hirano

C

Choegoe	町絵越
Chojagamori	長者ケ森

D

Dai	台

E

Edo	絵堂

F

Fujigakochi	藤ケ河内
Fumoto	麓
Futagami	二神

G

Gampi-san	雁飛山
Gomigahara	五味ケ原

H

Hagiwara	荻原
Hanao-san	花尾山
Handa	半田
Hase	長谷
Higashibun	東分
Higashishibukura	東渋倉
Hinaga	日永
Hinotake	日ノ岳
Hirakunigi	平国木
Hirano (formerly Byodare)	平野（旧平下）
Hiranobashi	平野橋
Hisage	久下
Hosoono	細小野

I

Imaono	今小野
Irimi	入見
Isa-machi	伊佐町
"Iwanagadai"	岩永台
Iwanaga-hongo	岩永本郷
Iwanaga-mura	岩永村
Iwanami	岩波
Iwaseto	岩瀬戸
"Iwayama"	岩山

J

Jigokudai	地獄台

K

Kaerimizu	帰リ水
Kagekiyo-cave	景清洞
Kajiya	鍛冶屋
Kamiryo	上領
Kamitashiro	上田代
Kamiyae	上八重
Katada	堅田
Katsurazaka	桂坂
Kawarakami	河原上
Kibe-mura	吉部村
"Kirigadai"	霧ケ台
Kobayashi	小林
"Komizu"	小水
Konokami-yama	甲ノ上山
Koto, River	厚東川
Kuroiwa	黒岩
Kuwabara	桑原
Kuzegahara	九瀬ケ原
Kyowa-mura	共和村
Kyozuka	経塚

M

Maki	真木
Managatake	真名ヶ岳
Manko	万光
Maruyama	丸山
Minamikochi	南河内
Minami-omine station (formerly Isa station)	南大嶺駅 (旧伊佐駅)
"Minami-yama"	南山
Miyama	御山(綾木村)
"Miyama"	御山(大嶺町)
"Mizunashi"	水無
Mizuta	水田
Mugikawa	麦川

N

Nakamura	中村
Narutaki	鳴滝
Nishihata	西畑
Nishiichi-machi	西市町
Nishishibukura	西渋倉
Nozako	野迫
Nukuyu	温湯

O

Ofuku	於福
"Ofuku-daiyama"	於福台山
Ofuku-mura	於福村
Ojigase	祖父ヶ瀬
Okotsu	大木津
Okubo	大久保
Okugawara	奥河原
Omine-machi	大嶺町
Onbo	御坊
Oniana	鬼穴
Ono	小野
Ota-machi	大田町
Ota, River	大田川

R

Ryugenji	龍現寺
"Ryugoho"	龍護峯

S

Saigato-pass	才ヶ峠
Sakamizu	坂水
Sakobata	目畑
Sakura-yama	桜山
"Sanbonmatsu"	三本松
Sayama	佐山
Sasanami-mura	佐々並村
"Sebato"	せばと
Serita	芹田
Sesegawa	瀬々川
Seto	瀬戸
Shigeyasu	重安
Shikanode	鹿出
Shimoyae	下八重
Shimoyama	下山
Shiraiwa	白岩
Shiromaeyama	城前山
Shiroyama	城山
Shishidedai	猪出台
Shohoji	正法寺
Sohara	曾原
Suhojin	周防陣
Sunaji	砂地

T

"Takayama"	高山(共和村)
Takayama	高山(綾木村)
Takiguchi	滝口
"Tanaiwa"	棚岩
Tateishi	立石
Tobinosu	鳶ノ巣
Toriyama	通山
Toyora-gun	豊浦郡
"Tsuguneno-atama"	つぐねの頭
Tsunemori	常森
Tsuzumigatake	鼓ヶ岳

U

Ueno	上野
Ueyama	植山

Y

"Yaegahara"	八重ヶ原
Yaguchi	矢口
Yakegakochi	焼ヶ河内
Yakuoji	薬王寺
Yamada	山田
Yamazuyu	山露
Yobara	江原
Yobiiwa	呼岩

Z

Zuitoku	随徳