PALYNOLOGICAL CONSIDERATION ON TERTIARY MARINE SEDIMENTS OF HOKKAIDO, COMPARED WITH ANIMAL FAUNAS

by

Seiji SATO

(with 16 tables, 10 text-figures and 4 plates)

(Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1231)

Introduction

The author has devoted himself to palynological study on the Tertiary and Cretaceous of Hokkaido with desiring to clear up the nature of floras of these ages and to settle certain stratigraphical problems by an aid of palynological method as much as possible. The Tertiary and Cretaceous formations in Hokkaido are, however, chiefly marine in facies, and the terrestrial members and formations have been considered to be rather limited in horizons, which may be likely to be more suitable for palynological studies. As a matter of fact, palynologists including the present author himself in Japan have mainly studied on non-marine deposits, especially on carbonaceous matter. There is almost no palynological contribution on marine sediments in Japan up to date. Nevertheless, the author lately became to think of necessity of palynological examination on the sediments of marine facies for clarifying the details of the floras in the above noted formations, since the marine deposits compose the main part of the Tertiary and Cretaceous formations in Hokkaido. Still, he has been suspicious whether or not the marine deposits of Hokkaido may really contain fossil pollen and spores being worth while to be studied.

It was a problem at first for the author to confirm the existence of such micro-fossils in marine Tertiary and Cretaceous formations, before stepping into the articles concerning to the floral nature in the past and problem of stratigraphical correlation by introducing of palynological study into marine sediments. The information we need in this concern may be as such, whether or not fossil pollen and spores exist in marine sediments, how about their assemblage in quantity if they really exist, how their distribution is in sediments, and so on. The present paper may answer for such questions to some extent. The sampled specimens for the present study were purposely collected from the Miocene and Oligocene deposits developed in Central

Hokkaido in which (1) molluscs, foraminiferas and macro-plant remains are richly found, and coal and petroleum are contained. (2) All those formations have been hitherto studied some in detail either from view point of paleontology or stratigraphy. (3) In addition to this, the author already published on some results for palynological study on carbonaceous matter contained in the Miocene formations, further to be dealt in this paper.

Fortunately, the author could find out numerous fossil pollen and spores even in the marine part of those deposits. They are actually very uniformly distributed in almost all marine sediments; as a matter of fact, pollen and spores were found in more than 90 per cent of the collected specimens.

It is an important problem for pollen analysis to know how a pollen assemblage in sediments represents the flora in composition, from which the pollen was derived. On certain recent sediments such as surface soil, lake deposit and peat, there are various publications reporting the evident proof on the pollen assemblages in the sediments which well represent the floras existing in the neighbourhood of the sedimentary basins. In turn, such data on marine sediments are very scarce, probably because of expensive and laborious researches.

Recently, papers of worth while to note in this concern are, however, published in succession on pollen and spores in the recent marine sediments: on the Orinoco delta, South America by MULLER (1959), on the sea of Okhotsk and the Mediterranean sea by KORENEVA (1957, 1967), on the Great Bahama Bank by TRAVERSE and GINSBURG (1966), on the Gulf of California by CROSS, THOMPSON and ZAITZEFF (1966), on the estuary of the Delaware river, U.S.A. by GROOT (1966) etc. From these investigations pollen assemblages in marine sediments became evident to also suggest the main elements of vegetation of adjacent lands to some extent, although the assemblages sometimes show more or less deviation in composition from the flora on land being nearly located to the sea. Pine pollen, for example, is always over-represented in number in marine sediment. Such an exceptional example on the recent marine sediments must be taken into consideration to evaluate fossil pollen assemblages to infer the vegetation over a wide area of land near the sea of those days. Nevertheless, the fossil pollen assemblages as a whole recognized in marine deposits may well indicate the climatic condition of the past, like the case of the terrestrial sediments.

The result of the author's own study on the marine Tertiary formations in Hokkaido seems to be fairly well in harmony with the paleoecological data brought forth either from molluscs, foraminiferas or macro-plant remains. Namely, this result on the palynological study may likely be well in accordance with the paleoclimatic condition of those deposits inferred by paleontologists in various fields of both macro and micro fossils. This may be considered that the pollen assemblage in marine sediments well represents the climatic condition at time when the sediments were deposited.

Samples

Specimens for the present study are collected from the areas shown in Fig. 4 and Figs. 4a–e. The stratigraphic positions of the samples are also shown in Fig. 5. The specimens are mainly sampled from mudstones* of each formation belonging to the Miocene as shown in Fig. 1. Of them, as to the ages of the Momijiyama and Magaribuchi formations, very diverse views have been held by geologists and paleontologists: some one viewed to be Paleogene in age, and others to be Neogene, and their stratigraphic position is not finally settled yet.

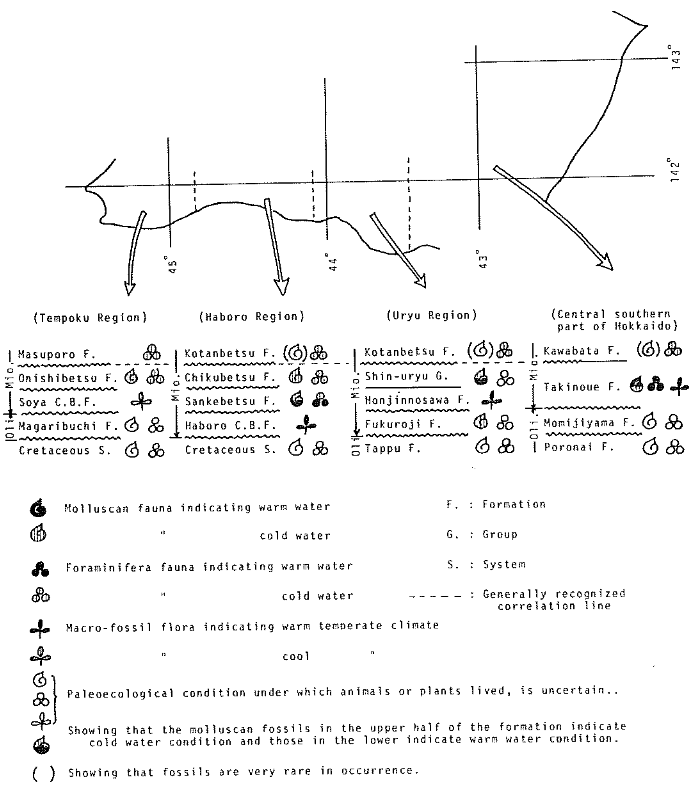


Fig. 1 General stratigraphic sequence of lower-middle Miocene sediments in Central Hokkaido

* GROOT (1966) reported that pollen grains transported in water with clastic sediments, show nearly same movement with the particles of silt size of the latter. Besides, it is reported by many authors that pollen grains are more frequently found out in mudstone than in any other kind of sediments.

	Tempoku R.	Haboro R.	Ishikari R.*
Miocene	Masuporo F.	Kotanbetsu F.	Kawabata F.
	?		
	Onishibetsu F.	Chikubetsu F.	Takinoue F.
	Soya C.B.F.	Haboro C.B.F.	
	Magaribuchi F.	Haranosawa F.	
Paleogene			Momijiyama F.
			Poronai F.

* Ishikari region ocorresponds to the northern part of Central Hokkaido

Fig. 2. Correlation chart of the Miocene in Central Hokkaido (After Cenozoic Correlation Commitee, 1949)

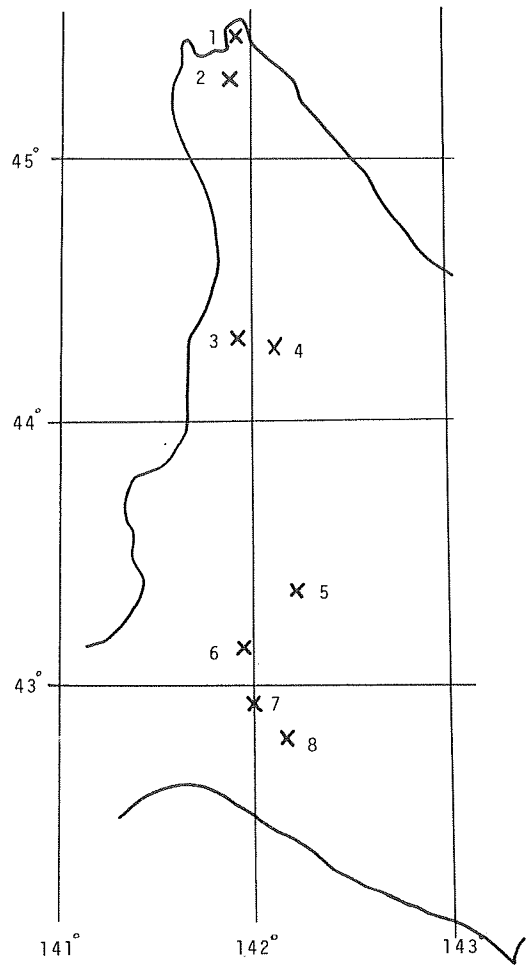
	Tempoku R.	Haboro R.	Ishikari R.*
Miocene	Masuporo F.	Kotanbetsu F.	Kawabata F.
	Onishibetsu F.	Chikubetsu F.	Takinoue F.
		Sankebetsu F.	
		Haboro F.	Asahi C.B.F. Horomui F.B.F.
	Soya C.B.F.		
Paleogene	Magaribuchi F.		Momijiyama F.
			Poronai F.

* Ishikari region ocorresponds to the northern part of Central Hokkaido

Fig. 2' Correlation chart of the Miocene in Central Hokkaido (After Hokkaido Mining Advancement Commitee 1968)

	Tempoku R.	Haboro R.	Central southern part of Hokkaido
Miocene	Masuporo F.	Kotanbetsu F.	Kawabata F.
	Onishibetsu F.	Chikubetsu F.	Takinoue F.
	Soya C.B.F.		
		Sankebetsu F.	
		Haboro F.	
Paleogene	Magaribuchi F.		Momijiyama F.
			Poronai F.

Fig. 3. Correlation chart of the Miocene in Central Hokkaido (After the author, 1970)



1 : Soya 2 : Magaribuchi 3 : Haboro 4 : Shumarinai
5 : Sakipenpetsu 6 : Asahi 7 : Momijiyama 8 : Hobetsu

