NEOGENE MOLLUSCAN FAUNAS IN HOKKAIDO

(Part 1. Sequence and distribution of Neogene Molluscan faunas)

By

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Contents

I. Introduction

Information on the molluscan faunas of the Neogene formation developed in Hokkaido is yet scanty: a few species were described by M. YOKOYAMA (1926, 27, 31), K. KANEHARA (1937, 42), T. OINOMIKADO (1935), Y. OTUKA (1937, 40), T. NAGAO (1941), K. OTATUME (1942), S. UOZUMI (1950–58) and others; assemblages of some faunas were only listed by scientists of the present writer's Department and others from time to time. However, this does not seem to signify that the fossil remains are very scare, but it may be, no doubt, due to the fact no particular efforts have hitherto been made by scientists in Hokkaido for investigating molluscan faunas.

Since 1952, the present writer has investigated the faunas biologically, the problems existing between the faunas and stratigraphical successions, and between the faunas and sedimentary basins. The general aspect of this study has been presented in his three reports (1957 a, b, 1958). Since their publication the present writer has endeavored as far as possible to make progress in the study of these problem, noted above. In the meanwhile, several other investigators have contributed very much understanding of the stratigraphical relation of the faunas and to some extent the historical change of faunas. Remarkably during the past five years, researches under the auspieces of both the Geological Survey of Japan and Geological Survey of Hokkaido, have yielded much information and as a result the ideas concerning the classifications of formations as well as their distributions and structures have become greatly modiefied.

The reports of these researches are mentioned in many "Explanatory Texts of the Geological Map of Japan, Scale 1 : 50,000".

The purpose of this work is to palce on record detailed data on the sequence and the paleobiographical provinces of Neogene molluscan faunas in Hokkaido on the basis of the writer's own study in addition to the stratigraphical information mentioned above.

II. Acknowledgements

The writer wishes to express his deep gratitude to Professor Masao MINATO of Hokkaido University, for his invaluable advice and for his constant encouragement, in the course of the present study.

During of this study, the writer has made use of the large collections o. Hokkaido University, the Geological Survey of Japan, Sapporo branch, and the Geological Survey of Hokkaido. To officials of these institutions thanks are offered.

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III. Classification of the Neogene deposition of Hokkaido by sedimentary province

It is known that the Neogene deposits are found in several basins of different characters extended all over Hokkaido; investigations concerning the origin, evolution and migration of these basins have been made by several stratigraphers and paleontologists. However, no complete report concerning this problem has yet been published. Recently, the present writer and others (1957) proposed a tentative classification of the Miocene sedimentary provinces of Hokkaido from sedimentary features and stratigraphical characters; consideration of the faunal characters as stated in the latter section of this paper is now added. Those provinces are:—

A) Green-tuff area
   a) Oshima province (southwestern part of Hokkaido)
   b) Kitami province (eastern part of Hokkaido)

B) Non-green-tuff area
   a) Ishikari province (central part of Hokkaido)
   b) Teshio province (〃 〃)
   c) Kushiro province (southeastern part of Hokkaido)

In this paper, the present writer will accept this classification covering the Neogene period for convenience in discussing the geological and geographical distribution of the Neogene faunas in Hokkaido. The general aspects of the lithological features and stratigraphical sequence of these provinces may be summarized respectively as in the following brief discussion.

A) Green-tuff Area

The so-called green-tuff area continued as land sustaining erosion during the Mesozoic and the Paleogene, was suddenly transformed into a region of violent volcanic diffusion, was covered with thick pyroclastic pilings and became a new-born geosyncline in the Neogene period in Hokkaido. The frequent presence of propylite, andesite, and rhyolite as dykes, lava, flow, and sheets within the lower half of the Neogene formations which are associated with various kinds of mafic to felsic tuffs, including green coloured tuff, is the characteristic feature of the Neogene formations of this area.

Prof. M. MINATO (1952) and the same author et al (1956) have already stated in detail the characters, the distribution and the geotectonic synthesis of the so-called green-tuff area. Consequently it is not neccessary to repeat them in

detail here, but Prof. M. MINATO has noticed the difference between the green-tuff and non-green tuff areas as follows:

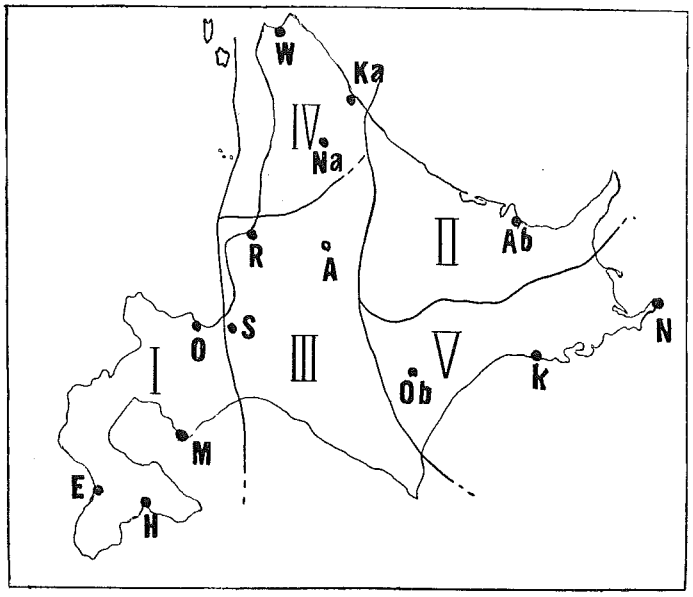

Figure 1. The Neogene sedimentary provinces of Hokkaido.

I:	Oshima province	K:	Kushiro
II:	Kitami province	Ka:	Kitami-Eashi
III:	Ishikari province	M:	Muroran
IV:	Teshio province	N:	Nemuro
V:	Kushiro province	Na:	Nayoro
		O:	Otaru
A:	Asahikawa	Ob:	Obihiro
Ab:	Abashiri	R:	Rumoe
E:	Esashi	S:	Sapporo
H:	Hakodate	W:	Wakkanai

"It should be noticed again that only green-tuff areas were attacked by violent igneous activity, while the marine strata of the Miocene period lying unconformably on the basement of the Yezo arc (central part of Hokkaido) were almost devoid of such igneous activity".

The green-tuff area in Hokkaido is divided into two provinces according to geographical position and different evolution of basins: One is the Oshima province, southwestern part of Hokkaido which is bounded by the Sapporo-Tomakomai line with non-green tuff area; its southern extension is stretched continuously along the inner side of the Japanese island arc. The other, the Kitami province, in the eastern part of Hokkaido, extends along the eastern foot of the Hidaka zone and southerly along the Kurile islands which constitute the basement of the Chishima volcanic chanin.

The generalized stratigraphic sequence for the Oshima province is as given below:

Asahi stage—Fukuyama formation: the rocks are of non-stratified pyroclastic materials; green tuff, agglomeratic tuff, brecciated tuff, andesite.

——————Unconformity——————

Takinoue stage—Kunnui formation: it consists of basal conglomerate, tuffaceous sandstone, tuffaceous shale, black shale, green tuff, alternation of shale and tuff. It contains the Kunnui fauna.

Wakkanai stage—Yakumo-Kuromatsunai formation: it consists of tuffaceous sandstone, sandy tuff, siltstone, sometimes predominantly of agglomerate; rather poor fossil content.

——————Unconformity——————

Setana stage—Setana formation: mostly composed of tuffaceous coarse sandstone with frequent intercalations of conglomerate beds; some fossiliferous beds present. It contains the Setana fauna.

B) Non-green tuff Area

The geological history of the Neogene in Hokkaido was much more influenced by the Hidaka orogenic movement than by any other. That is to say, the back bone range of Hokkaido, "Hidaka Zone" is said to have occurred as a geocyncline in the Middle Mesozoic era and from time to time this geocyncline was transformed to geoanticline which was associated with many sorts of metamorphism. Thus, it may be said that this movement, named the Hidaka Alpine Orogenic Movement by Prof. Mitsuo HUNAHASHI, Hokkaido University (1957), more than any other activitity dominated the geological picture of the Neogene in the central part of Hokkaido, and no matter whether it was great or trifling, the sedimentary basins and features were influenced by this movement.

Especially, it can not but be recognized that Miocene-Pliocene had a great upheaval of the Hidaka zone to form a definite mountain range which divided the geocynclinal basin into two parts, front and rearward. The front basin is named the Ishikari and Teshio provinces which are located in the central part of Hokkaido, and the rearward one is named the Kushiro province in the southeastern part of Hokkaido.

a) Ishikari province

Generally speaking, the Neogene deposits in this province are gradually younger towards west along the western slope of the N–S trending two parallel running distributive tectonic zones, vis. the Hidaka and Kamuikotan zones. The Neogene deposits consist of terrigenous and brackish deposits which frequently contain thin coal seams. Moreover, they are wholly controlled by the Hidaka orogenic movement and lie under a very complicated geological structure which is characterized by such features as thrust, nappe or overturned folding etc.

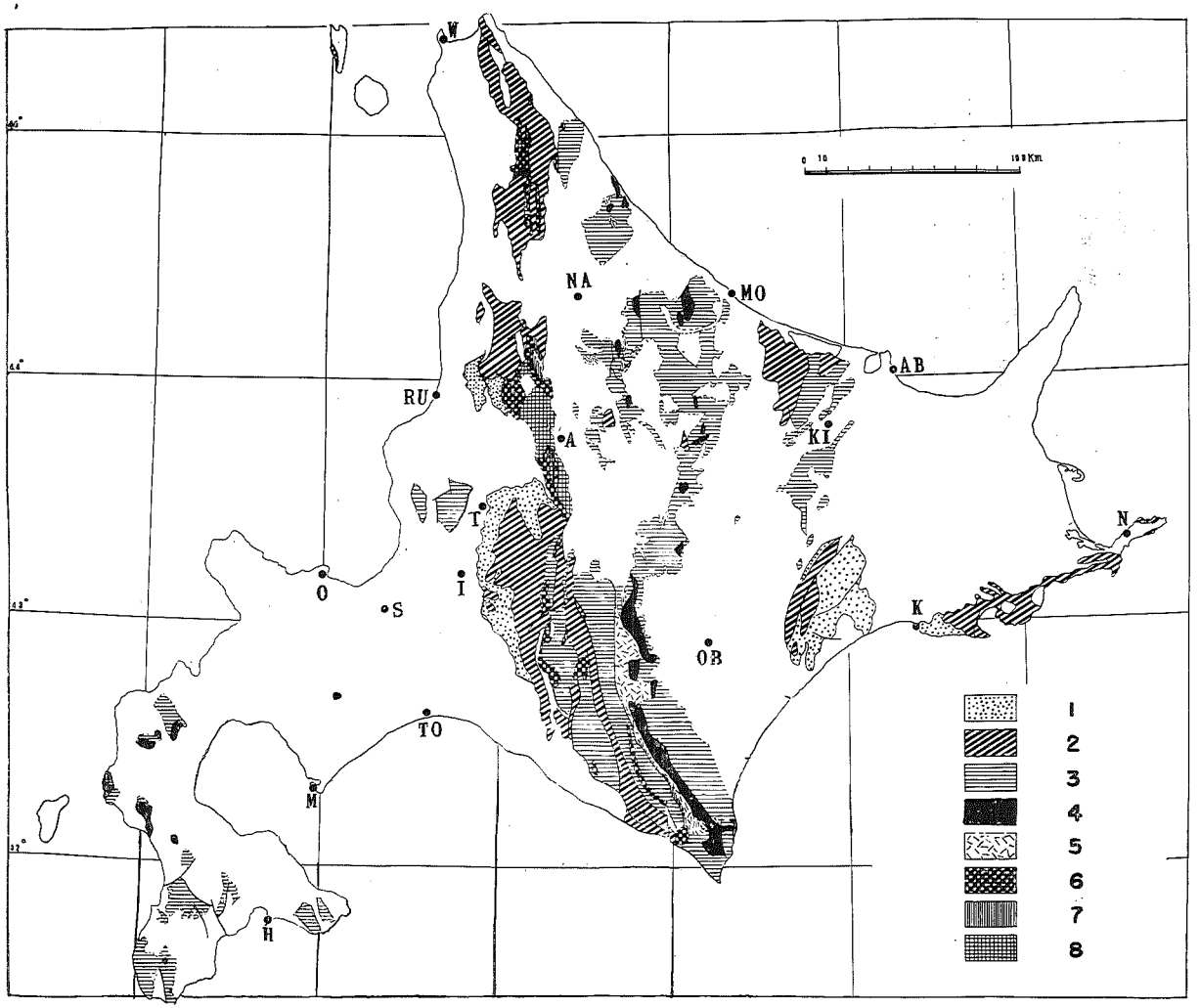

Figure 2.

Generalized geological map of the pre-Neogene formations.

1. Paleogene formations
2. Cretaceous formations
3. Unknown Mesozoic-Paleozoic formations
4. Granitic rocks
5. Gabbro
6. Serpentine
7. Amphibolite
8. Kamuikotan metamorphic rocks

Below such a complicated geological structure, the stratigraphical sequence and the correlation of the Neogene strata in this province are not always settled. The opinion seems to have prevailed, however, that the Kawabata group is underlain with unconformity by the Paleogene formation and pre-Tertiary rocks, that the Wakkanai group overlies the Kawabata group with local unconformity and that the Pliocene deposits are located over the pre-Pliocene rocks: Miocene, Paleogene, Cretaceous and metamorphic rocks.

