The Zonal Distribution of the Non-marine Fauna in the Upper Mesozoic Wakino Subgroup : Studies of the Molluscan fauna of the non-marine Upper Mesozoic Kwanmon group. Part5

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The Zonal Distribution of the Non-marine Fauna in the Upper Mesozoic Wakino Subgroup

(Studies of the Molluscan fauna of the non-marine Upper Mesozoic Kwanmon group. Part 5)*

By

Yoshihisa OTA**

Contents

I. Introduction and Acknowledgements

The Mesozoic non-marine deposits are fairly extensively distributed in Eastern Asia. They have long been studied by many geologists and paleontologists. The paleontological studies of mollusca by KOBAYASHI and SUZUKI (1936, 1937, 1939, 1941, 1942) and SUZUKI (1940, 1941a, 1941b, 1942, 1943a, 1943b, 1949), Estherites by KOBAYASHI and HUZITA (1942), KOBAYASHI and KIDO (1947), and fish by TAKAI (1942, 1943) made an epoch. KOBAYASHI, SUZUKI and TAKAI (1942) distinguished four distinct suites in Mesozoic fresh-water faunas in the Eastern Asiatic continent, i.e. the Taidong and Jehol of Jurassic age and the Kyongsyang and Sungari of Cretaceous. The first two authors (1936) have already proved that the Wakino subgroup of north Kyushu can be correlated to the Naktong subgroup of the Kyongsyang group of South Korea.

* Manuscript received November 30, 1959. Communicated by Professor Tatsuro MATSUMOTO at whose suggestion this work has been undertaken as a part of the "Systematic studies of the Upper Mesozoic in Japan".

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It must be also emphasized that MATSUMOTO (1938, 1939, 1952, 1954) has contributed to the problem of correlation with his discovery of non-marine fossiliferous beds intercalated between the shallow sea deposits of the Gosyonoura group, Mifune group and the Hinagu formation of central Kyushu.

Since 1945 studies of the Late Mesozoic in Japan under the leadership of Prof. T. MATSUMOTO have been made more precisely by a nation-wide group of investigators. A great deal of new observation on the non-marine Upper Mesozoic Kwanmon group has been added by several members of the research group and a part of it was concisely described in chapter VI of "The Cretaceous System in the Japanese Islands" (1954). L.R. COX (1955) examined the pelecypod specimens with V-shaped ornament which the writer obtained from the lower Wakino subgroup. As a result of his study, he withdrew Trigonioididae COX, 1952, because their hinge structures and characteristic ornaments are so common with those of the typical unionids such as *Castalia* and *Nippononaia*. KOBAYASHI (1956a) redescribed the dentition of *Trigonioides* and clarified its distinction from that of the unionid. Thus the Trigonioididae was revived as a valid family. He reviewed, furthermore, *Plicatounio* and *Nippononaia*. Recently, HASE (1958), a member of that group, reported the stratigraphy and geological structure of the Kwanmon group in detail. The paleontological studies on *Estherites* have been succeeded by KUSUMI. The writer himself, as a member of that group, has been mainly engaged in the stratigraphic and paleontologic study of the Kwanmon group in northern Kyushu (1953, 1955, 1957, 1958, 1959a, b, c, d, 1960).

The Kwanmon group consists of the upper, Shimonoseki and the lower, Wakino subgroups, which are separated by a disconformity. While the former, consisting mainly of volcanic ejectas, contains very few fossils, the latter contains a considerable amount of fossils at many horizons. This subgroup is valuable for biostratigraphic study, as it is one of the typical representatives of the non-marine Lower Cretaceous deposits in Eastern Asia. This paper is a biostratigraphic summary of the Wakino fauna.

The Wakino gubgroup is fairly widely distributed from northern Kyushu (type area) to western Yamaguchi Prefecture. According to recent researches, it has become evident that the equivalents of the Wakino subgroup extend further to Hiroshima, Okayama, Hyogo, Fukui and the adjacent Prefectures from west to east. As KOBAYASHI and MATSUMOTO have already suggested, whether or not the Naktong-Wakino faunal group is subdivisible into successive faunas has been a question to be settled. The writer has attempted the zoning of the type Wakino subgroup, with the hope that this will make clear the problem of correlation between the so-called Wakino equivalents in the above districts. In order to solve the questions thoroughly the type area of the Naktong group should also be reexamined, but it is unfortunately impossible for the writer to extend his work to Korea in the present circumstances. Therefore this study is based mainly on the Wakino subgroup in northern Kyushu, although some of the previous collections of the Tokyo University from the continental regions have been restudied.

Before going further, the writer wishes to express his most sincere appreciation to Professor Teiichi KOBAYASHI of the Tokyo University and Professor Tatsuro MATSUMOTO of the Kyushu University for their invaluable advices and their kindness of giving me the privileges of studying their own collections. Prof. T. MATSUMOTO, furthermore, critically read the typescript. Professor Jiro MAKIYAMA, Doctor Tokubei KURODA of the Kyoto University, Professor Sotoji IMAMURA of the Hiroshima University, Doctor Koichi SUZUKI of the Research Institute for Natural Resources and Doctor Isao TAKI of the National Science Museum (Tokyo) gave him many valuable suggestions and criticisms. The writer also expresses his gratitude for the grant provided by the Department of Education.

II. Zonal distribution of the Wakino fauna

1. Outline of the stratigraphy

The writer has already reported in Japanese (1953, 1955, 1957, 1958, 1959d) the stratigraphy of the late Mesozoic in five areas (Fig. 1) of northern Kyushu. In this chapter a summary of the stratigraphy is presented, in which the previously unpublished records of the Mt. Sarakura and Mt. Syakudake areas are also taken into consideration.

The following marks indicate the formations of the Wakino subgroup:

W_1=lower formation (Sengoku formation)
W_2=middle " (Nyoraida ")
W_3=upper " (Lower Wakamiya ")
W_4=uppermost " (Upper Wakamiya ")

For convenience sake the writer calls the outcropping areas of the Wakino subgroup in northern Kyushu from east to west: Moji, Eastern Kokura-Yahata, Western Kokura-Yahata, Naogata, Wakino and Tennobo areas (See Fig. 1).

As standards for the biostratigraphic subdivisions can be taken the Wakino district (the type area) and the Kokura-Yahata area where fossils occur abundantly.

W_1: 250-500 m thick. This overlies directly the Paleozoic phyllitic and slaty rocks with a remarkable clino-unconformity. The basal part consists of conglomerate; the main part sandstone and black shale in alternation. In the Tennobo area coarse-grained sandstones are more predominant than in other areas. The black shales are partly laminated and partly massive, sometimes with interbedded thin coaly shale and small lenticular oolitic limestone. There are fossiliferous

