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The Permian Maizuru Group, its Stratigraphy and Syntectonic Faunal Succession through the Latest Paleozoic Orogeny

By

Daikichiro SHIMIZU

Geological and Mineralogical Institute, University of Kyoto

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Abstract

The Permian Maizuru Group in the Maizuru Zone, southwest Japan, is generally described, and classified into five lithofacies. In this group, also, five faunules—two fusulinids- and three brachiopod-molluscan-faunules—are distinguished and their stratigraphic relations are discussed. This group is correlated to the middle to upper Permians in Japan and Asia. Faunal succession is discussed with paleogeographic aspects in the latest paleozoic orogeny.

I. Introduction

Japanese paleozoic formations in areas all over Japan have been studied for years since the beginning of geological studies in this country. In particular, enormous transactions concerning the southern Kitakami Mountains were presented. After that, several features of the orogenic movements in the paleozoic era have been made clear. With regards to the late Permian orogeny, MINATO proposed a paleogeographic view of the Toyoma Inland Sea, which was surrounded by uplifting lands and deposited with black mud. This Toyoma series contains poor fossils (some *Berellophon* and other gastropods), although formations lower than this are rich in fossils of brachiopods, fusulinids and many other animals.

On the other hand, in southwest Japan, the problem is more complex. Noncalcareous rocks forming almost the entire part are poor in fossils, and small areas are occupied by fossiliferous limestone plateaus. After a number of studies were carried out on these paleozoic and mesozoic formations, some orogenic hypotheses were proposed, and also denied by others. Nevertheles, that there is a stratigraphic break between some Permian epoch and some Triassic epoch was supported by many geologists, and its minute profile was discussed. Besides, a characteristic late Permian formations is found, as the Kuma formation in Kyushu. Similar formations are also discovered in Shikoku

and the inner side of southwest Japan. These formations are characterized by peculiar lithologic features and a fusulinid faunule—namely *Lepidolina* faunule—in all cases. They are composed of black shale, greywacke sandstone and conglomerate. By fossil evidences they are assigned to the uppermost part of the Permian. They are found to be distributed in narrow zones, and have some tectonic significance like the Kurosegawa Tectonic Line in Shikoku. Geologists, who have studied these formations estimate that, these late Permian formations must be a product of the late Permian orogenic movement around the Japanese Islands. Unfortunately, the Kuma and other correlative formations in Kyushu and Shikoku have no stratigraphic relation with other upper or lower formations

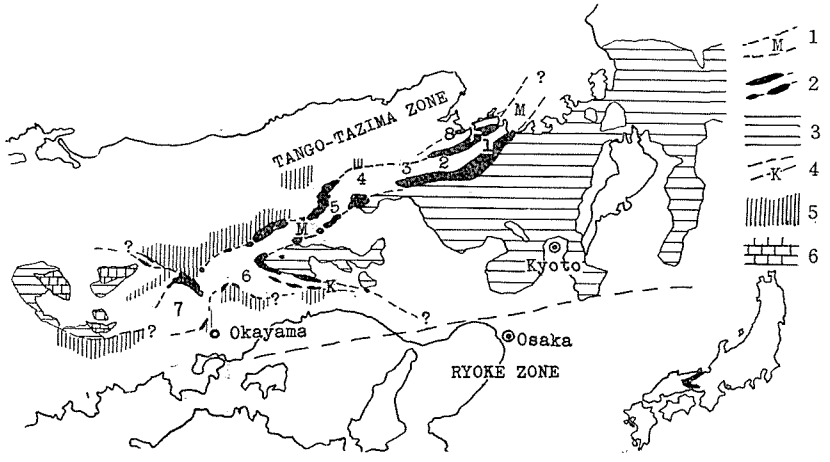


Fig. 1. General Map of the Maizuru Zone.

Legend 1. Maizuru Zone, 2. Yakuno Intrusive Rocks & Complex,
3. non-metamorphic Paleozoics of the Tanba Zone and other Regions,
4. Kamigori Zone, 5. Sangun Metamorphic Rocks.
6. Limestone Plateaus.

Districts. 1. Maizuru, 2. Ôe (Kawahigashi & Kawanishi), 3. Yakuno, 4. Miharaiyama, 5. Mikata, 6. Fukumoto, 7. Kanagawa (Mitsu), 8. Shidaka.

excepting faults, and they have no effective fossils except fusulines and corals. In short, these late Permian formations are not appropriate for analysing the faunal and stratigraphic development in the late Permian.

The Maizuru group, now discussed, is capable of providing much information on these stratigraphic and faunal successions along the orogenic movement. Especially, this group is deeply influenced by subtectonic igneous activities, which signifies more important tectonic effects. Since the beginning of geologic studies of the Maizuru Zone, Triassic geohistory has been described accurately and summarised by NAKAZAWA and others (1958), but that of the Permian has

remained as an unsolved problem. The Permian stratigraphy and fossils of some districts of the Maizuru Zone were noticed and described briefly by them before. Fossils were dealt with and many transactions have been published. NOGAMI's studies on fusulinids, NAKAZAWA's studies on the pelecypods and also SHIMIZU's studies on brachiopods have been presented. Also, the petrography of sandstone and other sedimentary rocks has been studied by SHIKI, and the sedimentary environment based on these has been discussed. Provenances of pebbles, especially of intrusive rocks, of conglomerates in this group have been estimated and discussed in relation to the Yakuno Intrusive Rocks. Much information has been obtained and we are now in a position to sum up these materials into a synthetic view of geohistory. Of the many problems concerning the Maizuru group, the writer intends to deal with its stratigraphy and fanules, especially of brachiopods and molluscas, and make clear their succession in connection with the tectonic development of this zone in the late Permian Period.

In the first chapter, the stratigraphy in the Mikata District, Hyôgo Prefecture will be described, and in addition, the stratigraphy in other districts will be referred to briefly. In the succeeding chapters, the Maizuru group will be divided according to its lithological and faunal aspects in mutual relationship, and then the biostratigraphy as well as the correlation will be discussed. The faunal succession and its relation to paleogeographic development and tectonics will be discussed in the last chapter.

The writer wishes to express his thanks to Prof. S. MATSUSHITA of Kyoto University for his kind encouragement and critical reading of the manuscript. He is much indebted to Asst. Prof. K. NAKAZAWA of the same University for his guidance and advices given throughout the study. Dr. T. SHIKI and Dr. Y. NOGAMI collaborated with the writer in field work and kindly joined in discussion. The writer also thanks to Mr. Y. SHINAGAWA and other friends for their kind help.

II. The Maizuru Group in the Mikata District, Hyogo Prefecture

This group was named and briefly described from the Maizuru District, Kyoto Prefecture by NAKAZAWA and OKADA (1949). Since then, this group in many districts of Okayama, Hyogo and Kyoto Prefectures has been discussed briefly by NAKAZAWA, SHIKI, SHIMIZU and NOGAMI. A good stratigraphic succession, however, has not been found, and this group in these district is not suitable for analysing its properties. For these reasons, these investigators surveyed the Maizuru District. The writer also intends to make clear the stratigraphy in the Mikata District, Hyôgo Prefecture. In the following part, the stratigraphy of the Maizuru group in this district will be discussed, and in addition, the Maizuru group in the other districts will be cited.

Former works:

In 1896, KOCHIBE surveyed this area for the geological map sheet "Ikuno" (in scale of 1:200,000), and described the "Mesozoic" formation from this. Recently, a survey for the geological map sheet "Ôyaichiba" (in scale of 1:50,000) was made. In the explanatory text of this sheet, HIROKAWA and KAMBE described the upper Paleozic "Akenobe" formation in this district, as follows.

"The Akenobe includes phyllitic clay slate, clay slate, sandstone, conglomerate, calcareous clay slate and limestone, variable in rock facies in places. The limestone and calcareous clayslate yield the fauna including Brachiopoda, Crinoid stems and Bryozoa. Crinoid stems are also found in some coarser-grained sandstone, and indeterminable Fusulind was discovered from some calcareous conglomerate sandstone,—". This "Akenobe" formation and the "Ôya" formation in the northern part of this sheet, have the same characters as the Maizuru group of the Maizuru District, Kyoto Prefecture., and must be equivalents of the latter. For that reason, the names of "Akenobe" and "Ôya" formations have been abandoned, and they are now included in the Maizuru group.

Stratigraphy:

The Permian Maizuru group in this district is composed of the following formations. In the course of study, it has been found that a part of the "Akenobe" formation is lower-middle Triassic System, yielding fossils of *Neoschizodus* and *Nuculana*, and have been separated from the Maizuru as the Kamikishida formation.

1) Iuchi Formation : Schalstein with phyllitic slate; no fossils—probably Middle Permian
2) Mikata Formation : Black slate with limestone lenses, fusulinid and brachiopoda etc.—Middle Permian
3) Yokoyama Formation: Sandstone and shale alternation with conglomerate; fusulinid fossils—Upper Permian
4) Kuratoko Formation : Graded alternations of shale to sandstone; no fossil—probably Middle to Upper Permian.

These formations form a syncline with Triassic Kamikishida formation, and is separated from each other by faults. They are generally extended in NE-SW trend, and bordered by Yakuno Intrusive Rocks on both sides.

Iuchi Formation:

This formation is a part of "Diabase" described in the geological map sheet "Ôyaichiba". Its explanatory text suggests that the "Diabase" might be divided

still further. In fact, the writer also, has found by his study, that the "Diabase" can be divided into evidently volcanic and sedimentary formation and intrusive diabase bodies. The latter intruded into the former and other paleozoic formations. In appearance, this formation is composed of meta-diabase with many tabulate joints, black slaty shale bed, tuffacious bed and rarely sandstone and siltstone. Black slates are phyllitic, and generally form thin layers and alternate with schalstein. In Omidani, this formation contains a conglomeratic layer of schalstein, which is greenish or sometimes reddish in color. Pebbles are angular and generally 3 cm. or less than 10 cm. in diameter and are of black phyllitic slate, diabase, crystal of quartz and acidic volcanic rocks etc.. This bed changes laterally into schalstein with pebbles of black shale. At Iuchi, this formation is about 350 m. thick, and at Ômidani, it has a thickness of about 500 m..

This formation has no observable stratigraphic relation with other formations and no fossil. Such being the case, the geological horizon of this formation is not clear. But judging from the fact that this formation is more metamorphosed than the other formations and is rich in schalsteins which are almost restricted to the middle or lower Permian or still lower horizons throughout Japan, the Iuchi formation is probably correlated to the middle Permian system. The upper part of this formation is composed of slate and sandstone at Iuchi, and it resembles a part of the Mikata formation. It is probable that the Iuchi formation forms a lower horizon than the Mikata formation. In the Maizuru District, whose Maizuru group will be described in the following chapter, the schalstein formation is overlain by the slate with limestone formation.

Mikata Formation:

This formation is mainly composed of black shale, slate and siltstone. Calcareous rocks are intercalated in them, forming lenses of black oolitic or massive limestone, calcareous shale and siltstone alternating in thin layers (thickness is generally several dm. or about 1 m. at most). The lens of calcareous rocks, as a whole, is about 20 m. thick and 30–40 m. long. Black slates are in some cases phyllitic, but calcareous rocks are massive and broken up into angular fragments with keen cracks. Coarse grained rocks are rather well-sorted and colored dark grey. The uppermost layer of this formation has many small discoidal pseudo-pebbles of sandstone (ca. 2 cm. in length and 5 mm. in thickness). These pebbles are arranged along the bedding plane of black slate. In some parts, conglomerate layers are intercalated in slate, and have round pebbles of chert and granite with a diameter of less than 10 cm.. Thickness of conglomerate is 1 m. or so, and its upper and lower parts change gradually into black slate or siltstone with pebbles.