The Kawabata group consists of the Asahi, Takinoue ane Kawabata formations in ascending order. It should be noted that the Asahi formation is not always developed everywhere in this province, but only in the Ikushunbetsu coal field, and the Asahi fauna proposed as the oldest Neogene fauna in Hokkaido by the present writer is yielded in this formation. The Takinoue formation is predominated by a mudstone facies which is intercalated by some thin coal seams and tuffaceous sandstone, contains the Takinoue fauna, and is directly overlain by the Kawabata formation which is constructed by a rhythmic alternation of conglomerate, sandstone and mudstone. The Kawabata formation contains "Nagelfruh"-like huge boulders of serpentinite which remind one of "Mollasse type of deposition" of European literature and this formation seem to be conformable with the Takinoue formation, excepting in the marginal area of the sedimentary basins.

The Wakkanai group is represented by the so-called "hard shale formation" and until a few years ago, had been known by the name of the Kitami or Oiwake group to many geologists. However, the present writer redefined this group under the name of the Wakkanai series and stage in a previous paper (1958). Generally speaking, this group is not always characterized by the so-called "hard shale facies", but rather shows changable facies of shale, conglomerate or sandstone according to the place, although "hard shale" is more or less contained in many locations. Moreover, it is essential that this group is characterized by the Wakkanai or Atsunai-Togeshita fauna which suggests Miocene in geological age. The representive formations belonging this group are the Motourakawa formation (Hidaka district), Kuriyama conglomerate and Oiwake formaions (Yubari district), Minami-Atsuta formation (Ishikari oil-field), and Mashike formation (Rumoi coal-field) as illustrated by the present writer's correlation table (1958).

The deposits belonging to Pliocene in this province are represented by the following: Takikawa and Hukagawa group which develop in the central part of this province. They are rather localized in small distribution but are characterized throughout by similar lithologic deposits. Namely, they consits of marine pyroclasic and terrigeneous deposits, they contain thin coal seams in their uppermost parts and they are characterized by the Takikawa fauna. Also these deposits are in common underlain by the variegated basement: Miocene, Paleogene, Cretaceous and metamorphic rocks with unconformity, but they are said to be contemporaneous with the Wakkanai group in some location.

b) Teshio province

The boundary between the Teshio and Ishikari provinces is marked by the northern limit of the so-called Kabato Plateau (about 44° N. latitude), which is made up of the so-called Paleozoic formation.

Compared with the Ishikari province, the following remarkable difference of the geological conditions is recognized in the Teshio province became a geosyncline in the Cretaceous period since the Paleozoic era but shifted again to an erosion area in the Paleogene, although the Ishikari province continued to be a geosyncline throughout the Cretaceous, Paleogene and Neogene periods. The Teshio province does not have such a complicated geological structure as to be seen in the Ishikari province.

Generally speaking, however, the Neogene sedimentary character is similar to that of the Ishikari province. That character is marked by an alternation of terrigeneous and brackish deposits, with a few proclastic rocks and coal seams interbedded, but it is noticed that the lithologic features are rather stable in the horizontal distribution, in comparison with the changable facies in the Ishikari province.

From the result of surveys carried on by many geologists the stratigraphical sequence of the Neogene formation developed in this province is schemed as follows.

Asahi stage—Haranosawa formation: white tuff, tuffaceous sandstone; it contains the Haranosawa fauna.

——————Unconformity——————

Takinoue stage—Haboro (Sōya) coal bearing formation: coal bearing sandstone.

——————Unconformity——————

Sankebetsu formation: tuffaceous sandstone, shale in alternation; it contains the Sankebetsu fauna.

——————Unconformity——————

Chikubetsu formation: mudstone predominated in the upper half, sandstone in the lower; it contains the Chikubetsu fauna.

Kawabata stage—Kotanbetsu formation: conglomerate, sandstone, mudstone, in alternation.

Wakkanai stage—Wakkanai formation: hard shale predominates; it contains the Wakkanai fauna.

——————Unconformity——————

Takikawa stage—Yuchi formation: sandstone, with intercalated con glomerate and mudstone; it contains the Takikawa fauna.

As to the separation of the Teshio and Ishikari provinces, taking into consideration together the sedimentary province and the paleontological data,

the writer is strongly inclined to regard some difference between them as suggesting the existance of some land barrier, which resulted from the geotectonic upheaval of the Kabato Paleozoic plateau, as will be discussed in detail below.

Here, attention should be given to the intermediate region* situated between the Kitami green-tuff and the Teshio (non-green tuff) provinces. This region has an intermingled character of the two provinces in the points of lithological aspect and features of the sedimentary basin. In more detail, it is similar to the character of the green-tuff area in the following points: 1) Neogene deposits directly overlie the so-called Paleozoic, metamorphic and granitic rocks, 2) throughout the Neogene period, volcanic activity was violent and resultant mineral deposits are occasionally found in this region.

At the same time the character of the marine deposits, excepting intercalating lava flow and agglomerate, is similar to that of the Teshio province which shows alternation of brackish and terrigenous deposits. Moreover, it is noteworthy that green coloured tuff the representative strata of the green-tuff area is wholly wanting. Also to be added is the fact that all deposits of this region are correlated to the strata of the stages younger than the Wakkanai stage: that is to say, this region had continued as land undergoing erosion until Middle Miocene and then was suddenly invaded by the sea bearing the Atsunai-Togeshita fauna, representive fauna of the Wakkanai stage, with volcanic infusion occurring at the same time.

c) Kushiro province

It is known that the Cretaceous and Paleogene deposits develop in this province which is generally called the Kushiro coal field; it has been surveyed in detail by many coal field geologists. However, investigations of the Neogene strata have not been made in such detail as those of the Paleogene strata. Recently, it has become clear from the results of the surveys by several geologists that the stratigraphical and paleontological features exhibit marked contrast to those of the Ishikari province.

The causal basis of the difference between the two provinces is considered to be the different geotectonic influence which the Hidaka Alpine orogenic movements had exerted respectively on the front basin and the rearward one. The latter is called the Kushiro province in this paper; the tectonic features of its Tertiary deformation are properly applied to that of block movements. On the contrary, in the former, Ishikari province, the tectonic disturbances such as thrust, nappe and overturned folding prominently prevailed. Also it is noteworthy that the Neogene marine formations are almost correlated to the strata of the stages younger than the Wakkanai stage in the Ishikari province. As

* In his paper, (1958) the present writer gave the name "Kitami-Esahi province" to the intermediate region and stated that the lower part of the strata developing in this province correlated to the Kawabata stage. However, this province will be included in the Teshio province in this paper. The lower part of the strata corresponds to the strata belonging to the Wakkanai stage according to latest knowledge.

to this points, the strata of this province are similar to those of the intermediate region situated between the Teshio and Kitami green-tuff province, mentioned in the foregoing section.

The Neogene stratigraphical sequence, in general, for this province is as given below in ascending order.

Wakkanai stage—Atsunai formation: conglomerate, sandstone and shale in alternation; it contains the Atsunai fauna.

Shiranuka formation: sandstone and shale, intercalated conglomerated.

——————Unconformity——————

Takikawa stage—Honbetsu formation: tuffaceous sandstone intercalated with tuff and fossiliferous sandstone; it contains the Honbetsu fauna.

——————Unconformity——————

Setana stage—Ikeda formation: tuffaceous sandstone, mudstone conglomerate, tuff, lignite; brackish-marine molluscan remains.

IV. Faunal Succession of Neogene Molluscan Fauna in Hokkaido

It is accepted that changes in faunal character are caused not only by the changes of time but may be regarded as results reflecting the various environmental conditions of sedimentation, deposition, temperature, oceanographical and geographical situation, etc. If one could work out the geological and geographical changes of the fauna throughout the Neogene period, one could draw an inference about the historical change of faunal provinces and some fauna environmental conditions. The present writer will describe here, the faunal sequence and the features of each fauna in order to arrive at some conception of the historical changes of faunal provinces which occurred during the Neogene period in Hokkaido.

The stratigraphical sequence of the Tertiary strata developed in the Ishikari province is generally accepted as the standard one for the Tertiary system in Hokkaido; they yield many fossils in each horizon. However, in the present status of study on time-stratigraphy concearning the Neogene deposits, there is no accepted standard that may be recognized and applied with satisfaction.

* In his articles, the writer, together with T. FUJIE, has proposed "Upper Takikawa stage" (provisional name). This stage is represented by the non-marine deposits intercalating the coal seams and underlain by the marine Takikawa formation. However, it is clear from recent study that these non-marine deposits of this stage are overlain conformably by the marine deposits bearing the Setana fauna. Consequently, the writer wishes to re-define here "Upper Takikawa" and Setana stages: the provisional name of "Upper Takikawa" stage is discarded and the deposits belonging to this stage and the Setana stage in his paper (1958) are to be included under the name of the Setana stage.

Recently, the present writer has treated the megafaunal succession in the Neogene strata of Hokkaido in his several articles (1957, 58)*, and recognized six independant faunas which characterize each horizon: they are as shown in the following table:

Generally speaking, it may be said safely that these faunas exhibit respectively rather remarkable boundaries between each other in the vertical distribution, while in the geographical distribution, each fauna is not always uniform anywhere in Hokkaido but may be localized variously according to its environmental conditions: some show similarity everywhere in Hokkaido, some are restricted from the neighbors with rather sharp boundary, and some extend into the different adjacent faunas to become partly mixed with them.

Series	Stage	Representive Fauna	General
Takikawa series	Setana stage	Setana fuana	←Marine retreat
			←Non-marine deposits
	Takikawa stage	Takikawa-Honbetsu fauna	←Cold water species only
			←Change in species
Wakkanai series	Wakkanai stage	Wakkanai fauna, Mōrai fauna, Yakumo fauna; Atsunai-Tōgeshita fauna, Tokushibetsu fauna, Kuriyama fauna.	←Exchange considerable number of species and genera
Kawabata series	Kawabata stage	Kawabata fauna	←Cold water species appearing
	Takinoue stage	Takinoue fauna, Chikubetsu-Sankebetsu fauna, Kunnui fauna	←Temperature-warm water species predominate
	Asahi stage	Asahi fauna, Harano-sawa fauna	←Cold water species predominate
			←Embryonic small basins

1) **Asahi stage**—Ashai fauna

About twenty years ago, Dr. Jiro MAKIYAMA, Professor of the Institute of Geology, Kyoto University (1934), described the Asagai fauna (Oligocene) on the specimens which were collected from Yotukura, Jo-ban coal field and Matchigar, northern Saghalin. In his paper, only *Mytilus tichanovitchi* was reported from the Neogene marl beds, which overlay the Asagaian sandstone in Matchigar. Consequently it is unknown what kind of fossils are associated with this species, in spite of the fact that paleontologists' interest has been drawn to the quite unique form of this species.

In 1953–54, the present writer was engaged in a geological survey of the Ikushunbetsu coal field in the Ishikari province, and traced the boundary between the Paleogene and Neogene formation. In this survey, it became evident that *Mytilus tichanovitchi* came from the lowest part of Neogene deposits which

part was underlain unconformably by the Poronai formation (Oligocene). The writer is of an opinion that this fauna, indicated by *Mytilus tichanovitchi* represents the next age following the Poronai fauna: in other words, that *Mytilus tichanovitchi* and its associated fossils seem to represent the initial stage of the Neogene formation that rests on the Paleogene formation with unconformity; he also wishes to propose a new name "Asahi Fauna", for this fauna.

The formation bearing the Asahi fauna is included frequently in the so-called Takinoue formation in many geological maps; it is composed of tuff, tuffaceous sandstone and conglomerate in the lower part, 80 meters in thickness and is transformed gradually into upper massive sandstone and silty parts.

The following are the notable fossils from the sandstone parts: *Yoldia biremis*, *Mytilus tichanovitchi*, *Lucinoma akibai*, *Peronidea elongata*, *Spisula onnechiuria*, *Thracia asahiensis*, *Siliqua elliptica* and *Ezochinus* sp. (gen. et sp. nov). Of these fossils, *Mytilus tichanovitchi* occurs in crowds in all localities and are always found with both valves tightly closed. The other fossils are imbedded together in a single valve; the number of individuals is not so small but the number of species is rather small.

From the silty part which overlies the above-mentioned fossiliferous zone, the present writer has collected several other species as follows: *Acila elongata*, *Portlandia tokunagai* var. *hayasakai*, *P. watasei*, *Solemya tokunagai*, *Macoma tokyoensis* and *Trominina* sp.

Judging from the above data concerning the faunal assemblage, this fauna is distinctly different from the Poronai fauna (Oligocene) and also fairly different from the elements of the so-called Takinoue fauna which is to be described in detail in the next section. Strictly speaking, this fauna exhibits an intermingling of a part of the elements of the Takinoue fauna: the species found in the latter are *Portlandia watasei*, *Spisula onnechiuria Peronidea elongata* and *Yoldia biremis*. However, the characteristic components of the Takinoue fauna are not such species but the warm and temperate water forms: *Anadara ogawai*, *Glycimeris vestitoides*, *Paphia siratoriensis*, *Batillaria tateiwai*, *B. yamanarii*, *Crepidula jimboana* and *Nassarius simizui*, all of which seem to suggest the so-called Middle Miocene in the Tertiary strata of northern Honshu, Japan.

