PALYNOLOGICAL STUDY ON MIOCENE SEDIMENTS OF HOKKAIDO, JAPAN

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I. Introduction

Recently, pollen analytical study, pioneered by J. FRÖH in 1855 and established in its modernized quantitative aspect by L. von POST in 1916, has developed conspicuously with a number of noteworthy publications in Europe, the United States and Russia. Especially, the study has shown that it is a very effective method to study the Quaternary: information on climatic and floral changes, many contributions for archaeology and geology and many other items of knowledge on the Quaternary period have resulted from pollen analytical stydies. Also, similar study applied to the Paleozoic which bears the most important coal resources in the world has brought on many valuable results on the correlation of strata.

For the Tertiary sediments, however, the study has not been applied so satisfactorily as for the Quaternary. Considering that fossil pollen grains were found from the Tertiary at a relative early day (1838), such a situation at the present may seem to be rather inexplicable. Presumably, one reason of such a situation is the poor preservation or the difficulty of identification of pollen in the Tertiary sediments and the complexity of the floral composition of Tertiary age. But, recently, many pollen analytical studies of the Tertiary have been reported in Germany, the United States, Russia and many other countries. Furthermore, the pollen analysis which has heretofore been applied to carbonaceous matter in sediments has been applied also to marine sediments by many oil companies in the United States or France etc.

On the other hand, it may be said that pollen analytical study is in its infancy in Japan as a whole, though there are a few studies in a rather early day in this field, for examples T. JIMBO (1932) and T. YAMAZAKI (1935). These studies, however, are aimed solely at Quaternary peats and not Tertiary sediments. From only a few years ago, pollen analytical studies on the Tertiary sediments (Pliocene—later Miocene) have reported in our country. Still more, the study of older sediments is not in such a satisfactory situation but that many more studies are required, although there are some works by S. TOKUNAGA, T. TAKAHASHI, K. SOHMA, Y. OKAZAKI, M. SHIMAKURA, etc. up to the present. The author desiring to help improve this situation has been carrying on his pollen analytical study on the Miocene sediments in Hokkaidô.

The reasons why the author made the Miocene sediments an object of his pollen analytical study of Tertiary sediments are as follows: 1) the Miocene sediments in Hokkaidô contain rather abundant carbonaceous matter in which fossil pollen grains are abundant, 2) the fossil pollen grains in the Miocene sediments are better in preservation than in the Paleogene sediments, and 3) fortunately, there is an excellent and detailed study of the Miocene floras based on macrofossil plants by Dr. T. TANAI, Hokkaidô University, and it was presumed that would be very helpful for the present author to carry on his pollen analytical study in combination with the study on macrofossil plants and in discussion with Dr. TANAI. Furthermore, if possible, the author hoped to gain by his study some key as to the correlation of the Miocene sediments in Hokkaidô on which some problems are remaining even at present. Under the above-described aims the author has collected samples for pollen analysis from various districts in Hokkaidô, and has got some results on the Miocene pollen floral change and the correlation of the Miocene of Hokkaidô. In the present paper he reports mainly of these results.

Only carbonaceous matter was gathered as samples for the pollen analysis. Though marine sediments also contain fossil pollens, they are so poor in quantity of fossil pollen content that it is not so easy to get enough pollens from them. Moreover, considering various complicated factors such as the mixture of reworked fossil pollens, much more data may be necessary to provide basis for correct interpretation of the pollen assemblage gotten from marine sediments. So, the author excluded marine sediments from the object of the present study, but pollen analytical study of the marine sediments will be surely required in the near future.

Pollen analysis has an excellent merit that it is possible to get fossil pollen grains in enough quantity for statistical treatment from even a bit of sample. It frequently happens that many fossil pollen grains can be gotten from such sediments that no other fossil remains can be found. Owing to this merit, it is expected that the pollen analysis will more develop in future. However, the pollen analysis also has an unsatisfactory point that the specific identification of fossil pollen grains is very difficult or impossible in some cases due to their small size. Therefore, the author is keenly feeling the necessity of carrying on the pollen analytical study in co-operation with the study of macrofossil plants and of filling up the mutual shortages.

At any rate, the present stage of pollen analytical study in Japan is in its infancy, especially in the field of pre-Quaternary sediments. Accordingly, in the first place, it is needed to collect more data on palynology. Besides, investigation of fossil pollens in marine sediments is also required for practical and academical applications for the future. It is necessary to promote pollen analytical study step by step at a steady pace, and we must always keep in mind the fact that the successful area at present of the pollen analysis as in study for Quaternary in Europe was opened up after the accumulation of many data at a steady pace over a long time.

II. Acknowledgements

It is pleasure for the author to take this opportunity to express his sincerest thank to Professor Yasuo SASA, Hokkaidô University, who introduced the author to pollen analytical study and has given much useful advice and encouragement for a long time from the beginning of the author's study. Also the author's hearty appreciation is due to Dr. Toshimasa TANAI, Hokkaidô University, an authority in the Tertiary paleobotany in Japan, who has also given the author much advice and many chances to discuss the present study. Hearty thanks, further, are due to Dr. Tsugio YAMAZAKI and Masaji TAKEOKA, Saikyô University, who kindly guided the author at the beginning of his study. Besides, deep appreciation is due to many other authors in pollen analytical study who have given many valuable suggestions. The author also wishes to express his cordial thanks to Sachio HATTORI and many other members of the staff of Haboro Coal Mine and Railway Company who have been very kind in helping at his sampling and much other field work for long years. During the course of the present work, the author has been offered many valuable samples from many coal mines, to the management of which he expresses his great thanks at the present opportunity. Furthermore, particular thanks must be paid to the members of the staff of the Geological Survey of Japan for their kind help in offering of samples and discussions of field data. Also, the author wishes to express his hearty thanks to Miss Akiko YAMADA for her help in preparing of the manuscript and figures of the present paper.

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III. On Miocene coal-bearing horizons in Hokkaido

In general, carbonaceous matter contains many fossil pollens (and spores) and is appropriate as an object of pollen analysis. However, since pollen grains have many chances to be included in all sediments owing to their likelihood of being carried for very long distances, it is considered that also marine sediments may contain fossil pollens. Certainly, when the author examined the Tertiary marine sediments containing foraminiferal remains in a boring from the neighbourhood of the City of Tomakomai, he found considerable numbers of fossil pollen grains among them (but, the numbers are far less than in carbonaceous matter). However, as it is presumed that it more frequently happens in marine sediments than in carbonaceous matters in terrestrial deposits that reworked fossil pollen grains are included, more careful considerations are needed and many unsolved problems remain in attempting an interpretation of the pollen flora in marine sediments. Moreover, immense time, cost and labour are necessary to get fossil pollen grains from the marine sediments in enough quantity correctly to interpret the pollen flora. For the above-described reasons, the author has carried on the present work mainly on carbonaceous matter but not on marine sediments. However, a pollen analytical study of the marine sediments is inevitably needed in the near future. In this chapter the stratigraphical horizons of the Miocene coal-bearing sediments of Hokkaidô will be discussed briefly.

In the western part of Hokkaidô the Miocene sediments are well distributed from the oldest to the youngest stage with considerably wide areal extension, and terrestrial facies with carbonaceous matter are frequently found in them. On the other hand, the Miocene in the southern part of eastern Hokkaidô is composed of marine sediments while in the northern part of eastern Hokkaidô terrestrial deposits do not develop well. So, the author studied mainly western Hokkaidô.