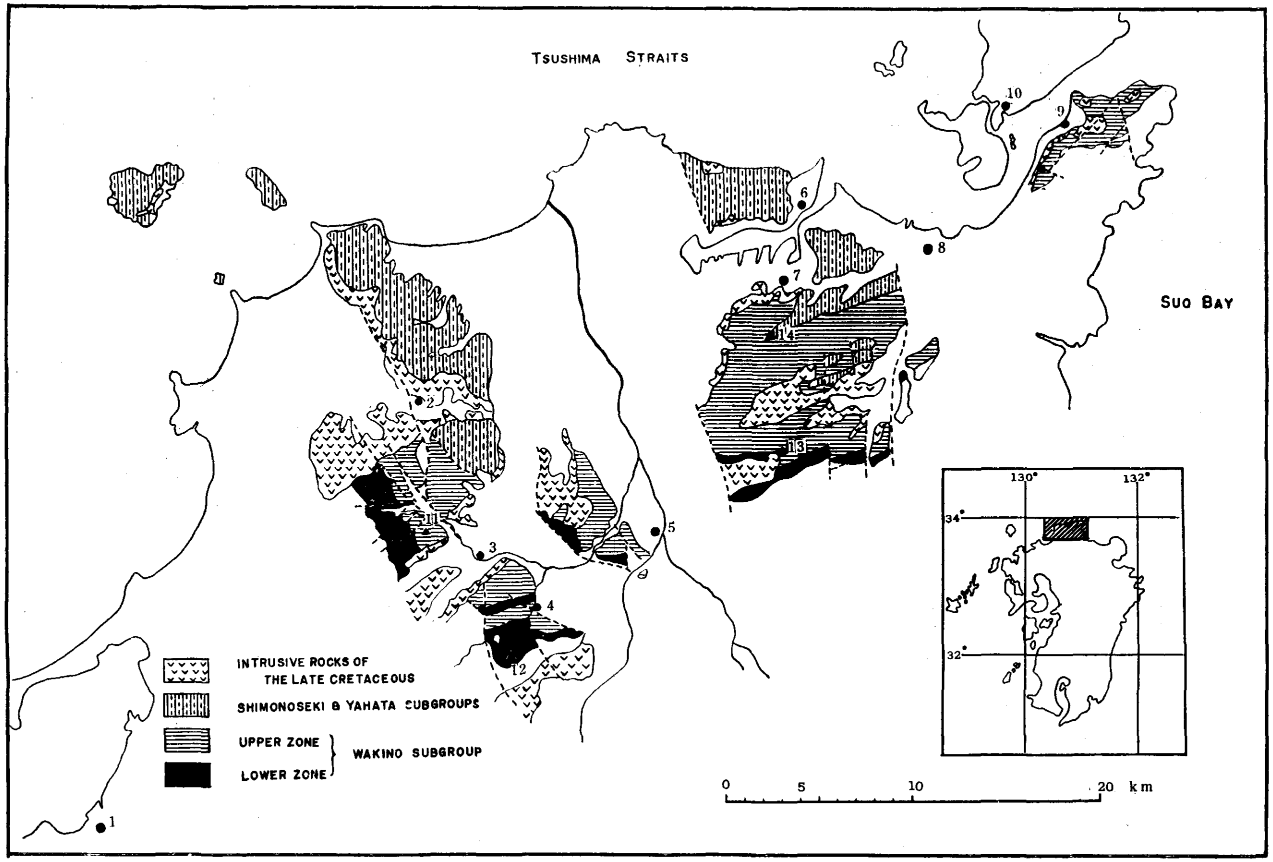

Figure 1. Outcrop map of the upper Mesozoic Kwanmon group in north Kyushu.

1. Fukuoka 2. Akama 3. Wakamiya 4. Wakino 5. Naogata 6. Wakamatsu
7. Yahata 8. Kokura 9. Moji 10. Shimonoseki 11. Mt. Tennobo
12. Mt. Kasagi 13. Mt. Syakudake 14. Mt. Sarakura

parts and the non-fossiliferous parts in the shale. The latter often contains iron sulfide crystals, suggesting the reducing environment. In the Naogata area this unit is covered partly with a marked unconformity by Tertiary deposits, while in the western Yahata and Kokura area they are partly contact-metamorphosed by the intrusion of granite.

W_2: 140–400 m thick. In Wakino area the conglomerate at the base of this unit is accompanied with tuffaceous sandy shale of purple-red or green colour, 40 m in thickness. The upper part consists mainly of black shale and dark sandstone in alternation, intercalating nodule bearing, green-gray, calcareous, fine sandstone. In the Tennobo and western Yahata areas the lower member of W_2 consists of predominant siliceous shale.

W_2 contains generally very few fossils but *Viviparus onogoensis* and others have been discovered by MATSUMOTO, HASE and the writer from W_2 in the Naogata and Moji areas, and also at Yoshimo in Yamaguchi Prefecture. In some places unit W_2 overlies disconformably or partly conformably unit W_1, but in others its basal conglomerate unconformably overlies directly the entirely older rocks as in the eastern part of northern Kyushu and Yamaguchi Pref. It should be noted that W_2 represents the age of transgression and volcanic activity and also the age of a remarkable faunal change.

W_3: 350–600 m thick. The basal member consists of conglomerate. The remaining main part generally consists of sandstone and shale in alternation. There is, however, some local variation. In the Tennobo area coarse-grained sandstones with thin interbeds of conglomerates predominate in the main part, but in the Wakino area black shales predominate containing lenticular limestones. In the Kokura-Yahata area the equivalent of W_3 is composed of thicker shales, 600 m in thickness as compared with 350 m in the Wakino area. In the western Yamaguchi Prefecture, the equivalent of W_3 consists of predominant coarse-grained sandstones and conglomerates, overlapping the various older rocks. Fossiliferous beds are found at many localities in Wakino, Naogata, Kokura and Yahata areas, but they are not so continuously traced as in W_1.

W_4: 350 m thick. This formation resembles W_3 in litho-facies, although siliceous rock is more predominant in the former than in the latter. In the Tennobo, Naogata, Kokura and Yahata areas, all or part of W_4 was eroded away and is disconformably overlain by the Shimonoseki subgroup in some places. In the Wakino area its exposure is limited to a narrow belt owing to the intrusion of granite. Fossils are rarely found in the eastern Yahata area. In the western area of Yamaguchi Prefecture the equivalent of W_4 consists of thicker deposits, about 550 m, in which coarse-grained sandstones with intercalated conglomerates predominate.

2. Occurrence of fossils

From the observed facts as reported in the papers of local stratigraphy of northern Kyushu, the following summary (1-8) can be lead concerning the occurrence of fossils in the Wakino subgroup:

(1) The non-marine molluscan fossils are contained abundantly in silty shale and rarely in sandstone and limestone. Many specimens are more or less deformed by the later deformation, but some, especially those preserved in limestone retain their original forms.

(2) As a general tendency a closed bivalve is most predominant, opened bivalve is next and separated one is rare.

An angle between the bedding plane and the direction of the siphon in the closed bivalve shell is very irregular.

(3) Gastropods occur as an accumulation, forming in many cases a fossiliferous bed but in some cases a small fossiliferous lense.

The direction of the columella of the shell is generally on a plane parallel to the bedding when the shell occurs in a fossil bed, in which the apices of many whorls are arranged in the same orientation. This phenomenon suggests the direction of a current. But in some cases the orientation of the apex is at random and, furthermore, it may be oblique to the bedding plane in some other cases. The specimens generally show irregular arrangements, when they form a shell-limestone.

(4) A certain species of *Viviparus* with a large apical angle may be a nekroplankton. The fossil bank consisting mostly of *Viviparus* shells may thus be a deposit near a lakeside.

(5) The apical whorls of the recent non-marine gastropods having high spire are frequently eroded away, while those from the Wakino subgroup are not. This difference is a question to be answered. Although there is no good evidence for reasoning, the difference in property of water might be the essential factor.

(6) *Estherites* occurs in a very fine laminated shale, forming an accumulation of a small lense. Generally it is evenly deformed.

(7) A fossil fish shows an isolated occurrence in a shale or associated with *Estherites*. Its body-side is generally parallel to the bedding plane.

(8) Plant fossils are generally rare. *Cladophlebis* sp. and stems of obscure kinds are rarely discovered and not intermingled with animal remains.

From the above occurrences it can be concluded that the fossils of the Wakino faunas were not buried in situ at their habitat but that they were probably embedded in the place not far from the habitat.