2) Takinoue stage

This stage is characterized by the faunas which contain many fossils generally considered to suggest the Middle Miocene age in the Tertiary strata of Japan. The representive faunas which correspond to this stage, have already been reported from the Neogene Tertiary of Japan in many papers; it is known by the following faunal names as occurring in the northern part of Honshu, Japan: Lower Kadonosawa fauna (Y. OTUKA 1934), the fauna associating with *Operculina-Miogypsina*, Siratorigawa fauna (S. AOKI 1960) and the fauna bearing *Desmostylus*.

In the Neogene Tertiary of Hokkaido, the fauna of this stage is found abundantly in the marine deposits, underlain by the coal-bearing series beds that

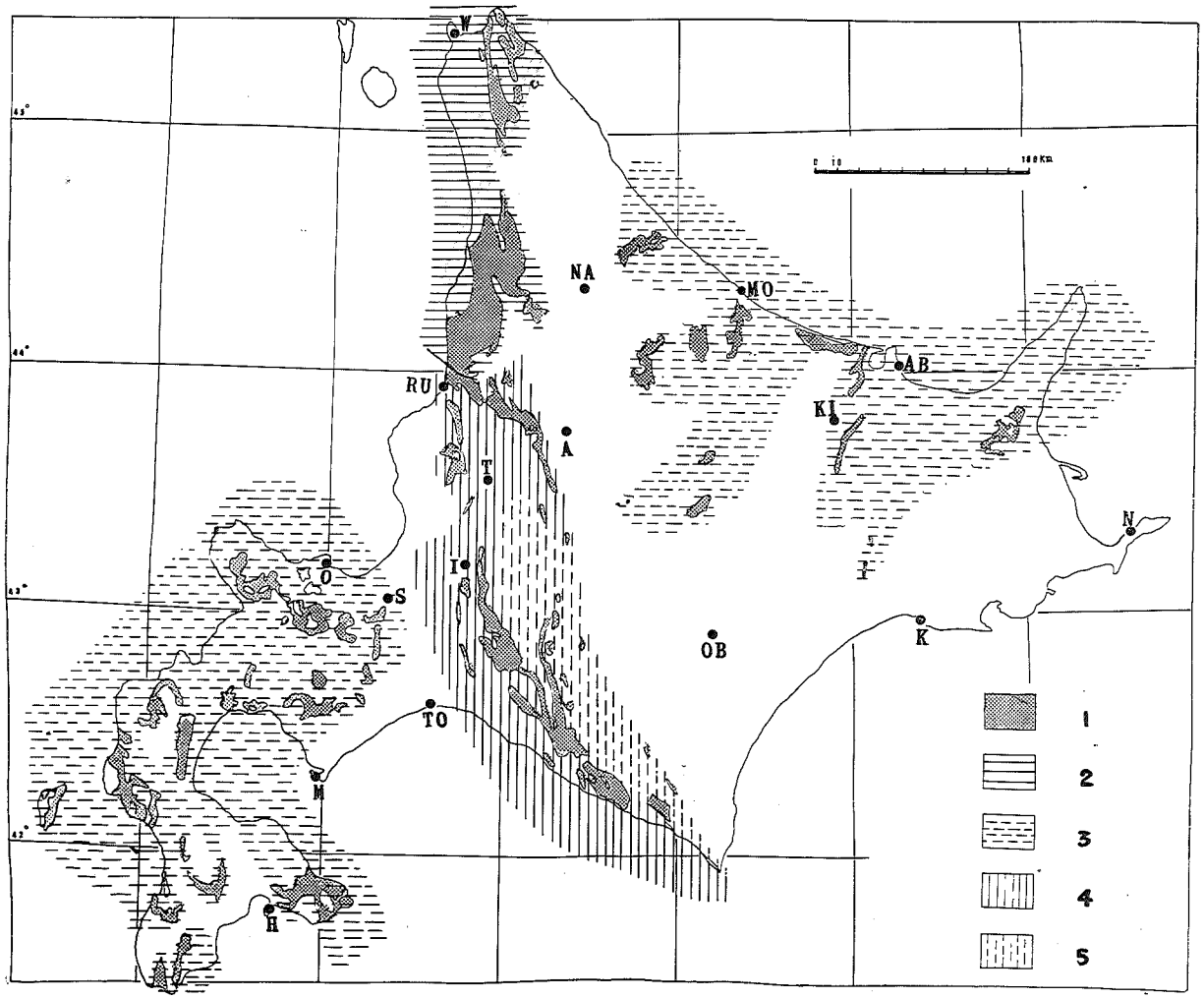

Figure 3.

Paleobiogeographic provinces of the Middle Miocene faunas in Hokkaido.

1. Areal distribution of the marine deposits belonging to the Takinoue stage.
2. Paleobiogeographic province of the Chikubetsu-Sankebetsu fauna.
   (This province is mostly overlaped by the faunal province of the Kawabata stage).
3. Paleobiogeographic provinces of the Kunnui fauna in the Oshima peninsula and of the Kitami green tuff fauna in the eastern part of Hokkaido.
4. Paleobiogeographic province of the Takinoue fauna
   (This province is mostly overlaped by the faunal province of the Kawabata stage.
5. Paleobiogeographic province of the Kawabata fauna expanding outside the area where overlap on the faunal provinces of the prior stage.

develop along the western slope of the backbone range of Hokkaido and in the green-tuff Kunnui formation developing in the Oshima green-tuff province. However, the assemblages of faunas on the basis of their formations are not always uniform everywhere in Hokkaido, but rather extremely localized in the close relation with each respective sedimentary basin.

The present writer has already proposed to recognize three independant faunas in this stage viz: Takinoue, Chikubetsu-Sankebetsu and Kunnui green tuff faunas. They are somewhat associated with each other but is necessary to point out the considerable difference between them respectively.

Next, the characters of each fauna and its geographic distribution will be treated.

a) Takinoue fauna

The Takinoue fauna, as discussed in this chapter, is widely distributed in the Ishikari province, the Uryu coal field, north limit, and Cape Erimo, the south one; it is almost always found in the terrigeneous or brackish deposits of this stage which are characterized by mudstone and pyroclastic facies and rest with unconformity on the Cretaceous or other pre-Neogene deposits.

Here, attention should be given at first to the relation between the sequences of the Asahi and Takinoue faunas: it should be kept in mind whether or not the differences of their faunal assemblage is due to change of environment or has some certain relation with the range of their vertical distribution in the Kawabata series.

From observations on the similarity of the lithic and embedding features containing these two faunas respectively, the writer is inclined to assume that the differences in characters between them are probably not due to change of environment. Moreover, the fact that the Takinoue fauna is found in a horizon slightly higher than is the Asahi fauna in the Ikushunbetsu coal field may support this assumption.

The assemblage of this fauna does not always show the same aspect everywhere but the species change more or less according to locations or different rock facies. However, generally speaking, it may be said that the assemblage of this fauna always contains a considerable number of species which characterize the so-called Middle Miocene in the Tertiary deposits in the northern part of Honshu. Most representive and widely distributed species in this fauna are as follows: *Yoldia uranoi*, *Anadara ogawai*, *A. abita*, *Glycimeris vestitoides*, *Patinopecten kimurai*, *Ostrea gravitesta*, *Clinocardium shinjiense*, *Pitar okadana*, *Meretrix matsuii*, *Dosinia nagaii*, *D. nomurai*, *Venericardia niniuensis*, *Mercenaria chitanii*, *Paphia siratoriensis*, *Mactra kurikoma*, *Spisula onnechiuria*, *Soletellina minoensis*, *Batillaria tateiwai*, *B. yamanarii*, *Cerithidea sirakii*, *Nassarius simizui*, *Crepidula jimboana* and *Polinices meisensis*. Of the species listed above, *Batillaria*, *Paphia*, *Ostrea* and *Soletellina* are occasionally found in the deposits which seem to be the marginal facies sur-

rounding the sedimentary basins in the Ishikari province: for example, in the Horoshin fine conglomerate deposits bordering the Bōzuyama serpentine mass, Uryu coal field; the Yūdoro brackish deposits contianing some plant fossils, *Comptoniphyllum* and *Liquidanber*, which are distributed around the so-called Kabato Paleozoic Massiff and develop at about 44° N. latitude in the Uryu coal field, and the Takinoue terrigeneous deposits abutting on the Paleogene Poronai formation near Takinoue, Yūbari City. In other words, it may be possible to say that these species have lived near the shore-line.

Here, if one checks the assemblage of this fauna in the annexed table 2 and 3, it will become quite clear that this fauna is closely associated with fauna from the so-called Middle Miocene deposits in the northern part of Honshu but it will also be recognized that some characteristic genera of the Middle Miocene in Honshu are not found in the Takinoue fauna in Hokkaido. They are as follows: *Placopecten*, *Cryptopecten*, *Miyagipecten*, *Clementia*, *Crenella*, *Geloina*, *Pholadomya*, *Vicarya*, *Vicaryella*, *Conus*, *Trochus*, *Cerithiopsis*, *Truncaria*, *Ringicula*, *Surculites*, *Sinum*, *Astriclypeous*, *Miogypsina* and *Operculina*.

The species of these genera seem to be habitants of subtropic and tropic regions, and so it may usually be considered that the representive fauna of the so-called Middle Miocene in Japan is clossely associated with the fauna of the southern hemisphere, especially with that of the area of India and southeastern Asia. Consequently, it may be biogeographically noteworthy that the species of these genera have north limits of distribution in Iwate, Akita or Aomori prefectures since they are not distributed in the central part of Hokkaido. The other characters of this fauna, generally recognized without regard the localities of the fossil specimens, are follows: 1) a considerable number of pelecypod fossils have characteristic, specialized thick test, and hunchkback-like convexity, 2) a few species belonging the Poronai fauna (Oligocene) are found in mudstone facies deposits of this stage, 3) in any locality, one species, in number of individuals, shows a tendency to dominate.

b) Chikubetsu-Sankebetsu fauna

It was already pointed out by the present writer and T. FUJIE (1956) that the representive formation bearing this fauna, Chikubetsu formation, was divided into two parts by an unconformity: the lower part of the Chikubetsu formation was represented by the symbols of $Ch_{1\text{-}2}$ and upper part Ch_3. Recently, S. KANNO and K. MATSUNO (1960) have proposed new names for them, viz., Sankebetsu and Chikubetsu formations. Fossil remains are found in both parts; the faunal assemblages are slightly different. However, the present writer is inclined to assume that the difference between them does not suggest different stages from the present paleontological knowledge. This fauna is also called by various faunal names by many scientists: Haboro-Chikubetsu fauna (M. YOKOYAMA 1927). Chikubetsu fauna (S. UOZUMI and T. FUJIE 1956) and Chikubetsu and Sankebetsu fauna (S. KANNO and K. MATSUNO 1960). Furthermore

this fauna is found in the Onishibetsu formation in the Teshio province; the Abeshinai fauna collected by T. MATSUMOTO and reported by Y. OTUKA (1937) may be a part of this fauna.

In this paper, the present writer wishes to treat this fauna as belonging to one stage under the name of the Chikubetsu-Sankebetsu fauna; the problems concerning the subdivision of this fauna will be discussed again when the stratigraphical and paleontological data have been further investigated in detail in future.

It may be said in general that this fauna consists of the so-called cold water elements of the mollusca viz: *Acila*, *Conchocele*, *Mactra*, *Spisula*, *Mya*, *Papyridea*; *Clinocardium*, *Serripes*, *Buccinum*, *Neptunea*, and *Flugoralia*, although this fauna is intermingled with a few members of temperate forms which are represented by *Lithophaga*, as pointed out by KANNO and MATSUNO (1960). However, it may not be necessary to repeat it in detail here that the representive species of the Takinoue fauna which are characterized by the temperate-warm forms are rarely contained in this fauna. Also to be added, is the fact that a few of the common species or genera belonging to the Poronai fauna (Oligocene) are found more abundantly in numbers of individuals, compared with those of the Takinoue fauna: they are *Nemocardium*, *Papyridea*, *Periploma besshoensis*, *Venericardia akagii* and *Portlandia watasei*. The other characters of this fauna, excepting the faunal assemblage, resemble those of the Takinoue fauna in the features of shell test and form, and in the features of their occurrence.

From the foregoing remarks concerning the constitution of this fauna, it is suggested that it is not in a close relation with the Takinoue fauna. However, the present writer is of opinion that the formation bearing this fauna is contemporaneous with the Takinoue formation bearing the Takinoue fauna discussed above. As to this point, the following facts may strengthen this possibility: *Desmostylus* was found from the Kotanbetsu formation which is underlain by the formation containing this fauna; the Takinoue fauna is yielded from a lower horizon than that of *Desmostylus* in the Uryū coal field (K. FUJII 1953); and the Yūdoro formation bearing the Takinoue fauna is overlain by the Kotanbetsu formation bearing the fossil *Desmostylus*.

c) Kunnui fauna (green-tuff fauna)

It is common knowledge that *Operculina* and *Miogypsina* found in the Miocene deposits of Japan are also found in the Oshima green-tuff province, southwest part of Hokkaido.

The Kunnui fauna, associated with these foraminiferal fossils, is commonly found in the Kunnui formation which is characterized by the intercalated green coloured tuff, and is another charateristic one which represents the Takinoue stage. This fauna is usually found in a slightly lower horizon than that of *Desmostylus* which is found in the uppermost part of the Kunnui formation

or in the lowest part of the Yakumo formation underlain immediately by the Kunnui formation. This faunal sequence is in the same relation with the sequence between the Takinoue fauna and *Desmostylus* or between the Chikubetsu-Sankebetsu fauna and *Desmostylus*. Consequently, this fact greatly strengthens the possibility that the horizon of this fauna is contemporaneous with that of the Takinoue and Chikubetsu-Sankebetsu faunas.