1. Southwestern Hokkaidô

The general stratigraphical succession of the Miocene sediments of this region is shown in Table 1. But, the stratigraphical relationship of the Miocene has not yet been completely settled, for example, some authors consider the Yoshioka formation to be a basal part of the Kunnui formation. Especially, there are some divergent opinions on the stratigraphical

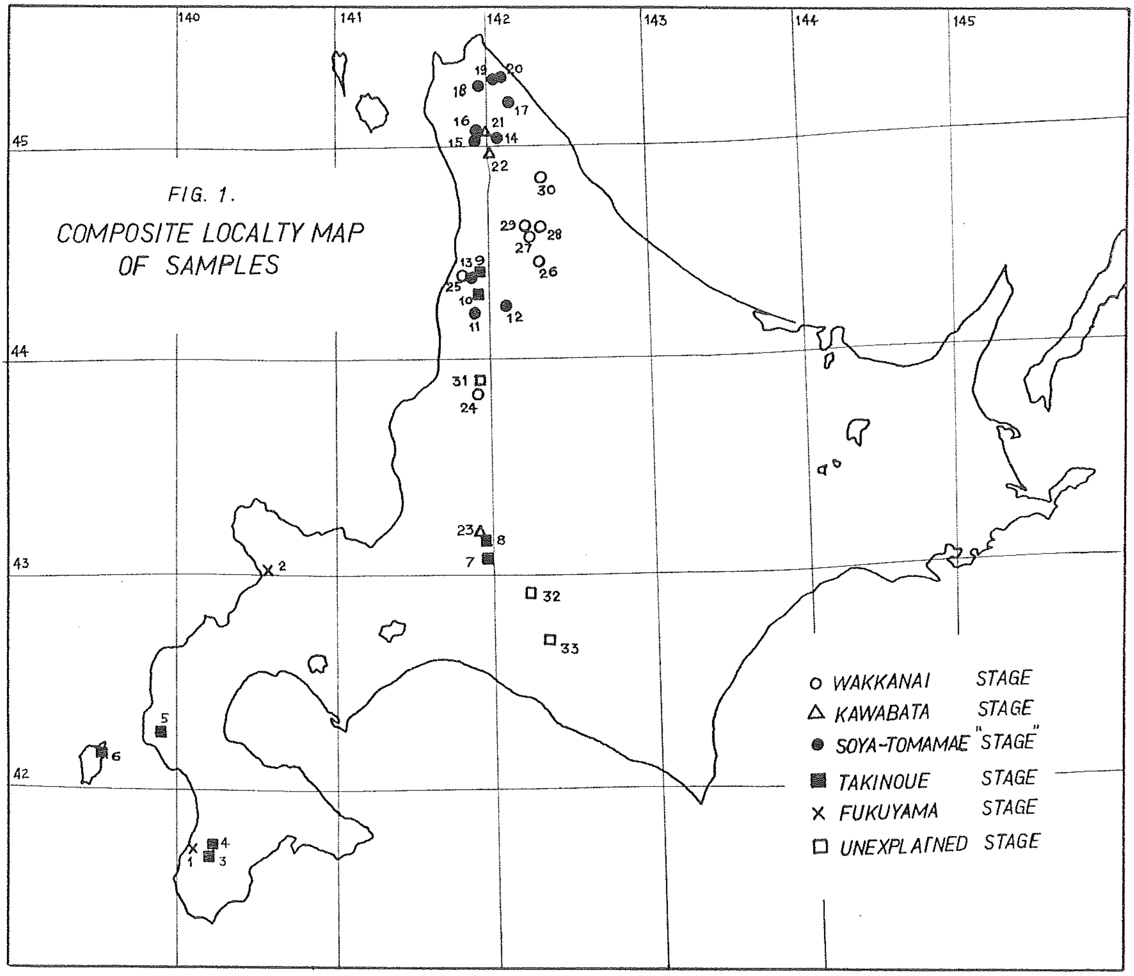


Fig. 1. Composite localty map of samples

1. Kinoko area; 2. Kayanuma coal mine; 3, 4. Yunotani area; 5. Wakamatsu coal mine; 6. Chatsu area; 7. Shinkakuta coal mine; 8, 23. Asahi coal mine area; 9. Chikubetsu main pit; 10. Haboro second pit; 11. Tomamae coal mine; 12. Shumarinai area; 13. Sekiyu-zawa; 14. Horonobe coal mine; 15, 16, 21. Nissô-teshio coal mine area; 17. Karibetsu river area; 18. Sôyamagaribuchi coal mine; 19. Hokutakukoishi coal mine; 20. Onishibetsu coal mine; 22. Toikanbetsu area; 24. Tôgeshita area; 25. Kamichikubetsu area; 26. Bifuka area; 27. Masuda-no-sawa; 28. Monponai coal mine; 29. Onnenai coal mine; 30. Kami-ketobetsu area; 31. Honjin-no-sawa; 32. Shinnoborikawa coal mine; 33. Kenomai coal mine

TABLE 1. General stratigraphic succession of Southwest Hokkaidô

	Southwest Hokkaidô	Standard succession of Hokkaidô
Miocene	? Kuromatsunai formation	Oiwake stage
	Yakumo formation	Wakkanai stage
	?	
	Kunnui formation	Kawabata stage
	Yoshioka formation	Takinoue stage
	Fukuyama formation	Fukuyama stage
	so-called Paleozoic rocks	

horizons of coal-bearing sediments. The main coal-bearing horizons are these of the Yoshioka formation and the upper part of the Fukuyama formation, but also the Kunnui formation contains carbonaceous matter, though the scale is poor. Coal of the Fukuyama formation is found in the Kaminokuni, Kayanuma and Shimamaki coal-bearing area etc. Though some of them have been worked on a small scale, the coal seams of this stage are not continuous in areal distribution and not so important in economical sense on the whole except that of the Kayanuma coal mine which has over ten coal seams of which five or six are workable; it is the oldest mine of all in Hokkaidô. The coal-bearing sediments of this stage are characterized by the occurrence of the Aniai-type flora which indicates a cool temperate climatic condition. The coal of the Yoshioka stage is found in the Kudô coal-bearing area where there are many mines small in scale; nearly all mines except the Wakamatsu mine are not in production at present. Furthermore, the coal of the Yunotai coal-bearing area is said to be of the Yoshioka stage by some authors, but on the other hand there is also an opinion that it is of the Kunnui formation. The coal of this stage is also discontinuous in lateral extension and not very important economically. The coal-bearing sediments of this stage are characterized by the occurrence of the Daijima-type flora which indicates a warm temperate—temperate climatic condition being clearly distinguished from the Aniai-type flora. The Kunnui formation is mainly composed of marine sediments from which the so-called "*Miogypsina—Operculina*" fauna is found. These sediments are very poor in coal, but, as noted above, the coal of the Yunotai coal-bearing area may be of this formation. The above facts are stated as generalizations for the present, but many problems remain on the correlation of the Miocene in the present region owing to the complexity of the geologic structure, intermittent areal distribution of sediments, richness of facies change of rocks and poorness of fossil evidences etc.

Among these occurrences of coal, the writer carried on his pollen analytical study of samples taken from six localities: the Kayanuma and Wakamatsu coal mines, the Kaminokuni, Yunotai and Shimamaki coal-bearing areas and Okushiri island (very thin coal seams in the Kunnui formation). But, no examples of fossil pollen in sufficiently good preservation for identification could be gotten from coal of the Shimamaki coal-bearing area and a part of the Kayanuma coal mine area owing to change in quantity caused by the intrusion of igneous rocks.

2. Central Hokkaidô (region west of the Hidaka range and east of Southwest Hokkaidô)

The Neogene coal-bearing sediments in this region are wide in areal distribution and contain many coal seams which are a very important coal resource in Hokkaidô; the seams are being worked in many mines. In this region one can recognize the Neogene sediments from the lowest to the uppermost horizon attended with many instances of coal-bearing sediment. So, this region is most favorable for the pollen analytical study of the Miocene sediments to establish the standard pollen floral succession during the Miocene age.