Fig. 4 Major localities for sampling

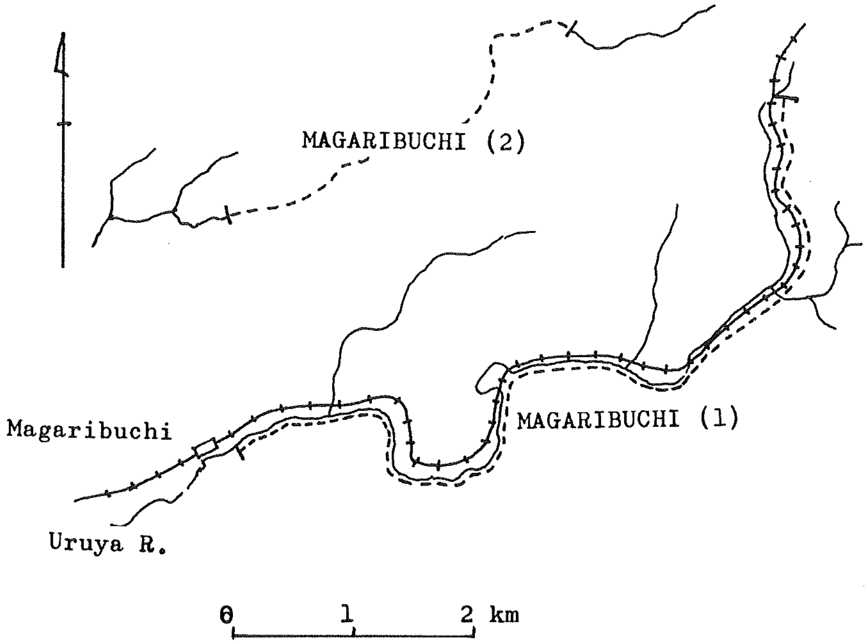


Fig. 4-a. Detailed Map of Sampling Localities in the Magaribuchi Area

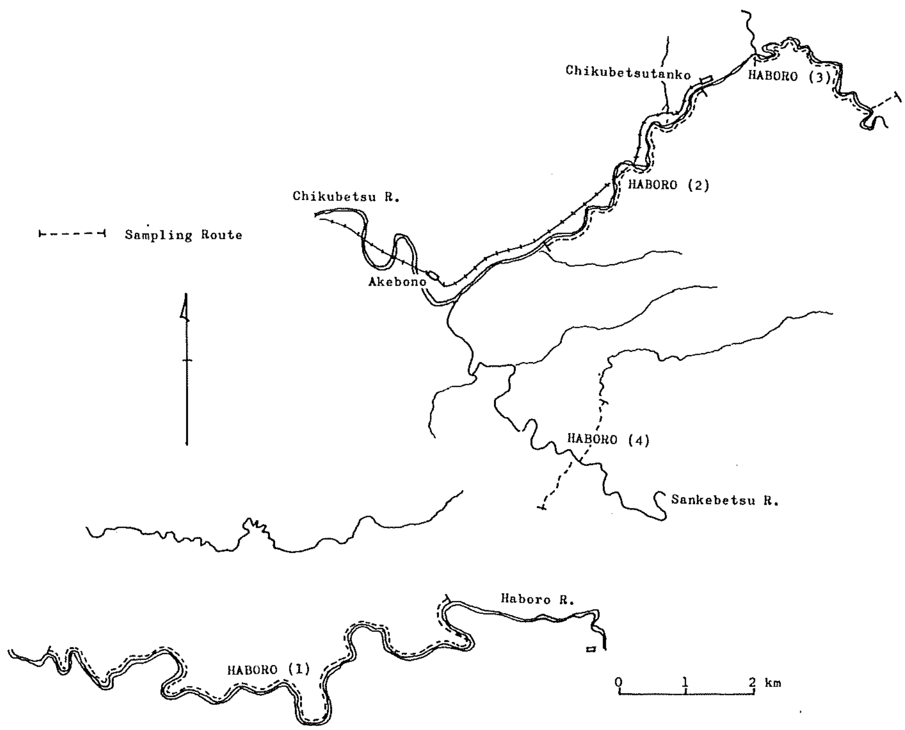


Fig. 4-b. Detailed Map of Sampling Localities in the Haboro Area

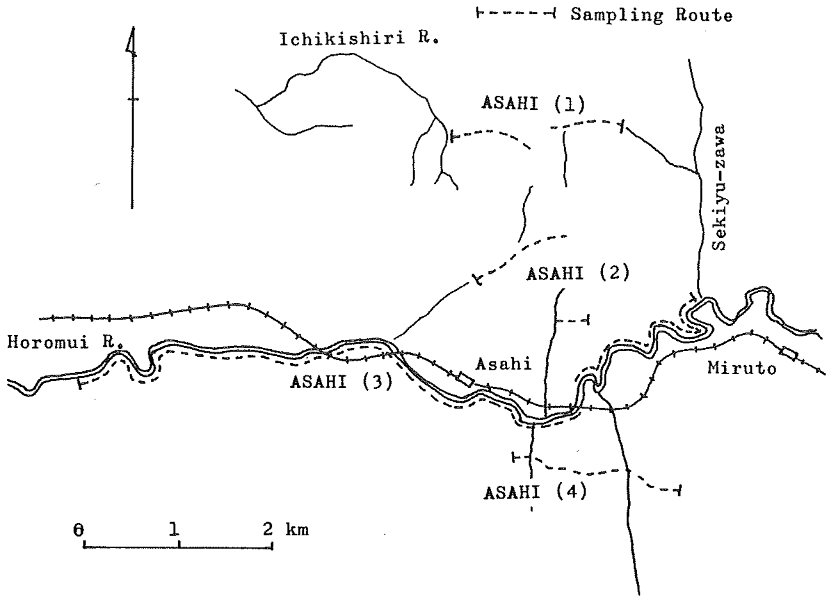


Fig. 4-c. Detailed Map of Sampling Localities in the Asahi Area

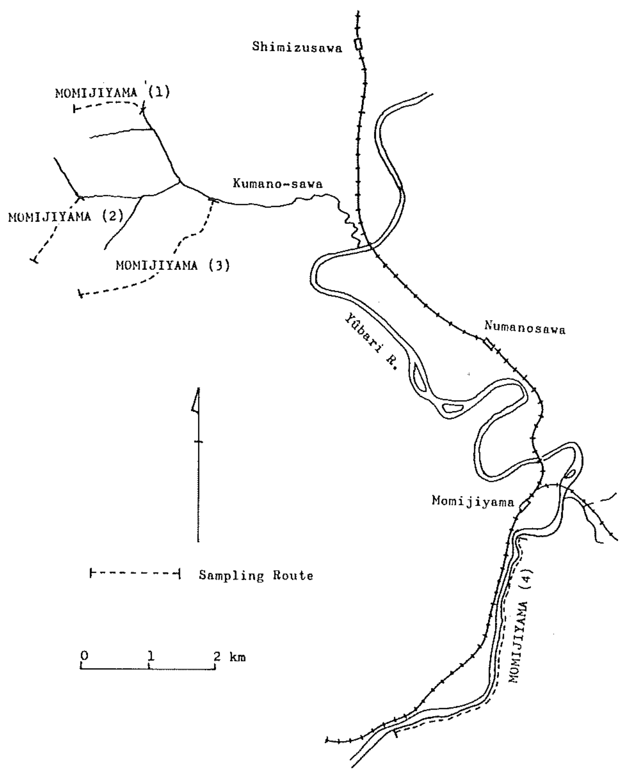


Fig. 4-d. Detailed Map of Sampling Localities in the Momijiyama Area

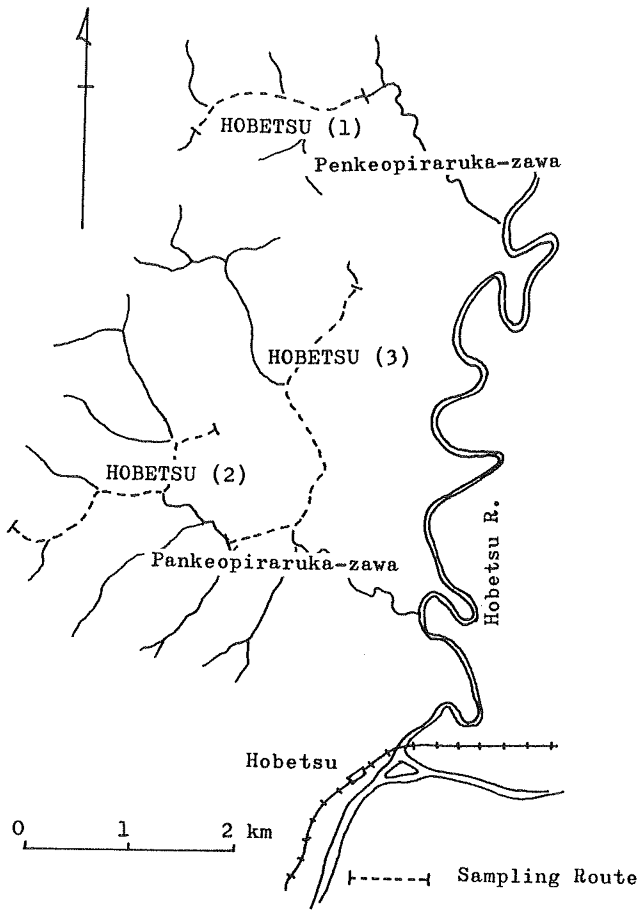


Fig. 4-e. Detailed Map of Sampling Localities in the Hobetsu Area

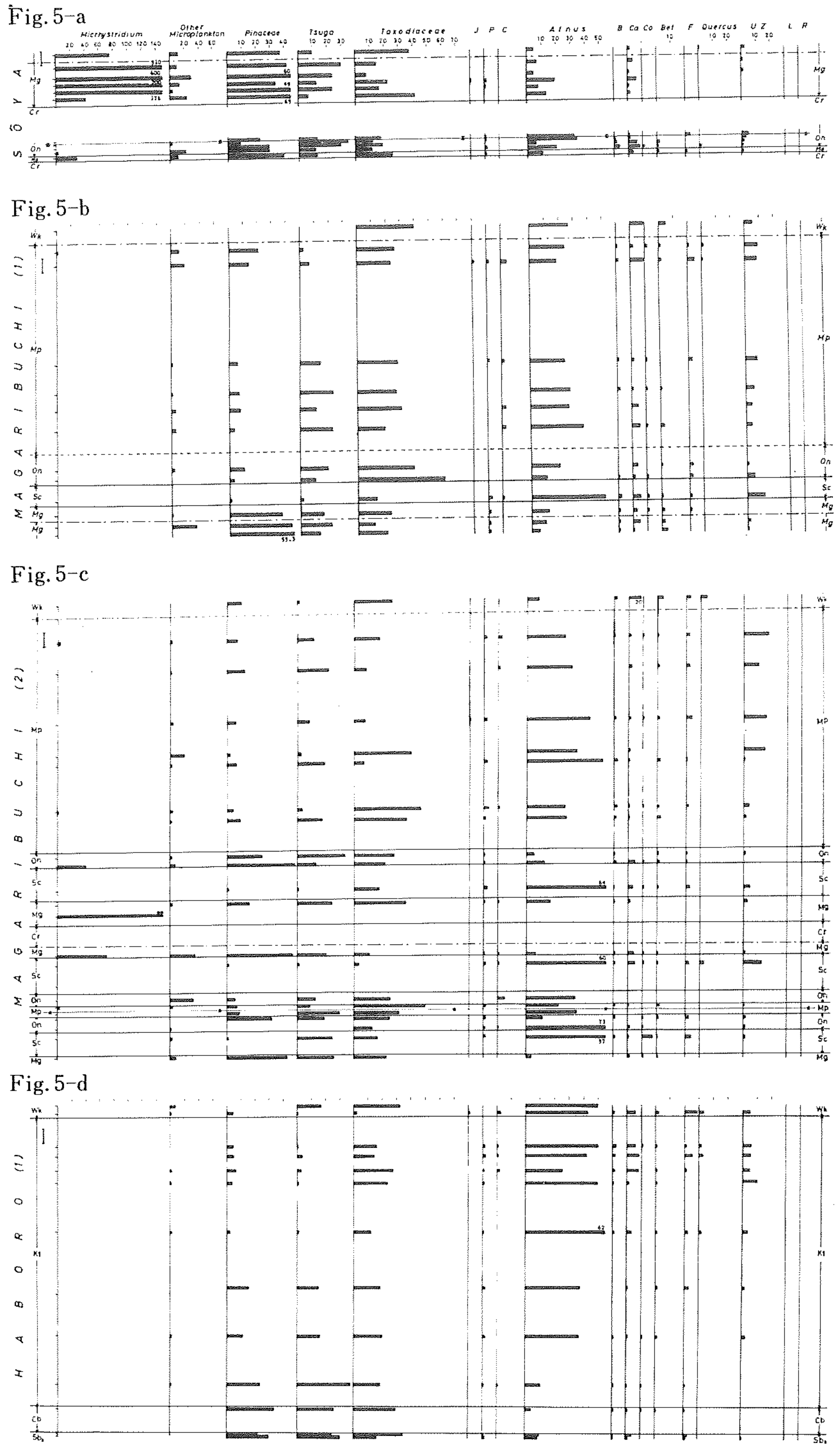


Fig. 5 Pollen Diagrams of the upper Oligocene ~ Miocene Sediments in Central Hokkaido