For the biostratigraphic purpose it has been examined whether or not the

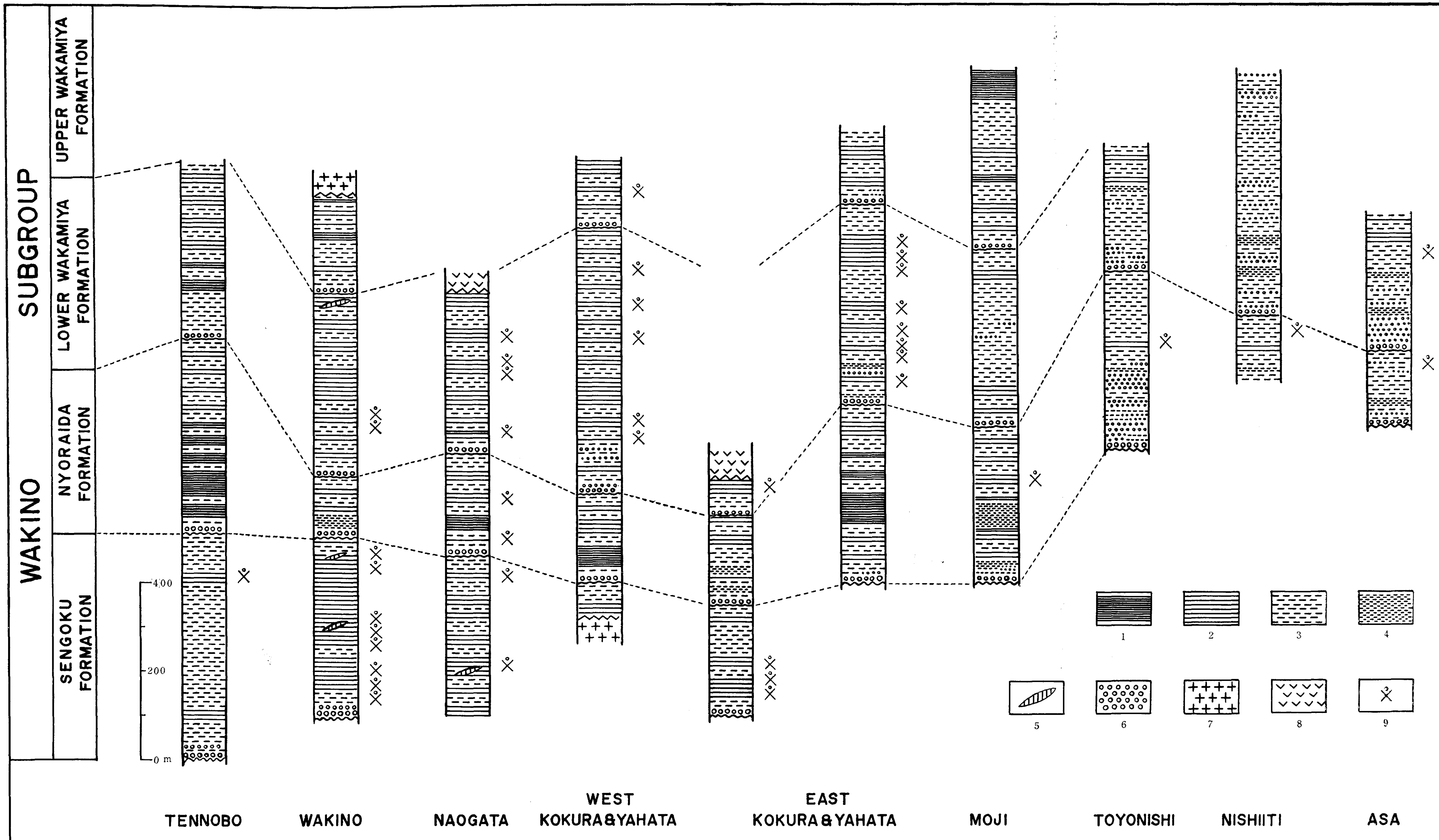

Figure 2. Stratigraphic sections of the Wakino subgroup in north Kyushu and west Chugoku.

1. Siliceous shale 2. Shale 3. Sandstone 4. Purple or green sandstone 5. Limestone 6. Conglomerate 7. Granite 8. Porphyrite 9. Fossiliferous bed

fossiliferous beds of various localities belong to the same age, using a key-bed of tuffaceous rock as a datum line. By so doing, the writer has recognized that remains of some species distribute extensively and those of others narrowly in a certain member. For example, *Brotiopsis wakinoensis*, *Viviparus onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* show the widest distribution of their remains, followed by species of *Plicatounio* and then *B. kobayashii*. The examples of the narrow distribution of remains are species of *Trigonioides*, "*Nippononaia*" *wakinoensis*, "*N.*" *sengokuensis*, *Yoshimonia katsukiensis*, *Manchurichytes* (?) sp. and species of *Estherites* and Ostracoda.

Through the investigation of the coexisting relation of species, the writer has noticed that the assemblage of species changes from place to place even at the same horizon. For example in the lower formation of the Wakino area, *B. wakinoensis*, *Plicatounio naktongensis* and *P. kwanmonensis* constitute a fossiliferous bed which extends about 4 km in distance. They are associate with few specimens of "*Nippononaia*" and *P. triangularis* in the western part but not at all in the eastern part of the area. *B. wakinoensis*, *V. onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* may sometimes coexist with other species, but in some other cases they do not accompany other species. Particularly, the exclusively abundant occurrence of *V. onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* in the upper formation is a remarkable example of the latter cases. Perhaps this phenomenon is related to a particular environment and may be explained by the law of Thienemann.

The abundance of a given species may change from place to place even in the same formation, resulting from the local difference in environment and mechanism of deposition. Accordingly it is not easy to determine the acme of the species from the apparent abundance of its fossilized remains preserved in beds of a limited area. If we examine, however, the entire basin of deposition, we may recognize that a certain species have a wide horizontal distribution and a limited stratigraphical range, occurring in large quantity in that limited part but rare or absent in other parts. In such a case it may be allowed to regard the acme of a certain species as being represented by that definite part.

For the biostratigraphic subdivision the species whose remains are widely distributed and predominating in number are most valuable. The writer has recognized such species in the Wakino subgroup and thus attempted a zonation. The abundance of the remains of a species in a given fossiliferous bed is ranked as very abundant, abundant, common, rare and very rare, as is usually done. To avoid the estimation of the abundance of a species becoming too gross, the writer has tested several cases by a quantitative treatment. The writer has tentatively tried regular sampling in 1000 cm^3, when the specimens are as small as *Brotiopsis*, *Viviparus* and *Nakamuranaia*. The results of the measurements are shown in Tables 1-4. Examples in Tables 1 and 2 are called "common", while those in Tables 3 and 4 are called "abundant".

Table 1

Species \ Sampling no.	I	II	III	IV	V	VI	VII	VIII	IX	X	F.	D.
V. onogoensis	26	13	19	18	3	26	30	38	24	25	100%	22.2
Nakamuranaia (?) sp. cf. *N. chingshanensis*	33	21	23	28	7	44	22	45	40	37	100%	30.0

Formation and Locality: the upper formation of the Wakino subgroup, at near Kotaniguchi pond, Kami-shinnyu, Naogata city, Fukuoka Pref.. F.=Frequency, D.=Density/1000 cm^3.

Table 2

Species \ Sampling no.	I	II	III	IV	V	F.	D.
B. wakinoensis	84	75	94	105	144	100%	100.4
P. naktongensis	2	1	3	0	4	80%	2.0

Formation and Locality: the lower formation of the Wakino subgroup, cutting near the Sengoku Pass, Sengoku, Miyata-machi, Kurate-gun, Fukuoka Pref..

Table 3

Species \ Sampling no.	I	II	III	IV	V	F.	D.
V. onogoensis	475	875	250	578	924	100%	620.4

Formation and Locality: the upper formation of the Wakino subgroup, Kotaniguchi pond side, Kami-shinnyu, Naogata-city, Fukuoka Pref..

Table 4

Species \ Sampling no.	I	II	III	IV	V	F.	D.
B. wakinoensis	342	106	512	211	251	100%	284.4

Formation and Locality: the lower formation of the Wakino subgroup, Sengoku, Miyata-machi, Kurate-gun, Fukuoka Pref..

3. Stratigraphic distribution of fossils in local sections

The Wakino subgroup has been subdivided into four formations. The writer has already reported that this subdivision is kept not only in the type area but also in the whole of the Wakino basin in north Kyushu. He has furthermore described serially some of the more important species (OTA, 1959a, 1959b, 1959c, 1960). The know species of the Wakino subgroup are 10 of pelecypods (including subspecies), 5 of gastropods, 1 of Ostracoda, 3 (?) of *Estherites*, 1 fish and some fragmentary plants. The zonal distribution of the Wakino fauna is best exemplified by pelecypods and gastropods which occur more abundantly and more extensively than remains of other groups.