2A. Tempoku coal field

The Tempoku coal field occupies the northernmost area of Hokkaidô. The field of about 900 km^2 (EW about 20 km, NS about 60 km) is the largest of the Neogene coal fields in Japan; it contains a great amount of Miocene brown coal. There are many mines in this field, though they are not so large in scale as in the Ishikari coal field. The stratigraphical succession of the Miocene in this field is as follows in ascending order: the Magaribuchi, Sôya, Onishibetsu, Masuporo, Wakkanai and Koitoi formations. There are some divergent opinions on their stratigraphical positions and correlation; they will be discussed in detail in chapter VIII. Coal-bearing sediments are found mainly in the Sôya formation, but also the Masuporo formation sometimes contains thin coal seams in discontinuous forms. Though the Sôya (coal-bearing) formation has been correlated to the Haboro coal-bearing formation, Takinoue stage, in the Tomamae coal field, the former yields a flora similar in composition to the Aniai-type flora which is not of the Takinoue stage; accordingly, the correlation seems to be questionable. The Sôya coal-bearing formation contains coal more than ten seams of which 3–6 are now being worked at many mines: for example, Nissô, Horonobe, Asajino, Hokutakukoishi, Sôya-magaribuchi and Onishibetsu coal mines etc. The coal is not of very high quality; lignite (F_1–F_2 according to the classification of JIS). Abundant well-preserved fossil pollens and spores are gotten from this coal, and many macrofossil plants which indicate a cool temperature climatic condition frequently are obtained from roofs of these coal seams.

Samples for the present study were taken from coal seams in the Sôya coal-bearing formation of the Nissô, Horonobe, Onishibetsu and Hokutakukoishi coal mines, from the catchment area of the Karibetsu river, and from a thin coal seam in the Masuporo formation of the Toikanbetsu district. Their localities are illustrated in Figs. 1 and 19.

2B. Tomamae coal field

This coal field is situated about 50 km south of the Tempoku coal field and is near the Japan Sea. This is one of the actively worked coal fields in Hokkaidô. The stratigraphic succession in this district is considered to be as the following two lists (Table 2). The main coal resource is in

TABLE 2. Two opinions on the stratigraphic succession in the Tomamae coal field

	AOYANAGI, N. (1951), HASHIMOTO, W. (1961) etc.	MATSUNO, K. (1959), HATTORI, S. (1961) etc.
Miocene	Enbetsu formation	Enbetsu formation
	Wakkanai formation	Chepotsunai formation
	Kotanbetsu formation	Kotanbetsu formation
	Chikubetsu formation	Chikubetsu formation
		Sankebetsu formation
	Haboro coal-bearing formation	Haboro formation
	Haranosawa formation	Haranosawa formation
	Cretaceous rocks	Cretaceous rocks

the Haboro (coal-bearing) formation. Though there is only one workable coal seam (Haboro-honsô), it is rather stable in lateral continuity and thickness and is less in parting; also the coal is low in ash content and is good in quality; it is subbituminous coal (D, E according to the classification of JIS). The Haboro coal mine composed of three pits (Chikubetsu main pit, Haboro main pit, Haboro second pit) is the only one working mine in the present coal field; it is one of the most efficient coal mines of Hokkaidô in the economic sense. The macrofossil plants in the Haboro formation, though they are not very abundant in quantity, belong to the Daijima-type flora, while many examples of well preserved fossil pollen and spores are found from the coal; also the pollen flora surely is the Daijima-type. Further, many molluscan fossils are gotten from the

Sankebetsu and Chikubetsu formation. From these fossil evidences and stratigraphic considerations, the Haboro-Chikubetsu formations are considered to be early-middle Miocene in age. The correlation of the stratigraphic successions in the present coal field and the neighbouring regions will be discussed below in chapter VIII. Besides, though poor in lateral continuity and in quantity, coal-bearing sediments have been recognized in the Tomamae coal-bearing formation which corresponds to the lowest part of the Chikubetsu formation, but the coal is not very good in quality and was worked only in a few localities on a very small scale, for example at the Tomamae mine. From the coal in the formation many examples of well preserved fossil pollen and spores of which the assemblage is similar to the Aniai-type flora in composition were obtained, but no macrofossil plant is known from the formation. Moreover, low grade lignite is recognized in the Chepotsunai (or Ogawa coal-bearing) formation which is the terrestrial facies of the Wakkanai formation; it is distributed along west margin of the present coal field. A coal seam exists near the base of the formation; the thickness of the seam is about 300 cm in the neighbourhood of Kamichikubetsu station and 160 cm at Ogawa near Kotanbetsu station. The coal is so bad in quality and lateral continuity that it has not yet been worked.

The samples for the present study are taken from coal seams in the Haboro coal-bearing formation at the Chikubetsu and Haboro second pits, in the Tomamae coal-bearing formation at the Tomamae mine and Sekiyuzawa (neighbourhood of the Chikubetsu mine), and in the Chepotsunai formation at Kamichikubetsu.

2C. Rumoe coal field

This coal field is adjacent to the Tomamae coal field on its northern margin; being about 300 km^2 in size, and divided into two areas: the Uryû and Ôwada areas. Owing to the complicated geologic structure in this field the stratigraphic succession is not yet clarified but various unsettled problems remain at present. For examples, the following various successions are offered by various authors as shown in Table 3. An important coal resource in the economic sense in this coal field is that in the Paleogene, whilst that in the Neogene is not so valuable; only some mines on a small scale are recognized. Besides, there are some workable coal seams of which the stratigraphic horizons are not yet settled: whether Paleogene or Neogene.

It is inappropriate to carry on a pollen analysis in an attempt to establish the standard pollen floral succession of such a field as it is so complex in geologic structure, as mentioned above, that a standard strati-

TABLE 3. Various opinions on the stratigraphic succession of the Rumoe coal field

1. Of the northern part of the field according to S. NISHIDA (1950)

Lower Miocene	Horoshin group
	Okinai coal-bearing formation
Oligocene	Poroshiri hard shale and sandstone formation
	Tappu shale formation

2. Of the northern part of the field according to K. TSUSHIMA et al (1958)

Miocene	Kotanbetsu formation	
	Neiraku formation	Chikubetsu formation
		Arakizawa coal-bearing formation
		Jûgosenzawa formation
	Tappu formation	

3. Of the whole field according to Mineral Resources of Japan (1960)

	(Ôwada area)	(Uryû are) (Main part)	(Uryû are) (Northeastern part)
Miocene	Mashike formation		
	Tôgeshita formation		
	Yûdoro formation	Kotanbetsu formation	Kotanbetsu formation
		Chikubetsu formation	Chikubetsu formation
		Okinai coal-bearing formation	Haboro formation
		Tappu group	
Paleogene	Ôwada coal-bearing formation	Uryû group	
	Paleozoic rocks	Cretaceous rocks	Cretaceous rocks

graphic succession is not yet settled. Even if in some cases a pollen analytical study may be able to give a clue to make clear the complicated geologic structure and stratigraphic relations, it is a matter claiming prior settlement to produce the clue that the standard pollen floral succession in that area is known in advance. Accordingly, a pollen analytical study in this field is a subject left for the near future. So, in the present paper the writer reports only result of a pollen analysis of a thin coal seam in the Honjin-no-sawa coal-bearing formation in the Horoshin group on the side of the Horonitachibetsu river in the neighbourhood of the Asano-uryû coal mine.

Besides the above-described three coal fields there are two small lignite fields: the Kita-uryû and Numata coal fields.