The following are the representive fossils in this fauna: *Patinopecten kimurai*, *P. protomollites*, *P. matsumorensis*, *Chlamys iwasakiana*, *Lima* cf. *smithii*, *Phaxus izumoensis*, *Pholadomya oshimaensis*, *Terebratalina innica*, *Echinolampus yosiwarai*, *Astriclypeous ambigenius* and examples of the species of *Yoldia*, *Anadara*, *Pandora*, *Siphonaria*, and *Conus*. Most of them are the Miocene characteristic species in the marine deposits which develop in north-eastern Honshū. Moreover, from the biogeographical viewpoint, it is noteworthy that this fauna characterized by the warm water elements, as in seen in the annexed table 2 and 3, is not found in Hokkaido, except in the Oshima province. That is to say, the present writer finds here that this fauna attains its northern limit of distribution in the Miocene period.

In the Kitami green tuff province, the fossil remains are very scare and it is uncertain what kind of fossils are yielded in this province. However, the present writer is disposed to except that the Kitami green-tuff fauna will prove in the future to be different from the Kunnui fauna and probably to be an independant one. From this assumption the writer will hypothesize only the province of the Kitami green-tuff fauna in this paper.

3) **Kawabata stage**—Kawabata fauna

This stage is represented by the Kawabata and Kotanbetsu formations which are distributed in the central part of Hokkaido and are characterized by rhythmic alternation of conglomerate, sandstone and mudstone, estimated about 2000–6000 meters in thickness. These formations are generally called the "Mollasse type of deposition" of European literature. In spite of such great thickness of these formations, the fossil remains are very scare in them, and it is an open question whether the assemblage of this fauna is related to the Takinoue fauna or to the Wakkanai fauna as will be discussed below. However, some fossils are found in the Ishikari province of the western slope of the Hidaka mountains. *Pitar okadana* found as a shell colony which consists of only one species; Species of *Solemya*, *Adulomya*, and *Phaxus* having large shell and some following species appearing newly or some exceeding in number of individual in this stage: *Acila hidakensis*, *Yoldia notabilis*, *Mytilus sakoi*, *Venericardia hidakensis*, *V. fujiei*, *Callista brevisiphonata*, *Mercenaria sigaramiensis*, *Spisula voyii*, and *Crepidula ezoana*.

Providing that the above fossil characters represent those of the fauna of this stage, then it follows that the general aspects of this fauna will be as given below.

1) Considerable number of individuals exists but they are rather scanty in number of species.

2) The number of species, representing the Takinoue fauna, if intermingled, is greatly inferior to that of the other fossils.

3) Many pelecypods have heavy shell or high convexity.

4) Some of the species appearing in this stage range up into the Wakkanai stage.

So far the present writer has tried only a tentative assumption concerning the character of this fauna. This problem can be more exhaustively discussed when the associated fossils are collected in abundance in future.

4) Wakkanai stage

This stage is represented by two essential different faunas: the Wakkanai fauna and the Atsunai-Togeshita fauna. These two faunas are associated with each other, but a considerable difference is recognized between them. Generally speaking, the former is occassionally found in the deposits of mudstone or siltstone facies in this stage: in the Wakkanai formation (Teshio province) Shintotsukawa formation (Kabato district), Mashike formation (Uryū coalfield), Minami-Atsunai formation (Ishikari province) and Atsunai formation (Kushiro province). The latter is found in the deposits of conglomerate and sandstone facies in this stage: in the Tōgeshita formation (Uryū coal field), Kuriyama conglomerate formation (Ishikari province), Atsunai formation (Kushiro province) and Tokushibetsu formation (Teshio province), all of which are found in the marginal area of the sedimentary basins.

On the basis of the stratigraphical evidence derived from field work, it is clear that the formation bearing the former fauna is graded horizontally from the formation bearing the latter and that they are heterofacies in respect to their origin. In other words, the difference between the faunal assemblages of the two faunas is in the close relation with the rock facies of their respective occurrence and it may reflect a change of their environmental condition. There is no doubt that these two faunas do not belong to respective different stages but to the same one.

a) Wakkanai fauna

This fauna characterizes mudstone and siltstone facies belonging to the Wakkanai stage: in other words, this fauna is found in the so-called hard shale formation which is named from its lithological characters, and shows a considerable differnt assemblage when compared with the Atsunai-Tōgeshita fauna, treated below. Namely, this fauna consists of species of such representive genera as *Portlandia*, *Yoldia*, *Adulomya*, *Lucinoma*, *Serripes*, *Clinocardium*, *Caliptogena*, *Chonchocele*, and *Neptunea*. Moreover, the species of the same genera ranging up from the Takinoue stage are mostly differentiated into the other species.

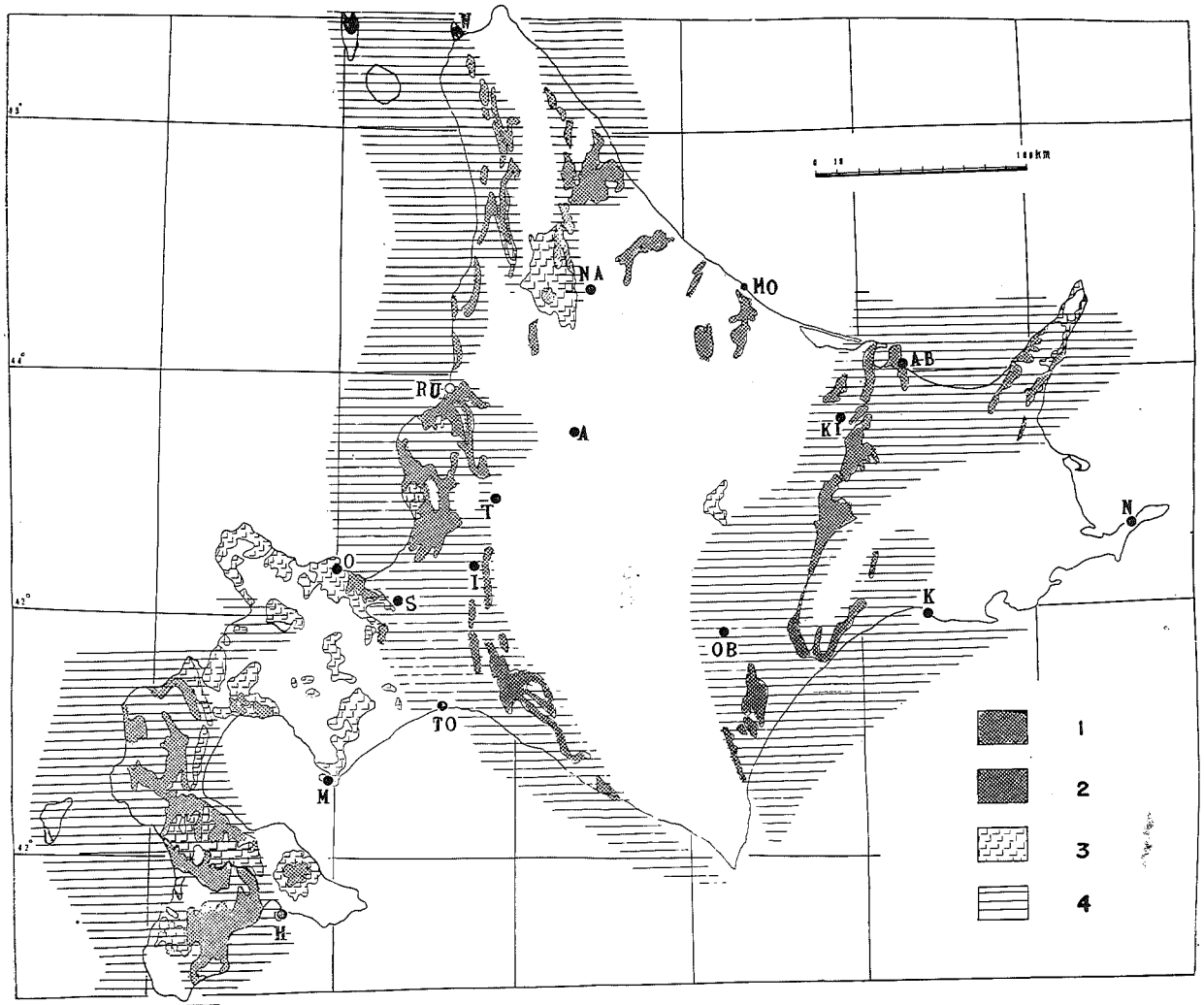

Figure 4.

Paleobiogeographic provinces of the mid-up Miocene faunas in Hokkaido.

1. Areal distribution of the marine deposits belonging to the Wakkanai stage.
2. Areal distribution of the non-marine deposits belonging to the Wakkanai stage.
3. Areal distribution of the volcanic rocks belonging to the Wakkanai stage.
4. Paleobiogeograpic province of the Wakkanai and Atunai-Tōgeshita faunas.

Recognized differences of species and genera between the Takinoue and the Wakkanai fauna

Common genera in the Takinoue fauna but not yet found in the Wakkanai fauna	Genera appearing in the Wakkanai stage
Paphia	*Lucinoma*
Cyclina	*Serripes*
Nemocardium	*Calyptogena*
Meretrix	*Seccurella*
Phaxus	*Polytropa*
Calliostoma	*Japelion*
Cerithium	
Nassarius	
Batillaria	
Proclava	
Conus	

Different species in the same genus

Takinoue fauna	Wakkanai fauna
Glycimeris vestitoides	*G. idensis*
Yoldia uranoi	*Y. sagittaria*
Portlandia watasei	*P. kakimii*
Periploma besshoensis	*P. yokoyamai*
Venericardia niniuensis	*V. ishii*
Spisula onnechiuria	*S. ishii*
Neptunea oomurai	*N. osanaii*
N. modestus	*N. eos*
Buccinum hattorii	*B. sinanoensis*
Crepidula jimboana	*C. grandii*

From the foregoing lines, as far as the present fauna is concerned, it is evident that it is characterized by the considerable number of species and genera which appear newly in this stage some of which became extinct before the close of this stage. Also to be added, is the fact that a few species and genera found newly in this stage range up to recent times and inhabit the boreal sea.

Taken as a whole, this fauna is certainly affected by the cold water current as seen in the annexed table 2 and 3. It is remarkable that the assemblage of this fauna is uniform everwhere in Hokkaido in spite of the fact that the fossils are found in formations distributed widely all over Hokkaido. Further, this fauna contains some fossils which have large shell as observed occasionally in the fossils of genera *Yoldia*, *Solemya*, *Clinocardium*, *Calyptogena* and *Echinodermata* etc. In the meantime, there is an indication that the cold current bearing this fauna ran down southward at least to the northern part of Honshu, Japan, as will be discussed in detail below.

b) Atsunai-Tōgeshita fauna

This fauna is characterized by the shallow water habitants which are intermingled with the so-called Miocene index fossils. They are as follows: *Anadara ogawai, Glycimeris vestitoides, Patinopecten kaneharai, Miyagipecten saromensis, Vasticardium siobarense, Pitar okadana, Dosinia* (*Kaneharaina*) *kaneharai* var. *mirabilis, Macoma optiva, Panomya simotemensis*, and *Mactra kurikoma.* All of them are found commonly in the Middle Miocene deposits in the central and northeastern parts of Honshu, Japan and in the fauna having a assemblage of temperate-warm water forms. However, it is noteworthy that these species are either not found at all or very rarely, if any, in the Miocene deposits of the Takinoue stage in Hokkaido. Excepting these shallow water types, this fauna consists of the characteristic species of the temperate-cold type genera which are predominant from this stage to Pliocene in succession to the Neogene Tertiary of Hokkaido, as seen in this list: *Yoldia, Portlandia, Patinopecten, Spisula, Serripes, Peronidea, Thracia, Mya* and *Neptunea.*

The general aspect of this fauna can be outlined in the following few lines.

1) Assemblage of this fauna consisting of many shallow water elements.
2) Some of the so-called Middle Miocene index species intermingling in this fauna.
3) The number of individuals of *Glycimeris, Pitar, Mactra* and *Anadara* which seem to be temperate water elements, exceeding those of other species.
4) The number of gastropoda being rather rare in respect to number of both individuals and species.
5) Some pelecypoda species having heavy shell test.

From the viewpoint of biogeography, it is remarkable that the occurrence of this fauna is almost limited to conglomerate and sandstone facies which seem to suggest the marginal area bordering the Kitami green-tuff province and the northern and eastern extremity of the Ishikari province in Hokkaido.