This formation occupies the southern part of the district from Mikatamachi to Kamikishida. Limestone lenses are found at the east of Mikatamachi, at Ochiyama and at the south of Kamikishida. Those of the first named place

were described in the text of the "Ôyaichiba" sheet, as yielding fossils of many crinoid stems, bryozoa and brachiopod. The limestone lenses of Ochiyama yield the following fossils.

Palaeofusulina sinensis
Spiriferina aff. *cristata*
Hustedia sp.
Bayozoa
Crinoid stems

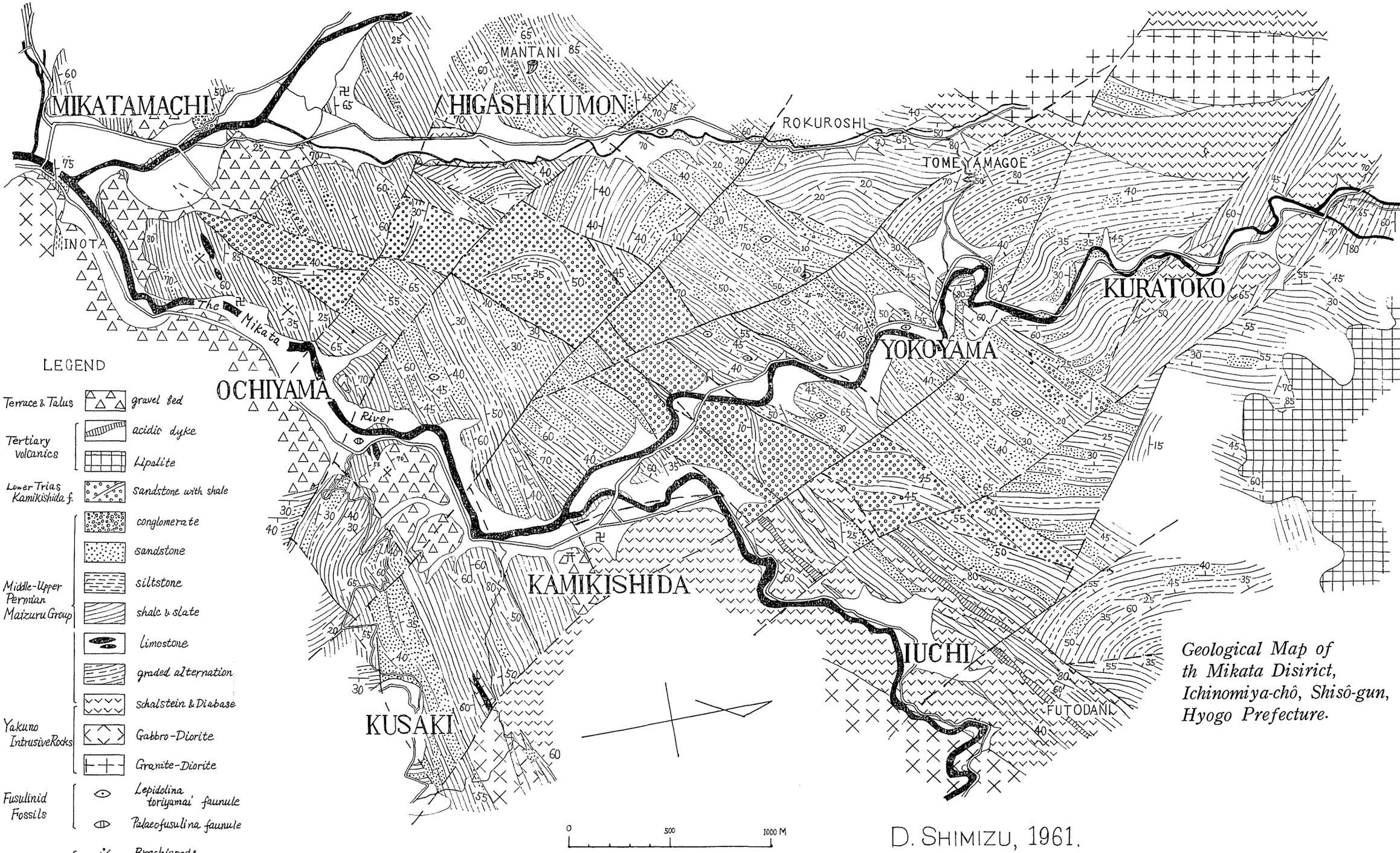
The fusuline was collected from a small dark limestone lens and the others from calcareous shales. At 850 m. west of this place, in a calcareous shale, *Eolyttonia nakazawai* subsp. together with many bryozoas were collected. The exact locality of this fossils is not known but it is probably somewhat higher than the horizon of Ochiyama limestone (see geological map). Limestone lens at the south of Kamikishida has no determinable fossils.

The lower part of this formation is not exposed owing to a fault, while the upper limit is conformably overlain by the Yokoyama formation. Thickness is measured 500 m. or more.

Yokoyama Formation:

This formation is composed of conglomerate, granulic sandstone, coarse to fine sandstone, siltstone, silty shale and shale, but of no limestone, no schalstein nor chert. Coarse grained facies are all of greywacke type and black-colored. These layers alternate with each other in thick or thin beds, and are small in lateral continuence. Conglomerate is thin and not persistent. It has much matrix of black mud (shale). The boundary between conglomerate and other layers is not obvious, in short, conglomerate is a part of shale or sandstone with much pebbles. Pebbles are subangular and usually have a diameter of a few cm., or less than 30 cm.. Pebbles are of black shale, siltstone, sandstone, green translucent chert-like rock, white chert, felsite, quartz porphyry and limestone. Of those, shale and sandstone are abundant and the others are rare. Discoidal pseudo-pebbles of shale less than 1 cm. in diameter are contained in some sandstones. Limestone pebbles are rare, and they are of two types; dark-colored and white-colored. The former are rather abundant but contain no fossil, and the latter are very rare, but contain fossils of indeterminable fusulines. Patches of pseudo-pebbles of limestones are intercalated in conglomerate or shale. They are less than 10 cm. in diameter and colored dark and have no fossils. On the other hand, in matrix of conglomerate fusulines of *Lepidolina toriyamai* faunule are contained. The crinoid stems are also found in matrix.

Granulic conglomerate with fusuline fossils is the most remarkable member of this formation. This rock is typically greywacke type with many rock fragments such as black shale, limestone, green tuffacious rock, felsite, chert and acidic volcanic rocks etc.. Of these, pebbles of black shale and limestone are numerous. The latter has no fossil except smaller foraminifera. Matrix



Geological Map of th Mikata Disirict, Ichinomiya-chô, Shisô-gun, Hyogo Prefecture.

D. SHIMIZU, 1961.

Fig. 2

of this bed is black mud and of small amount. Some calcareous parts of this bed yield fusulines and form small irregular lenses in other beds. Fusuline bearing granulic conglomerate changes into the most coarse-grained part of sandstone. In common sandstone of this formation, fusuline fossils are also found, but they are fragmental. Fusulines are commonly found among granules which have equal or nearly equal size with fusuline fossils. Crinoid stems and bryozoas are found in this rock.

Sandstones vary in grain size from granule to very fine, and are of large quantity in this formation. All the features are similar to those of granulic conglomerate, but limestone pebbles are rare. Sandstone forms matrix of conglomerate, and sometimes changes into siltstone or alternation with other layers.

Siltstone and shale are most common in this formation, and siltstone is more abundant of the two. They alternate with each other in thin beds or lamina, but graded bedding is rare. These layers are less metamorphosed than those of the above mentioned Mikata formation. They form a massive block and are broken into angular bodies. Except near faults, slaty cleavages are not developed.

The Yokoyama formation lies conformably on the Mikata formation at the north of Ochiyama. It comes in contact with the Iuchi and Kamikishida formations by faults. This formation is distributed on the north and south side of the Kamikishida formation, and forms, as a whole, a syncline having NE-SW trend.

The maximum thickness of this formation is measured at 500 m..

Fusuline fossils contained in granulic conglomerates are not preserved in complete form, and all of these lack their outmost whorls, or are more or less fragmental. They are found individually among other pebbles in matrix. NAKAZAWA considered that these fusulines are not pebbles, but contemporary sediments which were transported from their living position and deposited in the beds. They are poorly preserved, especially at inner volutions. Their species are as follows.

Yabeina shiraiwensis
Yabeina cf. *gubleri*
Yabeina cf. *columbiana*
Yabeina sp.
Lepidolina kumaensis
Lepidolina toriyamai
Lepidolina toriyamai maizurensis
Neoschwagerina ? sp.
Pseudodoliolina gravitesta
Codonofusiella cuniculata
Schwagerina aff. *acris*
Schwagerina sp.

This faunule is quite identical with that of the other destrict in the Maizuru Zone and that of the Kuma formation in Kyushu. *Neoschwagerina* is not con-

tained in that of the Kuma formation and very rarely found in the Maizuru group. In this district, only one specimen of doubtful *Neoschwagerina* was obtained.

Kuratoko Formation:

In this formation, black shale and siltstone with sandstone alternate in thickness of about 1 m.. In some cases, the thickness is less than 10 cm.. It is very characteristic of this formation that graded bedding with a thickness of several tens of cm. or less than 10 cm. is common in all the distributions. Lithological features of sandstone or shale are very similar to those of the Yokoyama formation and some parts of the Mikata formation. Laminations or beddings are very distinct, but cleavages and joints are not developed.

This formation is distributed on the north side of the Yokoyama formation but possesses a nearly N–S strike and inclines steeply. It is in contact with the other formations by faults. No fossils are collected from this formation and correlation is not possible. As for the lithologic similarity with the other formations, it is presumable that this formation is a stratigraphic equivalent of the Yokoyama and the Mikata formations, in other words, a different facies of them.

Thickness of this formation is measured at 400 m. or more.

Correlation:

Fossil evidences of this group are presented in the Mikata and the Yokoyama formations, and the Iuchi and the Kuratoko formations have no fossils.

In the Mikata formation, brachiopods and fusulines are collected. Of which fusuline *Palaeofusulina sinensis* from a limestone is identical to that of the Changsing Limestone of the Loping Series in south China, which is overlain by Triassic thin bedded limestone and underlain by the Loping Coal Series and the Chihsia and the Maokou Limestones with *Verbeekina-Neoschwagerina* Zone. SHENG suggested that this *Palaeofusulina* Zone of China is most probably equivalent to the *Polidiexodina* Zone of North America, but this correlation is doubtful. According to the writer's studies on brachiopod fossils of the Maizuru group, the Takauchi fauna and the Kawahigashi fauna are referable to the Loping fauna. The Kawahigashi fauna has a similar stratigraphic value as that of the *Lepidolina toriyamai* fauna. The Mikata formation is overlain conformably by the Yokoyama formation which contains *Lepidolina toriyamai* faunule, and accordingly the Mikata formation can be correlated to the upper part of the Middle Permian (probably *Yabeina* Zone).

Brachiopods of this formation are not sufficient for determing the age, but *Eolyttonia nakazawai* subsp. is most referable to that of the Kawahigashi faunule collected at Yakuno.