2D. Kita-uryû coal field

This coal field is adjacent to the Tomamae coal field at its western margin with the extension of about 60 km from north to south and 10–15 km east to west. The stratigraphic succession in this field is as follows (Table 4). Coal-bearing facies is in two horizons: the lower is in the

TABLE 4. Stratigraphic succession of the Kita-uryû coal field

Miocene	Wakkanai formation
	Kotanbetsu formation
	Chikubetsu formation
	Cretaceous rocks

Shumarinai coal-bearing formation which seems to be correlated to the Tomamae coal-bearing formation in the Tomamae coal field though it has been correlated to the Haboro coal-bearing formation in the past; the upper is a terrestrial facies of the Wakkanai formation. Two or three coal seams in the lower horizon are recognized in the Kamienbetsu district of the northern part of this field and the Shumarinai district, but they are discontinuous laterally and their coal is not sufficiently good in quality so that they are not being worked except at some localities in the neighbourhood of Shumarinai where the coal is worked on a very small scale. It is from there that the samples for the present study were taken. Though there is no report of any macrofossil plants from the horizon, many examples of well preserved fossil pollen and spores were found in these samples; the pollen flora is similar to that of the Tomamae coal-bearing formation and indicates rather cool temperate climatic condition. The upper coal-bearing horizon contains many coal seams in its lower and middle parts; the seams over 80 cm in thickness are three in number in the lower part and fifteen in the middle part. Some of them have been worked mainly at the Fukinotai area in the past: for example, at the Kamagafuchi and Takinosawa coal mines.

2E. Numata coal field

This coal field is situated south of the Rumoe coal field in adjacency. The geologic succession in this field is as follows in ascending order: the Ôwada coal-bearing formation (Paleogene), Yûdoro, Tôgeshita, Mashike (Miocene) and Rumoe formations (Pliocene). The main coal-bearing facies of the Miocene is in the Tôgeshita formation; three or four coal seams are recognized in it, but only one seam (80 cm in thickness) of them has been worked at the Ebishima coal mine. These coal seams are poor in lateral continuity and become thin southwards. The sample for the present work was taken from the Ebishima coal mine. The coal is lignite: F_2 according to the classification of JIS.

2F. Utanobori coal-bearing area

In addition to the above-described coal fields the writer had a chance to make a pollen analysis of a sample from the Tachikaraushinai (or Shôtonbetsu) formation in the Utanobori coal-bearing area, about 30 km north of the Nakagawa coal field. The coal-bearing sediments are considered to be a marginal facies of the Wakkanai formation; they overlie Cretaceous rocks with unconformity. Though the thickness and number of the coal seams vary in each locality, some reach to 250 cm in thickness and the number varies from one to four. These coal seams have been worked in some mines on a small scale. The sample for the present study is taken in the neighbourhood of Kamiketobetsu.

2G. Ishikari coal field

This coal field, situated near the central part of Hokkaidô, is the largest and the most important coal field in Japan economically speaking. But, the main coal resource is in the Ishikari group, Paleogene, and the Neogene coal is almost not being worked except at the Asahi and Shinnoborikawa coal mines. The general stratigraphic succession of the Miocene sediments in this field is shown in Table 5.

TABLE 5. General stratigraphic succession of the Miocene in the Ishikari coal field

Miocene	Oiwake	formation
	Iwamizawa	formation
	Kawabata	formation
	Takinoue	formation
Oligocene	? Momijiyama	formation
	Poronai	formation

Though the stratigraphic position of the Momijimaya formation has been hitherto considered to be the uppermost part of the Paleogene sediments in general, there are various different opinions about it; for example, recently T. SHIMOKAWARA and J. TEJIMA (1961) have advocated that the formation in the southern part of the Yûbari coal field, southern part of the Ishikari coal field, is correlated to the following: to the Takinoue formation in the northern part of the Yûbari coal field, to the Magaribuchi formation in the Tempoku coal field, to the Harnosawa formation in the Tomamae coal field, to the Sakae formation in the Hidaka coal field and to the lower part of the Honjin group in the Rumoe coal field. Though carbonaceous matter exists in almost all the Miocene sediments, the main instance is that of the Takinoue formation. The formation is divided into three members at the type locality, and contains some coal seams which are partly developed into a workable one in the middle member; the coal-bearing sediments are called under the local names of the Asahi and Hobetsu coal-bearing formations in the Ishikari field. But there is room for discussion of the stratigraphic positions of these coal-bearing formations. For example, while macrofossil plants of the Aniai-type flora of the lower part of the middle Miocene are reported from the Asahi coal-bearing formation, the pollen flora in it represents a typical Daijima-type flora which is found from the higher horizon in stratigraphical sense than the Aniai-type flora. In other words, the distribution area of the Asahi coal-bearing formation is so complicated in geologic structure and fossil evidences that the geologic succession therein is not yet settled. The coal in the Takinoue formation is lignite—low grade bituminous coal, and it has been actively worked at the Asahi coal mine where five or six workable coal seams are found. But these coal seams in the Takinoue formation change their thickness and quality laterally as a whole. Besides, also the Kawabata formation contains some coal seams in some places in lenticular form which reaches to several meters in thickness in some cases; the coal has been worked on a very small scale in several localities. Also, a coal-bearing facies is recognized in the Iwamizawa formation at the west of Oiwake-machi where the coal-bearing sediments are called under the local name of the Chitose coal-bearing formation. They have been worked in the past on a small scale, but the mine is completely in ruins at the present. A coal-bearing facies of the Iwamizawa formation is reported only from there.

The samples for the pollen analysis are taken from five coal seams of the Asahi coal mine, from a lenticular coal seam in the Kawabata formation in the neighbourhood of the Asahi coal mine and from a thin coal seam in the neighbourhood of the Shinkakuta coal mine to the west of Yûbari City.

2H. Hidaka coal field

This coal field extends southeastwards along the coast of the Pacific from the southern end of the Ishikari coal field. The stratigraphic succession is shown in Table 6. Some coal seams in lenticular form are recognized in these coal-bearing formations along near the base in this field. Though these coal-bearing formations have been hitherto considered to be in the same horizon and to be correlated to the Asahi coal-bearing

TABLE 6. Stratigraphic succession in the Hidaka coal field

	(Northern part)	(Southern part)
Miocene	Kawabata formation	Kawabata or Niikappu formation
Miocene	Takinoue formation (Hobetsu coal-bearing formation is the lower part of this formation)	Noya or Kenomai coal-bearing formation
	? Momijiyama formation	Cretaceous rocks

formation, such a correlation leaves room for discussion owing to the intermittent distribution of the formation; moreover, the Hakobuchi group, the uppermost Cretaceous, frequently is found with coal seams along the Neogene sediments and it is not rarely difficult to discriminate whether a coal-bearing facies is of Cretaceous or Tertiary. The coal in the Neogene coal-bearing formation varies in quality from sub-bituminous to lignite in each area; it has been mined in many small mines on a small scale.

The samples for the present study come from the Shinnoborikawa and Kenomai coal mines; their localities are indicated in Fig. 1. But, the present coal field is inappropriate for the present study for the same reason as that in the Rumoe coal field; accordingly, many more samples and further investigations of the geologic structure are needed in future.