Fig. 5-e

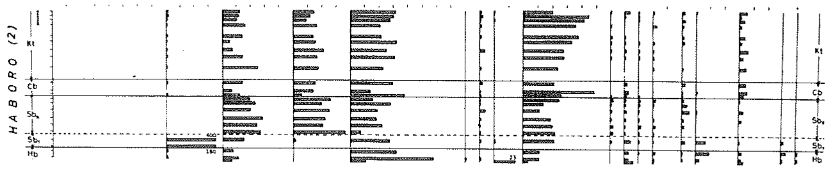


Fig. 5-f

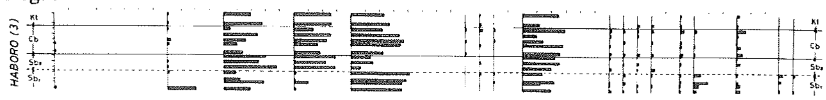


Fig. 5-g

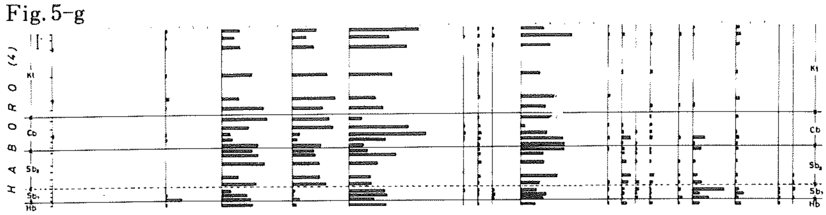


Fig. 5-h

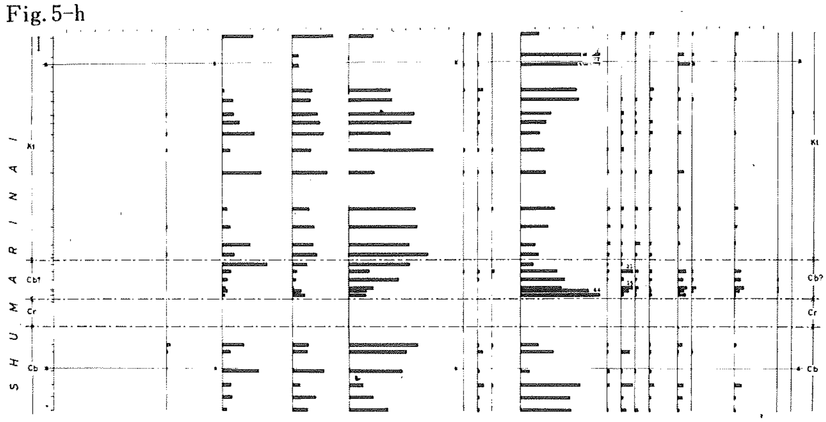


Fig. 5-i

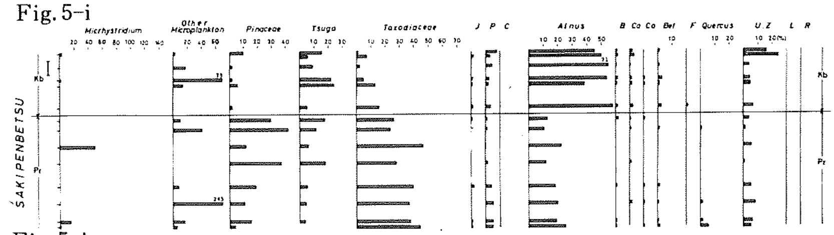


Fig. 5-j

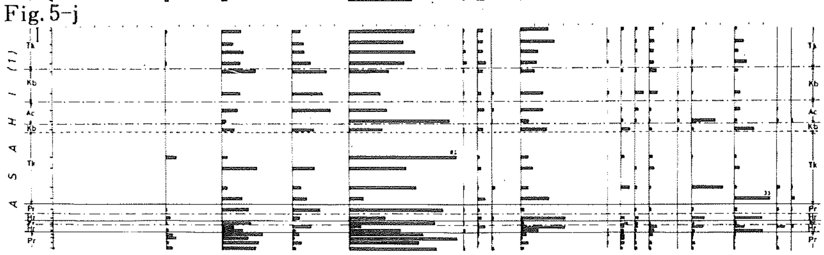


Fig. 5-k

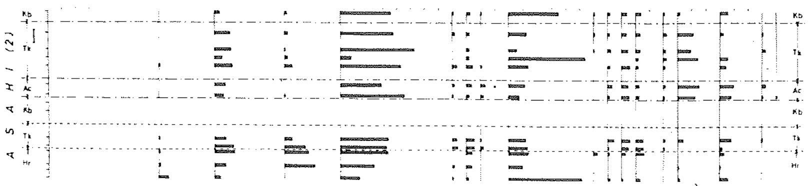


Fig. 5-l

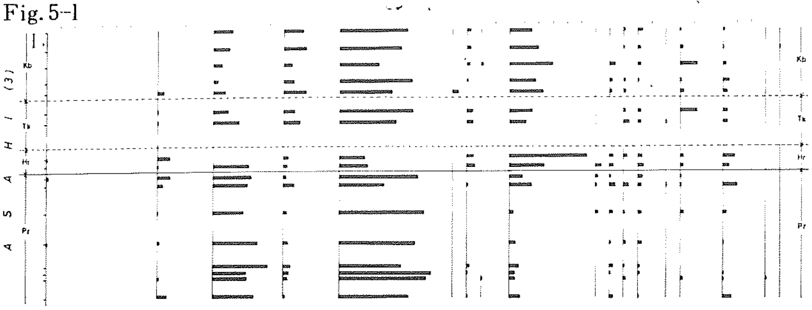


Fig. 5-m

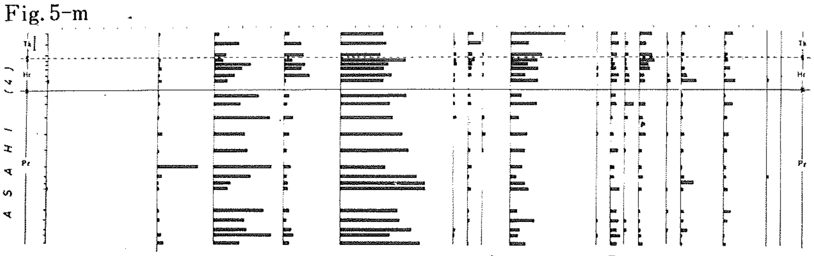


Fig. 5-n

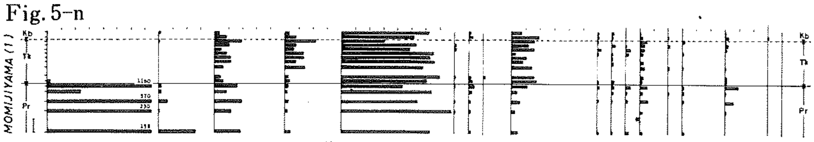


Fig. 5-o

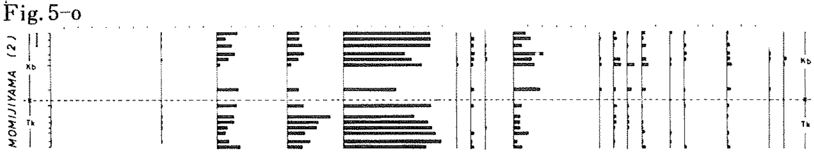


Fig. 5-p

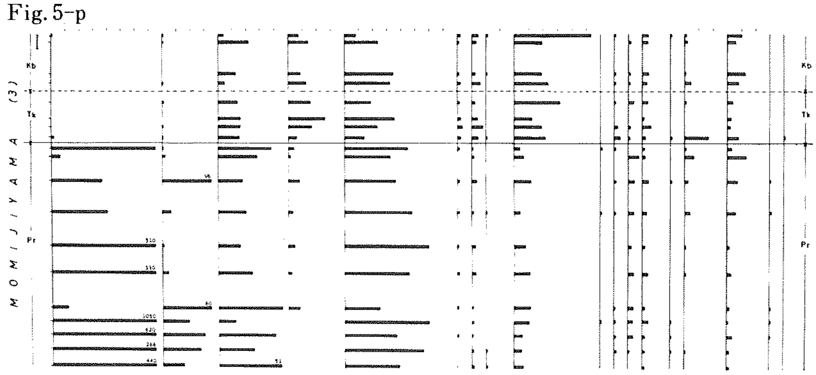


Fig. 5-q

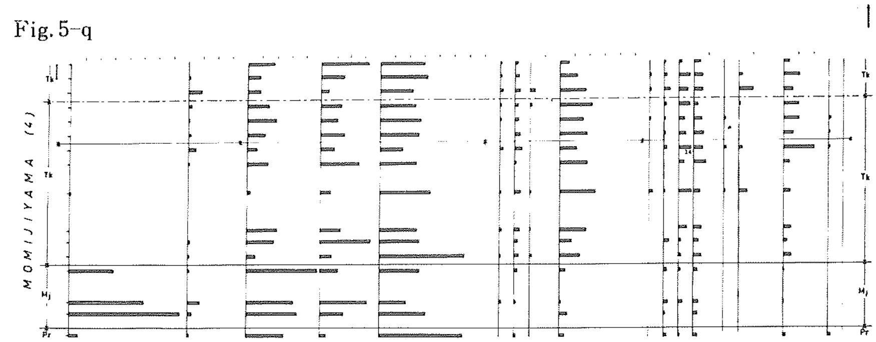


Fig. 5-r

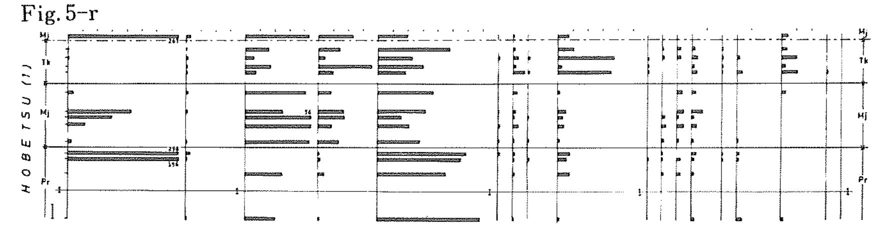


Fig. 5-s

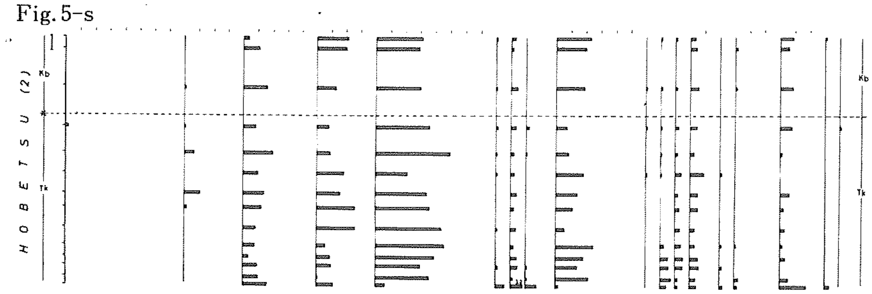
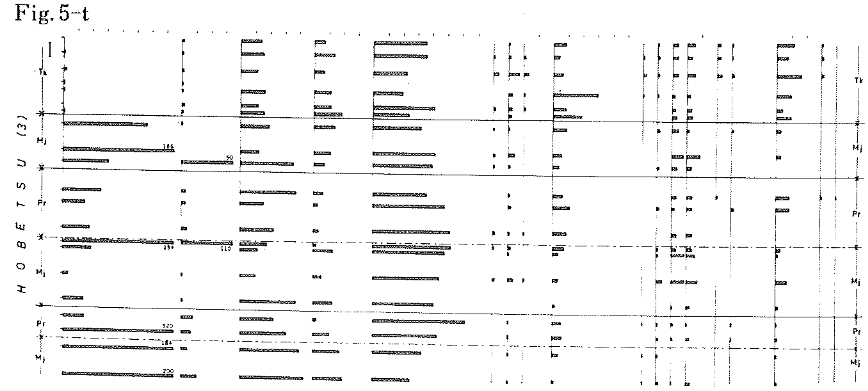


Fig. 5-t



EXPLANATION

[I] showing 100m in thickness of sediments; anticlinal axis; synclinal axis; conformity; unconformity; fault

Cr Cretaceous system; Pr Poronai formation; Mj Momijiyama formation; Mg Magaribuchi formation; Hb Haboro coal-bearing formation

Sb_1 Sankebetsu formation (sandstone member); Sb_2 Sankebetsu formation (alternation member); Cb Chikubetsu formation

Cb? sediments which are reported as the Chikubetsu formation, but are different in pollen assemblage from the Chikubetsu formation

Sc Sôya coal-bearing formation; On Onishibetsu formation; Hr Horomui formation; Ac Asahi coal-bearing formation

Tk Takinoue formation; MP Masuporo formation; Kt Kotanbetsu formation; Kb Kawabata formation; Wk Wakkanai formation

Results

Poronai formation

The present formation is almost entirely composed of very monotonous massive mudstone, mostly silt in grain size, 1800m in the maximum thickness. This formation is very abundant in marine molluscan and foraminifera fossils as a whole; the former of which has been called the "Poronai fauna" because of most representative fossils of this formation. Further, macro-plant remains are rarely found.

Molluscan fossils have been studied by many authors; especially by TAKEDA (1953) and TESHIMA (1958–'62). The specific names of them may be listed up in the Table 1. MIZUNO (1964) further listed up the more characteristic molluscs of this formation which may be referred in the Table 2. According to OYAMA, MIZUNO & SAKAMOTO (1960), more dominant genera of this formation may be as follows: *Acila (Truncacila), Saccella, Yoldia, Portlandia (Portlandella), Venericardia (Cyclocardia), Turritella* and *Trominina.* TESHIMA (1955) held a view that this formation may be divisible into nine zones based on molluscan assemblages as is referred in the Table 3. Further, he considered the Poronai formation shows cyclic sedimentation from shallow to shallow through deep environment in between; viz, from A zone (basal part) to I zone (top). According to TAKEDA (1953), the fauna is a mixture of warm and cold water inhabitants; although the cold water inhabitants may be more numerous than the warm water forms either in specific or individual number. SASA, TANAKA & HATA (1964) were also in the same opinion in this regard. Meanwhile, *Aturia* indicating warm current was found in this formation (KOBAYASHI, 1957).

Foraminifera fossils: There are numerous contributions on the foraminiferas of this formation. Specific names hitherto known may be listed in the Table 4, 4′ and 4″. The specialists in this field, however, had interest in biostratigraphical correlation of this formation, and scarcely stated in detail on the environmental condition under which the fauna inhabited. Amongst them UCHIO 's remarks (1961) may be worth while noted here, since he concluded the depositional condition of the Poronai formation to have been a continental shelf or continental slope under cold water. In addition to this, almost all the specialists who treated foraminifera of this formation, held a view that the Poronai sea might be a closed bay because of lacking of planktonic foraminifera of the open sea type. UCHIO (1961) subdivided the formation into twelve zones based on the assemblages of foraminifera fossils.

Macro-plant fossils: The following forms have been hitherto reported from this formation: *Glyptostrobus europaeus* (BRONGN.) HEER, *Cunninghamia* sp.,

Table 1 Molluscan fossils of the Poronai formation
(After T. SHIMOKAWARA, 1963)

Solemya (Achrax) tokunagai YOK.
Neilonella poronaica (YOKOYAMA)
Saccella hokkaidoensis OYAMA et MIZUNO
S. nagaoi (TAKEDA)
S. sp.
Nuculana sp.
Yoldia (Yoldia) laudabilis YOKOYAMA
Y. (Y.) saitoi UOZUMI
Y. (Tepidoleda) sobrina TAKEDA
Y. sp.
Portlandia (Portlandella) watasei (KANEHARA)
P. (P.) watasei semiovata UOZUMI
Nucula hokkaidoensis MIZUNO et INOUE
Acila (Truncacila) picturata (YOKOYAMA)
A. (Acila) elongata NAGAO et HUZIOKA
A. (A.) sp.
Isogunomon (Isogunomon) murayamai YOKOYAMA
Palliolum ikushunbetsuensis UTASHIRO
P. poronaiensis UTASHIRO
P. numanosawaensis TESHIMA
Lima (Acesta) j-suzukii TAKEDA
Lima poronaiensis HONDA
Crassatellites teshimai INOUE et MIZUNO
Venericardia (Cyclocardia) yokoyamai OYAMA et MIZUNO
V. (C.) akagii KANEHARA
V. (C.) tokudai TAKEDA
V. (C.) ezoensis TAKEDA
V. (C.) satisparva MIZUNO et INOUE
Anodontia poronaiensis (YOKOYAMA)
Thyasira (Conchocele) bisecta omarui OYAMA et MIZUNO
Nemocardium yokoyamai TAKEDA
N. ezoense TAKEDA
Crenella nagahamai MIZUNO
Hubertschenckia ezoensis (YOKOYAMA)
Merisca onishii INOUE et MIZUNO
Macoma poronaiensis INOUE et MIZUNO
Mya sp.
Pholadomya poronaiensis TESHIMA
Thracia sp.
Periploma besshoense (YOKOYAMA)
P. ezoense MIZUNO *et I*NOUE
Cuspidaria sp.
Dentalium nunomae TAKEDA
D. sp.

Siphonodentalium sp.
S. sp.
"Minolia" funiculata (YOKOYAMA)
Orectospira wadana (YOKOYAMA)
O. shimokawarai URATA
Turritella poronaiensis TAKEDA
T. sp.
Clathrus cf. *submaculosus* (NAGAO)
Cirsotrema (Cirsotremopsis ?) sp.
Ampullina asagaiensis MAKIYAMA
Euspira sp
Crepidula sp.
Colus aff. *fujimotoi* HIRAYAMA
Ancistrolepis modestoideus (TAKEDA)
A. ncistroepis sp.
Trominina japonica (TAKEDA)
Neptunea sp.
Buccinum sp.
Molopophorus poronaiensis TESHIMA
Tudicula japonica TAKEDA
Fulgoraria (Psephaea) antiquior (TAKEDA)
Eocylichna multistriata (TAKEDA)
Olivella sp.
Aturia yokoyamai NAGAO
Callianassa muratai NAGAO
Portunites hexagonalis NAGAO
Hyas ? sp.
Linthia sp.
Salenia sp.
Platycyathus sp.
Flabellum sp.
Ophiuroidea sp.
Graphularia ? sasai YABE
Brachiopoda, gen. et. sp. indet.
Vertebral column of shark
fish scale
Sponge

Table 2 Characteristic molluscs of the Poronai group
(After A. MIZUNO, 1964)

GASTROPODA
Orectospira wadana (YOKOYAMA)
Turritella "poronaiensis TAKEDA"
Fulgoraria antiguior (TAKEDA)
Eocylichna multistiata (TAKEDA)

SCAPHOPODA

Siphonodentalium sp.
Dentalium nunomae TAKEDA

PELECYPODA

Neilonella poronaica (YOKOYAMA)
Yoldia saitoi UOZUMI
Y. cfr. *akanensis* UOZUMI
Y. *sobrina* TAKEDA
Y. *nagaoi* (TAKEDA)
Portlandia watasei (KANEHARA)
Nucula hokkaidoensis MIZUNO et INOUE
Acila picturata (YOKOYAMA)
Crenella nagahamai MIZUNO
Isognomon murayamai (YOKOYAMA)
Lima j-suzukii TAKEDA
Palliolum ikushunbetsuensis UTASHIRO
Ctenamusium kushiroense (TAKEDA)
Venericardia yokoyamai OYAMA et MIZUNO
V. *akagii* KANEHARA
V. *tokudai* TAKEDA
V. *satisparva* MIZUNO et INOUE
Crassatellites teshimai INOUE et MIZUNO
Thyasira bisecta CONRAD
Nemocardium yokoyamai TAKEDA
Hubertschenckia ezoensis (YOKOYAMA)
Macoma poronaiensis INOUE et MIZUNO
Merisca onishii INOUE et MIZUNO
Periploma besshoense (YOKOYAMA)
P. *ezoense* MIZUNO et INOUE

Table 3 Subdivision of the Poronai formation based on molluscan fossils
(Complied by Y. SASA et al, 1964)

In descending order

I Zone : *Venericardia* spp. – *Neilonella poronaica–Linthia* sp. Zone
H Zone : *Callianassa muratai* – *Crassatellites teshimai–Linthia* sp. Zone
G Zone : *Nemocardium yokoyamai* Zone
F Zone : *Lima j–suzuki* Zone
E Zone : *Merisca onishii* Zone
D. Zone : *Portlandia watasei* Zone
C Zone : *Callianassa muratai* Zone
B Zone : *Venericardia* spp. – *Neilonella poronaica* Zone
A Zone : *Macoma poronaiensis* – *Yoldia sobrina* Zone

Table 4 Foraminifera fossils from the Poronai formation
(After K. ASANO, Complied by T. SHIMOKAWARA, 1963)

Bathysiphon eocenicus CUSHMAN et HANNA
Haplophragmoides spp.
Cyclammina ezoensis ASANO
C. incisa (STACHE)
C. pacifica (BECK)
Ammodiscus sp.
Ammobaculites akabiraensis ASANO
Trochammina asagaiensis ASANO
T. cf. *pacifica* CUSHMAN
T. spp.
Dorothia sp.
Nodosaria sp.
Guttulina cff. *irregularis* (d' OBRIGNY)
Globulina minuta (ROEMER)
Sigmoidella plummerae CUSHMAN et OZAWA
Plectofrondicularia packardi CUSHMAN et SCHENCK
P. packardi multilimeata CUSHMAN et SIMONSON
P. gracilis SMITH
Bulimina ezoensis YOKOYAMA
B. schwageri YOKOYAMA
B. spp.
Gyroidina cf. *soldanii* d'OBRIGNY
Cassidulina globosa HANTKEN
C. margareta KARRER
Planulina poronaiensis ASANO
Cibicides yabei ASANO
Angulogerina n. sp.
Anomalina n. sp.
Elphidium yumotoense ASANO
Nonion pompilioides Shmokinense ASANO
N. sorachiense ASANO
Plectina poronaiensis ASANO
Cornuspiroides oinomikadoi HANZAWA et ASANO
Quinqueloculina sp.