As conclusion, the Mikata formation can be correlated to the upper part of the Middle Permian, and the upper part of this formation may be correlated to the Upper Permian.

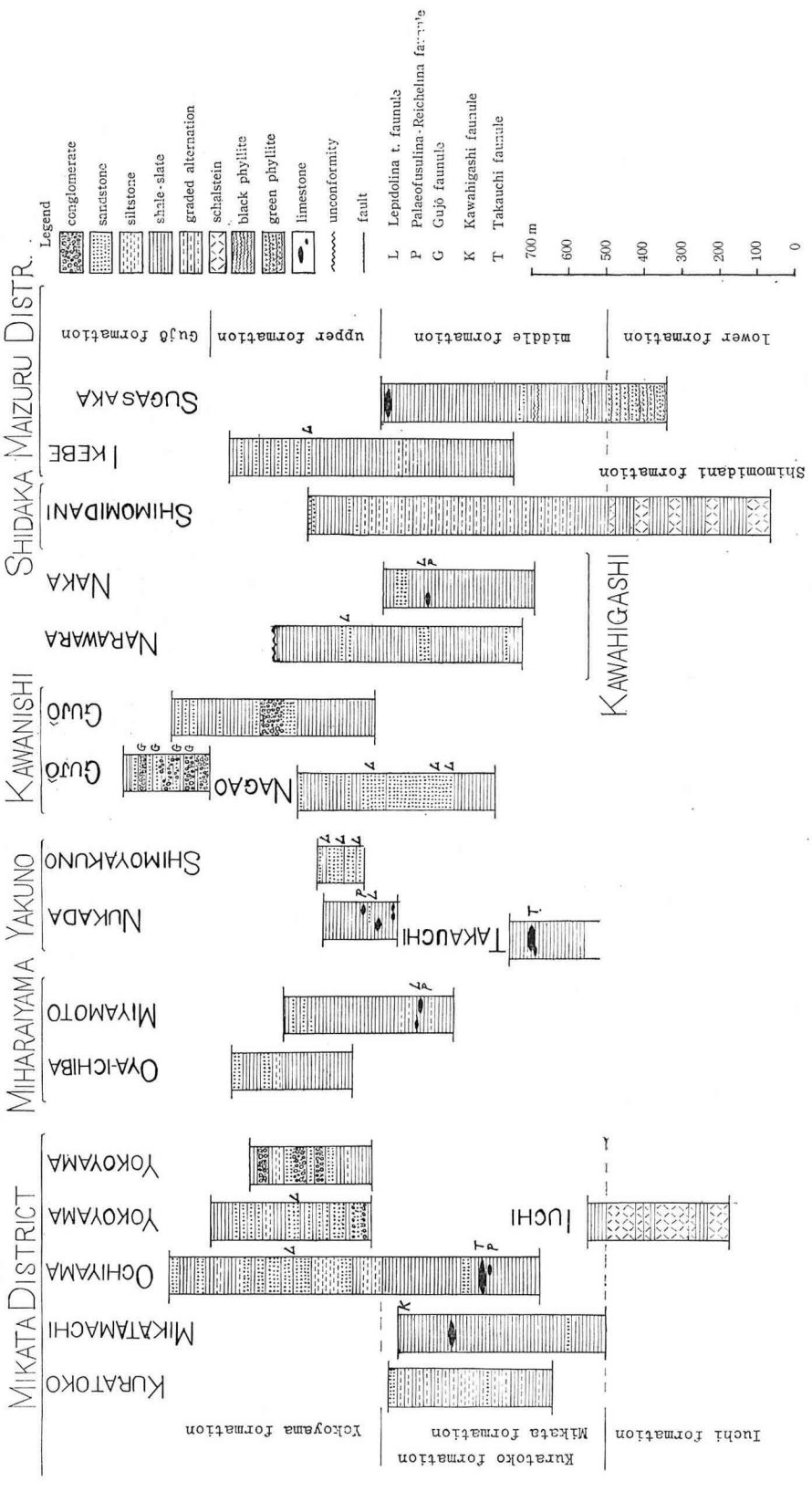


Fig. 3. Columnar Sections of the Maizuru Group.

The Yokoyama formation is characterized by many fusuline fossils of *Lepidolina toriyamai* faunule, and, as described by NOGAMI (1958, 1959), is quite identical to that of the Upper Permian Kuma formation in Kyushu. Brachiopod fossils are not collected from this formation. A coral *Waagenophyllum* sp. is collected from calcareous granule-stone at Mantani of Higashikumon, and according to YAMAGIWA (1960), it resembles *W. indicum* or *akasakensis*, but is indeterminable.

III. The Maizuru Group in other Districts

1. Fukumoto District, Okayama Prefecture.

A non-metamorphic paleozoic formation in the Fukumoto District, Aita-gun, Okayama Prefecture, together with several Triassic formations, were decribed by NAKAZAWA, SHIKI and SHIMIZU (1954), and named the "Kose" group. This group is composed of black shale to silty shale, and rarely of sandstone and lenticular conglomerate. Shales are generally bedded in layers several cm. to 10 cm. thick, and never change into slate. Conglomerate has many pebbles of black shale, chert, limestone, sandstone, andesite, andesitic tuff, biotite granite, gneissose diorite and quartz porphyry with a diameter of 0.5 to 0.3 cm.. Shale pebbles are most abundant, and judging from their angular form, are most probably contemporaneous erosin pebbles. In groundmass of conglomerate, fusulines of *Lep. t.* faunule are collected. They are *Lepidolina* sp., *Yabeina* sp., *Schwagerina* sp., and *Nankinella* ? sp.. Similar paleozoic formations are distributed near this district, that is, the famous Dôdo conglomerate reported by KONISHI and non-metamorphic black shale formation around Yanahara Mine doubtlessly belong to the same group. Since the "Kose" group is similar to the Maizuru group in many features, the name "Kose" group must be abandoned.

2. Miharaiyama District, Hyōgo Prefecture.

NAKAZAWA and SHIKI (1954) described the "Minamidani" group in the Miharaiyama District of northern Hyōgo Prefecture, composed of sandstone, shale, conglomerate and limestone. From calcareous granulic conglomerate, many fusulines are collected, by which this group can be correlated to the Upper Permian Kuma formation of Kyushu. From limestones of this group, especially those at Miyamoto of Ôya-cho (formerly Minamidani-mura), some indeterminable fusulinids and corals were reported by them. Recently SHIKI and the writer collected from the same limestone many fusulines belonging to two fossil groups. One group is an assemblage of *Lepidolina* sp. (probably *Lepidolina toriyamai* or *kumaensis*) with *Codonofusiella cuniculata*. The other group contains *Palaeofusulina* cf. *sinensis*. The former fossils are irregularly deformed in calcareous shale, but the latter is not deformed in limestone. These two groups are not collected from out-crops but are found in other cobbles probably derived from a very narrow area. They were probably contained in

different but very nearly situated limestone masses. In short, they are not the same as the faunal element but show very similar stratigraphic value.

To the south of the main distribution of this group, basic rocks with several rock features extend. Some parts show schalstein-like features and are assumed to lie conformably below the "Minamidani" group proper. This rock must be a menber of the paleozoic, and should be included in the Maizuru group with the "Minamidani" group. This schalstein formation and slaty facies with limestone occupy the southern border of the Maizuru group and coarser facies with *Lepidolina toriyamai* faunule is distributed to the north of them.

The Maizuru group in this district is obverlain by the Triassic Yakuno group (formerly Miharaiyama group) with unconformity.

3. Yakuno District, Kyoto Prefecture.

In a previous description of the paleozoic and mesozoic formations in this district, NAKAZAWA, SHIKI and the writer (1957) named the paleozoic formations in the southern border of the Triassic Yakuno group the Nukada formation. Afterwards, the writer separated it into two formations, the Nukada and the Takauchi formations (1961).

The Nukada formation is composed of shale, sandstone, conglomerate and limestone lenses, and contains fossils in some beds. From granulic conglomerate *Lepidolina toriyamai* faunule are collected, and from calcareous sandstone brachiopods of the Kawahigashi faunule and from limestone lenses many gastropods (*Bellerophon, Bucanopsis* and *Pleurotomaria*) with Dentalium are collected. At Kashiwadani of Nukada, *Reichelina matsushitai* is collected from a small limestone lens neighbouring granulic conglomerate, from which *Lepidolina toriyami* faunule is found.

The Takauchi formation is composed of slate and limestone and separated from the Nukada formation by other rocks. From Takauchi limestone we collected brachiopod of the Takauchi faunule with *Leptodus richthofeni*.

These two formations have no lithologic similarity and no stratigraphic relation, but it is evident from the fossil species that the Takauchi formation occupies a horizon lower than the Nukada formation in the Maizuru group.

4. Kawanishi District, Kyoto Prefecture.

The Gujô formation and the "Maizuru Group" proper form the Maizuru group in this district. The former had been reported as Triassic with peculiar fossils, but was recently corrected to Permian (NAKAZAWA, 1951; NAKAZAWA and NOGAMI, 1958).

This Gujô formation is characterized by frequent alternations of conglomerate, sandstone and shale. In this formation, we find rapid laterl changes of lithofacies and in some cases contemporaneous erosion, and it is presumable that this formation was formed in a deltaic or fan-like condition. Conglomerates are similar to those of the "Maizuru group" proper, but pebbles are more

angular. Sandstones also resemble those of the "Maizuru group". Shales are massive with somewhat greenish color, and rerely bear nodules. Fossils are accumulated in thin beds or fossil-banks. They are named the Gujô faunule, and composed of many pelecypods, gastropods and a few brachiopods and bryozoas (NAKAZAWA, 1959, 1960; SHIMIZU, 1961).

The "Maizuru Group" proper is distributed on the north side of the Gujô formation and the Trissic Yakuno group, and composed of shale, sandstone and conglomerate. Near Gujô, abundant conglomerates are found containing many sub-angular pebbles of chert, sandstone, shale, limestone, trachy-andesite, porphyrite and granitic rocks (sheared adamelite, granophyre and others). Rarely, spilite, diorite and quartz diorite are contained.

Fossils of the "Maizuru group" proper are collected from calcareous granulic conglomerate as *Lepidolina toriyamai* faunule. Among the pebbles of conglomerate, some limestone pebbles yield fusuline fossils, such as *Neoschwagerina margaritae*, *Neosch.* cf. *simplex*, *Neosch.* cf. *douvilleri*, *Schwagerina* sp. *Pseudodoliolina* sp., *Fusulinella* sp., and corals *Siphonodendron nakazawai* and *Waagenophyllum* sp.. These derived fossils prove that the *Lepidolina toriyamai* faunule is higher than *Neoschwagerina* Zone and higher even than *Yabeina* Zone. (NOGAMI, 1958, 1959)

5. Kawahigashi District, Kyoto Prefecture.

The Maizuru group in this district is intercalated as a narrow area in a lenticular distribution of the Triassic Yakuno group. On the other hand, it is distributed in a rather wide area surrounding the Triassic and in the north and south borders on the Yakuno Intrusive Rocks. This group is composed mainly of muddy shale with sandstone, granulic conglomerate and limestone lens. Along the southern border of distribution, slaty facies with limestone lenses extends in E-W direction and sandstone and granulic conglomerate are intercalated. This group among the Triassics is composed of alternations of shale, sandstone, granulic conglomerate and conglomerate. The northeastern part of this district is characterized by a rather much-graded alternation of sandstone to shale with lenticular sandstone and conglomerate.