IV. On the treatments in laboratory

All the samples are ground in an iron mortar and their size are made uniform by means of 35–40 mesh sieve. Of the grain size of the sample for pollen analysis, A. RAISTRICK (1934, p. 142) has reported as follows: "trial of various grades of grinding from 30 to 90 mesh indicates that 50 to 60 is the best size for the reactions involved, and is large enough in comparison with the actual microscope sizes to prevent excessive breakage of the spores. With coal ground to 70 mesh, as much as 50% of all the spore-content may be broken, but with 50 to 60 mesh, the broken material is very small." The coal investigated by RAISTRICK was Paleozoic in age, while the samples for the present study are all of Neogene age. The sizes of the spores in the former were all under 100 μ, but the latter includes more comparatively larger (over 150 μ) pollen grains as coniferous pollens. So, the size, 50 mesh, may not be strictly applied to the present specimens. The writer adopts larger size than 50 mesh for the sake of safety: 40–50 mesh. The ground sample is ready for chemical treatment to separate pollen grains from the sample.

The chemical treatment for the pollen analysis of coal is not a strictly fixed one but some variations in intensity of the treatment are allowed for each specimen, since the chemical composition of coal is not uniform. Also a specimen has tolerance to intensity and duration of chemical treatments to some extent. As a result of the writer's experiments it seems to be proven that it is not necessary to be ovresensitive as to the intensity or duration of the chemical treatments except in the case of very low grade lignite.

A pollen grain is composed of a pollen membrane and protoplasma enveloped by the membrane. The pollen membrane consists of two main concentric layers: the outer is exine and the inner is intine. The protoplasma does not exist in fossil pollen but only the membrane is left. Of the two layers of the membrane the exine is so strong in resistance to chemical attacks that it frequently suffers no damage from intensive chemical treatments even after many various chemical, physical and bacterial attacks in the fossil state during many hundreds of million years. The material made the object of the pollen analysis is no other than the exine. The chemical composition of the exine is not yet made clear enough since it frequently is not possible to analyse its chemical composition by the use of various chemical solvents owing to its high resistance to many chemical solvents. A satisfactory result on the chemical composition of the exine can not be obtained in spite of many efforts since early days. BERZELIUS pointed out the great resistance of various pollens to alkali; this discovery became a base of the classical method of preparing peat for pollen analysis. At length in 1928, F. ZETZSCH and his collaborators isolated a characteristic substance, which is called sporonine, from *Lycopodium* spores by extraction of the spore with boiling alkali. The insoluble residue obtained by this means consists mainly of cellulose (2 per cent of the spore) and a specific substance termed sporonine (25 per cent of the spore). Furthermore, in 1930, ZETZSCHE and VICARI reported the formulae of sporonine of the following pollens:

Lycopodium clavatum	$C_{90}H_{142}O_{27}$ to $C_{90}H_{127}O_{12}(OH)_{15}$	(23.8% of the spore)
Picea orientalis	$C_{90}H_{142}O_{25}$	(20% ,,)
Pinus sylvestris	$C_{90}H_{144}O_{24}$ to $C_{90}H_{131}O_{11}(OH)_{13}$	(21.9% ,,)
Corylus avellane	$C_{90}H_{138}O_{22}$	(8.3% ,,)

But, as to other pollens their composition is not yet ascertained. When even such a resistant material as sporonine is subjected to prolonged action of air, it increases its oxygen content (auto-oxidation) and it is eventually destroyed. Such a phenomenon is worth notice by pollen analysts in preparation of samples or in interpretation of the absence of pollen in the samples. Besides, it is reported by many investigators that some sorts of pollen, for examples *Acer, Fraxinus, Populus* and *Juniperus*, are only rarely or not at all found as fossils; such a fact may indicate that the chemical compositions of the exine of all pollens are not uniform. The comparatively small quantity of sporonine in *Corylus* pollen as noted above indicates an example of such difference in the chemical composition of exine. It is also reported by some authors that the spores of Pteridophyta or fungi are more resistant to chemical reagents than pollens; also the writer has sometimes recognized under microscope occurrences suggesting these above-mentioned facts. It is recognized by some authors that fossil pollen membrane is more resistant to chemical reagents than that of living: a fossil exine seems to become more resistant with longer continuance as fossil. For example it was the writer's experience, when treatment was carried out for oxidizing the lignite taken from the Chepotsunai formation (upper Miocene) with Schultze solution no pollen could be found under microscope, but without the oxidizing treatment pollen grains were recognized; pollen could not be separated from any of samples older in age than these of the upper Miocene without the oxidizing treatment. But, at any rate, pollen membrane is a material highly resistant to chemical reagents; the principle of the chemical treatments in pollen analysis is to separate and concentrate fossil pollen grains with removal of sedimentary materials including the fossil pollens by utilization of this character of the high resistance of fossil exine.

The chemical treatment in course of pollen analysis of coal is mainly composed of two parts: one is an oxidizing treatment by the use of Schultze solution or nitric acid, and the other is dissolution and removal of humic substance, the main component of coal, by using an alkali solution such as KOH or NaOH.

Coal is a reducing material converted from peat. There are many methods for concentration of pollen grains from peat; for example, the KOH method or the acetolysis method. So, if one can return coal to peat by any treatment, he can apply the method of recovery from peat for coal after that treatment. The above-noted oxidizing treatment corresponds to this treatment. The writer used Schultze solution as the oxidizing agent in most cases. The solution used by F. SCHULTZE for the first time is a mixture of nitric acid 20 parts and potassium chlorate crystal ($KClO_3$) 3 parts. This rate, however, is not a fixed one for all coal, but some variations of the rate are allowed in compliance with the character of coal. The writer is using a mixture of nitric acid 30 parts and potassium chlolate crystal 2 parts in volume. But, it is not necessary to keep the rate very accurately. About 0.3–0.5 g of sample is soaked with the Schultze solution (4–5 cc) in a centrifugal tube. After 1–2 days* the solution becomes reddish in color and the sample brownish black to brown; but such a reaction is not always the same for all coal, but is various for coal of different horizons or even in the same coal seam in some cases. Then the sample is washed several times with distilled water until the Schultze solution is completely removed. S. TOKUNAGA (1958, p. 5) reported that the treatment with Schultze solution over one day damages pollen membrane of Paleogene coal. However, according to the writer's experiments, it seems that the treatment with Schultze solution over one day is necessary to take out pollens from Paleogene coal with good result. Even in Neogene coal used in the present study, many samples show good results after the treatment with Schultze solution over one day. In the preparation of Cretaceous coal, 2–5 days of treatment are needed to get good result. Next, one should add 10% KOH solution (5 cc) to the sample in the centrifugal tube. If the oxidizing treatment is effectively carried out, the solution changes from colorless to dark brown or nearly black as soon as the KOH solution is added. The color is due to extraction of humic matter in the sample into the KOH solution. The centrifugal tube containing the solution and the sample is heated in a water-bath at 100–50°C for 60–30 minutes**. Then the sample is washed several times with distilled water by use of a centrifuge until the color of the solution is completely removed. When the sample is high in ash content, it is treated with hydrofluoric acid (HF); namely, the sample after the above-described treatments is transferred into a polyethylene centrifugal tube and soaked in hydrofluoric acid (about 5 cc) for 1–2 days. The time for this treatment can be shortened by heating in a water-bath. Then wash the sample with distilled water several times, and the treatments are entirely finished. Though TRAVERSE (1955) used the acetolysis treatment of a mixture of acetic anhydride and concentrated sulphuric acid for Tertiary lignite, this treatment is unnecessary for the samples in the present study. Material thus obtained is mounted with glycerinjelly and readed for examination under microscope.

A matter that demands special attention is the contraction in volume of fossil pollen grains. There are many studies as to the effects on pollen grains of many chemicals used in various methods to take out fossil pollen from sediments; for example, expansion in volume of pollen grains in

* Some low grade lignites show an intensive reaction with bubbling in this treatment and only 1–2 hours is enough for the time of this treatment.