For the zonal subdivision the writer made at first stratigraphic sections as many as possible in every district and then made range charts in which results of quantitative measurements are also indicated by the breadth of black belts. The local zonules in every district have been determined from the stratigraphic sections and the range charts.

The stratigraphic distribution of the species in the Wakino subgroup is summaried in Fig. 3. From this foundation the Wakino group can be subdivided into the lower and upper zones which can be further subdivided, as will be fully explained shortly afterwards.

(1) *Wakino area.—Brotiopsis wakinoensis* occurs very abundantly throughout the entire thickness and horizontal extension of W_1. It occurs also in W_3 although only in a small lense. This is exceptional, because in the areas other than Wakino it is confined to and abundant in W_1. Regarding thus the occurrence in W_3 as exceptional, the writer calls the whole of W_1 the beds with *B. wakinoensis*.

Plicatounio naktongensis occurs commonly in the middle part of W_1 between 100 m and 150 m from the base of W_1, distributing in the whole of the Wakino area. "*Nippononaia*" *wakinoensis*, "*N.*" *sengokuensis*, *Plicatounio naktongensis multiplicatus*, *P. triangularis* and *P. kwanmonensis*, occur in nearly the same bed as *P. naktongensis naktongensis*, but they are very rare and limited in horizonal distribution than the latter. Anyhow the zonule of *P. naktongensis naktongensis* can be recognized in the middle of W_1. In the upper W_1 *B. wakinoensis* coexists with *Dreisenia* (?) sp. and very rarely with *V. onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis*. The *B. wakinoensis* zonule can thus be subdivided into the following three divisions in ascending order.

1. lower *B. wakinoensis* zonule
2. *P. naktongensis naktongensis* zonule
3. upper *B. wakinoensis* zonule

No fossils have been discovered from W_2. *B. wakinoensis* occurs in a small lenticular bed at about 110 m above the base of W_3, and is accompanied commonly with *P. naktongensis multiplicatus* and very rarely with *Trigonioides* sp. In the equivalent bed on the western extension, *Nakamuranaia* (?) sp. cf. *N. chingshanensis* is common. *P. naktongensis multiplicatus*, which is morphologically more advanced than *P. naktongensis naktongensis*, is associated with it. "*Nippononaia*" *wakinoensis*, "*N.*" *sengokuensis*, *P. kwanmonensis* and *P. triangularis*, all of which occur in W_1, do not appear in W_3. Therefore, W_3 faunule can be distinguished from the W_1 faunule. Thus W_3 can be called the beds with *Nakamuranaia* (?) sp. cf. *N. ching-*

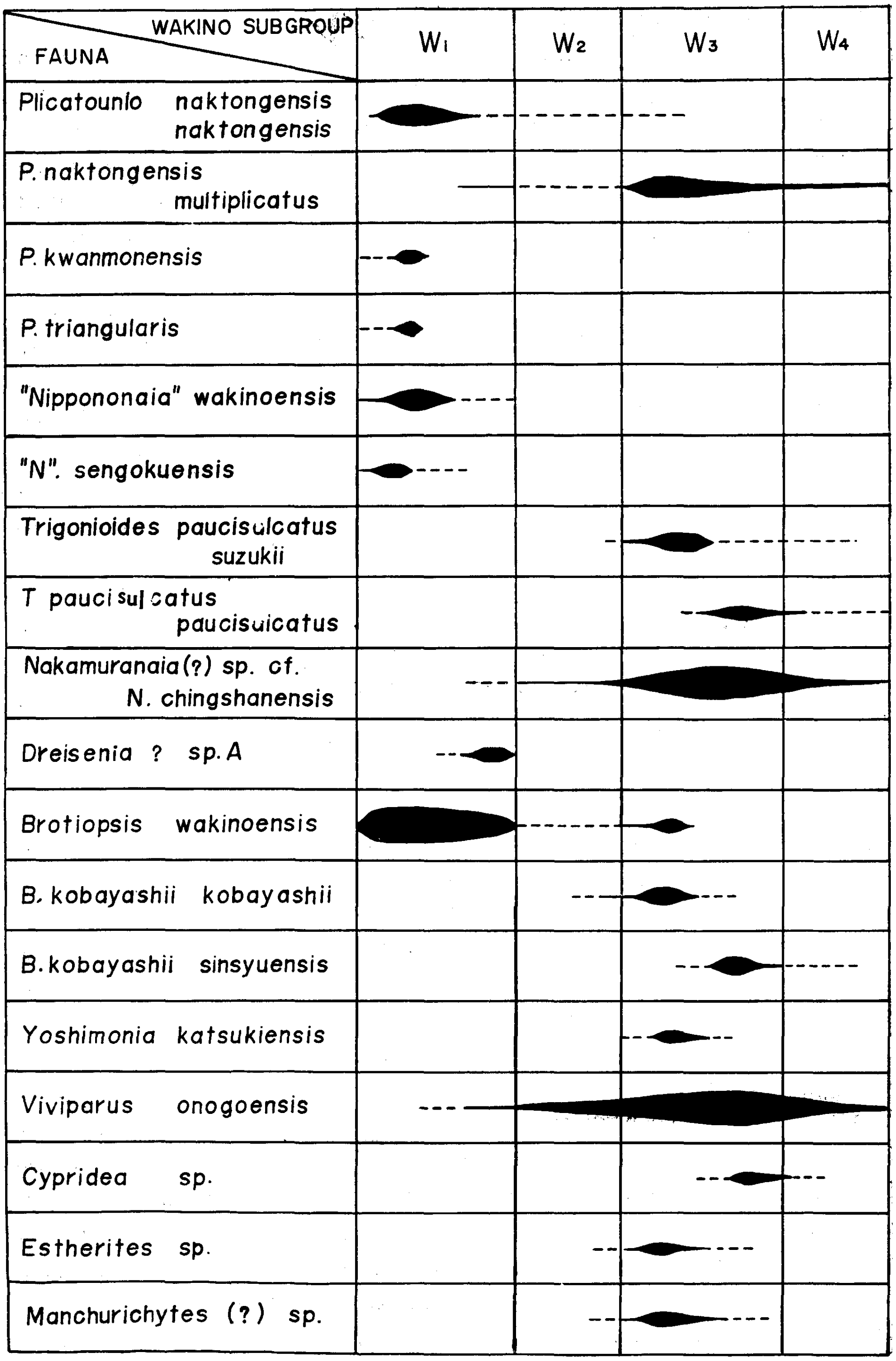

Figure 3. Stratigraphic distribution of the species in the Wakino subgroup.

shanensis-P. naktongensis multiplicatus.

W_4 has a narrowly distribution and is mostly metamorphosed to hornfels, whence no fossils were obtained.

(2) *Eastern Kokura-Yahata.*—*Brotiopsis wakinoensis* occurs very abundantly in the lower 80 m of W_1. It is accompanied commonly with *P. naktongensis naktongensis* in the upper part of its range. Therefore lower W_1 can again be called the beds with *B. wakinoensis* and *P. naktongensis naktongensis* zonule may be distinguished in the upper part of it.

No fossils have been discovered from the upper member of W_1 and the whole of W_2 in this area. W_3 is narrowly exposed in the southern part of this area because of erosion, faulting and intrusion of igneous rocks. It is, however, widely distributed in the northern area, as it is repeated by folding. Fairly numerous fossils have been found at many localities but the fossiliferous beds are generally small and lenticular. In many cases it is difficult to determine whether or not a given bed is at exactly the same horizon as others. *V. onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* occur very abundantly not only in the lower member but also in the upper member of W_3. Therefore the whole of W_3 in this area can be called as the beds with *Nakamuranaia* (?) sp. cf. *N. chingshanensis*. *Brotiopsis kobayashii* occurs in W_3 but is less numerous and shows a narrower distribution than the former two species. It has two subspecies, of which *B. kobayashii kobayashii* is common in the lower 200 m and *B. kobayashii sinsyuensis* is common in the upper member and does not occur in the lower member. Therefore W_3 can be subdivided into two, the *B. kobayashii kobayashii* zonule and *B. kobayashii sinsyuensis* zonule. Fish (*Manchurichthys* (?) sp.) and *Estherites* occur rarely in the lower member, and Ostracoda (*Cypridea* sp.) occurs as a small lenticular bed in the upper part.