Many fossils are collected as reported. They are fusulinids of *Lepidolina toriyamai* faunule, brachiopods, molluscas and trilobites of the Kawahigashi faunule and *Reichelina*. The last fusuline is obtained from a limestone near the southern borders. This species is identical to that of the Yakuno District, and is likewise bordering the *Lepidolina toriyamai* faunule but is never associated.

This group is covered by the lower Triassic group with unconformity.

6. Maizuru District, Kyoto Prefecture.

This district is a type locality of the group and was described briefly by NAKAZAWA and OKADA. Their report was brief as regrads type locality, so NAKAZAWA, SHIKI and the writer restudied its strstigraphy in 1960. According

to them, the group in this district is divided into the following three formations.

The upper formation:

Sandstone and shale alternation with conglomerate containing *Lepidolina toriyamai* faunule.

The middle formation:

Black shale or slate with limestone lenses and, rarely with conglomerate; bearing coral (*Waagenophyllum* ? sp.) and bryozoa in limestone.

The lower formation:

Green schalstein with black slate, partly phyllites. A coral fossil (Lophophyroid) has been obtained.

The relation between the formations is conformable, and the degree of metamorphism increases in the same direction. This succession is similar to that of the Mikata District, and is apparently general in stratigraphy in the Maizuru Zone. But this is restricted only to the southern part of the Zone, and in the middle and the northern parts the succession shows other features.

7. Shidaka District, Kyoto Prefecture.

Paleozoic formations in this district were described by KAMBE (1950). According to him the formation are divided into the upper and the lower formations. The upper one is characterized by alternations of sandstone and shale with "*Neoschwagerina*" limestone. The lower one is composed of siliceous shale and chert. His "*Neoschwagerina*" limestone was proved to be nothing but calcareous granulic conglomerate with *Lepidolina toriyamai* faunule. KURODA (1960) named the upper formation the "Maizuru Group" and the lower formation the Shimomidani formation. He noted many schalstein beds in the formation and also red chert beds. According to SHIKI's and the writer's observations, the "Maizuru Group" is characterized by graded-bedding-alternations of shale to siltstone or sandstone. Fusuline fossils are obtained from granulic conglomerate which is intercalated in sandstone or shale and never found in graded beds. It is noticeable, that these fossil-bearing beds are restricted to uppermost part of the "Maizuru Group." The Shimomidani formation rather resembles the schalstein beds like the Iuchi formation of the Mikata District, and can be correlated to the latter. Below these schalstein beds in the Shimomidani formation, thick slate or shale beds lie conformably.

The lower Triassic Shidaka group overlies these paleozoic formations with unconformity, and its basement rocks are schalstein menbers of the Shimomidani formation and the Yakuno Intrusive Rocks (granite) which intruded into paleozoics (NAKAZAWA, KANÔ and SHIKI, 1961).

8. Nabae District, Fukui Prefecture.

This district is a type locality of the upper Triassic Nabae group and is situated on the eastmost part of the Maizuru Zone. In this district, fossils of *Lepidolina toriyamai* faunule and a coral *Wentzellella nabaensis* have been col-

lected from a calcareous conglomerate (or muddy limestone in broader sense) (YAMAGIWA, 1960). From a conglomerate an ammonite (*Stacheoceras* ? sp.) has been obtained (HIROKAWA and KURODA, 1957). (This specific name is used according to KURODA's personal communication)

9. East of Yamasaki-cho, Hyogo Prefecture.

A Triassic ammonite *Glyptophiceras* has been found from the east of Yamasaki-cho, Hyogo Prefecture, and in the neighbourhood of this locality, the Maizuru group is also distributed. This group is composed of shale, sandstone and conglomerate with *Lepidolina toriyamai* faunule. It is worth notice that this area is situated in the midst of the western part of the Tanba Zone where the Maizuru group is not found in general. The Maizuru group contacts by faults with the other paleozoic formations composed of dark grey to greenish massive sandstone and blush grey slate. These rocks form the uppermost formation of the Permian Tanba group named by SAKAGUCHI (1958, 1960) in the eastern part of the Tanba Zone. Such a formation lies conformably on the schalstein formation with limestone and is decidedly upper than the "*Neoschwagerina* Zone" and probably similar to or somewhat higher than the "*Yabeina* Zone". From the occurrence in this area, the formation of *Lepidolina toriyamai* of the Maizuru group is inferred to be different from and probably higher than the uppermost sandstone formation of the Tanba Zone.

IV. Lithologic Subdivisions of the Maizuru Group

As mentioned above, the Maizuru group has some lithologic elements common to each district and can be divided into the following several lithofacies in every district.

a. Schalstein facies
b. Slate facies
c. Graded bedding facies
d. Coarser grained facies
e. Gujō facies

These facies are not restricted stratigraphically, but rather geographically arranged.

a. Schalstein Facies.

"Schalstein" is composed of meta-basalt, meta-diabase, basic tuff and rarely of agglomerate, and alternates with slate and sandstone. In some cases, these rocks are metamorphosed into green or black phyllites. This facies occupies the lower part of the Maizuru group in all districts, that is, the lower formation of the Maizuru District and the Iuchi formation of the Mikata District. Although fossils are very rare in this facies (only one coral Lophophyroid has been obtained in the Maizuru District), this facies (lower formation) can be correlated to the middle Permian, for in the neighbouring Tanba Zone many

basic volcanic beds are found in the Permian and its uppermost part reaches the *Neoschwagerina* Zone or somewhat higher (probably *Yabeina*) Zone. In all other regions in Japan, basic volcanic eruption ceased before the late Permian and was violent in early to middle Permian.

b. Slate Facies

This facies is mainly composed of black slate or phyllitic slate, shale and snadstone or, rarely, conglomerate is intercalated. Limestones are intercalated in slate as small lenses 10 to 30 m long and several meters thick. Calcareous slate or siltstone is also found in slates.

This facies is restricted to the southern part of the Maizuru Zone and is not found in the middle to northern parts. This facies occupies the middle formation of the group in the Maizuru and the Mikata Districts, and in the northern parts, the same portion is probably replaced by other facies—coarser or graded bedding facies.

c. Graded Bedding Facies

The so-called "Flysch" type alternation forms this facies. This is characterized by monotonous alternation of sand to shale or silt with grading having thickness of several tens of cm.. Coarser and thick sandstones with a thickness of several meters are in some cases intercalated in these alternations. Shales of this facies are generally black or dark bluish in color and sandstones are of greywacke type. They are transported by turbidity currents and deposited in an inland sea.

This facies occupies the northern part of the Maizuru Zone, that is, the Kuratoko formation of the Mikata District, a part of the formations in the northern region of the Maizuru District, a formation in the northeastern part of the Kawahigashi District, and especially almost all the formations of the "Maizuru Group" in the Shidaka Disirict. This facies is also intercalated in coarser facies in other districts, but it is not common.

d. Coarser Grained Facies

This most typical facies of the Group is most widely distributed in the Zone, and in some cases, outside the Maizuru Zone proper, it appears in the midst of the Tanba Zone. This facies is composed of shale, sandstone and conglomerate and no limestone and schalstein. They alternate and gradually change into each other. Graded bedding is not common. Pebbles of conglomerate of this facies give us valuable information on the "Hinterland" of sedimentary basin of the Maizuru group. This facies occupies the upper part of the group in the southern part of the Zone, but it reaches to a somewhat lower horizon in the middle or northern part of the Zone.

e. Gujô Facies

One of the most peculiar beds in the Japanese paleozoic formations is the

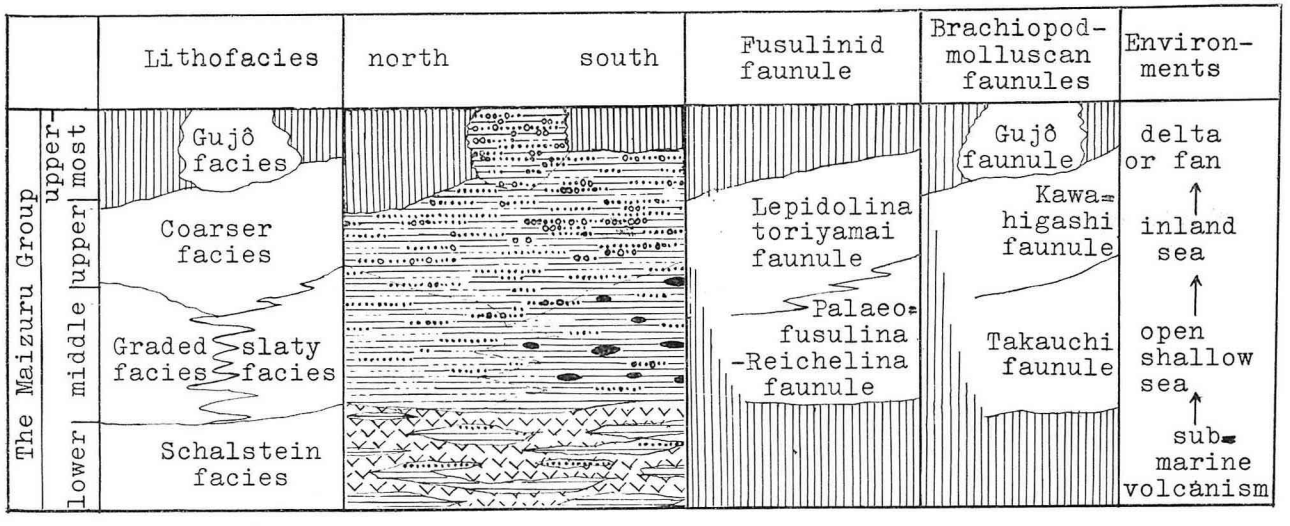


Fig. 4. Schematic diagram of relations between lithofacies and faunules of the Maizuru Group.

Gujō formation. It is characterized by frequent alternations of shale, siltstone, sandstone and conglomerate with frequent lateral changes. In some cases, contemporaneous erosion is also found in this facies. Nakazawa and other have supposed that this facies might have been formed in a deltaic or fan-like depositional condition. This facies is restricted to the Kawanishi District and especially at Gujō, where situates in the midst of the Zone. This facies occupies the uppermost part of the group.

V. Faunules

Fusulinid, brachiopod and mollusca form the main part of the many fossils of the Maizuru group. Besides, coral and trilobite are associated, and bryozoa and crinoid stem are also found in common. These fossils bear several fossil groups—two fusulinid faunules and three brachiopod-molluscan faunules, and these are not associated with each other.

1. Fusulinid faunules.

Lepidolina toriyamai faunule and *Palaeofusulina-Reichelina* faunule are found in the Maizuru group.

a. *Lepidolina toriyamai* faunule

This faunule is composed of the following species (NOGAMI, 1958).

Lepidolina kumaensis
Lepidolina toriyamai
Lepidolina toriyamai maizurensis
Yabeina columbiana
Yabeina shiraiwensis
Yabeina gubleri
Neoschwagerina cf. *margaritae*
Pseudodoliolina gravitesta
Schwagerina acris
Schwagerina pseudocrassa
Schwagerina sp.
Parafuslina ? sp.
Codonofusiella cuniculata
Nankinella spp.
Wentzellella nabaensis
Waagenophyllum sp. indet.