** The temperature and time of this treatment vary in accordance with quality of samples.

using the acetolysis method or degree of damage to pollen membrane in proportion to intensity of the treatment by means of alkali solution. But, there is no report on the influence by HF acid on pollen membrane so far as the writer knows. If there is any effect on pollen membrane caused by the acid, it may be needful to pay attention to the effect, because the HF

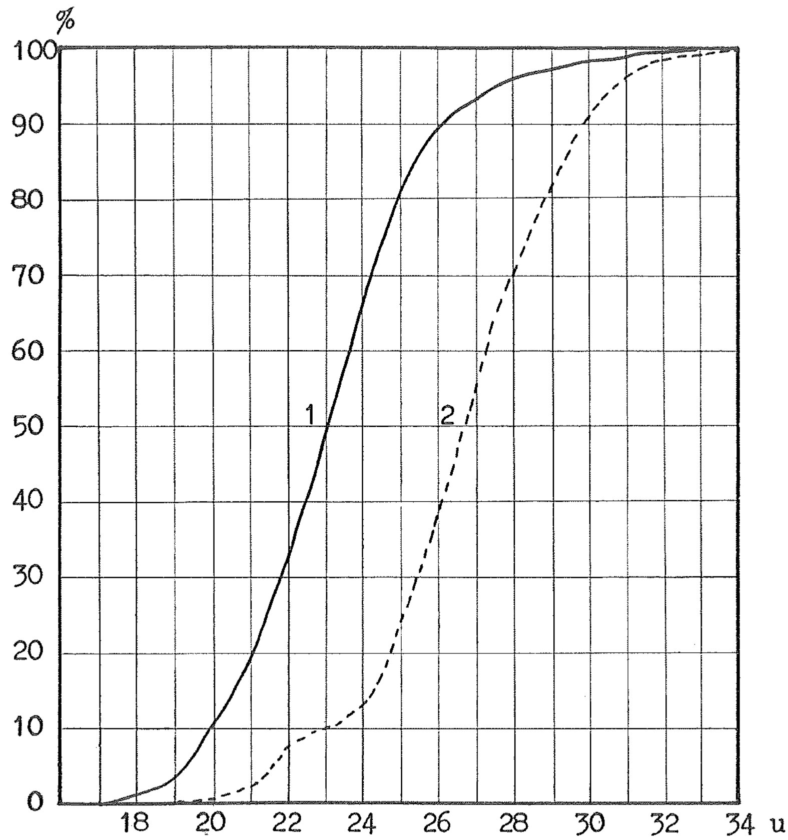


Fig. 2. Cumulative curves on size frequency showing shrinkage of fossil pollen (*Alnus*) owing to HF treatment
Curve 1: with HF treatment
Curve 2: without HF treatment
(Used samples were taken from the Shumarinai district)

treatment is needed in many cases to take out fossil pollens from sediments, especially in study of pre-Quaternary fossil pollens. The writer recognized contraction in volume of fossil pollen grains after the HF treatment. Cumulative curves as to size frequency in Figs. 2 and 3 show the contraction of *Alnus* pollen*. As seen clearly in these cumulative curves, the size of fossil pollen grains treated with HF acid is smaller than that of untreated; the reduction in size is about 15 per cent in comparison with those without treatment. Then, what is the cause of such reduction of size? The writer compared sizes (length of the polar axis) of living pollen grains of *Quercus crispula* treated with HF acid for one day and those without the treatment. Fig. 4 shows the result of the comparison

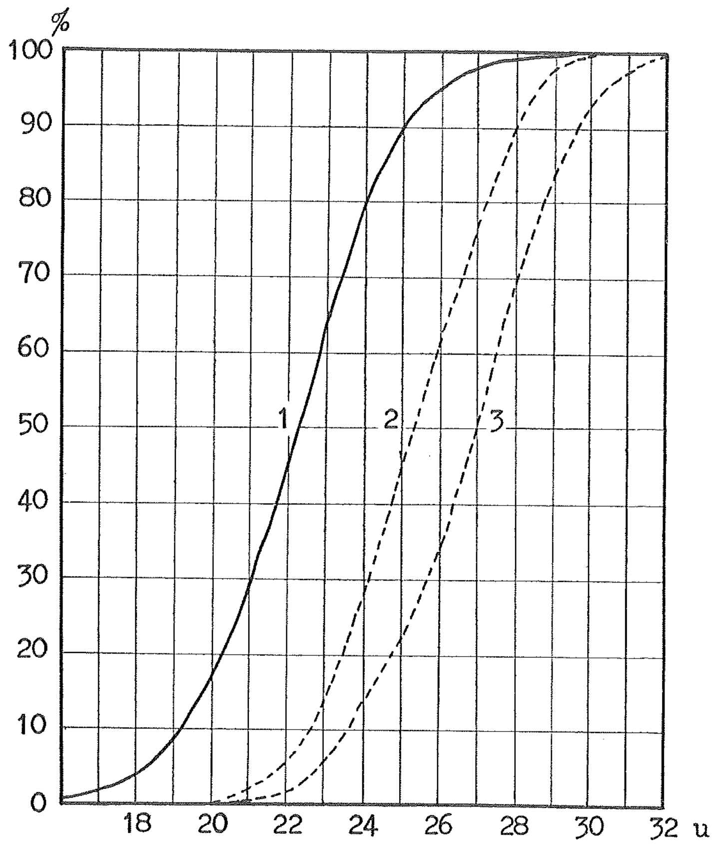


Fig. 3. Shrinkage of fossil pollen (*Alnus*) owing to HF treatment

Curve 1: with HF treatment (on sample L_{12})
Curve 2: without HF treatment (〃 L_4)
Curve 3: without HF treatment (〃 L_8)
(All samples were taken from Haboro Second Pit)

* The reason why the writer chooses *Alnus* pollen for the object of this test is only that the pollen is so abundantly found that is convenient to take statistics.

by the cumulative curves of size frequency. As seen in curve 1 and curve 2, the reduction in size resultant from the HF treatment is not recognized in these living pollen grains*; accordingly, the contraction by HF treatment in fossil pollens may be due to removal of inorganic material that permeated into their membrane. If so, the degree of the contraction may

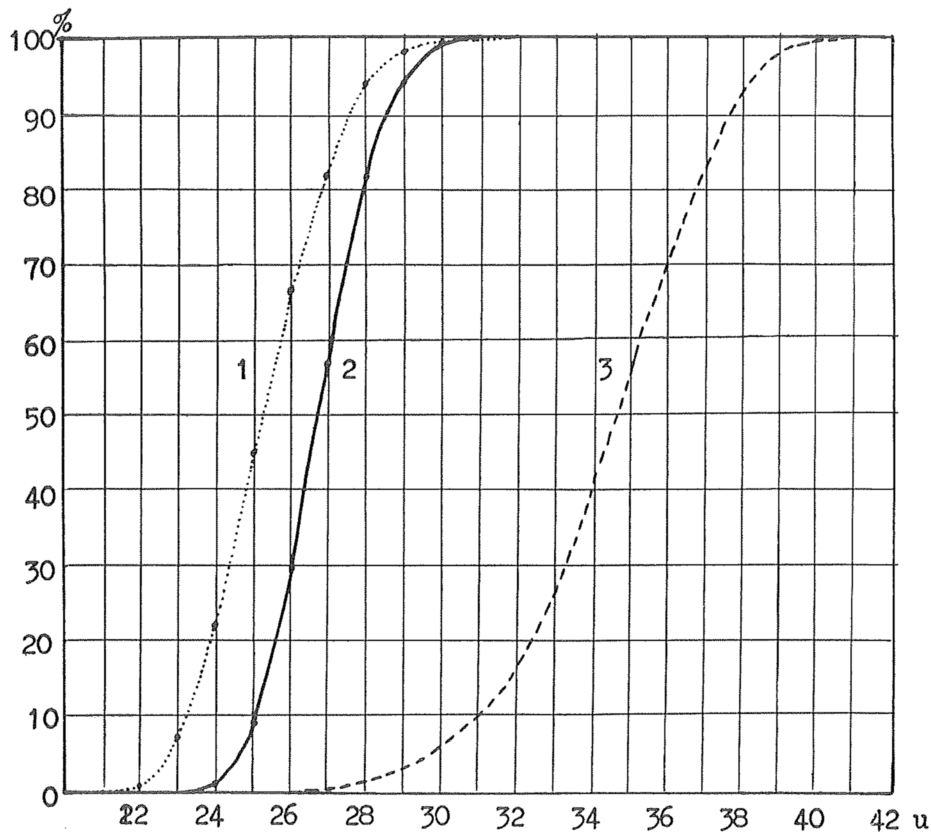


Fig. 4. Cumulative curves on Size sreqency of living pollen grains of *Quercus crispula* BLUME