In addition to the above described species, UCHIO (1963) and UJIIE et al (1960) recognized the following species shown in Table 4′ and 4″.

Table 4′

Cyclammina cf. *ezoensis* ASANO
Alveolophragmium (?) sp.

Ammobaculites sp.
Involutina sp.
Goesella sp.
Trifarina sp.
Bolivina sp.
Sigmomorphina (?) sp.
Guttulina sp.
Robulus sp.
Entosolenia sp.
Protelphidium (Nonion sorachiense ?) sp.
Quinqueloculina goodspeedi HANNA et HANNA
Globobulimina ezoensis YOKOYAMA

Table 4″ (After UJIIE & WATANABE)

Rhabdammina sp.
Reophax sp.
Ammodiscus incertus (d'OBRIGNY)
Haplophragmoides cf. *emaciata* (BRADY)
Cribrostomoides cf. *cretacea* CUSHMAN et GOUDKOFF
Alveolophragmium ? sp.
Cyclammina orbicularis BRADY
C. cf. *tani* ISHIZAKI
Ammobaculites aff. *dilatatus* CUSHMAN et BRONNIMANN
A. aff. *mauricensis* HOWE
A. spp.
Flabellammina poronaiensis UJIIE et WATANABE
Spiroplectammina sp.
Textularia sp.
Trochammina symmetrica UJIIE et WATANABE
Ammocibicides hashimotoi UJIIE et WATANABE
Valvulina aff. *chapmani* CUSHMAN
Verneuilinidae ? gen. indet.
Sigmoilinopsis sp.
Lagena cf. *laevis* (MONTAGU)
L. aff. *costata* (WILLIAMSON)
L. spp.
Oolina hexagona (WILLIAMSON)
Fissurina ? sp.
Guttulina cf. *austriaca* d'ORBIGNY
G. *(Sigmoidina)* aff. *pacifica* CUSHMAN et OZAWA
Globulina sp.
Glandulina laevigata ovata CUSHMAN et APPLIN
Plectofrondicularia spp.
Buliminella robertsi HOWE et ELLIS
Bulimina sculptilis CUSHMAN

B. yabei ASANO et MURATA
Globobulimina sp.
Virgulina cf. dibollensis CUSHMAN et APPLIN
Bolisina euplectella YOKOYAMA
B. sp.
Cassidulina aff. *margareta* KARRER
Nonion pompilioides (FICHTEL et MOLL)
N. cf. *floscularium* (YOKOYAMA)
N. sp.
N. ? spp.
Nonionella japonica (YOKOYAMA)
Pullenia salisburyi K.C. et R.E. STEWART
Discorbis sp.
Gyroidinoides yokoyamai UJIIE et WATANABE
Volvulineria lymani (YOKOYAMA)
V. cf. *globosa* (KLEINPELL)
Cibicides sp.
Globigerina cf. *linaperta* FINLAY
Globorotaloides suteri BOLLI

Pinus sp., *Picea* sp., *Carya* sp., *Fagus* sp., *Laurophyllum* sp., *Acer* (Samara) sp., *Engelhardtia koreanica* OISHI, *Macclintockia trinervis* HEER. Based on the occurrence of *Engelhardtia* and *Cunninghamia*, SHIMOKAWARA (1963) and SASA, TANAKA & HATA (1964) once inferred the climate of the Poronai stage to have been as warm as the Ishikari stage, Eocene – Oligocene in age.

Fossil pollen and spores and microplanktons are now richly found throughout the entire formation.* According to the author's result, the pollen assemblage (Fig. 5i–t) is always observed to be largely composed of Taxodiaceae and Pinaceae**. Besides those components above mentioned, *Tsuga, Alnus, Pterocarya,* Betulaceae excepting *Alnus,* and Ulmaceae also nearly always found, though they do not exceed more than several per cent of the total grains. Existence of warm elements such as *Liquidambar* and *Engelhardtia* may be noteworthy, although they are far scarce in total composition. From this pollen assemblage, the climatic condition at that time is not inferred to have been as warm as inferred from the macro-plant fossils.

In summarizing the view on the climatic condition of the Poronai stage, the evidence of mollusca may be formulated as warmer elements <cooler elements

* The localities sampled by the author from this formation will be shown in the Fig. 5i-t. His sampling covered nearly every horizon of this formation from basal part to the top, but the discussion on the result of palynological study of the present paper is chiefly concerned on the samples collected from the upper part of the Poronai formation.

** In the present paper, Pinaceae means bi-saccate grain like *Pinus, Picea* and *Abies.*

as a whole, foraminiferal assemblage is believed to show rather colder environment on the continental shelf or slope, while the information on macro-plant fossils suggests us as warmer elements> cooler elements. According to the author's result, however, dominant forms of pollen and spores of this formation are Taxodiaceae and Pinaceae, with definitely less amount (several per cent) of other temperate forms including warmer elements of less than 2 or 3 per cent. The climate of those days may be accordingly concluded to be temperate as a whole, although it might be a little warmer than the sea of present day. Compared to the flora and fauna of the Ishakari series chiefly consisting in macro plants, molluscs and foraminiferas, and pollen assemblage of the Poronai formation, the Poronai age may be eventually concluded to have been cooler than the Ishikari time, and also cooler than the Takinoue-Haboro stage (Middle Miocene) as will be later stated in detail. It has been generally believed that the climatic condition of the Ishakari stage was warmer or subtropical and that of the Takinoue-Haboro stage was warm to temperate.

As mentioned above, the evidences on the molluscan and foraminiferal fossils of the Poranai formation are not inconsistent with that on the pollen assemblage of the formation in respect to the thermal condition of the Poronai age. The evidence on the macro-plant fossils and the author's pollen assemblage seems not to be consistent with each other in climatic condition. We should, however, take the following fact into consideration to presume the paleo-climate in this case: that major plants under the warmer climate have thick leaves which might be probably more adequate to have been remained as drift fossils in clastic sediments, than those plants under the cooler temperate climate which commonly have thin leaves. Consequently the more numerous warm elements of plants might be brought forth as fossil remains than the cooler forms in such sediments as the Poronai formation. Eventually the pollen assemblage shows that the climatic condition at that time was not very warm, and this is rather well consistent with the general view on the paleoclimate based on macro-plant fossils (Huzioka & Tanai, 1966) distributed in various regions of Japan. According to Huzioka and Tanai (1966), it became cooler from the dawn of the Oligocene towards the end of this stage, in comparison with the Eocene in Japan.

Momijiyama formation

The formation is composed of greenish tuffaceous, arenaceous rocks intercalated with several seams of volcanic rocks and siltstone in the lower part and dark gray hard siltstone in the upper part at its type locality*. About 400

* Except for the type locality of this formation, very diverse view has been held among our geological circle in Hokkaido, how to settle the stratigraphical horizon of the formation having been assigned into the Momijiyama formation. Namely, there is a few localities, where the so-called Momijiyama formation has been regarded as to be belonging to the Takinoue formation.

m in total thickness. The formation is also fairly rich in marine molluscan fossils called the Momijiyama fauna.

Molluscan fossils: Although many paleontologists and geologists have studied the molluscan fossils of this formation, they paid unfortunately little attention to the ecological condition that the fossils indicate. Discussion has been made by them chiefly on the problem of the stratigraphical correlation on this formation. Whether this formation may be correlatable to the lowest Miocene or late Paleogene, is not settled yet. In respect to this fauna, KANNO & OGAWA (1964) were in opinion that "the Momijiyama fauna is characterized by having some species of the Poronai fauna and its own characteristics, though a few lower Miocene species are included". Prior to this, HAYASAKA & UOZUMI (1954) held a same view. Meanwhile, OHARA (1966) stated that the Momijiyama fauna is indistinguishable from the Poronai fauna in composition of species, although it may be possibly distinct from the Takinoue fauna to be later stated. Eventually ecological condition of this fauna has been little discussed in the former studies. The species from this formation may be listed up in Table 5.

Foraminifera fossils: They are very rare: only *Plectofrondicularia packardi* were reported by ASANO (1952) and existence of *Haplophragmoides* (?) spp., *Cyclammina* sp. and *Plectofrondicularia dicularia* aff. *gracilis* were recorded by UCHIO (1962). Ecological condition of them has been however unknown, although ASANO (1954) was of opinion, existence of *Plectofrondicuralia* to be an evident proof, that it was rather deep but more southern sea water, probably a little warmer in condition than it has been currently held a view by most other paleontologists for both the Poronai and Momijiyama sea.

No macroplant fossil is reported.

Abundant fossil pollen, spores and microplanktons are found in argillaceous sediments of this formation. The sampling localities and horizons for the present note may be shown on the figs, 4, 4–d, 4–e, 5–q, 5–r, 5–t. The pollen assemblage is almost as similar as that of the Poronai formation in composition; viz. it is mainly composed of Taxodiaceae and Pinaceae. However, the former is definitely distinguishable from the latter by the complete absence of warm elements such as *Liquidambar, Engelhardtia, Rhus,* etc. and by the more numerous occurrence of *Tsuga* in the Momijiyama formation. From this composition of the pollen assemblage, the climate at that time is presumed by the present author to have become cooler than that of the Poronai age. Another characteristic feature of the assemblage lies in the extremely abundant occurrence of *Micrhystridium,* a geuns of microplankton, although similar rich occurrence of the same form is also found in the uppermost part of the Poronai formation, immediately below the Momijiyama formation.

Table 5 Molluscan fossils of the Momijiyama formation
(After S. KANNO et H. OGAWA, 1964)

Acila elongata NAGAO et HUZIOKA
A. brevis NAGAO et HUZIOKA
A. pictulata (YOKOYAMA)
A. sp.
Yoldia laudabillis YOKOYAMA
Y. biremis NAGAO et HUZIOKA
Y. sobrina TAKEDA
Y. sp.
Portlandia ovata (TAKEDA)
P. watasei (KANEHARA)
Conchocele disjuncta GABB
Venericardia hobetsuensis HAYASAKA et UOZUMI
V. harukii OYAMA et MIZUNO
Macoma cf. *sejugata* (YOKOYAMA)
Periploma besshoense (YOKOYAMA)
P. iesakai OYAMA et MIZUNO
Dentalium sp.
Turritella poronaiensis TAKEDA
Orectospira wadana (YOKOYAMA)
Ampullina cf. *asagaiensis* MAKIYAMA
Neptunea hobetsuensis MATSUI
Trominina onnaica (YOKOYAMA)
T. hokkaidoensis (HAYASAKA et UOZUMI)
T. umbelliformis (HAYASAKA et UOZUMI)

Now, the stratigraphical correlation of the Momijiyama formation will be discussed below. According to the result of the pollen analysis, the similarity between the Oligocene Poronai formation and this formation is evident. Especially, *Micrhystridium* is very abundantly found only in the upper part of the Poronai formation and the Momijiyama formation as above stated, but never found out in the Miocene deposits of Hokkaido so far as the writer is concerned. The author is accordingly now inclining to accept the Oligocene age of the Momijiyama formation, as most of Paleontologists lately held a same view, based on either molluscs or foraminifera.

Magaribuchi formation

The formation is composed of tuffaceous sandstone and mudstone sometimes intercalated by conglomerate and tuff, 60 – 15 m in total thickness. Fossils are rather poorly known. Only the following foraminifera fossils are reported by TSUCHIDA (1957–'58): *Haplophragmoides* sp., *Cyclammina incisa* and *Cyclammina japonica;* on molluscan fossils we have only two published reports, in which the following species are listed: *Acila (A.)* sp., *Acila (A.)*

vigilia var. *brevis, Acila (T.)* sp., *Yoldia* sp., *Clamys* sp., *Clinocardium californiense, Venericardia (Cyclocardia) abeshinaiensis, V. (Megacardita) ferruginosa, Lucinoma* sp., *Macoma* (s.s.) *optiva, M.* (s.s.) *tokyoensis, M.* (s.s.) n. sp., *Periploma besshoensis, Ancistrolepis* sp., *Turritella* sp., *Trochocerithium wadanum, Dentalium* sp. from the Sôya area (OSANAI et al, 1959), and *Portlandia* sp., *Venericardia* sp., *Orectospira wadana, Dentalium* sp., *Macoma* sp., *Yoldia* sp., *Periploma* sp. from the type locality of this formation (NEMOTO & YAMAYA, 1966). No comment of the ecological condition inferred from the fauna is however given. The formation has been long considered to be Neogene (Early Miocene) in age. Recently the fossils indicating Paleogene (late Oligocene) were however disclosed from this formation (unpublished data of Japan Petroleum Development Corporation). Also, Hokkaido Mining Advancement Committee (1968) published the correlation chart of the Tertiary in Hokkaido in which this formation was correlated to the Momijiyama formation (late Oligocene).

The pollen assemblage of the Magaribuchi formation (Fig. 5–a,b,c) is very similar to that of the Momijiyama formation either in the general composition of forms or rich occurrence of *Micrhystridium.* It must be however mentioned that *Micrhystridium* is decidedly fewer in the formation developed at the type locality than in the other (Sôya) area. It may be an open question whether such difference is due to the different stratigraphic horizon or different depositional environment at that time.

Since there is no available data on ecological condition of the fauna and flora of this formation, paleoecological condition inferred by the pollen assemblage can not be checked by other paleontological data.

Haboro and Sôya coal-bearing formation

It has already reported in detail by the author (1963) that the macro-plant fossil floras of these formations are well consistent with the pollen flora in general composition: the Haboro formation is represented by the Daijima-type flora indicating warm temperate climate and the latter the Aniai-type flora indicating cool temperate climate.

The pollen assemblage of the Haboro coal-bearing formation, which will be called the Haboro pollen assemblage, is composed of *Picea, Pinus, Abies, Keteleeria?* , *Podocarpus, Tsuga, Metasequoia, Glyprostrobus, Taxodium,* other Taxodiaceae, *Salix, Juglans, Pterocarya, Carya, Engelhardtia, Alnus, Betula, Carpinus, Corylus, Fagus, Quercus, Castanea, Ulmus, Zelkova, Morus, Myrica,* Nymphaeaceae, Magnoliaceae, *Cinnamomum?* , *Alangium,* Ericaceae, Sapotaceae, *Lonicera, Typha,* Oleaceae, Violaceae, *Symplocos?* and other several indeterminable pollen and many sort of spores. As is generally the case of the Daijima-type pollen flora the main components of the assemblage of this formation are Taxodiaceae and *Quercus,* but the Haboro pollen flora is definitely distinct from other assemblages of the Miocene sediments in Hokkaido by the following two characteristic features: (1) the richness of kinds of pollen and spores and (2) the existence of the warm elements such as *Liquidambar, Nyssa,* Sapotaceae, *Symplocos?* , *Engelhardtia,* etc. On the other hand, the pollen assemblage of the Sôya coal-bearing formation is characterized by the lesser forms in composition: the main components are Taxodiaceae and Betulaceae (especially, *Alnus*). The assemblage is very similar in composition to those of the Onishibetsu and Chikubetsu formations to be later described in this paper.