This faunule is most commonly found in calcareous granulic conglomerate of coarser grained facies of the Maizuru Group. Even in case it is found among slate facies, fossil-bearing bed is restricted to conglomerate or sandy layers intercalated in slates. This faunule is never collected in graded bedding facies. In general, fusulines are found in limestone or muddy limestone beds, but the

present faunule has in this point a most peculiar charactor among the fusulinid faunule. The nature of this faunule and its sedimentary environment have been discussed by NAKAZAWA (1950) as cited in the former chapter.

b. *Palaeofusulina-Reichelina* faunule.

The other group of fusulinids contains *Palaeofusulina* and *Reichelina*. These small and peculiar fusulines are found in limestones of slate facies of the Mikata, the Miharaiyama, the Yakuno and the Kawahigashi Districts. These genera are not associated with each other, but their occurrences are very similar.

In the Mikata District, from a small limestone lens of the Mikata formation, *Palaeofusulina sinensis* has been collected. This formation is overlain by the Yokoyama formation with the *Lepidolina toriyamai* faunule. In the Miharaiyama District, this faunule (*Palaeofusulina* cf. *sinensis*) and the *Lepidolina toriyamai* faunule have very similar straigraphic value, but are different as faunal elements.

Reichelina matsushitai from limestone lenses in the Kawahigashi and the Yakuno Districts has already been described by NOGAMI. Although his description does not mentioned clearly the occurrences and this species has been found from very near the locality of the *Lepidolina toaiyamai* faunule, it is evident that these two fusuline groups are not associated with each other in a strict sense and are found from separate rock bodies. The *Lepidolina toriyamai* faunule is found from calcareous granulic conglomerate, while *Reichelina* is collected from a dark limestone. The relation between them is quite similar to that between the *Lepidolina toriyamai* faunule and *Palaeofusulina* at Miyamoto of the Miharaiyama District. *Reichelina* and *Palaeofusulina* are not yet found in association in the Maizuru group, but they are collected from very similar rocks and probably show a similar environmental and stratigraphic value. They are found in association in the late Permian of southern China—in the Changsing Limestone of Loping Series. The writer therefore wishes to tentatively group them as a faunule and name it *Palaeofusulina-Reichelina* faunule.

In cases all over the world, *Palaeofusulina* is not associated with other larger fusulines, except only one case in Indochina reported by DEPRAT, where a *Palaeofusulina prisca* is associated with "*Doliolina*" sp.. *Reichelina* is also very rarely associated with other larger fusulines. In the Chichibu Mountains of Japan, *Reichelina*, described by MORIKAWA is not associated with *Yabeina*, although it is collected from a very near locality.

There arises a question whether these two fossil groups (faunules) are equivalent stratigraphically, and belong to the one and same horizon or not. The writer is of the opinion that such a question is nonsense. Genus *Reichelina* and genus *Palaeofusulina* do not belong to a group of fusulines such as Neoschwagerinae, and there is no means to determine the phylogenetical succession of *Lepidolina* and *Reichelina* or *Palaeofusulina*. Their stratigraphic significance is controlled rather by environmental—ecological effects than phylogenetical.

2. Brachiopod-Molluscan Fanules

Brachiopods and mollusks are found in the group, accompanied by brayozoa, crinoid stems and trilobite, and are classified into the following three groups. These groups can be descriminated from each other in faunal constitution and also in lithologic features. They are arranged stratigraphically in ascending order as follows.

1. Takauchi Faunule
2. Kawahigashi Faunule
3. Gujō faunule

a. Takauchi Faunle

This most famous faunule in the Maizuru group was at first discovered by YOKOYAMA in 1891. He reported crinoid stems from a limestone at Takauchi, Yakuno-cho of Kyoto Prefecture, and estimated its age as Jurrasic Period. Afterwards, in 1934, MASHIKO discovered "*Lyttonia*" *richthofeni* from this limestone and settled its age to Permian. According to the writer's study (1961), the Takauchi faunule including the following species shows the age to be middle Permian. Judging from these species, the Takauchi faunule is correlated to those of Loping Series in south China and of the middle Productus Limestone of the Salt Range. This faunule does not contain fusulines, but judging from other facts it must be correlated to the upper part of the middle Permian—probably "*Yabeina*" Zone.

Leptodus richthofeni
Squamularia indica
Squamularia elegantula
Squamularia cf. *calori*
Streptorhynchus kayseri
Streptorhynchus semiplanus
Martinia elegans
Kiangsiella deltoidens
Strophalosiina tibetica
Neospirifer sp.
Tachylasma sp. indet.

The main part of this faunule is 10 species of brachiopods (4 spp. of Strophomenacea, 1 sp. of Productacea and 5 spp. of Spiriferacea). No mollusks have been collected, except one indeterminable pelecypod.

This faunule is only found in the Takauchi formation (slate facies) of the Yakuno District. In the Mikata District, fossils contained in the lower part of the Mikata formation (slaty facies) are referable to this faunule. At Ochiyama in this district, *Spiriferina* aff. *cristata* and other fossils have been collected from calcareous shale as described in the former chapter. This faunule may be correlated to the Takauchi faunule.

This Takauchi faunule is restricted to slate facies of the southern part of the Maizuru Zone and is never found in the middle and northern parts.

b. Kawahigashi Faunule

As described in the writer's previous report, this Kawahigashi faunule is composed of the following species.

Derbyia altestriata
Derbyia cf. *grandis*
Derbyia hemispaerica var. *radiata*
Derbyia sp.
Chonetina substrophomenoides
Chonetina cf. *strophomenoids*
Chonetina matsushitai
Lissochonetes bipartita
Lissochonetes morahensis
Lissochonetes cf. *avicula*
Lissochonetes sp.
Productus (*Dictyoclostus*) *gratiosus*
Prod. (*Dictyocl.*) cf. *margaritatus*
Prod. (*Dictyocl.*) sp.
Linoproductus kiangsiensis
Linoproductus interruptus
Aulosteges dalhousi
Hustedia grandicosta
Hustedia indica
Eolyttonia nakazawai
Aviculopecten sp.
Pleurophorus sp.
Pseudophyllipsia sp.
Bryozoa
Crinoid stems

The greater part of this faunule is occupied by 13 spp. of Productacea (7 spp. of Chonetidae and 6 spp. of Productidae) and 4 spp. of Strophomenacea (Orthotetinae). Pelecypods form a small part (3 spp.). It was noticed that this faunle contains one species of Trilobite and no coral.

Pseudophyllipsia has been obtained from two localities, of the Kawahigashi District (Kuwanoé-toge, KP-16; and Katsuradani, KP-5). They are only fragments of pygidium, but their specific characters enable us to determine them as *Pseudophyllipsia*. According to Dr. OKUBO of Tokyo University, the species is very similar to that of the Kitakami and the Abukuma Mountains of Northeast Japan, and especially most referable to that of the uppermost part of the Iwaizaki Limestone of Kitakami (to that of the *Yabeina* Zone). On the other hand, this species is very similar to *Pseudophyllipsia obtusicauda* of the Loping

Series described by KAYSER. These species may belong to the same species.

These brachiopods and other fossils are identical or referable to those of the Loping fauna of southern China and also of the middle to upper divisions of the Productus Limestone of the Salt Range. Among Japanese faunas, they can be correlated to faunule of the Karita formation in Hiroshima Prefecure, which yields many fusulinids of *Lepidolina toriyamai* faunule.

c. Gujô Faunule

Gujô faunule, first estimated as Triassic and lately corrected to Permian is composed of the following species.

Costatoria kobayashii
Neoschizodus permicus
Bakevellia gujoensis
Actinodontophora aff. *katsurensis*
"Pleurophorus" tenuistriatus
Aviculopecten sp.
Septimyalina sp.
Allorisma sp.
Bellerophon sp.
Bucanopsis sp.
Spinomarginifera nipponica
Schellwienella ruber
Schellwienella regularis
Orthotetina sp.
Bryozoa

As for the number of specimens, this faunule is composed almost wholly of pelecypods with 8 spp., gastropods having 2 spp.. Brachiopods consist of 3 spp. of Strophomenacea and 1 sp. of Productacea, but the latter is more numerous in faunule. No coral and crinoid are found in this faunule.

Pelecypod genera of this faunule are commonly found in Triassic, but they originate in the Permian Period and are never restricted to mesozoic. All brachiopods are paleozoic genera. Among the pelecypods, *Actinodontophora* aff. *katsurensis* is referable to this species of the Katsura formation of Shikoku described by ICHIKAWA (1951) (NAKAZAWA, 1959, 1960). *Spinomarginifera nipponica* resembles *Spinomarginifera kueichowensis* of Loping fauna in South China, and this species is also reported from the middle Permian Kanokura fauna of the Kitakami Mountains. Other two species are identical with those of the Loping fauna. *Schellwienella ruber* is reported from the Karita formation of Hiroshima Prefecture.

Fossil species of this faunule are not abundant enongh for determining whether the age is late or middle Permian, but it is presumable that this faunule represents the upper-most Permian in the Maizuru Zone. That is, this faunule

is found only in the neighbourhood of Gujô of the Kawanishi District, which is situated in the midst of the distribution of the Maizuru group. We can not suppose that in some age of the Permian, a delta was constructed in the midst of coarse or graded bedding facies. Accordingly, we can estimate that the Gujô formation is the uppermost part of the Maizuru group.

VI. Biostratigraphy

Lithofacies and faunules:

There are 5 lithofacies and 5 faunules in the Maizuru Group. They correspond with each other as follows.

Schalstein facies	no fossils, except one coral.
Slate facies	*Palaeofusulina-Reichelina* faunule and the Takauchi faunule.
Graded bedding facies	no fossils
Coarser grained facies	*Lepidolina toriyamai* faunule and the Kawahigashi faunule
Gujô facies	the Gujô faunule

In almost every case each faunule is restricted to one facies. Some faunules are found from intermediate facies, but this is rather exceptional. *Lepidolina toriyamai* faunule, although it is found in even slate facies, is restricted to coarser sandstone or granulestone. The Takauchi faunule is restricted to limestone or calcareous slate, and on the contrary, the Kawahigashi faunule is restricted to coarser clastic rocks. These facies and faunules form a biostratigraphic succession of the Maizuru Group as will be discussed below.

Stratigraphic relations between faunules and facies:

The above-mentioned five faunules are stratigraphically and palaeontologically individual elements of the Maizuru Group, but their stratigraphical relations are not so clearly represented. From a paleontological point of view, the Takauchi faunule is lowermost among the brachiopod-molluscan faunules.

The Gujô faunule, as mentioned above, probably shows the highest horizon among these faunules judging from the environmental situation. Accordingly, stratigraphic relations between brachiopod-molluscan faunules are as shown in the preceding chapter.

Concerning the fusulinid faunules, many problems remain to be solved. In the Mikata District, *Lepidolina toriyamai* faunule is higher than *Palaeofusulina*, but in the Miharaiyama District, they are collected from similar or very near localities. A similar relation is reported to be found in the Yakuno District between *Lepidolina toriyamai* faunule and *Reichelina*. As the writer has discussed in the preceding chapters, there is no means to determine the phylogenetic succession between the two fusulinid groups, and their relation may be solved as a lithologic-environmental problem. *Lepidolina toriyamai* faunule and *Palaeo-*

fusulina-Reichelina faunule belong to coarser facies and to slate facies respectively, and the latter faunule is restricted to limestone. It is evident that in southern part of the Maizuru Zone, slate facies is succeeded upwards by coarser facies. Accordingly, in some cases the *Lepidolina toriyamai* faunule is higher than *Palaeofusulina-Reichelina* faunule. On the other hand, these lithological facies interfinger with each other in some cases, and these two faunules have no stratigraphic difference. Toward the middle part of the Zone, the slate facies diminishes and is replaced by graded bedding facies or coarser facies, and *Palaeofusulina-Reichelina* faunule is excluded.