W_4 is considerably widely distributed in this area, but contains very few fossils. A small number of *V. onogoensis* was obtained from the lower part. Possibly W_4 may be still included in the beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*.

(3) *Western Kokura-Yahata.*—Only the upper member of W_1 is narrowly distributed in this area owing to the intrusion of granite and no fossil has been discovered from it. W_2 is similarly barren. W_3 is widely distributed, as it is repeated by folding, but the fossil localities are not so numerous as in the eastern area. The known localities are only five. *V. onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* occur very abundantly throughout W_3. Therefore W_3 corresponds to the beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*. In the lower part of W_3 in this area *V. onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* coexist with abundant *Trigonioides paucisulcatus suzukii* and *Plicatounio naktongensis multiplicatus*, common *Brotiopsis kobayashii* and rare *Yoshimonia katsukiensis*. As *Trigonioides paucisulcatus suzukii* and *P. naktongensis multiplicatus* are

considerably widely distributed than others, the *T. paucisulcatus suzukii-P. naktongensis multiplicatus* zonule can be recognized in the lower part of the beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*.

Viviparus sp. was discovered from a locality in W_4. Further careful collecting is needed to decide that W_4 in this area should be included in the beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*.

(4) *Tennobo area.*—As the equivalents of W_1 and W_3 in the Tennobo area consist mostly of coarse sandstone, they greatly differ in lithofacies from those of the Wakino, Kokura and Yahata areas. Fossils are also scarce. Only *Brotiopsis wakinoensis* is at present discovered from two localities in the upper of W_1. This probably corresponds to the extension of the *B. wakinoensis* zonule of the Wakino area.

(5) *Naogata area.*—In this area W_1 is not wholy exposed, being partly covered with Tertiary deposits. *Brotiopsis wakinoensis*, which occurs very abundantly in W_1 of the neighboring Wakino area, has not yet been discovered in this area. *Viviparus onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* occur very rarely in the upper part of W_1, rarely in W_2, but very abundantly in many beds of W_3. The whole of W_3 is an unmistakable representative of *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis* zonule. W_2 is probably included in the same zonule, because *B. kobayashii* (*s. s.*) occurs rarely in W_2 and the lower part of W_3. The *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis* zonule, as in Kokura-Yahata area, can be subdivided, with the *B. kobayashii kobayashii* zonule in its lower part.

(6) *Moji area.*—W_1 is lacking and W_2 overlies directly the Paleozoic rocks. Fossil is generally scarce. Small specimens of *B. kobayashii kobayashii* occur from two localities which belong to the upper part of W_2. This probably corresponds to the zonule of *B. kobayashii kobayashii* i. e. the lower part of the beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*.

4. Summary of zonation

Correlation of local zonules between various areas is shown in Fig. 4.

A. Zones

(1) *Brotiopsis wakinoensis zone.*—The beds with *B. wakinoensis* can be connected between various areas from the eastern area of Kokura to the western Tennobo area for about 30 km in distance. The zone of *B. wakinoensis* can thus be recognized, being represented by the whole of the lower formation (W_1) of the Wakino subgroup.

(2) *Viviparus onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis zone.*—The beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*, which consist

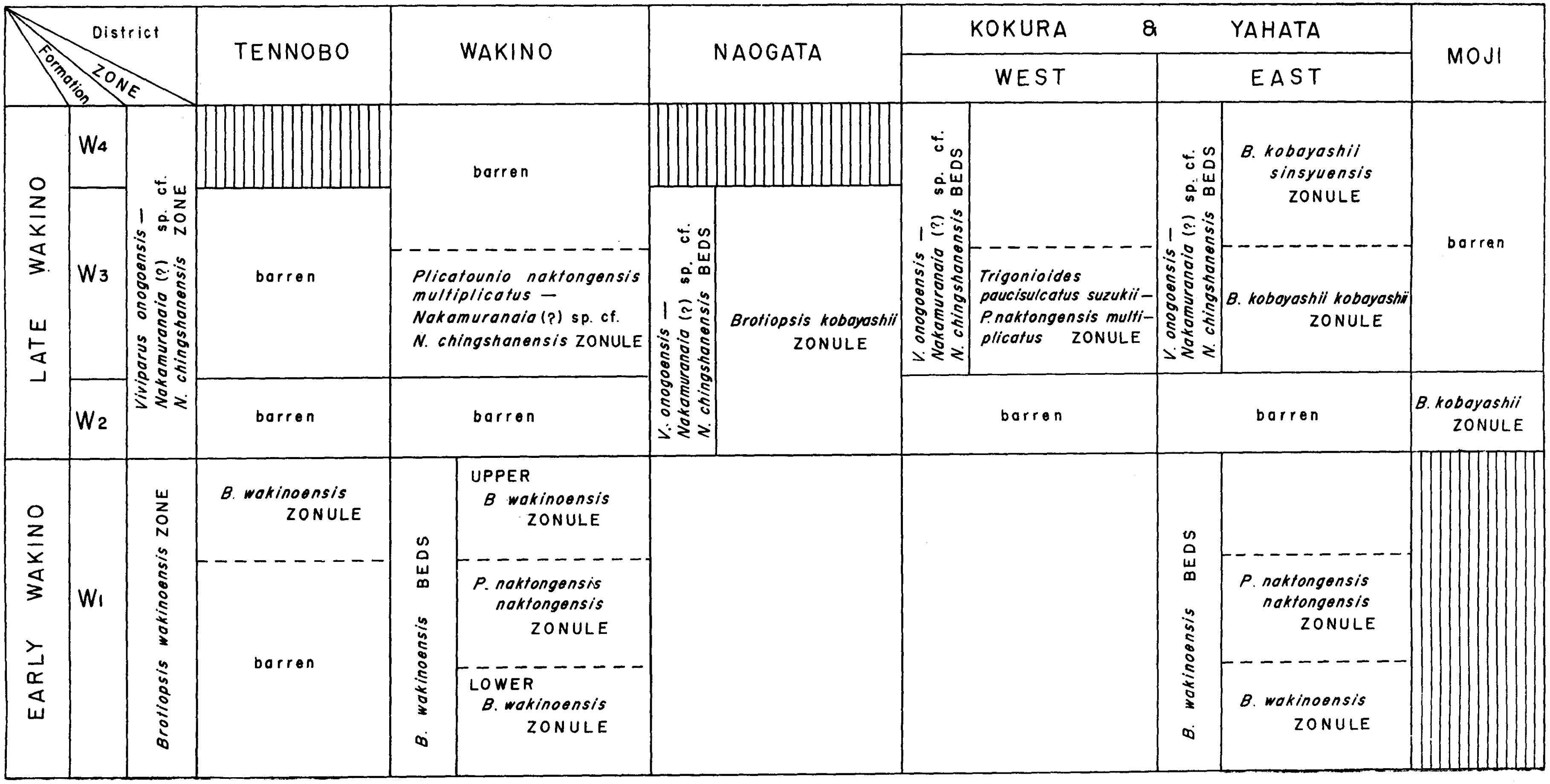

Figure 4. Zonation of the Wakino subgroup in north Kyushu.

of W_3 and W_4, extend for about 10 km from east to west in Kokura and Yahata areas. The named species seem to range down to W_2 in the Naogata area, as they occur in fairly numerous beds of W_2. In the Wakino area *V. onogoensis* occurs in the beds with *P. naktongensis multiplicatus-Nakamuranaia* (?) sp. cf. *N. chingshanensis*, although it is very rare. The writer regards the zonule of *P. naktongensis multiplicatus-Nakamuranaia* (?) sp. cf. *N. chingshanensis* as a local variation of the zone of *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*. In Moji area *Brotiopsis kobayashii* occurs only in W_2, but in other areas it is common in W_2 and the lower part of W_3, which represents the lower part of the beds with *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*. Thus the *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis* zone can be proposed for the upper three formations, W_2, W_3 and W_4, of the Wakino subgroup, although they show a local variation.