Sankebetsu formation

The formation is about 800 m in maximum thickness and is composed of sandstone in the lower part and of the alternation of sandstone and mudstone in the upper part. Molluscan fossils are richly found in the sandstone member of the lower part.

Molluscan fossils: UOZUMI (1961) and KANNO & MATSUNO (1960) published on the molluscan fauna of this formation, the list of the fossils may be shown in Table 6. According to UOZUMI, molluscs of this formation were considered to have been inhabitants of the cold water in general, although the fauna was more or less different in specific composition between the lower and upper part of this formation. He concluded the difference in specific composition observed between the lower and upper part to have been probably resulted from the difference of depth of water, where the molluscs inhabited. Thus, UOZUMI grouped all the molluscan fossils of both lower and upper part of the Sankebetsu formation into as a single fauna. Further, he grouped the fauna of the Sankebetsu formation and that of the Chikubetsu formation altogether into a single fauna called the Sankebetsu–Chikubetsu fauna, the latter of which is however stratigraphically distinct from the former, viz. the Chikubetsu formation definitely lies on the Sankebetsu formation. He stated, however, the Sankebetsu–Chikubetsu fauna indicates a cool water environment. On the other hand, KANNO & MATSUNO (1960) held a view that the Sankebetsu fauna may have lived under rather warm to temperate thermal condition and that the fauna should be distinguished from the Chikubetsu fauna, representative of the temperate to subboreal thermal condition. They further placed a stress especially on an occurrence of *Lithophaga* and *Dosinia* in the Sankebetsu formation which are rather characteristic elements in the subtropical to temperate zone.

Foraminifera fossils: Foraminifera fossils of this formation are not known in detail; only two papers may be referable: TSUCHIDA (1957–'58) and MATSUNO & KINO (1960). TSUCHIDA reported that the foraminiferas occur

Table 6 Molluscan fossils from the Sankebetsu and the Chikubetsu formation
(After S. KANNO and K. MATSUNO, 1960)

Formation	Sankebetsu		Chikubetsu	
Species	S 1	S 2	C 1	C 2
Ennucula haboroensi KANNO et MATSUNO n. sp.	R			
Acila (s.s.) *Vigilia elongata* N. & H.	F			
*A.*cia sp.	R			
Yoldia (s.s.) *biremis* UOZUMI	A			
Y. (s.s.) cf. akanensis UOZUMI	F			
Y. (Cnesterium) notabilis YOKOYAMA	R		F	
Portlandia (*Portlandella*) *tokunagai* var. *hayasakai* UOZUMI		R		
P. (P.) tokunagai (YOKOYAMA)		F		
P. (P.) cf. watasei (KANEHARA)		F		
P. sp.		R		
Nuculana sp.		F		
Malletia cf. *poronaica* (YOKOYAMA)		F		
Anadara sp.			F	
Mytilus sp.	R			
Lithophaga chikubetsuensis KANNO et MATSUNO, n. sp.	C			
L. Nomura NOMURA et HATAI	F			
Fortipecten ? sp.			F	
Venericardia cf. *abeshinaiensis* OTUKA	R			
V. sp. 1	F			
V. sp. 2	R			
Lucinoma aff. *hannibali* (CLARK)			R	
Conchocele disjuncta GABB	A			
Nemocardium yokoyamai TAKEDA	A		R	
Papyridea harrimanni (DALI)	A			
Serripes groenlandica (BRUGUIERE)			A	
S. fujinensis (YOKOYAMA)			R	
Dosinia yamaguchie KNNO et MATSUNO, n. sp.	A			
Mercenaria chitaniana (YOKOYAMA)			A	
M. y-iizukai (KANAEHARA)			C	
Spisula onnechiuria (OTUKA)	R?		A	
S. ? sp.	R			
Platyodon nipponica UOZUMI			A	
Peronidia t-matumotoi OTUKA	R		F	
Macoma optiva (YOKOYAMA)	F			
M. cf. *tokyoensis* MAKIYAMAM. aoma	F			
M.			F	
M. calcarea (Gmelin)			R	
M. sp.	R		R	
Periploma besshoensis (YOKOYAMA)	A			
Mya cuneiformis (BOHM)	C		A	

Species \ Formation	Sankebetsu		Chikubetsu	
	S 1	S 2	C 1	C 2
M. cuneiformis (BOHM) var.			R	
M. truncata LINNE			R	
Panomya ? sp.			R	
Pholadidea kotakae KANNO et MATSUNO, n. sp.	R			
Crepidula sp.	R			
Polinices didymoides MANNO et MATSUNO, n. sp.	R			
Natica (Tectonatica) severa (GOULD)	C			
N. (T.) ezoana KANNO et MATSUNO, n. sp.	F		A	
Trophonopsis felix (YOKOYAMA)	R		R	
Ancistrolepis sp.	R		F	
Melongena ? sp.	R		R	
Buccinum cf. *chishimanum* PLISBRY			R	
B. sp.	F			
Neptunea oomurai OTSUKA	C		R	
N. ? sp.	R			
Beringius sp.			R	
Fulgoraria sp.	R		R	

only in the upper member of the Sankebetsu formation* and not in the lower sandstone member in the Chikubetsu area, the type locality of the formation (Table 7). The fossils indicate deep and cold water. Further, he also stated on the foraminiferal fossils from deposits developed in the Kyowa area, about 40 km north of the Chikubetsu area, which may be correlatable to the Sankebetsu-Chikubetsu formation in the type locality (Table 8). The basal part of the deposits is called the Kyowa sandstone member and may be probably correlatable to the lower member of the Sankebetsu formation in the Chikubetsu area. The foraminiferas found in this member are remarkably different from those in other members of this deposit. According to TSUCHIDA, the Kyowa sandstone member is characterized by shallow water species, while the high horizon by rather deep water forms.

From the type locality for the Sankebetsu formation, MATSUNO & KINO (1960) listed up certain foraminiferal remains (Table 9).

The sharp boundary in foraminiferal composition recognized by TSUCHIDA in the deposits developed in the Kyowa area being correlatable to the Sankebetsu formation, may be of importance in stratigraphy, because similar distinct difference in the composition of pollen assemblage is now newly

* Instead of the upper member of the Sankebetsu formation of the present author, TUCHIDA applied the term, the middle alternation member of the Chikubetsu formation in those days, because the Sankebetsu formation was not yet stratigraphically separated from the Chikubetsu formation.

Table 7 Foraminifera fossils from the Chikubetsu and Sankebetsu formations cropped out at the Chikubetsu river

	1	2
Ammodiscus incertus d'ORB.	1	R
Bathysiphon arenacea CUSHMAN		R
Cyclammina pusilla BRADY		R
C. pusilla BRADY?	R	
C. orbicularis BRADY		R
Goesella schencki ASANO(?)		C
Haplophragmoides cf. *emaciatum* (BRADY)	R	C
H. adovenum CUSHMAN?		R
Martinottiella communis (d'ORB.)	R	R

1: Upper member of the Chikubetsu formation
2: Upper member of the Sankebetsu formation
(After S. TSUCHIDA, 1957)

Table 8 Foraminiferas from the Chikubetsu formation* of the Hannoki stream and the Wakkawenbetsu river (both in the Kyowa area). After S. Tsuchida (1957)

	1	2	3	4	5
Cyclammina japonica ASANO	R				
Uvigerina sp.	F				
Ammodiscus incertus d'ORBIGNY	F	R			
Bulimina marginata d'ORBIGNY		F			
Rotalia japonica ASANO		R			
Cyclammina orbicularis BRADY	F	R	C		
Haplophragmoides subglobosum (SARS)	R	F	R		
H. cf. *evoluta* NATLAND	R		F		
Martinottiella communis d'ORBIGNY	R		C		
Cyclammina sp.			R		
Hormosina globulifera BRADY			R		
Sigmoilina schlumbergeri SILVERSTRI			R		
Elphidium fax barbarense NICOL				F	
Sigmoilina sp. (cf. *sigmoidea* BR.)			R		C
Gyroidina soldani d'ORBIGNY					E
Dentalina subsoluta (CUSHMAN)					R
Nodosalia obliqua (L.)					C
Quinqueloculina seminula (L.)					R
Reussella sp.					R
Robulus lucidus (CUSHMAN)					R
Uvigerina yabei ASANO					R

1: Black mudstone correlated to the upper member of the Chikubetsu formation.

2: Sandstone & conglomerate correlated to the lower member of the Chikubetsu f.
3: Black mudstone correlated to the Upper member of the Sankebetsu f.
4: Sandstone correlated to the lower member of the Sankebetsu f.
5: Kyowa sandstone correlated to the lower member of the Sankebetsu f.
*Chikubetsu formation he used is old one, which includes the Sankebetsu formation.

Table 9 Foraminifera fossils from the Sankebetsu and Chikubetsu formation (After K. MATSUNO & Y. KINO, 1960)

Species / Occurrence	Sb 1	Sb 2	Sb ?	Ch
Bathysiphon sp.				F
Haplophragmoides sp.	F			F
H. (?) sp.	R			
Cyclammina sp.				R
C. (?) sp.		R		
Quinqueloculina sp.	R			
Sigmoilina sp.	R			
Nonion pompilioides (FICHITEL et MOLL)			A	
N. sp.	R			
N. (?) sp.	R			
Elphidium takinouense ASANO	F			

Sb: Sankebetsu formation Ch: Chikubetsu formation
1: lower sandstone member 2: upper alternation member
?: detailed horizon uncertain

confirmed by the present author between the lower sandstone member being correlatable to the Kyowa sandstone and the overlying members.

Namely, the pollen assemblage of the Sankebetsu formation is divisible into two groups at its type locality: the lower part indicates warm-temperate climate and the upper indicates cool-temperate climate. The lower part of this formation is very similar in pollen composition to that of Haboro coal-bearing formation, underlying the Sankebetsu formation. The upper part of the Sankebetsu formation is very similar to the Chikubetsu formation overlying the Sankebetsu formation. The lithologic boundary between two members is well coincided with the sharp boundary observed in the pollen assemblage as is definitely shown in Fig. 5e–g. This is one of the interesting fact found in the present study. Although KANNO, MATSUNO, UOZUMI and TSUCHIDA concluded the change in molluscan and foraminiferal assemblages between the lower and the upper member of the Sankebetsu formation to have been brought forth by the change in depth of sea water, the difference might be unable to be interpretated by the change in depth of sea water since a difference is found also in the pollen assemblage between the two members. It would be more reasonable, the author convinces, to conclude as follows: the thermal condition of the water was different within the Sankebetsu stage: the lower member was deposited under warm water and the upper was under cold water; so, the fauna must have been also different with each member. In spite of the presence of two different faunas in the single formation, many paleontologists unfortunately overlooked it up to date. Some one held a view, the Sankebetsu fauna to have been under cold water and others, under warm water. But it was actually different between the earlier and later stage of the formation in ecological condition. In this regard, it will be further stated in detail in the present paper.

Chikubetsu formation

The formation is about 300m in whole thickness, and is divisible into two members: the upper shale member and the lower sandstone member. The marine molluscan fossils are abundant in the lower member.

Molluscan fossils: The Chikubetsu fauna is composed of species shown in Table 6. According to KANNO & MATSUNO (1960), the following species are especially dominant: *Yoldia (Cnesterium) notabilis, Anadara* sp., *Serripes groenlandica, Mercenaria chitaniana, M. y–iizukai, Spisula onnechiuria, Platydon nipponica, Peronidia t–matsumotoi, Macoma optiva, Mya cuneiformis, Pholadidea kotakae* and *Natica ezoana.* Of them, KANNO & MATSUNO listed up the followings as cold water element: *Yoldia (Cnesterium) notabilis, Serripes groenlandica, Platydon, Peronidea* and *Mya* and they concluded the fauna lived under temperate to sub-boreal thermal conditions. UOZUMI * (1962) held a same view as the preceding paleontologists. He counted such species as cold water element from the Chikubetsu formation: *Acila, Conchocele, Mactra, Spisula, Mya, Papyridea, Clinocardium, Serripes, Buccinum, Neptunea* and *Flugoralia.*

Foraminifera fossils: There are only three published reports on the foraminiferal fossil of the present formation: TSUCHIDA (1957–'58), MATSUNO & KINO (1960) and HATA & TSUSHIMA (1960)(Table 10). TSUCHIDA reported that the foraminiferas in the formation shown in Table 7–10 were far colder and deeper water inhabitants than these in the Takinoue formation to be described below.

The pollen assemblage of the present formation is composed of Taxodiaceae, Pinaceae, *Tsuga* and *Alnus*; the composition is not distinguishable

* As was already stated, UOZUMI dealt the fossils from both the Sankebetsu and Chikubetsu formation as a single fauna, Sankebetsu-Chikubetsu fauna.

Table 10 Forminifera fossils from the Chikubetsu formation
(locality: upper stream of Rubeshube River, about 15 km north
of the Chikubetsu coal mine)
(After M. HATA & K. TUSHIMA, 1969)

Cyclammina cancellata BRADY	C
C. japonica ASANO	C
Eggerella matsunoi n. sp.	A
Haplophragmoides nishikizawaensis n. sp.	A
H. hatae n. sp.	C
Martinottiella communis (d' ORBIGNY)	VA
Nodosaria sp.	R
Nonion pompilioides (FICHTEL et MOLL)	R
Rotalia cf. *yubariensis* SSANO	C
Spirosigmoilinella compressa MATSUNAGA	A

from that of the upper member of the Sankebetsu formation. The climatic condition of the Chikubetsu stage was cool temperate like the late Sankebetsu stage. Sometimes coal-bearing sediments develop in the basal part of the present formation; they are called under the name of Tomamae coal-bearing formation (Haboro area) or Shumarinai coal-bearing measure (Shumarinai area). The pollen assemblages* of these carbonaceous matter are mainly composed of Taxodiaceae, Alnus, Polypodiaceae, Pinaceae, Betulaceae, *Tsuga*; the composition is similar to that of the Sôya coal-bearing formation (SATO, 1963).

Of the present formation, there is no incosistency between the molluscan and foraminiferal fossils and pollen fossils concerning thermal condition deduced from these fossils.

Onishibetsu formation

The formation is about 150 m in maximum thickness and is very similar in fossil content (mollusca, foraminifera and pollen and spores) with the Chikubetsu formation.

Horomui formation

This name was given by OHARA (1966) to the deposits in the Asahi area which cover the Poronai formation with unconformity and contain a characteristic molluscan fossils. It is composed of arenaceous rocks intercalated by thick tuff in the lower part and argillaceous rocks in the upper part. The maximum thickness of the formation is about 190 m.

* As the assemblage is of the non-marine sediments, it is not just the same in composition with those of the other parts (marine) of the Chikubetsu formation.