Stratigraphic relations between fusulinid faunules and brachiopod-molluscan faunules are represented by the following facts.

a. No fusulinid faunule corresponds to Gujô faunule.
b. Kawahigashi faunule is stratigraphically equivalent to *Lepidolina toriyamai* faunule.
c. Takauchi faunule has no relation with fusulinids, but its equivalent—Ochiyama brachiopods has the same stratigraphic value as *Palaeofusulina*. Consequently, Takauchi faunule may be correlated to *Palaeofusulina-Reichlina* faunule in some parts.

The writer has summed these facts up in a schematic biostratigraphic relation as shown in Fig. 4.

VII. Correlations

Correlations of faunules:

Two fusulinid faunules and three brachiopod-molluscan faunules are identical with or may be correlated to some of the other faunules in Japan.

Lepidolina toriyamai faunule is identical with same faunas of the Kuma formation of Kyushu, of the Karita formation of Hiroshima Prefecture, and of the Haigyu and the other formations in Shikoku.

Palaeofusulina-Reichelina faunule has no correlative elements in Japan.

Gujô faunule has some similar elements in the Karita fauna and probably in that of the Katsura formation in Sakawa Basin of Shikoku.

Some species of the Kawahigashi faunule are also found in the Karita faunua, but they are not of the Gujô faunule.

Leptodus richthofeni of the Takauchi faunule, is distributed in many faunules of Japan, especially in the Karita fauna and in the Kanokura fauna of the Kitakami Mountains.

The Karita formation greatly resembles the Maizuru group in lithologic features, and each fossil species is identical with that of the Maizuru group. Unfortunately, its features are not made clear although its stratigraphy was reported. It is probable that the Karita formation and the Maizuru group are correlatable to each other as a whole.

Doi group in Shikoku contains fossils of *Yabeina shiraiwensis* etc. and lacks

Lepidolina toriyamai or *L. kumaensis*. The lowermost part of the Kuma formation is also without *Lepidolina*. These beds probably come below the *Lepidolina toriyamai* Zone and may be correlated to the uppermost formations of the Limestone Plateaus with *Yabeina shiraiwensis* Zone. (Atetsu, Taishaku and Akiyoshi). Accordingly, as mentioned below, these formations may be a horizon identical with the Takauchi formation or other slate facies in the Maizuru group.

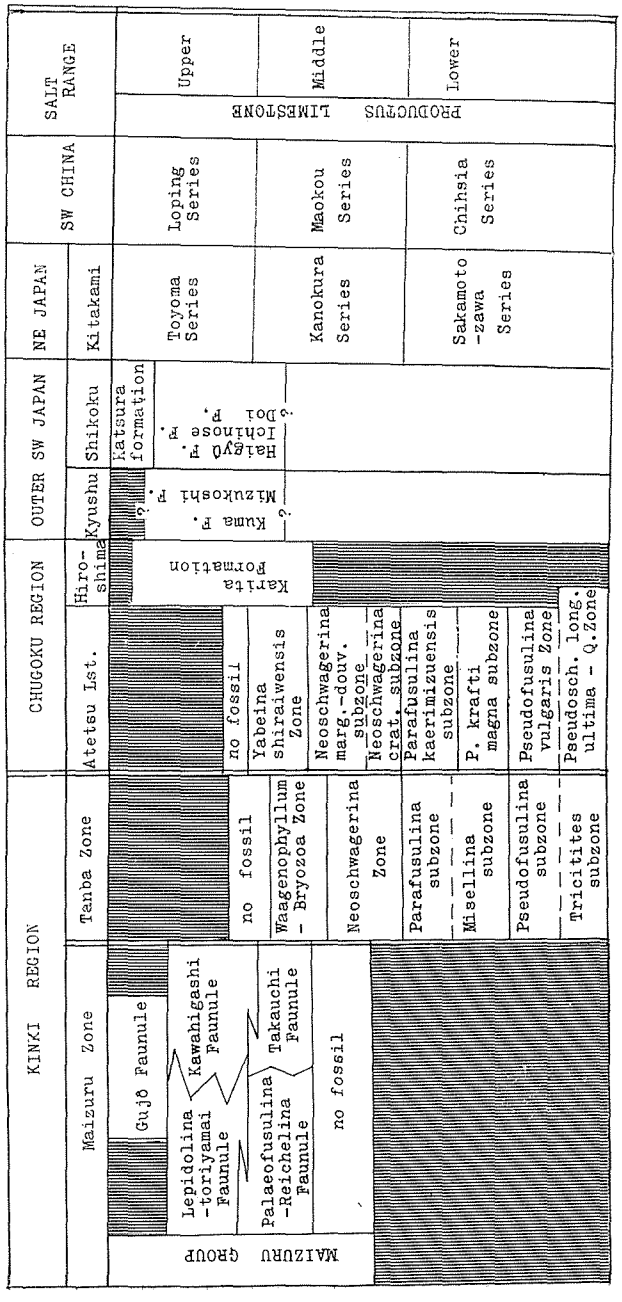
Correlation to the Tanba Group:

No fossil evidences sufficient to determine the correlation between the Maizuru- and the Tanba groups have been obtained. They are merely correlatable with each other with respect to lithologic similarity and other geological circumstances. The uppermost fusuline fossils in the Tanba group are *Yabeina katoi* and *Yabeina globosa* reported from near Obama City, Fukui Prefecture (HIROKAWA, ISOMI and KURODA, 1957). These fusulines are not clear in their stratigraphic position, and no decided horizontal situation is represented. In the typical distribution of the Tanba group in Nishiyama District, Kyoto Prefecture and in Sasayama Basin, Hyogo Prefecture or other districts, the uppermost fossil zone is "*Neoschwagerina* zone". Above this zone, a fossil bearing bed with bryozoa, *Waagenophyllum indicum* and pelecypods (*Halobia* ? sp.) is found, and SAKAGUCHI estimated this to be correlatable to the "*Yabeina* Zone". These two horizons are composed of thick schalstein formation with limestone lenses. The similarity between them and the lower schalstein formation in the Maizuru group may signify their stratigraphic equivalency. Sandstone formations (the Takatsuki and the Takashiroyama formations) above the schalstein formations of the Tanba group must be lower than the *Lepidolina toriyamai* faunule as mentioned in the case of the east to Yamasaki-cho, Hyogo Pref.. According to SAKAGUCHI and other writers, the sandstone formations are composed of thick beds of sub-greywacke type of greenish or bluish grey color, and contains no chert, schalstein and limestone. The writer correlated these sandstone formations with the Takauchi formation and other slate facies, and considers that they may be also correlated to the graded bedding facies of the Maizuru group. These situations are shown in the distribution map of facies (Fig. 6).

Correlation with Limestone Plateaus in the Inner Southwest Japan:

The uppermost part of the Limestone groups in Limestone Plateaus such as the Atetsu, the Taishaku and the Akiyoshi and others, are composed of thick sandstone beds which have changed from dark muddy limestones. The lower part of the sandstone contains many limestone lenses yielding *Yabeina shiraiwensis* and other fusulines. They may be correlatable to the horizon below that of *Lepidolina toriyamai* faunule (NOGAMI, 1961 a, b). YOKOYAMA and SADA settled a "*Lepidolina*" Zone in these formations and correlated them to the Kuma formation. This correlation is not preferable according to NOGAMI,

Table 1. Correlation Table.



since these "*Lepidolina*" are not similar to *Lepidolina toriyamai* or *L. kumaensis* and this faunule is mainly composed of *Yabeina shiraiwensis*. There is some doubts as to the generic identification of some of their "*Lepidolina*".

Correlation with the formations of the Kitakami Mountains:

No fossil evidences, except a few brachiopods, are presented for correlation. It is probable that the Takauchi faunule is correlatable to a part of the Kanokura Fauna. *Lepidolina toriyamai* faunule and the Gujô faunule may have the same stratigraphic value as the Toyoma series from their paleogeographic similarity.

VIII. Syntectonic Faunal Succession through the Latest Paleozoic Orogeny

The Permian Maizuru group is rather rich in fossils unlike other non-calcareous paleozoics in southwest Japan, and yields fusulines, brachiopods, molluscas, corals, bryozoas and even trilobites. They are contained in formations corresponding to lithofacies as faunules, and give us much interesting information on the faunal succession in the Maizuru Zone in the middle to late Permian Period. They changed their own consitution according to the environmental development, which was caused by the latest paleozoic orogenic movement around Japan.

Changes of faunal constitution in the Maizuru Group: (Fig. 5)

As already mentioned, fusulinid fossils are classified into two groups—*Lepidolina toriyamai* faunule and *Palaeofusulina-Reichelina* faunule. The former replaced the latter gradually, although they occupied a similar position in some cases. This faunal change must have accompanied the lithologic change as shown in columnar sections, from slate facies to coarser facies.

A similar faunal succession is clearly represented by brachiopod-molluscan faunules. Three faunules succeeded one after another following the lithologic change. The faunal constitution in these faunules changed, as presented in diagram (Fig. 5). Among them, the earliest Takauchi faunule is characterized by many Spiriferacea and Strophomenacea brachiopods and especially *Leptodus richthofeni*. Chonetidae species is not found in this faunule. Pelecypods are also very rare.

The most abundant Kawahigashi faunule is composed of many Chonetidae and Productidae brachiopods, some pelecypods and gastropods. Spiriferacea which florished in the Takauchi faunule is obsolete and replaced by another brachiopods. It is worth notice that some mollusca and trilobrite are collected from this faunule.

The latest faunule of this group—the Gujô faunule—is rather a pelecypod- than brachiopod-faunule. Some Myophoriidae (*Costatoria* and *Neoschizodus*)

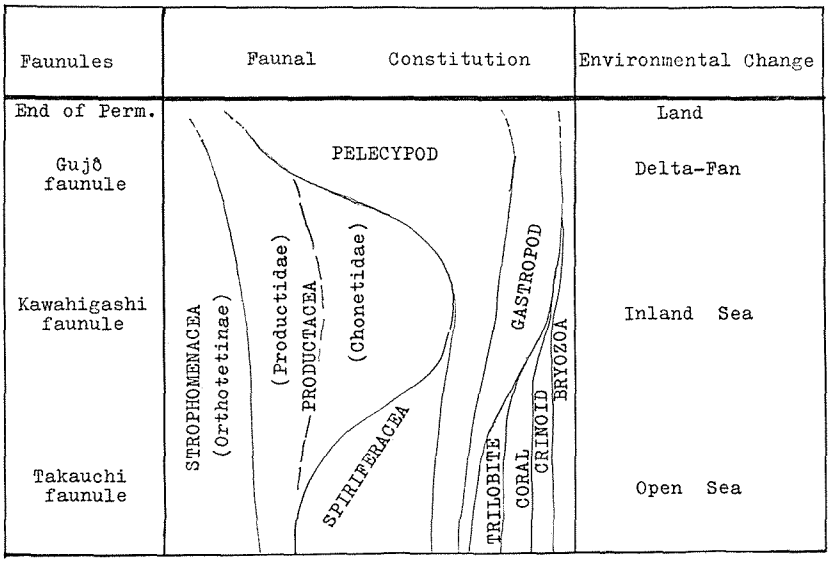


Fig. 5. Idealised Change of faunal constitution in the Maizuru Group.

and *Bakevellia* form the main part of this faunule. Chonetidae extinct and Productidae and Orthotetinae form a small part of this faunule. Crinoids and Bryozoas are almost obsolete, although they fluorished in the ancestral two faunules. Trilobite died out before the Gujô faunule.