5) **Takikawa stage**—Takikawa-Honbetsu fauna

The Takikawa stage is characterized by the Takikawa-Honbetsu fauna, which is associated with *Fortipecten takahashii* and is considered to suggest the lower Pliocene in Japan. The representative formations bearing this fauna are as follows: Takikawa formation (Ishikari province), Mukawa formation (Hidaka district), Tōbetsu formation (Ishikari oil-field), Yūchi formation (Teshio province). Shibiutan formation (Teshio province) and Honbetsu formation (Kushiro province). They are not widely distributed in one area, but found here and there in rather scant distribution in the central part of Hokkaido and in the Kushiro province. However, without regard to location, they show similar lithic facies which contain many tuffaceous coarse materials and may marine molluscan remains. In the same way, the molluscan assemblage of the fauna found in them is also unchangable being in a close relation with the lithofacies and

always containing some characteristic species. The present writer's investigation concerning the Saghalin molluscan fossils of this stage has also led to similar conclusions and moreover, it is well known that this fauna extends in distribution not only to Hokkaido and Saghalin but to the northeastern part of Honshu, Japan, as will be treated in detail later (Text Figure 5). Consequently as far as the present fauna is concerned, it may be said that the paleontological evidences suggest uniform ecological conditions in a large area of sea at that time. The characters of this fauna have the following points in common:

1) Large number of individuals but rather scantly numer of species.
2) The number of species of Pectinidae and Mactridae greatly exceeding that of the other fossils.
3) Abundant number of single valve of Pectinidae making occasionally a particular shell bed or shell-colony.
4) Most of species and genera decidedly having northerly aspect.
5) Many pelecypods having large and heavy shell, as seen the index fossils, *Fortipecten takahashii*, and *Anadara trilineata* var. *calcarea*.
6) Fauna consisting of essentially shallow-water forms.
7) Few of them ranging down to the Miocene deposits and a considerable number of species appearing and becoming extinct during this stage, and some species having many individuals ranging up to recent boreal sea.

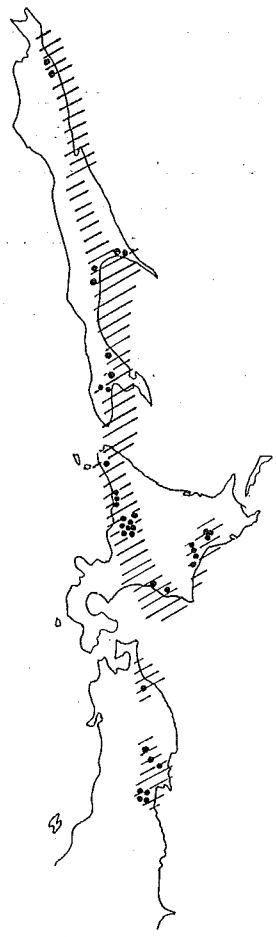

Figure 5.
Map showing the distribution of *Fortipecten takahashii*

6) Setana stage—Setana fauna

In this stage, the depostis bearing marine molluscan fossils are restricted within the Oshima peninsula (Setana formation) and within a small area in the vicinity of the City of Obihiro (Ikeda formation).

In the central part of Hokkaido, it seems that the marine invasion at that time was extremely restricted, if this area had a period of submergence. It seems the main land of Hokkaido changed to an erosion area with some terrestial sedimentary basins, in view of the coal seams developing occasionally in the upper part of the Takikawa marine formation. Consequently the stratigraphical relation between the formation bearing Takikawa fauna and the one bearing the Setana fauna can not be

observed excepting the case of the succession of the Ikeda and Honbetsu formation in the vicinity of the City of Obihiro (MITANI 1960).

The present writer, together with T. FUJIE, proposed "Upper Takikawa stage" (provisional name) for the terrestial deposits underlain by the Takikawa marine formation. However, the writer now whishes to re-define this stage here on the basis of present knowledge and proposed a new opinion that this stage should be included with the Setana stage in a new sence: that is to say, the Setana stage is represented by the marine formation bearing the Setana fauna or by the terrestial deposits which were placed in the "Upper Takikawa stage" in his 1958 paper. They may be contemporaneous with each other and heterofacies is origin.

The Setana formation contains rich fossil remains such as Mollusca, Foraminifera and Bryozoa, some of which have been studied by M. YOKOYAMA (1938), T. NAGAO and Y. SASA (1935), Y. OINOMIKADO (1935), S. NOMURA and K. HATAI (1938). K. KANEHARA (1942), K. KUBOTA (1950), and K. ASANO (1938). However, it seems that the previous paleontological and stratigraphical investigations concerning the Setana formation have not always yielded fully satisfactory results. Especially, adundant molluscan remains of this formation have not been completely described or illustrated. The present writer and T. FUJIE are investigating now the molluscan fauna and K. SHIRAI the foraminiferal fauna, but their studies not yet been completed. Consequently, results of such studies cannot be incorporated in the present paper. However, on the basis of present knowledge the writer feels confident at this point that the characters of this fauna are as follows:

1) This fauna consists of an intermingled assemblage of the Oyashio and Kuroshio forms.
2) Taken as a whole, the fauna is typically the Oyashio type in view of the individual number of fossils.
3) In the assemblage of species, a considerable number are of the Kuroshio type, and show a temperature even slightly warmer than that adjacent waters of the Oshima peninsula as will be seen from the following list.
4) Extinct or not-yet-known to be living forms are not so remarkable in regard to the individual number of species. However, the fossils species and recent species of Pectinidae are not only represented by a large number of individuals but also by a remarkable degree of variation. They are *Patinopecten yessoensis*, *Chlamys swiftii*, *C. cosibensis*, and *C. heteroglyptus* groups. This fact may suggest that the period of maximum flourishing occurred at Pliocene period.

From the foregoing information concerning the faunal characters, it may be said that the area where the Setana marine formation is developed under the influence of both currents, Oyashio (cold) and Kuroshio (warm).

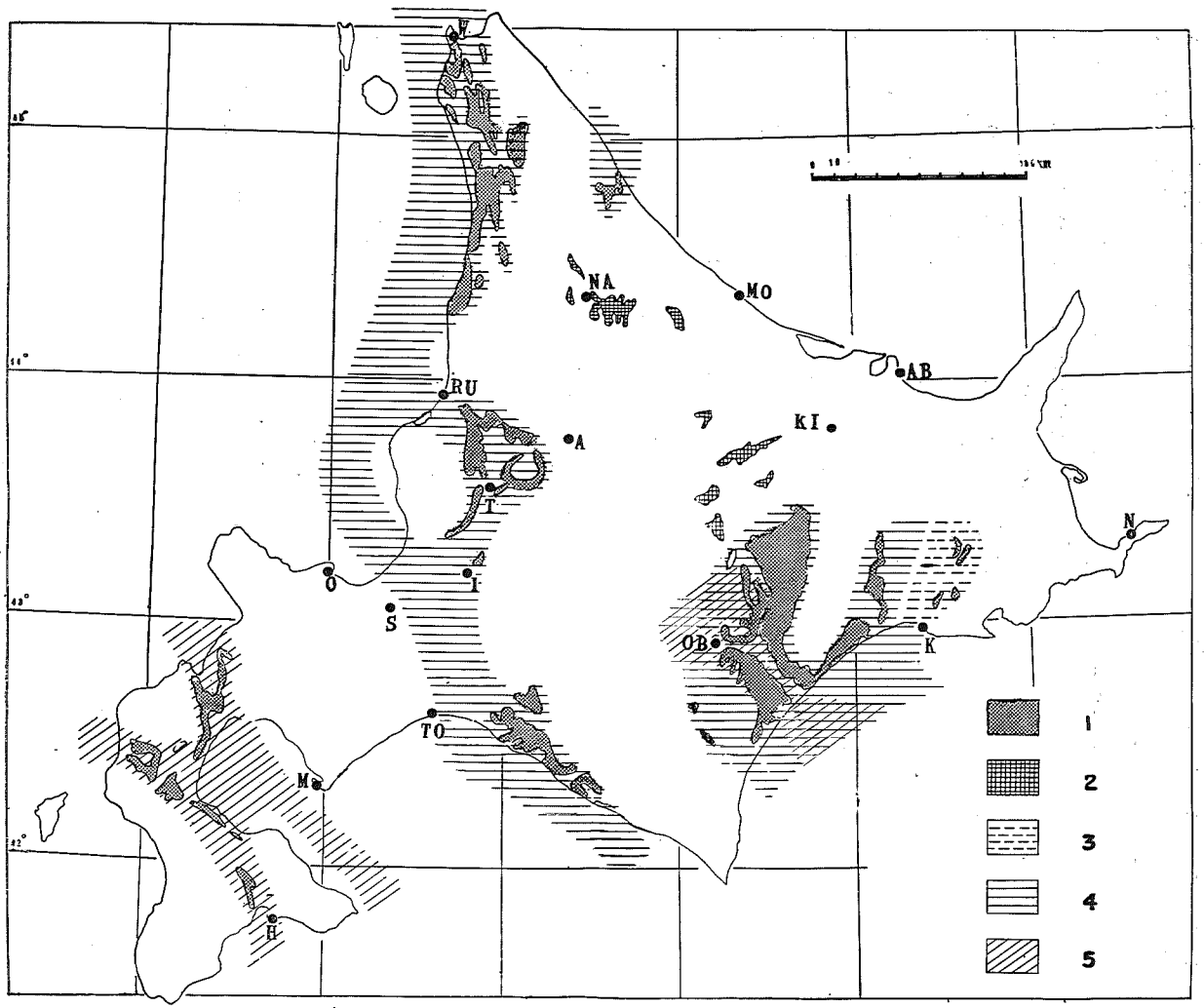

Figure 6.

Paleobiogeographic provinces of the Pliocene faunas in Hokkaido.

1. Areal distribution of the marine deposits belonging to the Takikawa stage in the central part of Hokkaido and Kushiro province, and of the marine deposits belonging to the Setana stage in the Oshima peninsula.
2. Areal distribution of the terrestial deposits belonging to the Takikawa stage.
3. Uncertain area of the distribution of the Takikawa fauna.
4. Paleobiogeographic province of the Takikawa-Honbetsu fauna (Lower Pliocene).
5. Paleobiogeographic province of the Setana fauna (Upper Pliocene).

The molluscan fauna of the Setana formation is characterized by the following species:

Acila gottschei, A. insignis, Nuculana sadoensis, Yoldia johanii, Y. notabilis, Arca boucardi, Barbartica stearnsi, Pseudogrammatodon dalli, Anadara broughtonii, A. subcrenata, Glycimeris yessoensis, G. setanaensis, Limopsis cumingii, L. abliqua, Crenella parvula, C. peramoena, Mytilus grayanus, Volsella cf. *difficilis, Lithophaga* sp., *Ostrea gigas, Polynemamussium intercostatum, Chlamys heteroglyptus, C. akazara, C. swifti, C. cosibensis, C. islandica, C. islandica* var., *C. iwakiana, Patinopecten tokyoensis, P. yessoensis, Acesta goliath, Lima vulgatula, Limatula* cf. *japonica, Monia macroshima, M. macroshima ezoanus, Anomia cytaeum, Astarte aomoriensis, A. hakodatensis, A. borealis, A. alaskensis, Venericardia ferruginea, V. crebricostata, V. paucicostata, V. setanensis, V. shiraii, V. prolongata nakamurai, Conchocele bisecta, Thyasira tokunagai, Leptaxinus rotaundata, Pillucina pisidium, Lucinoma spectabilis, L. acutilineata, Mysella japonica, Chama semipurpurata, Fulvia mutica, Clinocardium ciliatum, C. californiense, C. nuttallii, Paphyridea nipponica, Serripes laperousii, S. groenladicum, Cyclina sinensis, Callista brevisiphonata, Saxidomus purpurata, Dosinia japonica, Mercenaria stimpsoni, Callithaca adammi, Venerupis varigata, Spisula sachalinensis, S. voyii. Mactra sulcataria, Macoma praetexta, M. incongura, M. tokyoensis, Peronidea venulosa, Mya truncata, M. japonica, Hiatella orientalis, Cuspidaria* sp., *Turcica corensis, Batillaria cumingii, Nassarius hypolius, Trichotropus bicarinata, Crepipatela lingulata, Lora yanamii, Crepidula grandis, Amathina nobilis, Neptunea intersculpta, N. arthritica, Buccinum perryi, Coptyris grayi, Terebratalia coreanica, T. kiiensis, T. cross,* and also many other species of *Turcica, Calliostoma, Turritella, Batillaria, Cerithium, Epitonium, Puncturella, Trichotropis, Crepidula, Polinices, Natica, Mitrella,* and *Neptunea* etc.

To be added here is the point that the species reported by K. KUBOTA (1950) as fossils from the Setana formation are mixed with some shells that are believed to have been derived from a stage lower than the Setana stage. They are *Placopecten setanensis, Chlamys islandica notoensis, Patinopecten kagamianus* and *P. tokoyoensis kimurai* from the so-called Setana formation near the Kaigara Bashi over the Meppu-Gawa, Tanekawa, Toshibetsu-Machi, Setana-Gun, Siribeshi province (locality numbers 37, 39 and 42 in KUBOTA's paper). The deposits bearing these fossils in those localities do not belong to the Setana stage which represents the uppermost of the Tertiary system developed in the southwestern part of Hokkaido, but to the so-called Kuromatsunai formation of the Wakkanai stage as used in this paper.

This misunderstanding concerning the Setana formation, developed in the vicinity of the Tanekawa, Toshibetsu-Machi is traceable to T. NAGAO and Y. SASA's paper (1934), but as already pointed out by the present writer and T. FUJIE (1958), it is well known on the basis of stratigraphical and paleontological knowledge that these deposits belong to the Miocene deposits of the Wakkanai stage.

V. Faunal provinces of Neogene molluscan fauna in Hokkaido

The Japanese islands, including Hokkaido, lie at the zone of convergence of two main currents and molluscan assemblage is considerably influenced by

these currents: Oyashiro, cold water temperature (0°–65°F) and Kuroshio, warm water temperature (68°–82°F).