Molluscan fossils: Prior to OHARA, FUJIE & UOZUMI (1957) first noted the existence of important molluscan fossils characterized by *Mytilus tichanovitchi* etc. in this area and designated it as the Asahi fauna. Later on, OHARA (1966) clerified that the fauna contains the Takinoue fauna in the upper part of the deposits and the Asahi fauna should be revised in this concern. Namely, the Takinoue elements must be excluded from it. From the revised Asahi fauna, the following molluscan fossils were reported by OHARA: *Mytilus tichanovitchi, Yoldia biremis, Adula asahiensis, Felaniella usta, Spisula onnechiuria, Peronidia t–matsumotoi, Thracia asahiensis, Pholadidea kotakae, Tectonatica ezoana* (above mentioned species are predominant in individuals), *Lucinoma akibai, Peronidia elongata, Siliqua elliptica, Cnestrium notabilis, Clinocardium* sp., *Macoma* cf. *tokyoensis, Mya (Arenomya)* aff. *grewingke* etc.; above all, *Mytilus tichanovitchi* is characteristic of the present fauna (KANNO OHARA & KAITEYA, 1968). The fauna was inferred to be inhabitants in cold water and to indicate the early Miocene in age (UOZUMI, , 1962; OHARA, 1966; KANNO, OHARA & KAITEYA, 1968). On the other hand, ASANO & IWAMOTO (1957), MATSUNO, TANAKA & MIZUNO (1964), SASA, TANAKA & HATA (1964), HOKKAIDO MINING ADVANCEMENT COMMITTEE (1968) and others did not accept the stratigraphical independence of the Asahi fauna from the Takinoue fauna, although the Takinoue fauna is evidently indicating warm water condition.

Nothing on the foraminiferal fossils of the present formation has been published yet.

The pollen assemblage of the present formation (Horomui formation with the Asahi molluscan fauna) can not be distinguished from that of the Takinoue formation in general composition as shown in Fig. 5j–m. Accordingly, the author is now inclining to accept the Horomui formation to be included into the Takinoue formation, although it may form a basal part of the latter.

According to the author's view pollen assemblage of the so-called Horomui formation show to be rather warmer condition as is indicated by the molluscan fauna of the Takinoue formation. In this regard, thermal condition of the horomui formation inferred from the pollen assemblage is not consistent with the conclusion based on the molluscan fossils given by the above-mentioned authors.

Takinoue formation (s. str.)

The present formation is composed of arenaceous rocks in its lower part and of black shale in its upper part in the type locality of the formation. The maximum thickness of the formation is about 450 m. The formation contains rich marine fossils. The formation sometimes contains carbonaceous matter which occasionally develops as well as the Asahi coal-bearing formation containing several workable coal seams.

Molluscan and foraminiferal fossils: The molluscan fossils, called the Takinoue fauna, are composed of species as shown in Table 11 and 12. All the authors agree that this fauna indicates warm sea water environment. From foraminiferal fossils, listed in Table 13 and 14, sea water of that age is also inferred to have been warm.

The pollen assemblage in the present formation is very similar to those in the Haboro and the lower Sankebetsu formation indicating a warm temperate climate (cf. Fig. 5j–t). Taxodiaceae is predominant in individual; *Quercus* and *Alnus* are rather commonly found. The characteristic features of the assemblage are: (1) rich kind of pollen and spores and (2) existence of elements of warm climate such as *Liquidambar, Engelhardtia, Nyssa,* etc., though they are not numerous in individual. The pollen assemblage in the carbonaceous matter is very similar in composition to that of the Haboro coal-bearing formation (SATO, 1963), besides in marine facies.

To the thermal condition of the Takinoue stage, the mollusca, foraminifera and pollen assemblage consequently reached the same conclusion.

Kotanbetsu and Masuporo formations

The formations consist of alternation of mudstone, sandstone and conglomerate containing huge boulders; black mudstone facies is prevalent in some areas. The formations are changeable in lithologic facies, and various abnormal sedimentary features such as either slumping, intraformational folding, Nagelflush type of block or poor sorted conglomerate with muddy matrix are found in the formations. Molluscs are rare, but foraminifera are rather common in the formations. The Kotanbetsu formation is over 3000m and the Masuporo formation is 2000m in maximum thickness.

Molluscan fossils: UOZUMI (1962) reported the molluscan species shown in Table 15 from the formations. He proposed the Kawabata fauna to the molluscan fossils of this stage; the fauna includes the species shown in Table 15 and those of the Kawabata formation which is distributed in central southern part of Hokkaido and is correlated to the Masuporo and Kotanbetsu formations. He stated that the fauna is distinguishable from those of the preceding stage, the Takinoue and Chikubetsu faunas, although he did not state in details on the paleoecological condition of the fauna.

Foraminifera fossils: Except for a summary note by TSUCHIDA (1957–'58) no information is available at present on foraminifera. He reported, however, many species from the present formations as is shown in Table 16, among which *Cyclammina, Martinottiella* and *Haplophragmoides* are especially richly found. He inferred the fauna to indicate deep and cold water condition.

The pollen assemblages of the present formations are very similar in

Table 11 Molluscan fossils from the Takinoue formation
(Momijuyama – Takinoue area)
(After S. KANNO & H.OGAWA, 1964)

	1	2
Acila sp.		X
Portlandia of. *tokunagai* (YOKOYAMA)		*
Malletia inermis (YOKOYAMA)		X
Sarepta shimokawarae KANNO et OGAWA		X
Mytilus sp.	X	
Swiftopecten swiftii (BERNADI)	X	
Patinopecten kobiyamai KAMADA	X	
Ostrea gravitesta YOKOYAMA	*	
Venericardia sp. 1		X
V. sp. 2		X
Akebiconcha chitanii (KNEHARA)		*
Felaniella usta (GOULD)	X	
Clinocardium mutuense (NOMURA et HATAI)	*	
Laevicardium decoratum (GREWINGK)	X	
Siratoria siratoriensis (OTUKA)	*	
Dosinia chikuzenensis NAGAO	X	
Cyclina japonica KAMADA	*	
Clementia sp.	X	
Spisula aff. *sachalinensis* (SCHRENCK)	X	
S. cf. *undilifera* (WEAVER)	*	
Macoma incongrua (v. MARTENS)	*	
M. cf. *asagaiensis* MAKIYAMA	X	
M. *calcarea* (GMELIN)		*
M. *izurensis* (YOKOYAMA)		X
M. cf. *praetexta* (v. MARTENS)		X
Solen sp.	X	X
Mya cuneiformis (BOHM)	*	
M. grewingki kushiroensis NAGAO et INOUE	X	
small pelecypods		X
Dentalium sp	*	X
Turbo ? sp	X	
Turritella s-hataii NOMURA	X	X
T. sp.	X	
Batillaria yamanarii MAKIYAMA	X	
Vicaryella teshimae KANNO et OGAWA	*	
V. sp.	X	
Calyptraea sp.	X	
Crepidula cf. *jimboana* YOKOYAMA	*	
Natica sp.		X
Tectonatica meisensis (MAKIYAMA)	X	X

Polinices coticazae MAKIYAMA	X	X
Coralliophila cf. *costularia* (LAMARCK)	X	
Ancistrolepis cf. *peulepis* (KANEHARA)		X
A. sp.		X
Fulgoraria striata (YOKOYAMA)		X
"Callianassa" sp.		X

1: lower part of the formation (sandy facies)
2: upper part of the formation (muddy facies)
*: showing the abundant occurrence compared with the other molluscs

Table 12 Molluscan fossils from the Takinoue formation (After S. UOZUMI, 1962)

Species	Occurrence 1	2
Acila gottschei (BOHM)	X	X
A. divaricata (HIND)	X	
Nuculana kongiensis KAN. et MAT	X	
Yoldia notabilis YOK	X	
Y. uranoi UOZ.	X	
Portlandia hayasakai UOZ	X	X
P. thraciaeformis (ST.)	X	
P. watasei (KAN.)	X	
Anadara abdita MAK.)	X	
A. ogawai (MAK.)	X	
A. ninohensis OT.)	X	
Glycimeris derelicata (YOK.)	X	
G. vestioides NOM.	X	X
Propeamussium tateiwai MAK.	X	
Patinopecten kimurai (YOK.)	X	
P. kobiyamai (KAN.)	X	
Lima cf. *smithi* DALL	X	
Ostrea gravitesta (YOK.)	X	X
Venericardia akagii KAN	X	
V. niniuensis UOZ	X	
Felaniella usta (GOULD)	X	
Nemocardium yokoyamai Tak.		X
Trachycardium siobarense (YOK.)	X	X
Clinocardium shinjiense (YOK.)	X	
Pitar okadana (YOK.)	X	X
Callista chinensis takagii MAS.	X	
Meretrix arugai OT	X	
M matsuii UOZ.		X
Dosinia nomurai OT	X	X

D nagaiii OT	X	X
Cyclina japonica KAN	X	
Mercenaria chitanii (YOK.)	X	
M. y-iizukai (KAN.)	X	
Paphia siratorensis (OT.)	X	
Spisula onnechiuria OT.)	X	X
S. ezodensata (KUB.)	X	X
Macoma asagaiensis MAK	X	
M. optiva (YOK.)	X	
M. tokyoensis (MAK.)	X	
Soletellina minoensis YOK	X	
Siliqua alta (BROD. et SOW.)	X	
Phaxus izumoensis (YOK.)	X	
Panomya simotomiensis OT.	X	
Panope japonica AD	X	
Mya cuneiformis BOHM	X	
Calliostoma hidakana UOZ.	X	
Turritella fortilirata chikubetsuensis KOT	X	
Orectospira wadana (YOKI.)	X	
Battilaria yamanarii MAK.		X
B. tateiwai MAK.		X
Proclava otukai NOM	X	X
Cerithium sirakii MAK.	X	
Calyptraea shibatai UOZ	X	
Crepidula jimboana YOK.	X	
Polinices meisensis MAK.	X	
P. diymides KAN. et MAT	X	
Ancistrolepis yudaensis OT.	X	X
Neptunea modestus (YOK.)	X	
Nassarius simizui OT.	X	X
Psephea magna TAK.	X	
Conus tokunagai OT.	X	

1: Hidaka district (south of the Momijiyama area)
2: Yûbari – Momijiyama area

Table 13 Foraminifera fossils from the Takinoue formation
(After Y. SASA, K. TANAKA & M. HATA, 1964)

Rhabdammina sp.
Bathysiphon sp.
Involuta sp.
Haplophragmoides cf. *emaciatum* (Brady)

Table 13 Foraminifera fossils from the Takinoue formation
(After Y. SASA, K. TANAKA & M. HATA, 1964)

	Rhabdammina	sp.
	Bathysiphon	sp.
	Involuta	sp.
	Haplophragmoides	cf. *emaciatum* (Brady)
	H.	cf. *evoluta* NATLAND
	H.	*hatae* n. sp.
*	*H.aplophragmodes*	*nishikizawaensis* n. sp.
	H.	*renzi* ASANO
	H.	cf. subglobosum (SAR.)
	H.	cf. *trullissatum* (BRADY)
	H.	sp.
	Cyclammina	*cancellata* BRADY
	C.	*japonica* ASANO
	C.	*orbicularis* BRADY
	C.	*pusilla* BRADY
	C.	sp.
	Verneuilina	*robusta* n. sp.
	Eggerlla	*matsunoi* n. sp.
	Dorothia	sp.
*	*Martinottiella*	*communis* (d' ORBIGNY)
*	*Spirosigmoilinella*	*compressa* MATSUNAGA
	Trochammina	sp.
	Lagena	spp.
	Nonion	*pompilioides* (FICHTEL & MOLL)
	Eponides	*frigidus* (CUSHMAN)
	Globigerina	spp.

* rather commonly found

The fossils of this list are found only from a few locality. Accordingly, it may be impossible to conclude that the list shows the general tendincy of the Formation.

Table 14 Foraminifera fossils from the Takinoue formation
(After S. TSUCHIDA, 1957)

Technitella	sp.
Haplophragmoides	*renzi* ASANO
Ammomarginulina	sp.
Dorothia	sp.
Quinqueloculina	sp.
Nonion	sp.
N.	*nicobarense* CUSHMAN
N.	*pupoides* (FICHTEL & MOLL)
N.	*subtugidium* (CUSHMAN) ?
Astrononion	*hamadaense* ASANO
Nonionella	sp.

Elphidium sp.
E. hughesi foraminosum CUSHMAN
Ozawaia sp.
Bulimina sp.
B. elongata d'ORBIGNY
Entosolenia takaoi ASANO
Eponides nipponicus (HUSEZIMA & MARUHASI)
E. procerus (BRADY)
Rotalia beccari (L.)
R. japonica HADA
R. cf. papillosa BRADY
R. yubariensis ASANO
Cassidulina sp.
Cibicides altamiraensis KLEINPELL

Table 15 Molluscan fossils from the Masuporo, Kotanbetsu and Kawabata formations (After S. UOZUMI, 1962)

Species	Masuporo F.	Kotanbetsu F.	Kawabata F.
Solemya tokunagai YOK.	X		X
Acila gottschei (BOHM)		X	X
A. divaricata (HIND.)			X
A. hidakensis NAG. et HUX.			X
Yoldia notabilis YOK.		X	X
Y. haboroensis UOZ.		X	
Portlandia hayasakai UOZ.	X	X	X
P. thraciaeformis (ST.)			X
Malletia cf. *poronaica* (YOK.)		X	X
Anadara ogawai (MAK.)			X
Propeamussium takeiwai MAK.			X
Patinopecten kimurai (YOK.)			X
P. kobiyamai (KAN.)			X
Lima cf. *smithi* DALL			X
Periploma besshoensis (YOK.)		X	X
Venericardia hidakensis UOZ.			X
V abeshinaiensis OT.		X	
V.			X
Conchocele bisecta (CON.)	X	X	X
Nemocardium yokoyamai TAK.		X	X
Trachycardium siobarense (YOK.)			X
Clinocardium shinjiense (YOK.)		X	X
Serripes fujiensis (YOK.)	X	X	X
S. groenlandica (BRUG.)	X	X	

Pitar okadana (YOK.)			X
Callista brevisiphonata CARP.		X	
Dosinia nagaii OT.			X
Mercenaria chitanii (YOK.)		X	X
M. y-iizukai (KAN.)		X	X
Paphia siratorensis (OT.)			X
Spisula onnechiuria OT.		X	X
S. ezodensata (KUB.)	X		X
Macoma optiva (YOK.)	X	X	X
M. tokyoensis (MAK.)			X
Peronidia t-matsumotoi OT.	X	X	X
Soletellina minoensis YOK.			X
Siliqua alta (BROD. et SOW.)			X
Phaxus izumoensis (YOK.)			X
Panomya simotomiensis OT.			X
Mya cuneiformis BOHM		X	X
M. truncata LINN.		X	
Platyodon nipponica UOZ. et FUJ.		X	
Pholzdidea kotakae KAN. et MAT.		X	
Turritella s-hataii NOM.		X	
Calyptraea shibatai UOZ.			X
Crepidula ezoana UOZ.		X	
Polinices diymides KAN. et MAT.			X
Natica ezoana KAN. et MAT.		X	
Geleodea onishibetsuensis (OT.)	X	X	
Trophonopsis felix (YOK.)	X	X	
Neptunea modestus (YOK.)			X

Table 16 Foraminifera fossils of the Kawabata stage in the central Hokkaido (After S. TSUCHIDA, 1957-'58)

Species	Masuporo F.	Kotanbetsu F. (Haboro area)	Kawabata F.
Rhabdammina sp.			X
Bathysiphon arenacea CUSHMAN	X	X	X
Hippocrepinella sp.	X		X
Saccammina sphaerica M. MARS			X
Pelosina sp.	X		X
Hormosina globulifera BRADY	X	X	X
Ammodiscus sp.	X		
A. incertus d'ORBIGNY	X	X	X
Ammodiscoides japonicus ASANO et INOMATA			X
Haplophragmoides sp.	X		X