Faunal Change and Paleogeographic Development:

As easily noticed by the lithologic change, the depositional environment changed from open shallow sea, through inland sea, to a deltaic or fan-like environment, in the ages of the Maizuru group. Owing to this depositional environment, animals which lived in the sea may have succeeded one after another and the faunal constitution may have changed. According to many paleontologists who studied fossils of the late paleozoic era, brachiopods and molluscas found distinctly favorable environments. ELIAS (1937) classified this distribution of animals into three zones; the zone of brachiopod, the zone of mixed and the zone of pelecypod. He related them to sea depth, and noticed them a mark of depositinal cycles. An intensive study on faunas of Pennsylvanian (SLOAN, 1955) concluds that benthonic animals are dependent principally upon depth and the conditions of the substrata, and marine benthonic communities vary with these two principal factors, and the faunal index (I=Brachiopods/Brachiopods+ Molluscas) can be used to make paleobathymetric maps based on samples taken from a single horizon.

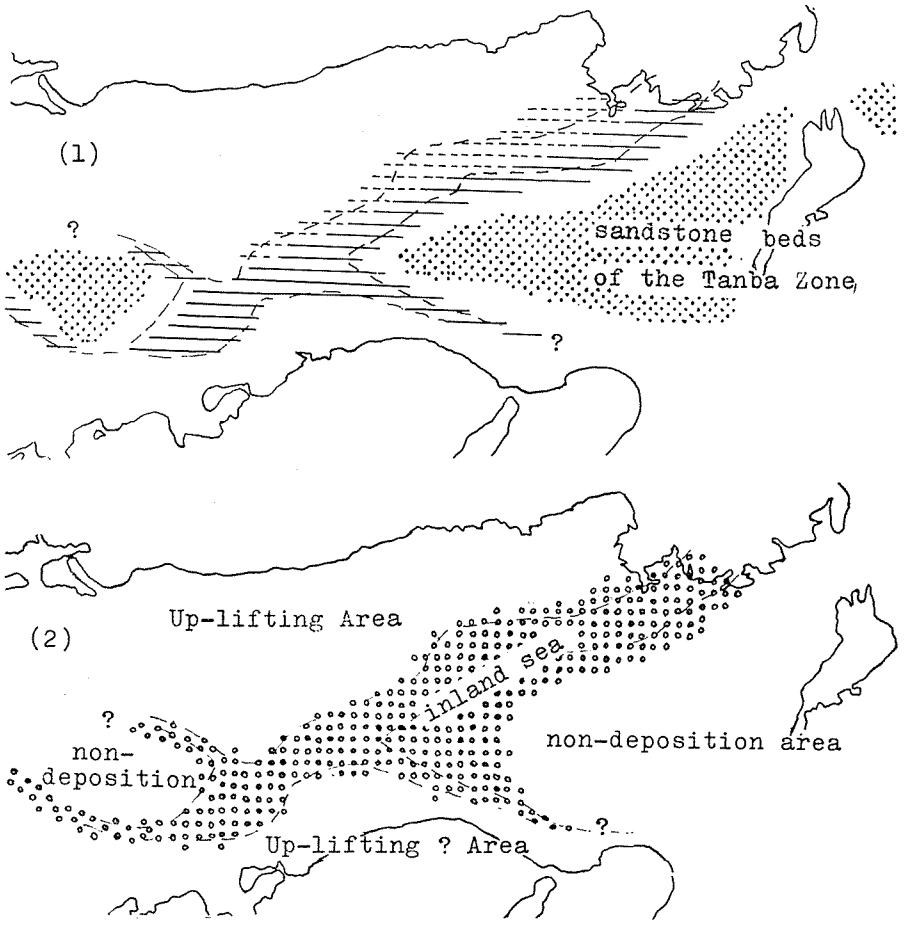
Similar separation of animals are found in not only among these different

animals, but also in brachiopod genera. In the southern Coastal Region of U. S. S. R., LICHAREV classified brachiopods of the upper Permian into two faunas. He also pointed that they are found separately from two formations, that is, an organogenic formation (limestone, partly reef-origin) and a volcano-terrigenous formation (sandstone etc.). The stratigraphic relation between them is not clearly observed, but LICHAREV estimates that brachiopods of the volcano-terrigenous formation is somewhat younger than that of the organogenic formation. The brachiopod fauna of the organogenic formation is characterised by the following genera, that is, *Enteletes*, *Streptorhynchus*, *Spiriferina*, *Camarophoria*, *Hemiptychina*, *Phricodothyris*, *Prorichthofenia* and *Spiriferella*. Productacea is very rare in this fauna and especially *Chonetes* s. l. is almost negligible. On the other hand, in the volcano-terrigenous formation, Productidae predominates. In the brachiopod fauna of that formation, we find many species of *Yakovlevia* and *Linoproductus*.

Faunules of the Maizuru group contain faunal-constitutions sufficient to determine that separation, and their changes correspond to lithological features. Brachiopods which greatly flourished in the Takauchi faunule become small elements in the latest Gujô faunule. Conversely, pelecypods formed an almost negligible part in the Takauchi faunule, but became larger in number in the Kawahigashi faunule, and at last they overwhelmed brachiopods in a deltaic facies of Gujô. Brachiopod genera are different in these faunules as above noted, and it may be depend on their bottom condition.

This environmental development must be corresponding to the orogenic movement. In the beginning of the Maizuru group—an age of basic submarine volcanism, no difference existed between the Maizuru and the neighbouring Tanba Zone in facies, and the sea covered these regions entirely. In the next stage—an age of the Takauchi faunule and also of the graded bedding facies a presumable land area was exposed to the north of the Maizuru Zone, and to the south (the Tanba Zone) thick sandstone beds are deposited. It is presumble that in an age of *Lepidolina toriyamai* faunule and the Kawahigashi faunule, an uplifting land on the immediate north side and much detrital materials derived from there and deposited in an inland sea of the Maizuru Zone. The last age of Gujô faunule was a deltaic or fan-like age formed in an emerging inland sea.

A similar faunal succession was reported by NICOL (1944) from the Kaibab formation (middle Permian) at Arizona, where brachiopods has been replaced by pelecypods and trilobites also been extinguished before some short epoch before the end of marine condition. He concludes that the faunal change must be caused by change of salinity in water, that pelecypods, particularly the genus *Schizodus* are well adapted to these shallow, land-locked and somewhat hypersaline sea condition. Some gastropod genera and a scaphopod could also stand the condition well, but brachiopods, which are very abundant in true marine conditions, did not find this environment favorable. In the case of



the Maizuru group, no concentration of salinity had occurred and faunal change must have been caused by some other factors like bottom conditions and depth.

Faunal change without orogeny :

But the environmental change caused by orogeny is not only the cause of faunal change, for a similar change is also found in the Products Limestone of the Salt Range, where we cannot find so remerkable an environmental change as in Japan and other countries. According to REED's monograph (1945), molluscas form a small part of fauna in the middle Productus Limestone and become abundant (almost one third in fauna on specific number) in the upper Productus Limestone. According to a more detailed study by SCHINDEWOLF, the specific number of molluscas is almost half of that of fauna and possess similar value as brachiopods in the upper Producturs Limestone. These

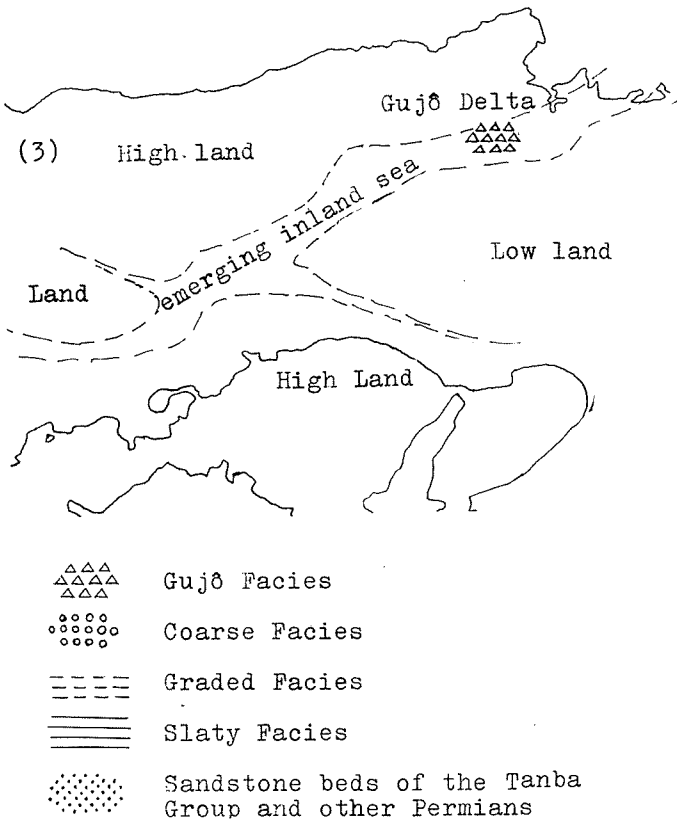


Fig. 6. Facies distributions of the Maizuru Group with paleogeographic aspects.
(1) Facies of the Takauchi faunule and correlatable ones.
(2) Facies of the Kawahigashi- and *Lepidolina toriyamai* faunules.
(3) Facies of the Gujô faunule.

paleozoic type animals were extinguished at the end of Paleozoic era without stratigraphic break. Many ammonoid genera are found in the Productus Limestone, but only one of them has survived into the Triassic period beyond a conformable boundary between the paleozoic and mesozoic eras. SCHINDEWOLF concludes from these facts, that faunal change are not caused by environmental elements, but are effected by more elemental factor based on animal phylogeny itself which must be influenced by intense readiation. He says that at the end of the paleozoic era an intense cosmic ray had killed off a whole marine fauna.

Development and extinction of animals as their own history of adaptation and specialization:

Such simplification of the problem may not be fruitful, although individual

causes fit in to the situation. We must go back to the first questions. A non-organic and/or non orogenic event like cosmic ray is not sufficient for explaining these facts. It does not solve the problem, but makes it more confusing. If the amount of cosmic ray changed to an amount sufficient to kill the paleozoic animals, why had the other animals survived ? The difference between them is not clearly explained by such a simple factor. The true reason why some animals were extinguished and others survied, must be explained by the evolutional history of their adaptation to environments and of the specialization during the long phylogenesis from their far ancestors.