Curve 1: After soaking in water for 1 day

Curve 2: After HF treatment for 1 day

Curve 3: Dry pollen grains without any treatment

* Though, as shown by curve 3, dry pollen grains are larger in size than those soaked for 1 day in water and HF acid, this fact may be attributable to the following reason: dry pollen grains of *Quercus crispula* are elongated ellipsoidal in shape, but the grains after the soaking in water or HF acid expand and approach spherical shape; such expansion of volume to approach spherical shape may cause reduction of the longet axis of these ellipsoidal grains.

be effected by the degree of the permeation of mineral matter; that is to say, effected by sedimentary condition in which the fossil pollen grains are included. At any rate, it may be necessary to pay attention to the contraction of size of fossil pollen grains, because the size of pollen grains is an important clue to their identity. But, there is no report paying attention to the contraction of size in fossil pollens.

V. On nomenclature of Tertiary fossil pollens and spores

Many arguments have been offered on the nomenclature of Tertiary fossil pollens and spores, but at present there is still no unified rule on the matter. To summarized briefly, some authors use artificial classifications and nomenclatures which are based on forms of grains and are independent of the natural classification of plants. POTONIE's, THOMSON's and PFLUG's systems are typical ones of such a classification and nomenclature. Under such classifications, even two pollens which are close in the taxonomic relation but different in their form, may be classified in very different positions. Also, even if two plants are very different in taxonomic position but the pollen is similar in forms, they may be classified in an organ-genus or an organ-species. On the other hand, opposite to such artificial classifications for pollens and spores, some authors for example TRAVERSE, propose to classify and to give the nomenclature in obedience to the natural classification of plants. In general, the problem of nomenclature of Tertiary fossil pollens and spores is: which classification should be adopted, artificial classifications or the natural classification, although also many other modified proposals have been offered.

On this problem of the nomenclature, the natural classification is now generally adopted for pollens and spores in the Quaternary sediments, and artificial classifications and nomenclatures for spores in Paleozoic sediments; so there is no confusion on the problem of nomenclature. But, only with respect to fossil pollens and spores of the late Cretaceous and Tertiary sediments such a problem is not yet settled. A reason why such a problem arises only in regard to the pollens and spores in the Tertiary (and late Cretaceous) sediments and not of them in the Quaternary and Paleozoic sediments, may be stated as follows under three heads: 1) on the fossil pollens and spores in the Quaternary sediments, the preservation of them is very good and almost all Quaternary fossil plants belong to living genera or species. So, provided he has enough information on recent vegetation, the student can confidently apply to them generic names (or sometimes even specific names) of living plants, 2) on the fossil pollens and spores in the Paleozoic sediments, they almost all belong to extinct plants which are not so well preserved as those of the Quaternary. Moreover, the fossil pollens and spores are rarely referable to macrofossil plants which have already been described. So, it is unavoidable that artificial classifications and nomenclatures are adopted for them, 3) the classification and nomenclature for the pollens and spores in the Tertiary sediments is situated between the above-described two cases: abundance in sort of plants, mixture of extinct and extant plants and variety in preservation of the fossil pollens and spores are all troublesome factors in the classification and nomenclature of Tertiary fossil pollens and spores. Of course, if it is possible, it is preferable to classify and to give fossil pollens and spores names in accordance with the natural taxonomic classification. But, when one considers many problems attendant with the nomenclature and classification for Tertiary fossil pollens and spores, it can be said to be inevitable in dealing with some cases that artificial classifications based on forms of pollens and spores have been adopted for Tertiary fossil pollens. Such artificial classifications are used by many authors, e.g., POTONIE, PFLUG and THOMSON, on Tertiary fossil pollens and spores. They have published many interesting and useful observations, though their results are more useful for stratigraphical purposes than for paleobotanical ones. However, the relationships between the natural classification and artificial classifications are ambiguous, for example, the organ-genus and organ-species do not correspond to the genus and species in the natural classification respectively; therefore many difficulties and complications occur when paleontological or paleoecological interpretations are attempted on the fossil pollens and spores of an artificial classification. Namely, when it is desired to discuss the fossil pollens and spores obeying to an artificial classification characters as a life, it is needful to relate them with the natural classification. Of course, though there is no objection to the use of an artificial classification for a private stratigraphic purpose, it is not adequate for universal stratigraphic correlation or paleontological or paleoecological interpretations in connection with other fossils which are classified according to the natural classification of life. At all events, it is only in the study of fossil pollens among the studies on fossils that completely artificial classifications and nomenclatures unrelated to the natural classification of life are found; such a situation is irrational. Especially, it is meaningless to give artificial names even to the pollens of which the generic names in the natural classification are known; TRAVERSES (1955, p. 89) spoke of such meaninglessness as "a gesture to uniformity." It is said by some authors who adopt artificial classifications that it is impossible to classify all Tertiary pollens according to the natural classification. But, it is necessary to have the following in mind: that is, though the relation of organ-genus and organ-species of artificial classifications to genus and species in the natural classification is not distinctly defined, it seems that the organ-species roughly corresponds to the genus or species in the natural classification. Now, identifications in the degree of organ-species are offered in many papers; accordingly, if it is possible to discriminate fossil pollens in the degree of organ-species, it should also not be impossible to classify the fossil pollens at the level of genera in the natural classification (even of species in some cases). As seen in pollen analytical studies on the Quaternary sediments, many items of important and useful knowledge (of climate, ecological condition and vegetational histories of the past, or geology or archaeology) are found even from the studies based on identification in the degree of genus. Besides, it is cleared up on the basis of knowledge regarding macrofossil plants that the vegetation in Tertiary age was almost common with the recent plants in respect to genera. So, if Tertiary fossil pollens are examined in conjunction with study on recent plants and macrofossil plants in the same sediments from which fossil pollens are found, it is expected that one can determine the positions of the fossil pollens in the natural classification with more certainty. As above mentioned, it is not always impossible to identify the genera in the natural classification of Tertiary fossil pollens and spores, though it is very difficult. In any case the writer is convinced that an endeavour must not be abandoned to attain to a pollen analysis based on the natural classification for Tertiary fossil pollens and spores. TRAVERSE offered a detailed discussion on such a problem and proposed a nomenclature for Tertiary pollens. The proposal is an expression of the endeavour to reach for the natural classification of Tertiary pollens, also the writer agrees in general with the above-noted author's opinion. TRAVERSE's proposal includes four points as follows:

"1) Pollen inseparable from an extant genus is referred to that genus, with an appropriate specific name, the same procedure that would be followed with specifically distinct material collected from modern plants. Note: The author has been conservative in not putting any of the Brandon pollen forms into extant species . Although there is no hard and fast rule that Tertiary pollen should not be placed in extant species, the author feels that such identification should not be made unless the corollary evidence is very strong.