H. compressum LE ROY	X	X	X
H. emaciatum (BRADY)		X	X
H. planissimum CUSHMAN			X
H. cf. *planissimum* CUSHMAN	X		
H. renzi ASANO		X	X
H. subglobosum (SARS)	X	X	X
H. trullissatum (BRADY)			X
Ammomarginulina sp.	X		X
Ammobaculites agglutinans d'ORBIGNY	X	X	X
Cyclammina sp.	X		X
C. cf. *cancellata* BRADY	X		
C. ezoensis ASANO	X	X	X
C. incisa (STACHE)	X	X	X
C. japonica ASANO	X	X	X
C. orbicularis BRADY	X	X	X
C. pusilla BRADY	X	X	X
Textularia sp.	X		
Gaudryina sp.	X		
Clavulinoides sp. ?	X		
Clavulina sp. ?	X		
Dorothia sp.	X		
Goesella schencki ASANO	X	X	X
Martinottiella sp.	X	X	X
M. bradyana tarukiensis ASANO			X
M. communis d'ORBIGNY	X	X	X
M. cf. *nodulosa* (CUSHMAN)	X	X	X
Quinqueloculina seminulum (L.)		X	
Q. vulgaris d'ORBIGNY		X	X
Massilina sp.			X
Sigmoilina celata (COSTA)	X		
S. schlumbergeri SILVESTRI	X		
Pyrgo sp.			X
P. vespertilio (SCHLUMBERGER)			X
Robulus lucidus (CUSHMAN)	X		
Dentalina inflexa (REUSS)	X		X
D. subsoluta (CUSHMAN)	X	X	X
Nodosalia longiscata d'ORBIGNY			X
Frondicularia sp.			X
F. adovena CUSHMAN			X
Lagena sp.			X
Nonion nicobarense CUSHMAN			X
N. pompilioides (FICHTEL et MOLL)	X		X
Elphidium fax barbarense NICOL	X		
E. subgranulosum ASANO			X
Bulimina sp.			X
B. (Desinobulimina) auriculata BAILY			X

B. inflata SEGUENAA			X
B. marginata d'ORBIGNY	X		X
B. ovata d'ORBIGNY	X		
B. pyrula d'ORBIGNY	X	X	
Entosolenia sp.	X		
Uvigerina akitaensis ASANO	X		X
U. bifurcata d'ORBIGNY			X
U. cf. *hootsi* RANKIN		X	X
U. yabei ASANO			X
Hopkinsina sp.	X		
Siphogenerina raphanus (PARKER et JONES)	X		
Angulogerina angulosa WILLIAMSON			X
Gyroidina sp.			X
G. orbicularis d'ORBIGNY			X
Eponides sp.		X	X
E. karsteni (REUSS)	X		X
E. haidingeri (d'ORBIGNY)			X
Rotalia japonica HADA			X
Cassidulina japonica ASANO et NAKAMURA			X
C. kasiwazakiensis HUSEZIMA et MARUHASI		X	X
C. orientale CUSHMAN			X
C. subglobosa BRADY	X		
C. subglobosa parva ASANO et NAKAMURA			X
Pullenia apertula CUSHMAN	X		X
P. sphaeroides (d'ORBIGNY)			X
P. sp.		X	
Globigerina bulloides d'ORBIGNY			X
Orbulina sp.	X		
O. universa d'ORBIGNY	X	X	X
Cibicides kamadai ASANO			X
C. refulgens MONTEORT	X		X
Acervulina sp.	X		

composition with those of the Chikubetsu and Onishibetsu formation as seen in Fig. 5b–h, although the pollen assemblages of these formations may be likely to gradually change from the lower towards the upper part. The gradual changing in composition of pollen and spores between the Kotanbetsu formation and the Wakkanai formation overlying the former formation, is also recognizable in which Pinaceae and *Tsuga* are decreasing while *Alnus, Carpinus, Fagus* and Ulmaceae are increasing upwards; this change may represent the transition between the Mitoku-type flora (TANAI, 1961) of the Wakkanai stage (late Miocene), indicating temperate climatic condition, and the Chikubetsu pollen flora of the present author. The climatic condition during the Kotanbetsu–Masuporo stage is inferred to be cool-temperate throughout the main part of it, like the preceding Chikubetsu–Onishibetsu stage, although it is inferred to have been tending more or less warmer towards the end of the Kotanbetsu–Masuporo stage. This conclusion on paleothermal condition based on the pollen assemblages seems to be coinciding at least with the result of foraminifera fossils. That is, the paleothermal condition of the Kotanbetsu–Masuporo stage was cold or cool from the foraminifera and pollen fossils.

Kawabata formation

The formation is very similar as the Masuporo and Kotanbetsu formations in lithologic facies. It is sometimes over 3,000m in thickness. Fossil evidence is very poor in the formation except for foraminifera.

Molluscan fossils: Very little is known about the fossils. Only, UOZUMI (1962) reported the species shown in Table 15, however, he did not state on details of ecological condition under which the fossil molluscs lived.

Foraminifera fossils: There is single publication regarding to the ecological condition based on foraminifera fossils of the formation: TSUCHIDA (1957–'58). He stated as follows: foraminiferas found in the Kawabata stage are rather poor in species and contain very few calcareous foraminiferas inhabiting in shallow sea water. *Cyclammina, Haplophragmoides* and *Martinottiella* are contained throughout the Sôya-Hidaka basin* from north to south. All these three genera are found in general with the foraminifera fauna supposed to indicate deep sea water . . . . . . In the regions where the Kawabata formation is developed not far from exposure of Cretaceous and Paleogene deposits, the Kawabata formation is apparently showing near shore facies composed of the alternation of conglomerate, sandstone and mudstone. According to TSUCHIDA, the foraminifera assemblage is, however, indicating off shore and probably the Kawabata formation above stated may have been deposited under rather deep sea water in condition . . . . As a whole, benthonic foraminiferas of the Kawabata stage show deep and cold sea water, although certain fluctuation of depth of water may have been occurred during the long time range of the Kawabata stage.

The pollen assemblage of the Kawabata formation is not distinguishable from that of the Takinoue formation: The climatic condition in the Kawabata stage might be therefore as warm–temperate as in the Takinoue stage.

* It is equivalent to the sedimentary basin of the Neogene sediments in Central Hokkaido in the present paper, it is divided into four parts: Tempoku, Haboro, Uryu and Central Hokkaido areas in the present paper.

Discussion

As stated above some in detail, paleothermal condition inferred from fossil pollen in the marine sediments may be fairly well consistent with the results of ecological condition based on either foraminifera or molluscan fossils in the same sediments. There are, however, two exceptions for this statement: the sediments of the lower part of the Takinoue formation (Horomui formation) and the Kawabata formation. Notable difference in these two cases in respect to the thermal condition between marine fossils and pollen assemblage should be a problem to be solved in future. Nevertheless, it has been well established that the pollen assemblages in the recent sediments rather well indicate the climatic condition of the forests existing near by the shores or lands. Likewise, the author's result on Tertiary formations may show the pollen assemblage of the geologic time to well represent the climatic condition in those days in comparison with molluscan and foraminiferal assemblages.

The sequence of pollen assemblages and the climatic conditions on the late Oligocene – Miocene age in Central Hokkaido may be summarized as in the Fig. 6. The Chikubetsu pollen assemblage of them, indicating a cool temperate climatic condition, during the late Sankebetsu – Kotanbetsu stage has not hitherto been known, because of lacking in megascopic plant fossils, but the

	(Tempoku – Haboro region)			(Southern part of Central Hokkaido)		
	Stage	Fossil pollen assemblage	Macro-fossil floras	Stage	Fossil pollen assemblage	Macro-fossil floras
Late Mio.	Wakkanai	Wakkanai-Togeshita pollen assemblage (temperate)	Mitoku-type flora (temperate)	Iwamizawa		
		(gradula change)				
Middle Miocene	Kitanbetsu			Kawabata		Unknown
	Chikubetsu	Chikubetsu pollen assemblage (cool temperate)	Unknown		Takinoue pollen assemblage (warm temperate)	
	Sankebetsu	(sudden change)		Takinoue		
	Haboro	Haboro pollen assemblage (warm temperate)	Daijima-type flora (warm temperate)			Daijima-type flora (warm temperate)
Early Mio.	*		Aniai-type flora (cool temperate)	*		Aniai-type flora (cool temperate)
Oligocene	Magaribuchi	Magaribuchi pollen assemblage (cool temperate)	Unknown	Momijiyama	Momijiyama pollen assemblage (cool temperate)	Unknown
				Poronai	Poronai pollen assemblage (temperate)	Details unknown

* Of the sediments of this stage the writer has a different opinion from that based on the macro-fossil plants. That is, the Sôya coal-bearing formation in the Tempoku region has been considered to be early Miocene in geologic age based on the fossil flora contained in it, which is composed of the elements of the Aniai-type flora indicating cool temperate climate. The writer is of opinion that the flora is to be correlated to that represented by the Chikubetsu pollen assemblage; accordingly, the age of the formation is middle Miocene. He concluded that the sediments of this stage do not exist in these region so far as he examined. This matter is discussed in detail in other papers (SATO, 1963, 1970).

Fig. 6 Sequence of the fossil pollen assemblages and the macro-fossil floras of the Miocene in the Central Hokkaido flora of this stage is suggested to be a transitional phase between the Daijima-type flora indicating a warm–temperate climate of the Haboro stage and the Mitoku-type flora indicating a temperate climate of the Wakkanai stage. On the other hand, the southern part of Central Hokkaido in the same stage is inferred to be represented by the Takinoue pollen assemblage, indicating warm–temperate. These two floras may be accordingly concluded to have been heterotopic during the middle Miocene in Central Hokkaido showing a rather distinct geographical boundary: one represented by the Chikubetsu pollen assemblage which occupied the northern part while the other, represented by the Takinoue pollen assemblage, in the southern part. The author has once held a view the heterotopic distribution of these two floras to have been resulted from the existence of a barrier in between which may have geographically divided the sedimentary basin of the Middle Miocene into two parts: northern and southern ones (SATO, 1970). The author especially stresses on the fact that palynological study enabled to clerify the paleogeographical condition. In the Sankebetsu formation in the present study seems to show especially a close relationship between sea water and climate.

The composition of a pollen assemblage in a marine sediment may be variously controlled by many factors. Of recent marine sediments we can directly observe the control effects of the factors to some extent; for examples, direction and strength of winds and currents, the distance from coast to the sites of the sedimants, plant communities on the lands from which the pollen and spores are supplied, climatic conditions, temperature or depth of the sea water in which pollen and spores are deposited and so on. However, in the older geologic ages, it is very difficult or almost impossible to know completely the effects of these factors. Accordingly, although the author showed in the present paper that pollen assemblages in Tertiary marine sedimantary rocks well represent the thermal conditions in these days based on only the comparison with data of foraminifera and molluscan fossils in the same rocks, it will be possible to analyse the pollen assemblages more in details, if more various data, for examples, distribution of paleocurrents, sources of the sedimentary rocks, etc., are clarified in future.

In addition to this, comparing the compositions of pollen assemblages in the marine sediments with these in the terrestrial sediments in the same age (cf. SATO , 1963), the former is generally more simple in composition than in the latter; for example, conifers are more dominant in individuals in the former than in the latter. This fact shows that sorting rather effectively occurred on the deposition of pollen into marine sediments, like the recent sediments described by TRAVERSE and GINSBURG (1966) and CROSS et al. (1966).

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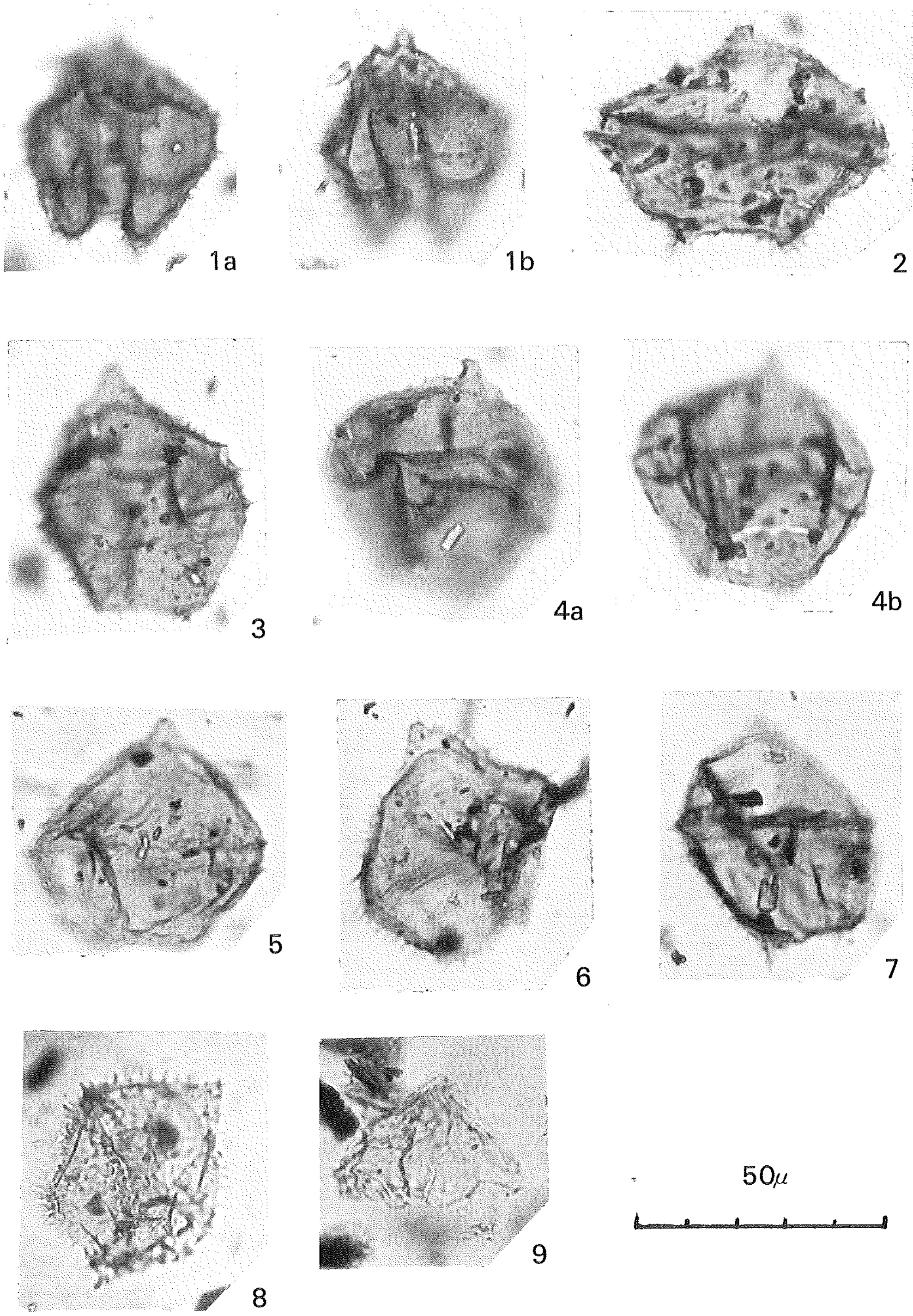
PLATES 1~4 AND EXPLANATION

Explanation of Plate 1

Figs. 1–7 *Gonyaulax* cf. *cladophora* DEFLANDRE
Sankebetsu Formation.
Fig. 8 *Gonyaulax* sp.
Kawabata Formation.
Fig. 9 *Gonyaulax* sp.
Momijiyama Formation.