Brachiopod groups which characterize the Permian originated in Ordovician to Carboniferous periods and flourished in Carboniferous to Permian periods. They may have adapted themselves to many different ecoligical niches of shallow sea during the great transgression in these periods, and were differentiated into many specialized forms. During their specialization, they gradually lost their flexible ability of adaptation to environmental change. In addition, orogenic movement covered the world, and shallow sea suited for their existence became extremely narrow. Paleozoic type animals diminished in the number of fauna, and were replaced by other group having greater ability of adaptation and less specialized. The latter group survived into the next period and became a main elemet of the animal group. This faunal change must have taken place all the regions with or without orogeny. We can follow these changes in the faunules in the Maizuru group, although they are not abundant and sufficient for presenting in detail. Some pelecypod genera and some brachiopod groups survived through the late paleozoic orogeny and their fossils are found abundantly beyond the unconformity between Permian and Triassic.

IX Geotectonic Perspective of the Late Permians in Japan

Geographically, the Maizuru Zone is noticed as a border between the Sangun Metamorphic Region on the west side and the non-metamorphic paleozoic region—the Tanba Zone on the east side. In addition, the Maizuru Zone crosses the main tectonic trend of southwest Japan (YAMASHITA, 1957; ICHIKAWA, 1958; NAKAZAWA, 1959).

Recently we find a tectonic zone resembling the Maizuru Zone in Hyogo Prefecture and named it the Kamigôri Zone (Geol. Map of Hyogo Pref., 1961). Paleozoic formations lying between the Yakuno Intrusive Rocks are composed of a formation of schalstein and slate, and a formation of shale-sandstone-conglomerate with limestone. They resemble the formations of the Maizuru Group although there are no decided fossil evidences. Pebbles in the Lipalitic breccia which cover older rocks are of paleozoic formations, and among them some limestone pebbles yield fusuline fossils of advanced species like *Lepidolina*. It must have been derived from the basement paleozoic rocks of this region. Another feature is their direction, that is, they extend from northwest to

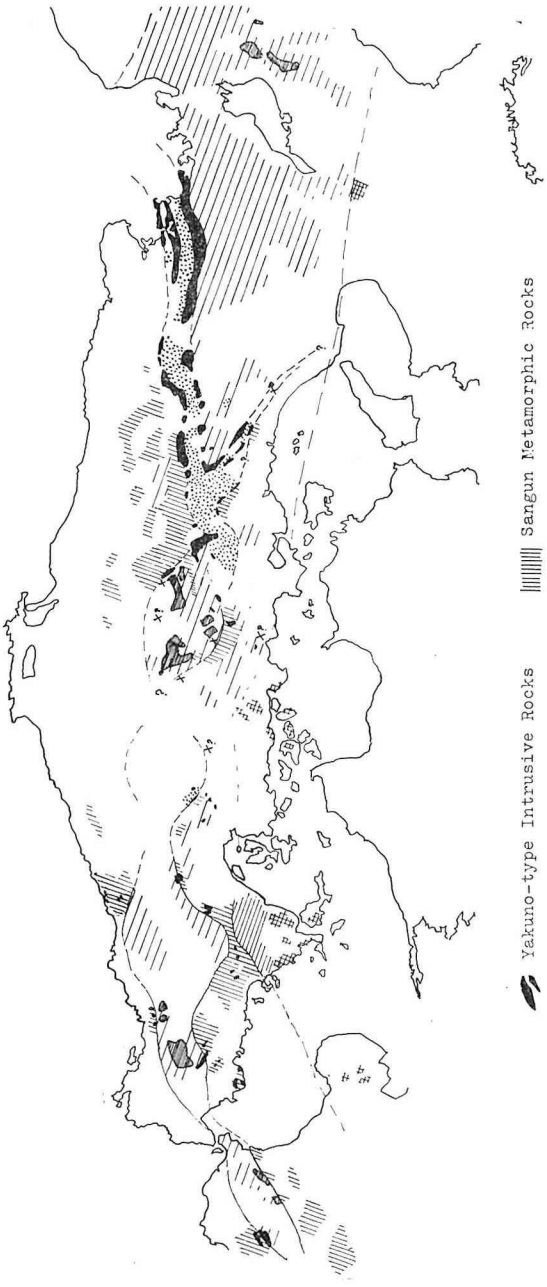


Fig. 7. Tectonic Relations between the Maizuru Group and other Rocks.

southeast and cross the Maizuru Zone. In other words, it branches off from the Maizuru Zone proper in Okayama Prefecture. On the southern side of the Kamigôri Zone, metamorphic rocks belonging to the Sangun Metamorphic Zone are distributed. Accordingly, the first indication of the Maizuru Zone—as the front of metamorphic Region—is still now available, but the second indication—that its direction crosses the main trend—becomes more a complex matter.

West extension of the Maizuru Zone:

The Maizuru Group is found in the Mitsu District around Kanagawa to the north of Okayama City, Okayama Prefecture. The geology is mainly composed of non-metamorphic paleozoics with the upper Triassic formations (correlatable to Carnian Nabae Group). Paleozoics are none other but the Maizuru Group composed of formations of schalstein, of slate with limestone and of sandstone-shale-conglomerate alternation. In limestone lenses near Kutani, the writer found many brachiopod fossils as follows: *Wellerella saxatilis*, *Terebratuloidea* cf. *minor*. *Terebratucoidea* ? cf. *davidsoni*, *Terebratuloidea* spp., *Dielasma nummulus*, *Dielasma* cf. *biplex*, *Dielasma* sp., *Athyris subtriangularis*, and *Athyris* sp.. These fossils have never been found before in Japan, and are identical to those of the Loping fauna in southwest China and of the middle Productus Limestone in the Salt Range. Immediately below this limestone, schalstein beds crop out. In calcareous conglomerate, many fusulinid fossils of *Lepidolina toriyamai* faunule are collected. These formation, their fossils and their occurrences are the same as those of the Maizuru Group, and show the west extension of the Maizuru Zone.

On the north and south sides of these paleozoic formation, Yakuno Intrusive rocks are distributed (MITSUNO, 1959, 1960). Those on the south side are very small rock bodies, and those on the north side form a wider area elongated in a northwest direction. It reaches near the Atetsu Limestone Plateau on its northeast side, forming a zone of intrusive rocks (sheared granite, gabbro and serpentine) and non-metamorphic paleozoic (sanstone-shale with limestone and conglomerate). The latter formation greatly resembles the Maizuru Group in lithological character, but no fossil evidences are obtained.

Between the Mitsu District and the Karita District in Hiroshima Prefecture, some formations similar to the Maizuru Group are distributed. Near Nariwa Region of Okayama Prefecture, characteristic paleozoic formations have been noticed by KAWAI (1957), namely the Shôdera and other formations, The Shôdera formation is composed of alternations of black fine sandstone and black slate with less persistent conglomerate. Cnglomerate beds are 10 to 20 meters thick and contain pebbles of limestone, chert, slate, schalstein and granite. This formation is situated between the northern non-metamorphic paleozoics (limestone group and non-calcareous formations) and the southern metamorphic paleozoic rocks (phyllites of the Sangun Metamorphic System), and

contacts with them by faults, but no stratigraphic relations are found.

To the west of this region, the writer found a peculiar paleozoic formation in Hiroshima Prefecture, which is situated on the boundary of the Taishaku Region (its southwestern end). This formation had been described by OGURA as a mesozoic formation (1927, geological map sheet "Shōbara" 1:75,000). According to the writer's preliminary research, this formation must be paleozoic, composed of black shale, black sandstone and conglomerate, which greatly resemble those of the Maizuru Group, although no fossil has been collected so far.

These non-metamorphic peculiar paleozoic formations are distributed in a narrow zone, which surrounds a large lenticular area of non-metamorphic paleozoics (plateau limestones and non-calcareous formations). This region was named the Central Non-metamorphic Zone by KOJIMA (1953) in comparision with the Sangun Metamorphic Zone. On accout of their relations, formations like the Maizuru Group probably occur along the boundary of the same region in western Chugoku, where the Nagato Tectonic Zone has already been noticed. The Karita region is connected with these districts in the same manner. These geographical relations were probably formed by causes similar to those of the metamorphism of the Sangun Region and also with the origin and development of the Maizuru Zone (Fig. 7).

According to MITSUNO's petrographic studies (1959, 1960), basic intrusive rocks resembling the Yakuno Intrusive Rocks are found in the Sangum Metamorphic Rocks or the border between them and the non-metamorphic paleozoics or the Maizuru Group. He concludes that these rocks must have intruded in the paleozoic formations during the metamorphic activity in the last phase of metamorphism. Accordingly, intrusion, metamorphism and the birth and development of the Maizuru Zone probably took place in the same age.

The problem of the Yakuno Intrusive Rocks is not so simple. KANO, NAKAZAWA and SHIKI (1961) noticed that the pebbles of conglomerates in the Maizuru Group are identical to those of the Yakuno Intrusive and Complex Rocks. They estimate that some of these rocks were exposed on north side of the recent Maizuru Zone, eroded and deposited in the basin of the Maizuru Group. Same rock bodies, on the other hand, intruded into the Maizuru Group in some cases. This camplicated matter must be solved as a problem of "Mantled gneiss dome" (ESKOLA) or "Reactivated basement in subsequent orogeny" (REED). These rocks may have been brought up through deep cracks in association with high-grade metamorphic rocks. Enormous basic volcanic rocks of the lower Maizuru Group came up these cracks and erupted in the basin. Accordingly, it is presumable that they were formed in the middle Permian period, and in the Triassic period formed a complex structure of this zone.

From another view point, these cracks are not essential in geotectonics, but may come under to the besement frame work. It has presented itself as scat-

tering limestone plateaus in the geosynclinal sea in the late paelozoic era, and as a difference between lithofacies in the basin of this geosyncline (thick chert beds are almost restricted to the Tanba-Mino Zone).

The late Permian formations in other regions of Japan also have tectonic significance as in the Maizuru Zone, and may represent a tectonic construction of the late paleozoic rocks. The writer proposes a working hypothesis, that we may clearly reconstrust a tectonic frame work and history of the late paelozoic and early mesozoic eras, using the late Permian formations, as tectonic markers.

X. Summary and Conclusion

The Permian Maizuru Group in the Maizuru Zone, of Southwest Japan, is a product of the latest paleozoic orogeny around Japan. This Group is classified into the following lithofacies; 1. schalstein facies (lower formation), 2. slaty facies, 3. graded facies (middle formation), 4. coarser facies (upper formation), 5. Gujô facies (uppermost formation). Fossils of this group are composed of two fusulinid groups and three brachiopod-molluscan groups, namely, *Lepidolina toriyamai* faunule and *Palaeofusulina-Reichelina* faunule of fusulinids, and the Takauchi-, the Kawahigashi- and the Gujô faunules of brachiopods and molluscas etc.. These lithofacies and faunules are connected with eachother and arranged stratigraphically as shown in the Fig. 4. They are also arranged geographically as shown in Fig. 6 with paleogeographic aspects.

The Maizuru Group is correlated to the upper to middle Permian System in Japan and other countries (Table 1).

Brachiopod-molluscan faunules succeeded one after another according to lithofacies and changed their constitution (Fig. 5). Brachiopods decrease in number, and molluscas somewhat increase from the earliest Takauchi- to the latest Gujô-faunule. This faunal change must have been caused not only by environmental development along orogeny, but also by the evolutional history of the adapation of animals to environments, and of their specialization.

The Maizuru Group and equivalent formation are distributed in narrow zones between the non-metamorphic- and the metamorphic-paleozoic regions, and are associated with the Yakuno Intrusive and Complex Rocks. This situation may represent the basement tectonic frame work of the paleozoics (Fig. 7).

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