The Wakino group, in short, can be subdivided into two zones: the lower, *Brotiopsis wakinoensis* zone and the upper, *Viviparus onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis* zone. The boundary of these two zones is the base of W_2. As has been stated above, W_2 overlies disconformably W_1 and overlaps on the various older systems, and its basal conglomerates accompanies tuffaceous rock. The difference between the lower and upper zones is not great in lithofacies and biofacies. Some of the upper zone-fossils indicate more evolved forms than the lower zone-fossils; for examples, *P. naktongensis multiplicatus* and *B. kobayashii* in the upper formations are derived respectivity from *P. naktongensis naktongensis* and *B. wakinoensis* in the lower formation. Accordingly the difference of faunules between the two divisions, as illustrated in Text-fig. 3, may be due to shift of time rather than to change of environment.

B. Subdivision of zones

(1) *Subdivision of the Brotiopsis wakinoensis zone.—Plicatounio naktongensis* seems to spread over a considerably wide extent, as it is not only found in the middle part of W_1 in the Wakino area but also in the equivalent beds in the eastern Kokura area. *P. naktongensis* is, however, far less abundant than *B. wakinoensis*. As has been stated above, in the Wakino area the *B. wakinoensis* zonule can be subdivided into three zonules, with *P. naktongensis* zonule in the middle part. This subdivision is also applicable to the southern Kokura area. Accordingly the *B. wakinoensis* zone can be subdivided into the following three subzones;

B. wakincensis zone
1. upper *B. wakinoensis* subzone
2. *P. naktongensis* „
3. lower *B. wakinoensis* „

(2) *Subdivision of the Viviparus onogoensis-Nakamuranaia* (?) sp. cf. *N. ching-*

shanensis zone.—The named species occur very abundantly in the upper part of W_3 but tend to become rare above and below this part, although they range up to W_4 and down to W_2. The *Brotiopsis kobayashii kobayashii* zonule which is most clearly recognized in the lower W_3 of the southern Kokura-Yahata area can be traced eastward to Moji and westward to the Naogata area. On the other hand the *B. kobayashii sinsyuensis* zonule can be recognized in the upper W_3 and W_4, although it is not so extensively traceable as the preceding subspecies. Phylogenetically *B. kobayashii sinsyuensis* is regarded as an advanced form derived from *B. kobayashii kobayashii.* Thus *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis* zone can be subdivided into the lower, *B. kobayashii kobayashii* subzone and the upper, *B. kobayashii sinsyuensis* subzone. *Trigonioides paucisulcatus suzukii* and *Plicatounio naktongensis multiplicatus,* which occur in the lower W_3 of the southern Yahata area, are not so widely distributed as the two subspecies of *B. kobayashii,* but they indicate the lower part of the *V. onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis* zone and probably the upper part of the *B. kobayashii kobayashii* subzone.

5. Notes on zonal indices

In this article the writer gives a synoptic list of the zcnal indices. Most of them have already been described as indicated in the list. A note of one more species is given.

Plicatounio naktongensis naktongensis KOBAYASHI and SUZUKI

KOBAYASHI and SUZUKI, (1936), *Japan. Jour. Geol. Geogr., Vol. 13, Nos. 3-4,* p. 252, pl. 28, figs. 1-4, 6-8.
SUZUKI, (1943b), *Jour. Sigen. Kenkyusyo, Vol. 1, No. 2,* p. 211, pl. 16, figs. 14, 15; pl. 17, fig. 11 (A).
OTA, (1959a), *Trans. Proc. Palaeont. Soc. Japan, N.S., No. 33,* pl. 3, figs. 4-8.

P. naktongensis multiplicatus SUZUKI

SUZUKI, (1943b), *Op. cit.,* p. 211, pl. 16, figs. 1-6.
OTA, (1959a), *Op. cit.,* p. 15, pl. 3, figs. 9-11.

Trigonioides paucisulcatus suzukii OTA

OTA, (1959b), *Op. cit.,* p. 102, pl. 11, figs. 12-20.

Brotiopsis wakinoensis (KOBAYASHI and SUZUKI)

KOBAYASHI and SUZUKI, (1936), *Japan. Jour. Geol. Geogr., Vol. 13, No.s 3-4,* p. 256, pl. 29, fig. 14.
SUZUKI, (1943b), *Op. cit.,* p. 206, pl. 15, pl. 17, fig. 11, except A, B.
OTA. (1960), *Jour. Sci. Rep. Hiroshima Univ., Vol. 3, No. 1,* p. 2, pl. 1, figs. 1-23; text-fig. 1.

B. kobayashii kobayashii SUZUKI

SUZUKI, (1943b), *Op. cit.*, p. 207, pl. 17, figs. 10a, b, 11 (B).
OTA, (1960), *Op. cit.*, p. 5, pl. 1, figs. 24-35.

B. kobayashii sinsyuensis SUZUKI

SUZUKI, (1943b), *Op. cit.*, p. 208, pl. 16, figs. 11-13.
OTA, (1960), *Op. cit.*, p. 5, pl. 2, figs. 1, 2.

Viviparus onogoensis KOBAYASHI and SUZUKI

KOBAYASHI and SUZUKI, (1937), *Japan. Jour. Geol. Geogr., Vol. 14, Nos. 1-2*, p. 48, pl. 5, figs. 13a, b.
SUZUKI, (1943b), *Op. cit.*, p. 199, pl. 14, figs. 1-16.
OTA, (1960), *Op. cit.*, p. 11, pl. 3, figs. 1-26.

Nakamuranaia (?) sp. cf. *N. chingshanensis* (GRABAU)

The genus *Nakamuranaia* was originally instituted by SUZUKI (1943b) on the type-species, *Leptesthes chingshanensis* GRABAU, 1923. All the specimens described by KOBAYASHI and SUZUKI (1936) as *Corbicula* (*Leptesthes* ?) *coreanica*, *Cristaria* ? sp. aff. "*Leptesthes*" *chingshanensis* GRABAU and "*Unio*" cfr. *menkei* DUNKER, were put in the synonymy of *Nakamuranaia chingshanensis* by the same author (SUZUKI, 1943b). Younger specimens of the last species are practically indistinguishable from the examples of the above three species, although their hinge features are not necessarily clear. Adult shells of *N. chingshanensis* have been found only from the Kinbu formation of the Naktong subgroup and they are generally far less numerous than the immature shells from the same Naktong subgroup. Many specimens resembling in outline and size the younger shells of *Nakamuranaia chingshanensis* occur in the Wakino subgroup and its equivalents in Japan, but strangely its adult examples have not yet been discovered in Japan. It is hardly decided to which of *Nakamuranaia*, *Leptesthes* or *Sphaerium* these specimens belong, unless their hinge are clearly shown. In this paper they are tentatively called *Nakamuranaia* (?) sp. cf. *N. chingshanensis*, since it may be identical with *Nakamuranaia chingshanensis* which are common in the Naktong subgroup, the probable equivalent of the Wakino subgroup in Korea.

III. Correlation

1. Non-marine Upper Mesozoic beds of various areas in the Inner Zone of Southwest Japan

(1) *Western Yamaguchi Prefecture.*—The equivalent of the Wakino subgroup outcrops in a considerably wide area in the western part of Yamaguchi Pref. This has been investigated by many geologists, but the outstanding contributions have

been made by MATSUMOTO, HASE and others in the last ten years. While W_1 is lacking here, W_2 overlies directly the older rocks of various ages, gradually becoming narrower and thinner towards the east. The writer discovered *Viviparus onogoensis* from the upper part of W_2 at Kuroshima near Yoshimo, Shimonoseki city.

The equivalents of W_3 and W_4 consist mainly of thick coarse-grained deposits of deltaic origin with some estuarine intercalation. HASE discovered *Nakamuranaia* (?) sp. cf. *N. chingshanensis* and *Brotiopsis kobayashii* in W_3, and lower W_4. Therefore the equivalents of W_2, W_3 and W_4 in western Yamaguchi Pref. are evidently assigned to the zone of *Viviparus onogoensis-Nakamuranaia* (?) sp. cf. *N. chingshanensis*.