(Plate 1 – 3: figures of microplanktons)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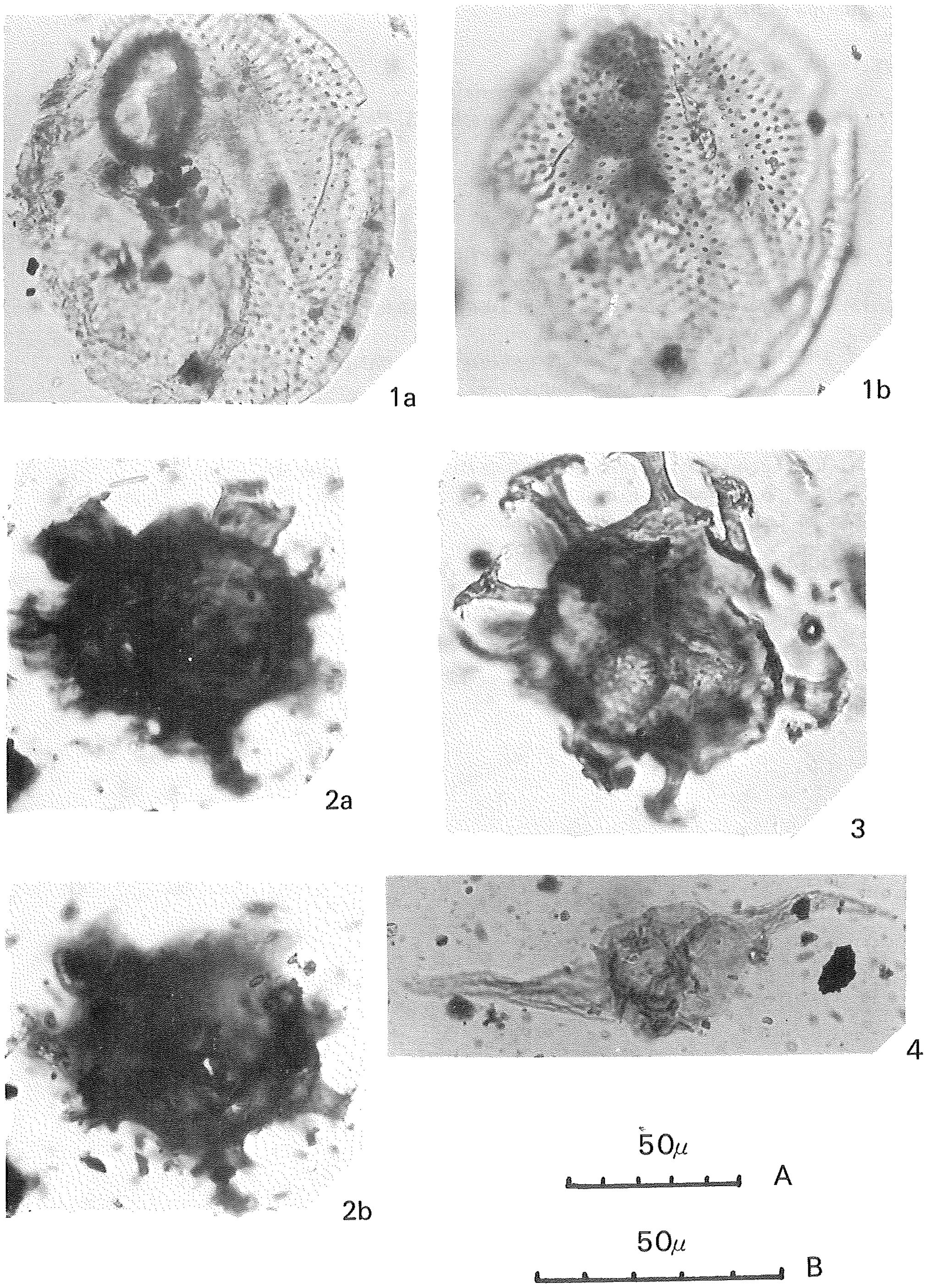
Explanation of Plate 2

Figs. 1a, b *Tasmanites* sp.
Sankebetsu Formation.
Figs. 2a, b Cf. *Cannosphaeropsis urnaformis* COOKSON
Kawabata Formation.
Fig. 3 *Hystrichosphaeridium indes* KLUMPP
Takinoue Formation.
Fig. 4 *Odontochitina* cf. *costata* ALBERTI
Kotanbetsu Formation.

Size of figures 1a, b shown by Scale A; others by Scale B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Explanation of Plate 3

Figs. 1–9 *Micrhystridium* spp.
1, 4–7: Momijiyama Formation.
2, 8, 9: Magaribuchi Formation. 3: Poronai Formation.

Fig. 10 *Hystrichosphaeridium* ? sp.
Takinoue Formation.

Fig. 11 *Cannosphaeropsis* ? sp.
Takinoue Formation.

Fig. 12 Cf. *Hystrichosphaera ramosa* (EHRENBERG)O. WETZEL
Chikubetsu Formation.

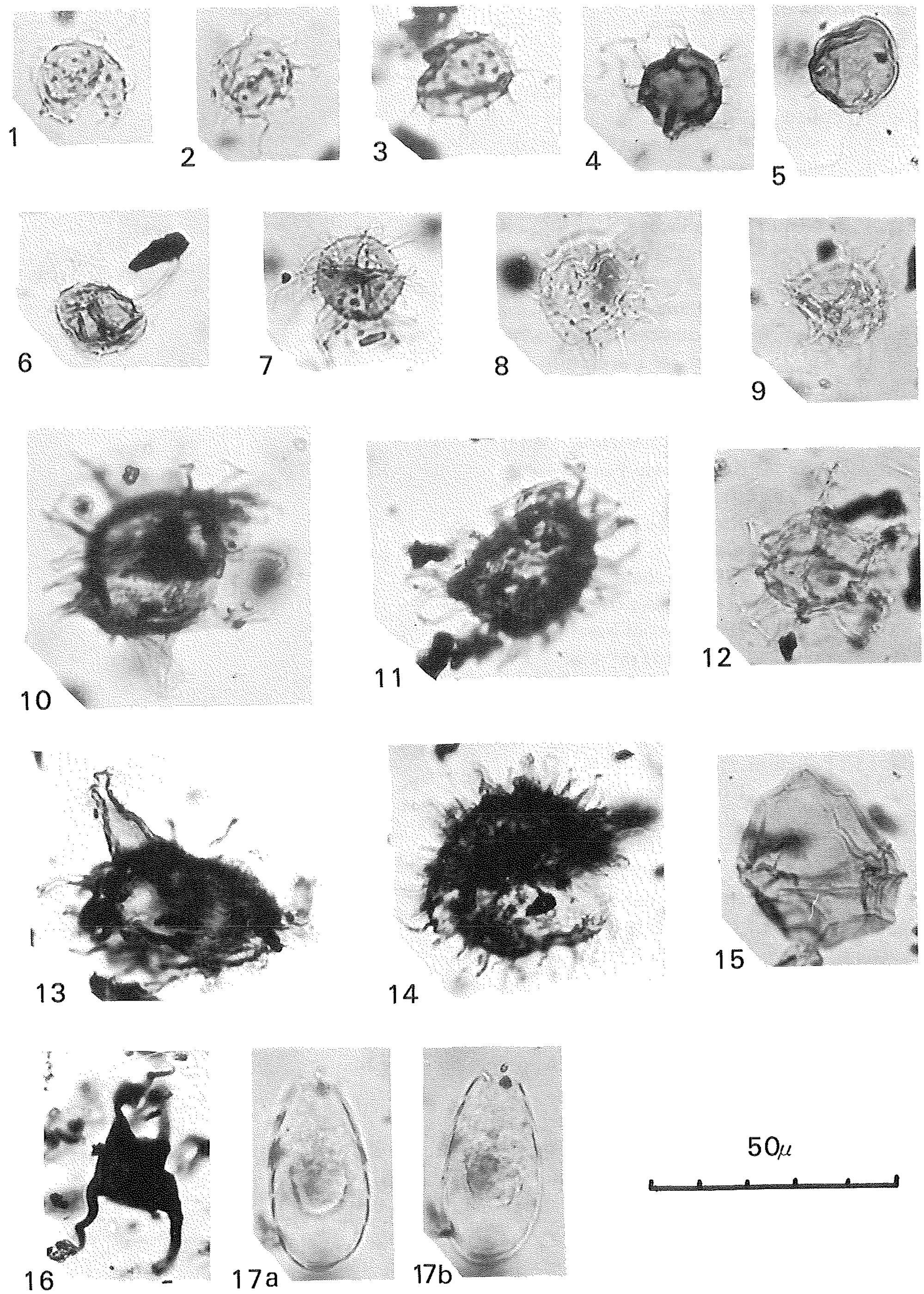
Fig. 13 Cf. *Hystrichosphaera colligerum* DEFLANDRE & COOKSON
Takinoue Formation.

Fig. 14 Cf. *Hystrichosphaera machaerophorum* DEFLANDRE & COOKSON
Takinoue Formation.

Fig. 15 *Gonyaulax* sp.
Kotanbetsu Formation.

Fig. 16 *Veryhachium reductum* DEUNFF or *Palaeotetradinium* sp.
Kawabata Formation.

Figs. 17a, b Indeterminable palynomorph
Sankebetsu Formation.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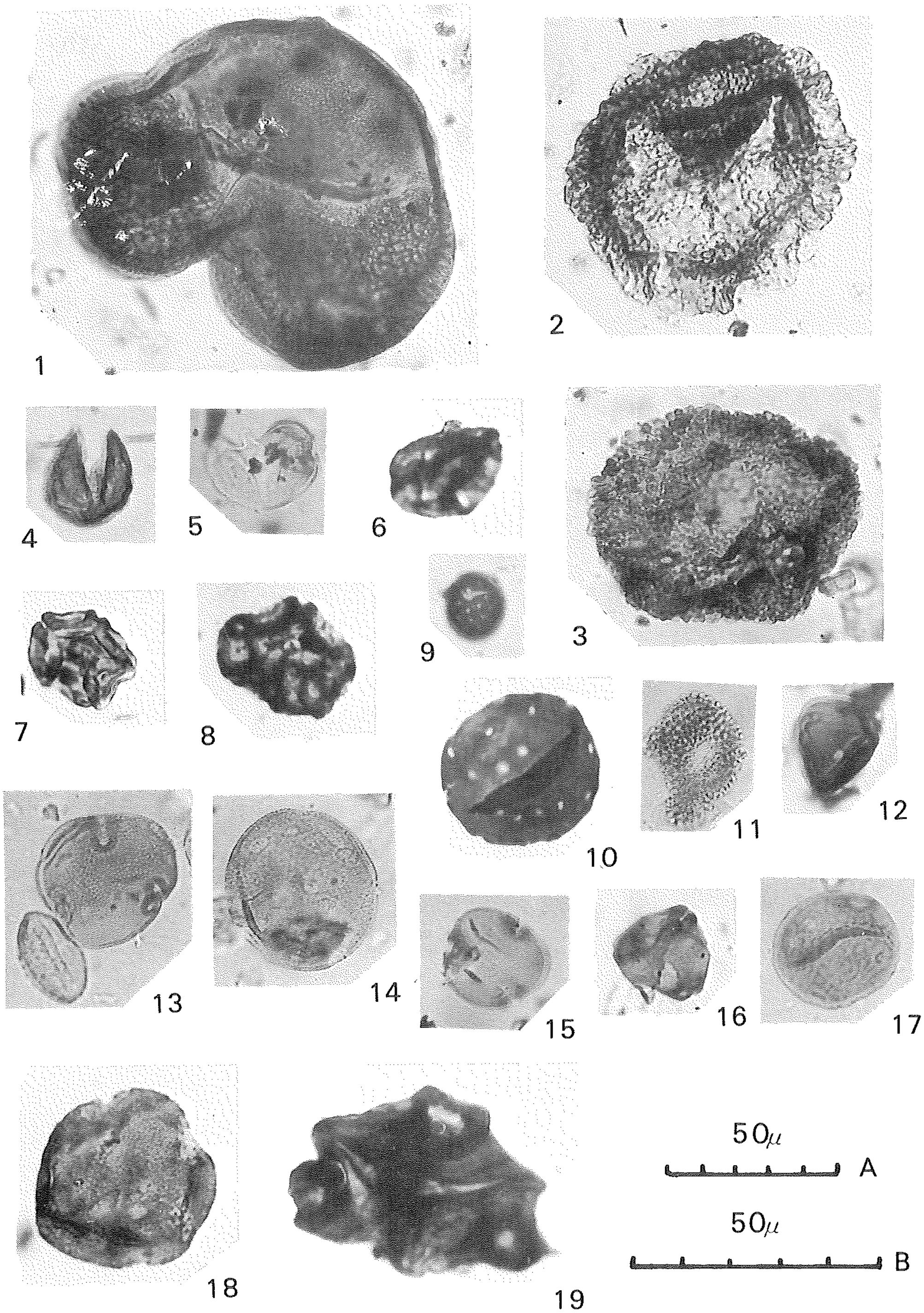
Explanation of Plate 4

Fig. 1 Pollen of *Picea*
Magaribuchi Formation.
Fig. 2 Pollen of *Tsuga*
Momijiyama Formation.
Fig. 3 Pollen of *Tsuga*
Magaribuchi Formation.
Fig. 4 Pollen of Taxodiaceae
Poronai Formation.
Fig. 5 Pollen of Taxodiaceae *(Cryptomeria?)*
Wakkanai Formation.
Fig. 6 Pollen of Taxodiaceae *(Glyptostrobus?)*
Takinoue Formation.
Figs. 7, 8 Pollen of *Alnus*
Takinoue Formation.
Fig. 9 Pollen of Chenopodiaceae
Sankebetsu Formation.
Fig. 10 Pollen of *Juglans*
Kawabata Formation.
Fig. 11 Pollen of *Ilex*
Haboro coal-bearing Formation.
Fig. 12 Pollen of *Rhus* or *Nyssa*
Haboro coal-bearing Formation.
Fig. 13 Pollen of *Tilia* and *Quercus*
Haboro coal-bearing Formation.
Fig. 14 Pollen of *Liquidambar*
Haboro coal-bearing Formation.
Fig. 15 Pollen of *Tilia*
Kotanbetsu Formation.
Fig. 16 Pollen of *Myrica*
Sankebetsu Formation.
Fig. 17 Pollen of *Ulmus* or *Zelkova*
Haboro coal-bearing Formation.
Fig. 18 Pollen of *Liquidambar*
Kawabata Formation.
Fig. 19 Pollen of *Epilobium*
Takinoue Formation.

Size of figures 1–17 shown by Scale A; others by Scale B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