The recent Japanese marine molluscan province has been studied by S. P. WOODWARD, A. ADAMS, W. KEFERSTEIN, P. P. CARPENTER, C. E. LISCHKE, P. FISCHER, S. NOMURA, K. HATAI, T. KURODA and T. HABE. Especially, from the recent finding of Japanese investigators, the following facts concerning molluscan faunas are known.

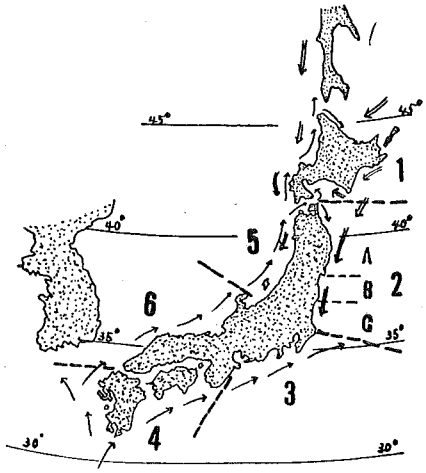

Figure 7. Map showing the current system and zoological provinces in Japanese waters (by S. NOMURA and K. HATAI 1936).

1. Hokkaido-Chishima province
2. Sanriku-Joban province
   A. Matsushima subprovince
   B. Miyako subprovince
   C. Kashima subprovince
3. Kii-Kwanto province
4. Kyushu-Shikoku province
5. Uetsu province
6. Noto-Sanin province

Generally speaking, the tropical forms following in the Kuroshio current are characteristically found in the vicinity of coral reefs, and thrive on the Pacific coast of Japan as far north as to 36°N. latitude and on the Japan Sea coast to 37°N. The boreal forms are found typically on the coast of Hokkaido, extend to the southward and are intermingled with the tropical forms on the eastern coast of Honshu island between 36°–41°N. latitude. On the Japan Sea coast, the boreal fauna in the Oyashio current extending southward is found at the depth of 200 meters along the coast near 37°N. lati tude where the tropical fauna inhabits the littoral zone.

In 1936, S. NOMURA and K. HATAI proposed six zoological provinces in the Japanese seas, based chiefly on the molluscan and brachiopoda distribution: namely they are Hokkaido-Chishima, Sanriku-Jōban, Kii-Kwanto and Kyushu-Shikoku on the Pacific ocean coast and Uetsu and Noto-Sanin provinces on the coast of the Japan Sea, as shown in Text-Figure 7.

In the same way, by investigation of the prosperity and decay in distribution of the fossil faunas, it seems that the historical change of the paleobiogeographical provinces during the Neogene period may somewhat by brought to light.

Under this presumption, taking the Neogene faunas of Hokkaido and northern Honshu into consideration together, firstly one must emphasize that the geographical situation of Hokkaido throughout Neogene period may not always have been under the cold oceanic current, but rather at the point of the convergence of both cold and warm currents.

It already has been noticed that the fauna of the Takinoue stage is divided

into three different ones. In this place, it must be remarked that each fauna of the Takinoue stage had its respectively independent zoological province in Hokkaido at the Middle Miocene period. Namely, the Kunnui fauna bearing such tropical species as *Miogypsina* and *Operculina*, lived only in the Oshima province in Hokkaido with the northern limit of the fauna laid on the Sapporo-Tomakomai line. It is not neccessary to repeat in detail that the fauna with such foraminiferal fossils distributed widely in the Japanese islands, outside Hokkaido.

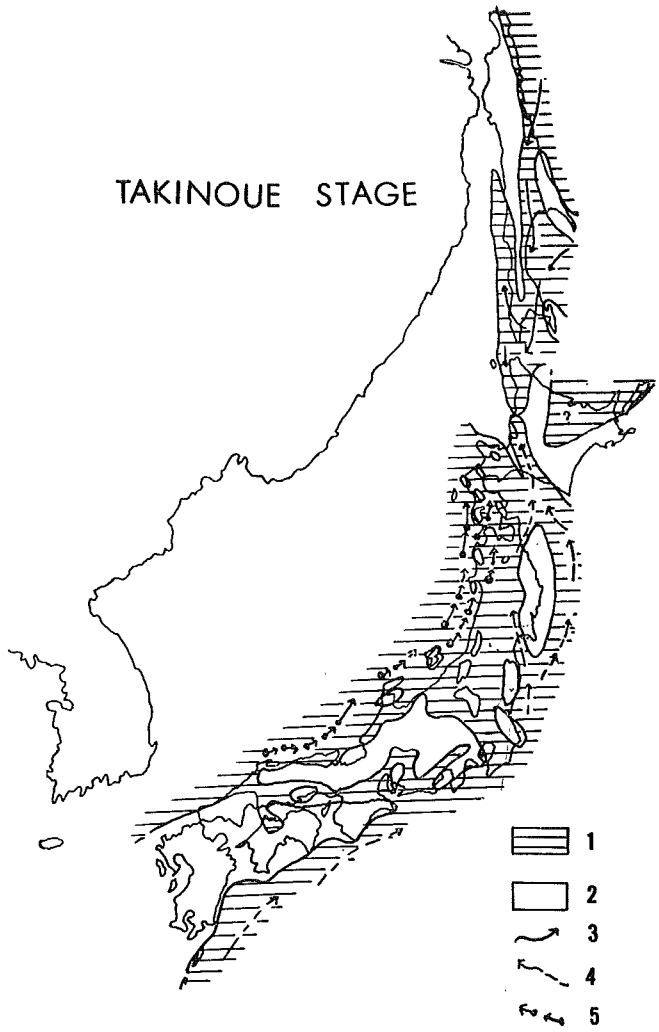

Figure 8. Map showing the shore-line and current systems during the Takinoue stage (Middle Miocene).

1. Sea area 2. Land area
3. Current bearing the cold-water fauna
4. Current bearing the temperate-water fauna
5. Current bearing the warm-water fauna

These findings may suggest that the warm current bearing this fauna moved northward to the Oshima province along the coast of the Japan Sea at that time. Meanwhile, the central part of Hokkaido at the same time was divided into two faunal provinces: One was characterized by the Chikubetsu-Sankebetsu fauna and the other by the Takinoue. The bounary of the distribution between these two faunas may be found on the line drawn at about 44°N. latitude for the following reasions: 1) The two faunas are not intermingled with each other as shown in the annexed table 1. 2) The marine formation bearing the Takinoue fauna gradually grades into brackish facies, which is generally called the Yūdoro formation bearing some plant fossils of *Comptoniphyllum* and *Liquidamber*; it develops near 43°56′N. latitude. 3) The formation bearing the Chikubetsu-Sankebetsu fauna decreases in thickness towards 44°N. latitude and disappears near this area.

Such stratigraphical phenomena, included with the paleontological evidence, supplies basis for the conclusion that the zoological province is separated completely, north and south in the central part of Hokkaido.

From the foregoing observations concerning the faunas of the Takinoue stage, it may be safely considered that the coast of Hokkaido at that time may have been washed by three currents, warm, temperate and cold as is suggested by the three faunas, Kunnui, Takioue and Chikubetsu-Sankebetsu.

In the Wakkanai stage, it may said, taken as a whole, that the warm current was pushed off to a farther southern area than its extension in the Takinoue stage, so on the contrary, the influence of the cold water current would have been predominant, compared with the prior stage.

It has already been noticed that the Atunai-Tōgeshita fauna is yielded from conglomerate and sandstone facies and consists predominantly of littoral forms. Moreover, this fauna is characterized by *Chlamys kaneharai*, *Dosinia kaneharai* var. *mirabilis*, *Pitar okadana*, *Vasticardium* sp., *Anadara ogawai*, *Miyagipecten saromensis* and others which are commonly associated with the Miocene temperate-warm water forms in the Neogene deposits of the northern part of Honshu, Japan. This fact may suggest that the littoral zone in the sea of this stage was under the influence of the temperate-water current. On the other hand, the fauna characterstic to mudstone and siltstone facies of this stage, Wakkanai fauna, was replaced by the cold water and off-shore forms, as seen from the annexed table. 2 and 3.

Now, taking these two faunas, Atsunai-Tōgeshita and Wakkanai, into joint consideration, the environmental conditions of each fauna may conceivably have been as follows:

The inhabited places and the water temperatures of these faunas seem to be in good agreement with lithology and depth, there being predominantly conglomerate-sand loving and temperate water forms in the shallow shore, and mud-loving and cold water forms in off-shore areas. Such phenomenon is apparently similar to the molluscan zonal assemblage which was recognized in

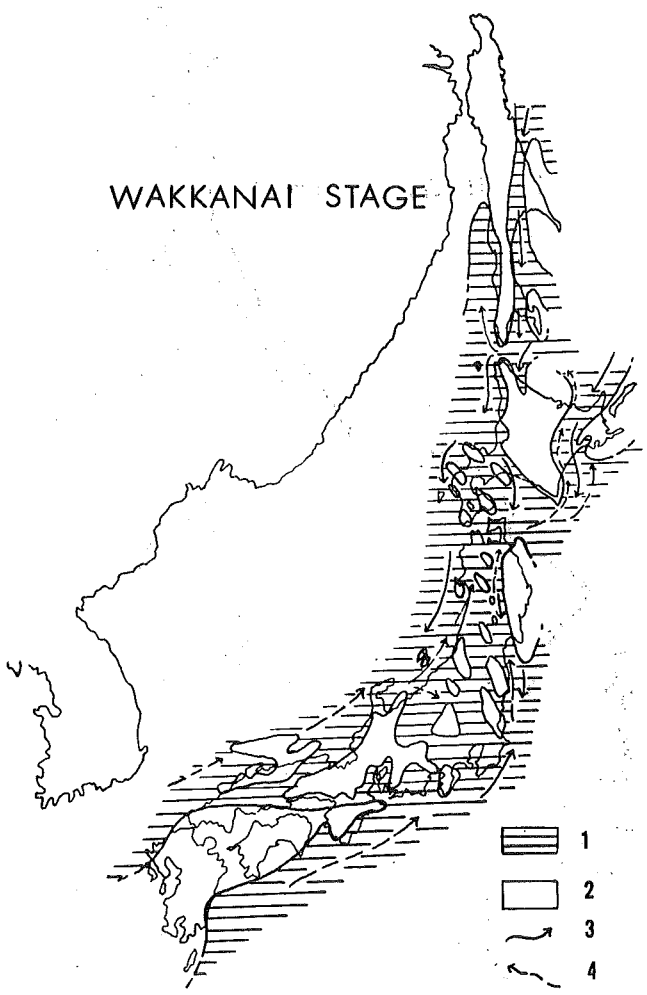

Figure 9. Map showing the shore-line and current systems during the Wakkanai stage (Middle-Upper Miocene).

1. Sea area
2. Land area
3. Current bearing the cold-water fauna
4. Current bearing the temperate-water fauna

the present Toyama Bay (37°N. latitude) and reported by T. KURODA and K. KIKUCHI (1933).

Putting all these items of information together, it may be said, though it's somewhat venturesome, that a part of the temperate-water current bearing the Atsunai-Tōgeshita fauna may have run northward along the shore line from the southern area of Japan, through the Kushiro-Abashiri line and extended to Kitami-Esashi district (45°N. latitude) in the side of the Okhotsk sea. Another part of that current ran up northward along the side of the Japan sea of that

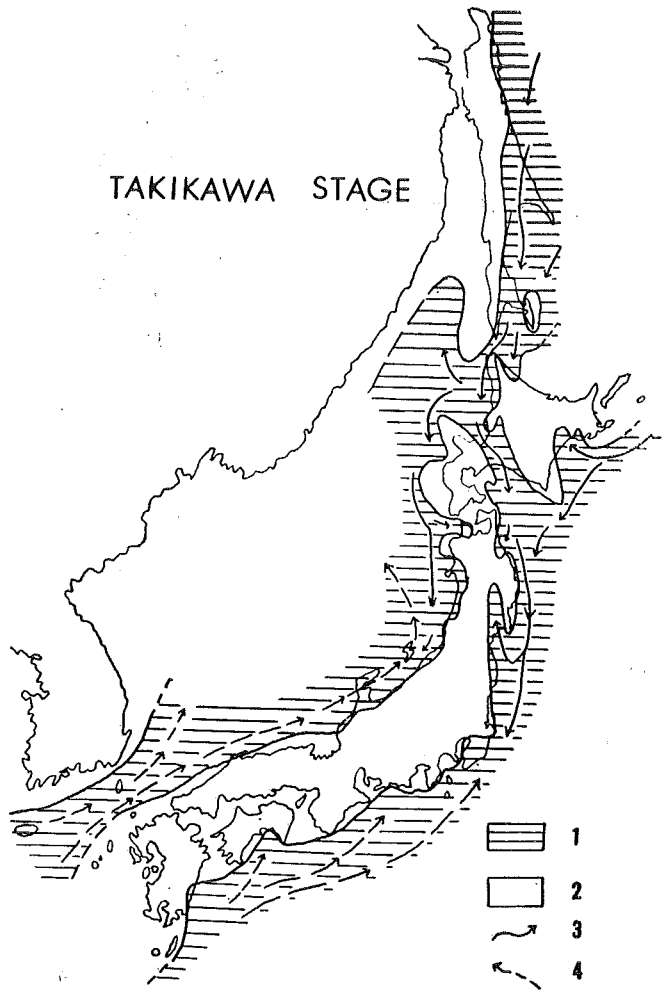

Figure 10. Map showing the shore-line and current systems during the Takikawa stage (Lower Pliocene).