(2) *Scattered areas in Hiroshima and Okayama Prefectures.*—The so-called Inkstone group (Kwanmon group) has been reported by IMAMURA and KUSUMI (1951) and KUSUMI (1950, 1951). It occurs rather frequently, though discontinuously, near the boundary of the two Prefectures. Among many localities the Inakura area (Inakura-mura, Oda-gun, Okayama Pref.) is stratigraphically the best known, for there is a detailed description by IMAMURA and KUSUMI (1951). According to their report, the Inakura group is subdivided into lower and upper Inakura formations. Mollusca and *Estherites* were found in considerable amount by IMAMURA and KUSUMI from the Yamaji shale beds of the lower formation. Examining KUSUMI's collections, by courtesy of Asst. Prof. H. KUSUMI of the Hiroshima University, the writer has identified *Viviparus onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis*. Therefore the lower formation of the Inakura group can be correlated with the upper zone of the Wakino subgroup. As has already been stated by IMAMURA and KUSUMI (1951), MATSUMOTO (1954) and HASE (1958), the upper formation can be probably correlated with the lower part of the Shimonoseki subgroup.

(3) *Sasayama group of Sasayama city, Hyogo Prefecture.*—The so-called Inkstone group is distributed within 4 km in and around Sasayama city and is sometimes called the Sasayama group. According to recent studies (ENMASU and NAKAZAWA, 1956; SAKAGUCHI, 1959*), it consists of lower, middle and upper formations. Mollusca and *Estherites* have been found in the shale of the upper formation of alternating shale and sandstone. Examining NAKAZAWA's collections of mollusca, by the kindness of Asst. Prof. K. NAKAZAWA of the Kyoto University, the writer has identified *Viviparus onogoensis* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis*. Therefore the upper formation can be correlated with the upper zone of the Wakino subgroup. According to the investigation by SAKAGUCHI, the agglomerate of hornbrend-andesite underlies the upper formation, followed by the 700 m thickness of conglomerate and alternating sandstone and shale with accompanying tuffaceous shale. The base

* SAKAGUCHI, Shigeo, On the Mesozoic and Paleozoic formations of Sasayama basin in Hyogo Prefecture. Talk at the Meeting of the Geol. Soc. Japan, Kwansai Branch, February, 1959, Kyoto.

is an unconformity with the paleozoic rocks. The lower formation is not accurately correlated with the Wakino subgroup in northern Kyushu, because no fossils have been obtained from it. From stratigraphic sequence and lithologic affinity the writer presumes that the middle formation is probably the equivalent of W_2 and the lower that of W_1.

(4) *Tetori group of the Hida Massif.*—The Hida area comprises the northern half of Gifu Pref., the eastern part of Fukui Pref., the southeastern part of Ishikawa Pref. and the southern part of Toyama Pref.. In this region is exposed the celebrated Tetori group, which has long been studied by many geologists and paleontologists. Its main part has been assigned to the Middle and Upper Jurassic from the evidences of ammonites, trigonians, brackish water mollusca and plants. MAEDA (1951-1958) and KAWAI (1955, 1956) have recently clarified that the upper part of the group is referable to the Cretaceous. This was confirmed by AMANO and ENDO (1952) who studied the fossil plants collected by KOBAYASHI and MAEDA. According to the recent knowledge, Tetori group is generally subdivided into the three subgroups, Kuzuryu, Itoshiro and Akaiwa subgroups in ascending order. Correlation between Akaiwa subgroup and the Wakino subgroup is still very questionable. There are two opinions. One holds that only the upper formation of the Akaiwa subgroup may be correlated with the Wakino subgroup, while the other considers that the upper formation of the Itoshiro subgroup added to the whole of the Akaiwa subgroup may be correlated with it. MAEDA listed from the Kitadani formation of the upper Akaiwa subgroup *Nakamuranaia chingshanensis* (GRABAU), "*Schistodesmus*" sp. *Plicatounio kobayashii* MAEDA (MS), *P. tetoriensis* MAEDA (MS), *Trigonioides suzukii* MAEDA (MS) (*non* OTA, 1959b), *T. kodairai* KOBAYASHI and SUZUKI, and "*Viviparus*" sp. As these fossils have not yet been fully described, the writer cannot give accurate remarks on them. It is not clear whether *Plicatounio* n. sp. of the Kitadani formation is older than *P. naktongensis naktongensis* or it is allied to *P. naktongensis multiplicatus*. Judging from an illustration (MAEDA, 1953, pl. 2, fig. 1), this form is rather similar to the latter than the former in that it has more numerous posterior radial plications than *P. naktongensis naktongensis*. If this presumption was correct, the writer would suggest that the Kitadani formation might be correlated to the upper zone of the Wakino subgroup, because *P. naktongensis multiplicatus* coexists with *Trigonioides paucisulcatus suzukii* and *Nakamuranaia* (?) sp. cf. *N. chingshanensis* in the lower part of the upper zone in northern Kyushu. The writer (1959c) has already described "*Nippononaia*" *wakinoensis* and "*N*". *sengokuensis* in the lower part of the lower formation (W_1) of Wakino subgroup. MAEDA reports that *Nippononaia* sp. coexists with *Unio*, *Polymesoda*, *Corbicula*, *Batissa*, *Melanoides* etc. in the Kuwajima formation. If *Nippononaia* sp. of the Kuwajima formation is closely allied to or identical with *Nippononaia* sp. of the Wakino subgroup, it may be allowed to suggest that a part

of the Itoshiro subgroup as represented by the Kuwajima formation may be possibly correlated to the lower zone. At all events, the writer hopes that the full description of the Tetori faunas will be published in the nearest future, so that the comparison with the Wakino fauna will become more accurate.

2. Naktong group in the continental area

(1) *Naktong group in Southern Korea.*—The Naktong fauna was described in detail by KOBAYASHI and SUZUKI (1936) and SUZUKI (1943b). In this paper only a summarized list of species (Table 5) is presented. Their detailed horizontal distribution was not clear, so the writer can not at present discuss the zonal distribution of the Naktong fauna. It should be noted, however, that the four formations of the Wakino subgroup resemble respectively in lithofacies the four formations of Naktong subgroup, although their thickness and their geological structure are very different between the two subgroups. The writer attemps below the comparison of the Wakino and the Naktong faunas.

Table 5. List of the non-marine fauna of the Naktong (Rakuto) subgroup in South Korea.

Fauna \ Formation	Kinbu formation	Kasando formation	Sinsyu formation	Sikkoku formation
Plicatounio naktongensis naktongensis	C		R	
P. naktongensis multiplicatus			C	
Trigonioides kodairai	NR		C	
Nakamuranaia chingshanensis	A	NR	A	
Brotiopsis wakinoensis wakinoensis	VA			
B. wakinoensis ryohoriensis	A			
B. kobayashii kobayashii	R			
B. kobayashii sinsyuensis			A	
Viviparus onogoensis [= *V. keisyoensis*]	C			
Hydrobia gyokusoensis	NR			
Bulimus rakutoensis	R	R		
Itomelania basicordata			VA	
Micromelania ? katoensis	R			
Anisus (*Gyraulus* ?) sp.	R			
Schistodesmus antiqus	VA			

VA: Very abundant A: Abundant C: Common NR: Not rare
VR: Very rare After SUZUKI, K. (1943b), with revision.