1. Sea area
2. Land area
3. Current bearing the cold-water fauna
4. Current bearing the temperate-water fauna

time, as shown in Text-Figures 4 and 9. In the meantime, the cold-water current bearing the Wakkanai fauna ran off-shore down to the southward and left the so-called Yama fauna (Y. OTUKA 1941) and Mabuchi fauna (S. AOKI 1960) as its foot-marks, and attained to its south limit of about 37° N. latitude.

In the Takikawa stage, it seems that the paleogeography of Japan showed a considerable difference compared with the prior stage and that it was rather similar to the geomorphic present outline of the Islands of Japan.

From the paleobiogeographical viewpoint, it must be firstly noticed that the

sides of the Japan Sea and the Pacific Ocean were completely separated by a land mass.

It is generally accepted that this stage is characterized by the Pliocene index fossil, *Fortipecten takahashii* and the distribution of this fossil extends from the northern part of Saghalin to the vicinity of the City of Sendai as shown in Text-figure 5. However, it is remarkable that this fossil is never found in the Pliocene deposits on the Japan Sea side which is considerated to be contemporaneous with this stage, but a different assemblage of the Pliocene fauna, Wakimoto, Onma and other faunas are known to have existed in them. That is to say, the cold water current bearing the Takikawa-Honbetsu fauna ran down southernward along the Pacific Ocean coast and left the Tatsunokuchi fauna in the vicinity of Sendai; moreover, it reached nearly to the Bōsō peninsula, 35° N. latitude, as pointed by T. KOTAKA (1959). Also, a branch of the cold water current running down along the side of the Japan Sea exerted a considerable influence on Sado Island, 38° N. latitude, and extended to the Noto peninsula where faunas intermingling the temperate and cold water forms are found.

Recently T. KOTAKA (1959) has expreseed an interesting opinion concerning the general aspect of such intermingled fauna, as stated above, that the characters of the fossil faunas found in the Sado and Noto peninsula are very similar to that of the present intermingled fauna in the Pacific ocean between 38°–35° N. latitude (Matsushima-Kashima province as reports by NOMURA and HATAI in Text-figure 7).

Taken as a whole, it may be generalized that Hokkaido, including the northern part of Honshu, Japan at the Lower Pliocene period was under the cold water current which tended to be predominant over any others nearby in the Wakkanai stage.

Approaching the close of the Takikawa stage, the Takikawa sea, as a result of land upheaval, was restricted in expansion and graded to the land mass with some terrestial sedimentary basins on most of the present land of Hokkaido. Continuously, the Setana sea which invaded Hokkaido only left behind deposits in a small area of the Kushiro and Oshima province. In the Kushiro province, the sea invasion of this stage is represented by the Ikeda formation which occupies a slightly higher horizon than that of non-marine deposits underlain by the marine Honbetsu formation; the Ikeda formation was extremely limited in distribution. In the Oshima province, the Setana formation; uppermost part of Tertiary system, overlain with unconformity the Miocene deposits and other old rocks. Judging from this present distribution, it is readily recognized that this formation was deposited in a comparatively low tract which was surrounded by higher land.

From the characters of the Setana fauna, it has already been noted that the Oshima province at that time was not only under the influence of cold water but under that of a slightly warmer water than in the Takikawa stage

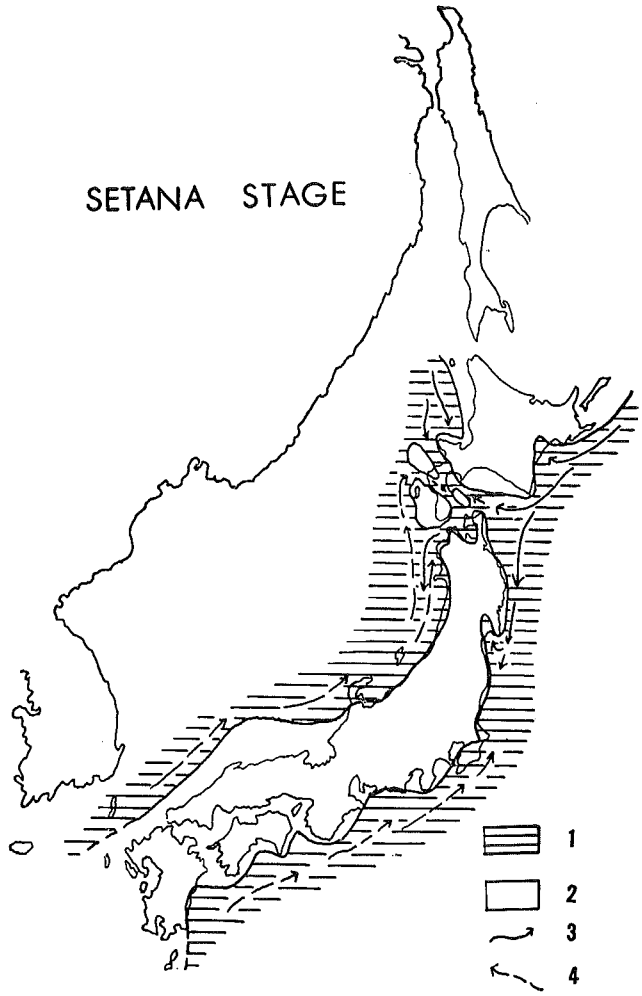

Figure 11. Map showing the shore-line and current systems during the Setana stage (Upper Pliocene).

1. Sea area
2. Land area
3. Current bearing the cold-water fauna
4. Current bearing the temperate-water fauna

and than the present water bordering the Oshima peninsula. Of course, it is not doubtful that this fauna was under the strong influence of the cold water current, but the present writer is inclined to assign the intermingled assemblage of this fauna to the intercalating of the warm water current.

On this point, K. SHIRAI of this University, agrees with the present writer's opinion from the results of his study concerning the foraminiferal fauna of this stage: he has mentioned to the writer that the formainiferal fanua is an intermingled fauna of the Japan Sea type (warm type) and Pacific Ocean

type (cold type) forms, as was asserted by K. ASANO (1937, 39).

Consequently, it may be said that this area was invaded alternately by the cold and warm currents from the side of the Japan Sea or of the Pacific Ocean, and that the two currents intermingled in this area. In other words, some narrow encroachments of the sea might have taken place on the present land and have connected with both sides, of that of the Japan Sea and that of the Pacific Ocean, as shown in Text-Figure 6. Moreover, the cold water current ran down southward farther: in the side of the Japan Sea, this current facilitated the migration of the cold-water forms found in the Shibikawa fauna in the northern part of Honshu, Japan and in the Dainenji fauna in the vicinity of Sendai on the Pacific Ocean side.

VI. Summary

I) From the investigations of the faunal succession in the Neogene Tertiary of Hokkaido, the present writer has established three series and six stages each characterized by its respective fauna.

- Takikawa Series
  - Setana stage ·····Setana fauna
  - Takikawa stage·····Takikawa-Honbetsu fauna
- Wakkanai Series
  - Wakkanai stage···
    - Wakkanai fauna
    - Atsunai-Tōgeshita fauna
- Kawabata Series
  - Kawabata stage·····Kawabata fauna
  - Takinoue stage ···
    - Takinoue fauna
    - Chikubetsu-Sankebetsu fauna
    - Kunnui fauna
  - Asahi stage ·····Asahi fauna

i) Asahi stage···This stage is characterized by the Asahi fauna which consists of cold water species in association with *Mytilus tichanovitchi*.

ii) Takinoue stage···The fauna characterizing this stage is divided into three groups by the respective different assemblages of fauna: Takinoue, Kunnui and Chikubetsu-Sankebetsu faunas. The first two of them are characterized by warm-temperate water species and the last by cold water species.

iii) Wakkanai stage···The fauna of this stage is divided into two: Atsunai-Tōgeshita and Wakkanai faunas. The former is yielded from conglomerate and sandstone facies and consists of temperate water species; the latter is found in mudstone and siltstone facies and consists of cold water species.

iv) Takikawa stage···This stage is represented by the Takikawa-Honbetsu fauna characterized by the Pliocene index fossil, *Fortipecten takahashii*.

v) Setana stage···The fauna of this stage is limited in distribution to only the Oshima and Kushiro provinces. It is characterized by predominant cold

water recent species, together with a considerable number of temperate water species.

II) From the paleobiogeographical viewpoint, it is suggested that there may be some interesting relation between the faunas and the water temperature, though the writer can offer only a tentative conclusion.

i) Takinoue stage···The boundary between the temperate and cold water currents might have existed at about 44° N. latitude and the faunal demarcation between the warm and temperate forms was near the Sapporo-Tomakomai line (Ishikari depression).

ii) Wakkanai stage···The littoral zone along the land mass at that time, was under the influence of temperate water currents and in off-shore under cold water current: that is, the littoral temperate current ran up northward and extended at least to about 45° N. latitude, while the cold current extended farther southward to about 37° N. latitude on both the Japan Sea and the Pacific Ocean sides.

iii) Takikawa stage···The water bordering Hokkaido, including the northern part of Honshu, Japan, was of cold temperature; the Japan Sea and the Pacific Ocean were completely separated from each other in view of the paleogeography and the faunas. On the side of the Pacific Ocean, the cold current bearing the Takikawa fauna moved down southward and extended at least to about 35° N. latitude, while on the side of Japan Sea, the influence of the cold water current is recognized in the Onma fauna at about 38° N. latitude.

iv) Setana stage···The Pacific Ocean might have been connected with the Japan Sea through the narrow encroachment of the sea on the present land of the Oshima peninsula, as indicated in Text-figures 6 and 11. Also the cold and temperate water currents which ran on each side of the Japan Sea and the Pacific Ocean might have converged in this area. At least, it may be recognized that the Oshima peninsula in this stage was partly under the influence of water slightly warmer than the present water bordering thereon, although the cold water was predominant in this stage. Also, a branch of this cold water current extened to 36° N. latitude on the side of the Pacific Ocean and to 39° N. latitude on the side of the Japan Sea.

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For much of reference, all of "Explanatry Text of the Geological Map of Japan" (Scale 1 : 50,000) will be ommited from this list.

Abbreviations of Localities of fossils used in the annexed list

S-C-H: Ishikari province, central part of Hokkaidô
N-C-H: Teshio province, central part of Hokkaido
S-E-H: Kushiro province, southeastern part of Hokkaido
N-E-H: Kitami province, northeastern part of Hokkaido
S-W-H: Oshima province, southwestern part of Hokkaido

1: Saru-Mitsuishi district and Hobetsu-Karumai oil-field
2: Yūbari and Ikushunbetsu districts
3: Bibai-Sunagawa and Utashinai-Ashibetsu districts
4: Ishikari oil-field and Tsukigata district
5: Shintotsukawa district
6: Rumoi and Uryū districts
7: Haboro-Tomamai district
8: Tenppoku district
9: Atsunai district
10: Honbetsu district
11: Kitamiesashi district
12: Shiretoko district
13: Abashiri and Kōnomai districts
14: Hukushima-Yoshioka district
15: Kaminokuni district
16: Okuziri district
17: Yakumo and Kunnui-Imagane districts
18: Shakotan and Jōzankei districts