<table>
<tr><th colspan="3">District / formation / Zone</th><th colspan="5">NORTH KYUSHU</th><th colspan="3">WEST YAMAGUCHI PREF.</th><th colspan="2">HIROSHIMA & OKAYAMA</th><th colspan="2">HYOGO PREF.</th><th colspan="2" rowspan="2">HIDA Area</th><th colspan="2" rowspan="2">KOREA</th><th rowspan="2">SOUTH MANCHURIA</th><th rowspan="2">NORTH CHINA</th></tr>
<tr><th colspan="3"></th><th>Tennobo</th><th>Wakino</th><th>Naogata</th><th>Kokura Yahata</th><th>Moji</th><th>Toyonishi Utsuhi</th><th>Takibe Tawara-yama</th><th>Asa</th><th colspan="2">Inakura</th><th colspan="2">Sasayama</th></tr>
<tr><td rowspan="4">WAKINO SUBGROUP</td><td>Upper Wakamiya formation (W_4)</td><td rowspan="3">Viviparus onogoensis–Nakamuranaia (?) sp. cf. N. chingshanensis ZONE</td><td></td><td>W_4</td><td></td><td>W_4</td><td>W_4</td><td>W_4</td><td>W_4</td><td>W_4</td><td rowspan="2">INAKURA FORMATION</td><td rowspan="2">Lower Inakura formation</td><td rowspan="4">SASAYAMA GROUP</td><td rowspan="2">Upper formation</td><td rowspan="3">AKAIWA SUBGROUP</td><td rowspan="2">Kitadani formation</td><td rowspan="4">NAKTONG SUBGROUP</td><td>Shikkoku formation</td><td rowspan="3">Talatzu group
Miyanohata group
Pulantien group
Yingpan formation</td><td rowspan="3">Chingshan formation</td></tr>
<tr><td>Lower Wakamiya formation (W_3)</td><td>W_3</td><td>W_3</td><td>W_3</td><td>W_3</td><td>W_3</td><td>W_3</td><td>W_3</td><td>W_3</td><td>Shinshu formation</td></tr>
<tr><td>Nyoraida formation (W_2)</td><td>W_2</td><td>W_2</td><td>W_2</td><td>W_2</td><td>W_2</td><td>W_2</td><td></td><td></td><td></td><td></td><td>Middle formation</td><td>Akaiwa formation</td><td>Kasando formation</td></tr>
<tr><td>Sengoku formation (W_1)</td><td>Brotiopsis wakinoensis ZONE</td><td>W_1</td><td>W_1</td><td>W_1</td><td>W_1</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Lower formation</td><td>ITOSHIRO SUBGROUP</td><td>Kuwajima formation</td><td>Kinbu formation</td><td></td><td></td></tr>
</table>

Figure 5. Correlation of the Wakino equivalents in Eastern Asia.

(a) *Points of similarity.*—The following species occur in the corresponding formations or members in the two regions: *Plicatounio naktongensis naktongensis, P. naktongensis multiplicatus, Brotiopsis wakinoensis* (including *B. wakinoensis ryohoriensis*) and *B. kobayashii sinsyuensis.*

(b) *Points of difference.*—(i) The occurrence of the following species is not necessarily harmoious between the two regions but the species themselves are identical or very closely allied: *B. kobayashii* and *V. onogoensis* (including *V. keisyoensis*) occur only from the lower formation of the Naktong subgroup but they are very rare in the lower formation and abundant in the upper formation of the Wakino subgroup. *Nakamuranaia chingshanensis* predominates in both the lower and upper formations of the Naktong subgroup but *Nakamuranaia* (?) sp. cf. *N. chingshanensis* is very rare in the lower formation and abundant in the upper formation of the Wakino subgroup.

(ii) Species not common between the two region are as follows: Species known only in the Naktong subgroup: Species of *Hydrobia, Bulimus, Itomelania, Micromelania* (?), *Anisus* and *Schistodesmus;* Species known only in the Wakino subgroup: *Yoshimonia katsukiensis, Manchurichytes* (?) sp. *Dreisenia* (?) sp. and "*Nippononaia*" spp.

As the writer has already reported (1959c), "*Nippononaia*" *wakinoensis* is very similar to *Trigonioides paucisulcatus suzukii* in the shell outline and surface ornamentation, although they differ remarkably in the character of hinge. *T. kodairai* from the lower formation of the Naktong subgroup (KOBAYASHI and SUZUKI, 1936) is again apparently similar to "*N.*" *wakinoensis.* Despite the designation of *T. kodairai* as the type-species of *Trigonioides,* the hinge of this species is not clear, for which restudy is needed.

The difference pointed out above (b) does not necessarily mean the difference of age between the Naktong and Wakino subgroups, but such a difference can naturally happen, because local variation of the faunules is recognized even in the Wakino basin itself, because the two regions are considerably separated, and because the difference in environment must be significant in view of the fact that the fossil plants predominate in the former but are very scarce in the latter. As has been already concluded by KOBAYASHI and SUZUKI (1936), the Wakino subgroup is certainly correlated in geological age with the Naktong subgroup.

(2) *Naktong subgroup in Southern Manchuria and Northern China.*—The non-marine Mesozoic formations from the Upper Triassic to the Upper Cretaceous are widely distributed in this part of the continent. Some of them are coal bearing. They have long been studied by many geologists and paleontologists. SUZUKI (1949) correlated the Talatz, Yingpan, Miyanohara and Pulantien groups in Southern Manchuria and the Chingshan group in Northern China to the Naktong subgroup from the paleontological evidence.

Viviparus onogoensis (including *V. keisyoensis*), *Nakamuranaia chingshanensis* and *Plicatounio naktongensis manchuricus* occur in the Yingpan, Miyanohara and Pulantien groups. These groups can be correlated with the upper zone of the Wakino subgroup, because *P. naktongensis manchuricus* has more advanced features than *P. naktongensis naktongensis* and because *V. onogoensis* and *Nakamuranaia chingshanensis* are predominant. In the Chingshan group *N. chingshanensis* occur abundantly, and from the Talatz group *Trigonioides kodairai* has been reported but *V. onogoensis* and *N. chingshanensis* are not known. As is mentioned above, *T. kodairai* from the type Naktong is very questionable, so the Chingshan representative might be something else. The writer would suggest that the Chingshan and Talatz groups may possibly be referred to the upper zone.

At any rate, for the correlation between the Wakino subgroup and the formations of the continental region, further stratigraphical and paleontological studies of the latter are required. Here the writer suggests only what formations should be taken into consideration as possible equivalents of the upper Wakino zone.

3. International correlation

Non-marine and brackish formations are frequently interfingured with the marine ones in the Japanese Mesozoic, for Japan was paleogeographically situated on the continental margin. Therefore the age of the non-marine formations can be tied up with that of the marine formations, which, in turn, can be readily determined in terms of the international scale.

The Wakino subgroup is covered with the Shimonoseki subgroup which is correlated to the non-marine Shiragi subgroup in Korea. As has been clarified by MATSUMOTO (1954, p. 174), the age of the Shiragi subgroup (=Shimonoseki subgroup in age) is assigned to the Miyakoan (Aptian+Albian) plus Gyliakian (Cenomanian +Turonian) series. As the writer (1959c) has discussed, *Trigonioides matsumotoi* KOBAYASHI and SUZUKI of the upper Gosyonoura group (Gyliakian) is morphologically more advanced than *T. paucisulcatus paucisulcatus* of the Shiragi subgroup and as well as than *T. paucisulcatus suzukii* of the upper Wakino subgroup.

The middle formation (W_2) of the Wakino subgroup unconformably overlies the Toyonishi group, which, in turn, contains in its upper part a fossil faunule of the Ryoseki aspect. Accordingly the upper zone of the Wakino subgroup is certainly referred to the middle series (Aritan series of Upper Neocomian) of the triple Lower Cretaceous of the Japanese scale (see MATSUMOTO, 1954).

It should be, furthermore, worthy to note that the lower formation (lower zone) of the Wakino subgroup does not overlie the brackish Yoshimo formation of the Toyonishi group but covers directly the basement rocks. The fossil fauna of the lower zone does not resemble that of the Yoshimo and Kawaguchi formations (Ryoseki or Kochian series of Lower Neocomian), but this dissimilarity may be due to the difference in facies. They are, however, partly related to that of the upper Itoshiro subgroup. The Itoshiro subgroup contains at its base trigonians of Kimmeridgian or Tithonian aspect (KOBAYASHI et al, 1959, p. 286) and overlies unconformably the Kuzuryu subgroup which contains ammonites indicating Oxfordian (ARKELL, 1956, p. 426) to Callovian (?) (KOBAYASHI, 1947). Accordingly, the lower zone of the Wakino subgroup may be post Kimmeridgian and pre-Upper Neocomian, but further study is needed for more precise determination of its age.

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