Table 1. GEOGRAPHICAL DISTRIBUTION OF THE SO-CALLED "KAWABATA" FAUNA (s. 1.)" IN CENTRAL HOKKAIDO

SPECIES \ OCCURRENCE	45°20'N	WAKKANAI	MAGARIBUCHI	45°N	ENHORO	HABORO	44°N	OWADA	NUMATA	IKUSHUNBETSU	YUBARI	43°N	MOMIJIYAMA	TOMIUCHI	BIRATORI	SIZUNAI	ERIMO	42°00'N
Solemya tokunagai Yok.					◑	◑		◑					◑	◑				
Acila gottschei (Böhm)					○	○												
Acila divaricata (Hind)														●		●		
Yoldia diremis Uoz.			○			○				○								
Yoldia haborensis Uoz.						○												
Yoldia uranoi Uoz.														●		●	●	
Portlandia hayasakai Uoz.			○			○												
Portlandia watasei (Kan.)										●			●	●			●	
Portlandia thraciaeformis (Stor.)			◑			◑							◑	◑	◑			
Anadara ogawai (Yok.)								●	●					●	●	●		
Anadara abdita (Mak.)														●	●	●		
Anadara ninohensis Otuka														●	●			
Glycimeris vestitoides Nom.					◑	◑		◑						◑	◑	◑	◑	
Lithophaga chikubetsensis Kan.et Mat.						○												
Lithophaga otukai Nom.						○												
Patinopecten kobiyamai (Yok.)														●	●			
Patinopecten kimurai (Yok.)														●	●	●		
Propeamussium tateiwai Mak.														●		●		
Ostrea gravitesta Yok.								●	●				●	●	●	●		
Venericardia magaributiensis Uoz.			○			○												
Venericardia niniuensis Uoz.														●	●	●		
Venericardia akagii Kan.						◑								◑	◑			
Lucinoma actilineata (Conr.)			◑			◑								◑	◑			
Conchocele bisecta (Conr.)			○			○												
Fulvia mutica (Rve.)			○			○												
Trachycardium shiobaraense (Yok.)								●	●					●	●	●		
Nemocardium yokoyamai Tak.						◑		◑	◑					◑				
Nemocardium minor Tak.								●	●					●	●	●		
Clinocardium shinjiense (Yok.)						◑		◑						◑	◑			
Papyridea ainuanus (Yok.)						○												
Serripes fujiensis (Yok.)			○			○												
Serripes groenlandica (Brug.)						○												
Pitar okadana (Yok.)								●	●					●	●	●		
Dosinia nagaii Ot.														●	●			
Dosinia nomurai Ot.														●	●			
Dosinia yamaguchii Kan. et Mat.						○												
Cyclina matsuii Uoz.													●		●			
Mercenaria sigaramiensis (Mak.)								●										
Mercenaria y-iizukai (Kan.)						◑		◑										
Mercenaria chitaniana (Yok.)			◑			◑		◑						◑	◑			
Paphia siratoriensis Ot.								●	●					●	●	●		
Spisula voyi (Gabb)			○			○												
Spisula onnechiuria (Ot.)			◑			◑		◑					◑		◑			
Spisula kurikoma (Nom.)						◑		◑					◑	◑	◑			
Spisula ezodensata (Kub.)			◑			◑							◑		◑			
Macoma calcarea (Gem.)					◑		◑											
Macoma optiva (Yok.)			◑		◑	◑								◑	◑	◑		
Macoma tokyoensis Mak.			◑			◑								◑	◑	◑		
Peronidia t-matsumotoi (Ot.)			○		○	○												
Siliqua alta (Brod. et Sow.)						◑								◑	◑	◑		
Phaxus izumoensis (Yok.)								●						●	●			
Panope japonica (A. Adamus)			○		○	○												
Pamomya shimotomiensis Ot.								●						●				
Mya cuneiformis chikubetsuensis Fuj.						○												
Mya truncata Linn.			○		○	○												
Pholadidea kotakai Kan. et Mat.			○		○	○												
Platyodon nipponica Uoz. et Fuj.						○												
Periploma besshoensis (Yok.)			◑		◑	◑		◑										
Periploma haborenis Uoz.						○												
Calliostoma hidakana Uoz.															●	●		
Turritella s-hatai Nom.						○												
Turritela fortilirata ckikubetsuensis Kot.			○			○												
Orectospira wadana (Yok.)			○			○												
Battilaria tateiwai Mak.								●						●	●			
Battilaria yamanarii Mak.								●						●				
Proclava otukai (Nom.)														●	●	●		
Crepidula jimboana Yok.								●						●		●		
Crepidula ezoana Uoz.						○												
Calyptraea shibatai Uoz										●				●				
Sigapatella ovata Uoz.						○												
Polinices kiritaniana Yok.								●	●					●				
Polinices meisensis Mak.														●	●			
Polinices diymides Kan. et Mat.						○												
Natica severa Kan. et Mat						○												
Natica ezoana Kan. et Mat.						○												
Geleodea onishibetsuensis (Ot.)			○			○												
Neptunea oomurai Otuka.					○	○												
Neptunea modestus (Kuroda)								●						●		●		
Ancistrolepis yudaensis Ot.															●			
Buccinum hattorii Uoz.						○												
Psephea antiquior Tak.			○			○												
Psephea magna Tak.					◑	◑								◑	◑			
Trophonopsis felix (Yok.)			○			○												
Trophonopsis uemurai (Yok.)								●										
Nassarius simizui Ot.															●			
Conus tokunagai Ot.															●			
Desmostylus mirabilis Nag.						◉		◉										

Table. 2 GEOLOGICAL DISTRIBUTION OF FOSSILS IN THE NEOGENE DEPOSITS OF HOKKAIDO (1)

SPECIES \ OCCURRENCE	Kawabata Series			Wakkanai Series		Takikawa Series		"Setana" S.
	Asahi F.	Takinoue F.	Kawabata E. (?)	Atsunai F. / Togeshita F.	Wakkanai F.	Takikawa F.	Upper Takikawa ~Setana F."	

LOCALITIES OF FOSSILS																		
S — C — H							N—C—H		S—E—H		N — E — H			S — W — H				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

PELECYPODA

Solemya tokunagai Yok.
Solemya yessoensis Kan.
Adulomya uchimurensis (Kur.)

Acila nakazimai Otuka.
Acila gottschei (Böhm)
Acila divaricata (Hind)
Acila hidakensis Nag. et Huz.
Acila kushirensis Nag. et Huz.
Acila vigilia Sch.
Acila elongata Nag. et Huz.
Ennucula hadorensis Kan. et Mat.
Nuculana kongiensis Ot.
Nuculana penula (Yok.)
Yoldia macroschema Uoz.
Yoldia notabilis Yok.
Yoldia sagittaria Yok.
Yoldia uranoi Uoz.
Yoldia haborensis Uoz.
Yoldia biremis Uoz.
Portlandia hayasakai Uoz.
Portlandia thraciaeformis (St.)
Portlandia kakimii Uoz.
Portlandia watasei (Kan.)
Malletia cf. poronaica (Yok.)
Limopsis takaiensis Yok.
Anadara abdita Mak.
Anadara ogawai (Mak.)
Anadara ninohensis Ot. t
Anadara trilineata var. calcalea Gran. et Gal.
Barbatia stearnsii pil.
Glycimeris derelicata (Yok.)
Glycimeris vestitoides Nom.
Glycimeris yessoensis Jay.
Glycimeris pilsbryi Yok.
Glycimeris oosugii Uoz.
Glycimeris idensis Kan.

Propeamusium tateiwai Mak.
Palliolium peckhami (Gab.)
Patinopecten kimurai (Yok.)
Patinopecten matsumoriensis Nak.
Patinopecten protomollitus Nom.
Patinopecten kaneharai (Yok.)
Patinopecten kobiyamai (Kan.) 1b
Patinopecten poculis (Yok.)
Patinopecten yessoensis (Yok.)
Chlamys akitanus (Yok.)
Chlamys izuensis (Yok.)
Chlamya cf. maruyamaensis (Mas.)
Chlamys iwasakiensis (Yok.)
Swiftopecten swiftii (Bern.)
Miyagipecten saromensis Has. et Kan.
Pracopecten setanensis Kub.
Fortipecten takahashii (Yok.)
Lima cf. smithi Dall
Ostrea gravitesta (Yok.)
Anomia lischkei Yok.

Crenella tomiyaensis Yok.
Mytilus tichanovitchi Mak.
Mytilus sakooi Uoz.
Mytilus grayana Yok.
Musculus laeviatus (Gray)
Periploma besshoensis (Yok.)
Periploma yokoyamai (Mak.)
Periploma haborensis Uoz.
Pholadomya ooshimensis Uoz.
Lithophaga chikubetsuensis Kan.
Lithophaga otukai Hat.
Thracia asahiensis Uoz.
Thracia yoshidai Uoz.
Thracia pertrapezoides Nom.
Pandora sp.
Cuspidaria makiyamai Kan.

Astarte alaskaensis Dall
Astarte borealis (Sch.)
Astarte hakodatensis Yok.
Astarte teshioensis Yok.
Astarte oosugii Uoz.
Venericardia akagii Kan.
Venericardia niniuensis Uoz
Venericardia hidakensis Uoz.
Venericardia teshioensis Uoz.
Venericardia ferruginea Ad. et Rve.
Venericardia saghalensis Uoz.
Venericardia setanensis Uoz.
Venericardia abeshinaiensis Ot.
Venericardia fujiei Uoz.
Callyptogena pacifica Dall
Callyptogena chishimana Uoz.
Diplodonta utanoborensis Uoz.
Felaniella usta (Gould)
Conchodele bisecta (Con.
Lucinoma cf. hannibali Dall
Lucinoma tanaii Uoz.
Lucinoma acutilineatum Con.
Lucinoma ishii Uoz.

Nemocardium yokoyamai Tak.
Nemocardium minor Tak.
Trachycardium siobarense (Yok.)
Clinocardium californensis (Yok.)
Clinocardium shinjiense (Yok.)
Clinocardium iwashiroense Nom.
Laevicardium elongata (Yok.)
Papyridea ainuanum (Yok.)
Papyridea nipponica (Yok.)
Serripes fujiensis (Yok.)
Serripes groenlandica (Brug.)
Serripes laperousii Desh.
Serripes yokoyamai Ot.
Serripes notabilis Sow.
Serripes pauperculus Yok.

Pitar okadana (Yok.)
Pitar hokkaidoensis Nom.
Callista brevisiphonata Carp.
Callista chinensis takagii Mas.
Meretrix arugai Ot.
Meretrix matsuii Uoz.
Dosinia mirabilis Uoz.
Dosinia japonica Rve.
Dosinia yamaguchii Kan. et Mat.
Dosinia tatunokutiensis Nom.
Dosinia nomurai Ot.
Dosinia nagaii Ot.
Cyclina matsuii Uoz.
Cyclina japonica Kan.
Mercenaria stimpsoni (Gould)
Mercenaria chitanii (Yok.)
Mercenaria y-iizukai (Kan.)
Mercenaria sigaramiensis (Ot.)
Seccurella hashimotoi Uoz.
Paphia stratorensis (Ot.)
Tapes uemurai Yok.
Protothaca kitamensis Uoz.
Mactra sulcataria Rve.
Spisula sachalinensis Sch.
Spisula voyii (Gab..)
Spisula onnechiuria Ot.
Spisula ezodensata (Kub.)
Spisula ishii Uoz.
Schizothaerus keenae kur. et Hab.

Macoma asagaiensis Mak.
Macoma optiva (Yok.) ttt
Macoma incongura (Mart.)
Macoma tokyoensis (Mak.)
Peronidia t-matsumotoi Ot.
Peronidia elongata Uoz.
Peronidia uryuensis Uoz.
Peronidia venulosa (Sch.)
Soletellina minoensis Yok.
Soletellina commoda (Yok.)

Siliqua pulchella (Dun.)
Siliqua elliptica Uoz.
Siliqua alta (Brod. et Sow.)
Phaxus izumoensis (Yok.)
Hiatella orientalis (Mak.)
Panomya ampla Dall
Panomya simotomiensis Ot.
Panope japonica Ad.
Mya japonica Jay.
Mya cuneiformis Bohm
Mya truncata Linn.
Mya grewingki haborensis Fuj.
Platyodon nipponica Uoz. et Fuj.
Pholadidea kotakae Kan. et Mat.

Table 3. GEOLOGICAL DISTRIBUTION OF FOSSILS IN THE NEOGENE DEPOSITS OF HOKKAIDO (2)

SPECIES \ OCCURRENCE	Kawabata Series: Asahi F.	Kawabata Series: Takinoue F.	Kawabata Series: Kawabata F. (?)	Wakkanai Series: Atunai Togeshita F.	Wakkanai Series: Wakkanai F.	Takikawa Series: Takikawa F.	Setana S.: Upper Takikawa ~Setetana F.	LOCALITIES OF FOSSILS: S–C–H 1	2	3	4	5	6	N–C–H 7	8	S–E–H 9	10	N–E–H 11	12	13	S–W–H 14	15	16	17	18
GASTROPODA																									
Calliostoma hidakana Uoz.								●																	
Turritella saishuensis Yok.												●		●				●							
Turritella s-hataii Nom.		?												●			●			●					
Turritella fortilirata chikubetsuensis Kot.								●						●											
Orectospira wadana (Yok.)								●						●	●										
Battilaria yamanarii Mak.									●				●												
Battilaria tateiwai Mak.									●				●												
Proclava otukai Nom.								●	●																
Cerithium sirakii Mak.								●				●													
Epitonium sp.																									
Calyptraea shibatai Uoz.								●		●		●													
Crepidula jimboana Yok.								●					●												
Crepidula ezoana Uoz.														●											
Sigapatella ovata Uoz.														●											
Polnices meisensis Mak.								●																	
Polinices diymides Kan. et Mat.								●					●												
Polinices kiritaniana (Yok.)														●											
Natica severa Kan. et Mat.														●											
Natica ezoana Kan. et Mat.														●											
Geleodea onishibetsuensis (Ot)														●	●										
Trophonopsis felix (Yok.)														●											
Trophonopsis uemurai (Yok.)													●												
Coralliophira tokudai (Yok.)				?									●												
Polytropa ishii Uoz.																●									
Ancistrolepis yudaensis Ot.								●	●																
Japelion tokunagai Kan.										●		●	●				●								
Neptunea phoenceous Dall																									
Neptunea eos Kur.																									
Neptunea oomurai Ot.															●										
Neptunea osanaii Uoz.															●										
Neptunea modestus (Yok.)								●																	
Neptunea yokoyamai Hat.																									
Buccinum chishimanum Dall.																									
Buccinum hattorii Uoz.															●										
Buccinum sinanoense Mak.																									
Nassarius simizui Ot.								●																	
Propebela yanamii (Yok.)								●																	
Psephea antiquior Tak.								●							●										
Psephea magna Tak.															●										
Conus tokunagai Ot.								●																	
Amathia notabilis Ad.				?												?!									
OTHERS																									
Desmostylus mirabilis Nag.																									
Linthia nipponica Tok.													●		●										
Echinarachnius subtumidus Nis. et Has.										●		●				●									
Echinarachnius rumoensis Hay. et Sib													●												
Echinolampas yoshiwarai de Lor.													●												
Astrichypeus amdigenus Nis.																						●			
Terebratalia innaiensis Hay.																						●			
																									●