(Example: *Vitis forestdalensis* sp. nov.

Alangium barghoornianum sp. nov.)

2) Pollen felt to be certainly representative of an extant family but not in a known genus, fossil or extant, is referred to a new genus of that family. In coining the name of the genus, conventional botanic practice is followed.

(Example: *Horniella* gen. nov.
Horniella clavaticosts sp. nov. (Rutaceae))

3) A well-characterized pollen form occurring abundantly in the deposit but of uncertain botanic relationships, is described as a member of an organ-genus, according to Pflug's system. But note that the particular organ-genera proposed by Pflug can be used only where they have been validly described. Kremp states that many of Pflug's genera are invalid because the type species have no holotype. Other organ genera, validly described, must replace such invalidated names.

(Example: *Tetradopollenites laxus* sp. nov.)

4) There are many pollen forms in the deposit not identificable with extant or fossil genera or families and about which there is doubt because of inadequate information as to range or size and structure. These are figured and described but not formally referred to a species. All the fossil pollen forms in this monograph were given catalogue numbers, and these "unknowns" can be referred to by number.

(Example: BT-65)"

The writer agrees with TRAVERSE in the opinion that Tertiary fossil pollens should be classified and named according to the natural classification of plants to the best of our ability. But, the present writer differs somewhat from TRAVERSE in only the following view-point: as seen in item 1) of the above-described proposal of TRAVERSE on the nomenclature, many fossil pollens were described by generic names of the recent plants and by new specific names. But, he did not report on the quantitative relationship of these species, but reported only on the genus. This will mean that discrimination of fossil pollens at the generic level may be possible, but the discrimination of species is very difficult. Now, as the quantitative dealing is an important element in pollen analysis, even if a species is newly established on the basis of fossil pollen, the species may not be of much use from paleobotanical and pollen analytical view-points unless the quantitative relation of it to other pollens and the relation to living species are clarified. But, such a point does not at all reduce the value of TRAVERSE's study; the writer is not in opposition as to giving specific names for fossil pollens, but he feels some doubts as to the character of the specific name to be given. That is, even if a fossil pollen in sediments is designated under a specific name, it is very difficult in many cases to find its affinity amongst the species of recent pollens or macrofossil plants found in the same deposit from which the fossil pollen was taken out. Accordingly, even though a specific name is given for a fossil pollen, it should be frequently impossible to decide whether or not the pollen species belongs that of macrofossil plants found in the same deposit. It is customary that a newly established specific name should not be abandoned or revised unless detailed and sufficient data to do so are found, but it is very difficult to find such detailed and sufficient data because other investigators who live in so remote place that they can not examine the new species under microscope with their own eyes may not be able to get detailed features of the new species through only simple description and photograph of it; description of fossil pollen grains is generally so simple that it does not express the characteristic feature of the species in very detailed manner, and also it can not be possible to convey to others the features under microscope of high magnifications by a printed photograph as well as by direct seeing. Scarcity of detailed data on new species for other investigators causes a situation that one can not neglect or affirm the new species positively; such a situation is infortunate (recently, T. YAMAZAKI and M. TANEOKA (1957, 1958) and J. UENO (1960, 1961) have reported on the discrimination of species of living pollen grains by using an electronic microscope, but under present conditions it is impossible to apply that method for fossl pollen grains). The writer is disturbed that, by TRAVERSE's proposal, a pollen belonging to a species of macrofossil plants already reported may be designated under a different specific name; though such a possibility is considered in other fossil remains, it occurs more frequently in fossil pollens than any other fossil remains. Moreover, as the specific name for a fossil pollen can not be discriminated according to TRAVERSE's nomenclature from one for a macrofossil plant by the name itself, it may be a cause of some confusion: namely, it is very probable that the number of species may become inflated because the same species of a plant may be given two different names, one as to its macrofossil and another to its pollen grain. TRAVERSE (1955, p. 86) has stated "fossil leaves referred to *Nyssa* are not, after all, described as species of *Nyssa-phyllites*", and it seems to be TRAVERSE's opinion that the designation of "specific names" for fossil pollen should be the same as that for macrofossil plants; the writer recognized it to be a desirable point, but in the present status of information about pollens (living and fossil) the specific nomenclature for fossil pollen in TRAVERSE's proposal may cause confusion rather than clarification. The present writer can not find a positive reason to give fossil pollens the "appropriate" specific name; he is convinced that a new specific name for fossil pollen must not be an "appropriate" one but much more consideration must be paid to the name to be given. Taking into consideration that palynology is much younger in its history than the study of macrofossil plants, the writer is of opinion that palynologists, a member of paleobotanists, should take much care not to throw confusion into accepted paleobotanical information.

From the above-described consideration the writer proposes the following dealing with the specific names of fossil pollens: it is preferable not to give fossil pollen any specific name which might be confusable with that of some macrofossil but it should be described under a name such as sp_1, sp_2 or sp .., with exceptions of some special cases like those where no other paleobotanical information is available of the sediments made an object of pollen analysis or where sufficient data is at hand to give a specific name. For example, when the present writer examined the fossil pollen and spores in the Hakobuchi group, the uppermost Cretaceous, from which which only a few macrofossil plants are reported, he found some pollen grains of *Podocarpus* which has not been reported from pre-Tertiary sediments in Japan and designated it as *Podocarpus ezoensis* SATO; besides, also when he examined specimens from the Hokutakukoishi coal mine, he found a sort of Taxodiaceae pollens occurring very abundantly; on the other hand, it is found from the study of macrofossil plants that *Metasequoia occidentalis* HU et CHANEY was very abundant, so he can surely identify the pollens as *Metasequoia occidentalis.*

In any case, it is a must to carry on the palynological study in cooperation with the study of macrofossil plants in order to get more rich result.

At last, it may be necessary to keep the following matter constantly in mind: though the writer has not had any chance to examine any foreign specimen of the Tertiary for the pollen analytical study, the Brandon lignite (Paleogene) investigated by TRAVERSE seems to be low in quality and the sediments which include the lignite are loose as judged from terms of silt, sand or clay in his description of them. The good preservation of fossil pollens reported by TRAVERSE may be due to such a nature of the sediments, and such good preservation may be a reason for TRAVERSE's proposal to use the natural classification for Tertiary fossil pollens and to say the following (TRAVERSE 1955, p. 13) : "the pollen and spore coats are the best preserved in original structure of all plant fossils and commonly permit exact comparison with living counterparts were easily than other fossil organs of plants." On the other hand, the Tertiary coal in our country and Germany seems to be higher in quality than the lignite investigated by TRAVERSE, and the preservation of fossil pollens in them seems to be not so good as seen in the latter; accordingly, investigators of them may intend to use artificial classifications for the fossil pollens and spores. Namely, such difference in the preservation of fossil pollens may be a cause of the difference in the nomenclature used for fossil pollens and spores.

VI. On the notation of pollen diagrams

Though various pollen diagrams are used by many authors, the writer uses an expression by bars of which the length represents the percentages of pollen frequency and of which the positions of the bars mean the positions from where samples are taken.

Fossil pollens belonging to Taxodiaceae are expressed in lump as Taxodiaceae in the diagrams. Such dealing is adopted by many authors because it is frequently very difficult to differentiate the fossil pollens of the genera of this family. Generic discrimination of Taxodiaceae pollens generally is based on the shapes of papilla and the size of the pollen grain, but fossil Taxodiaceae pollens in the Tertiary sediments are so deformed or damaged that it is not rare that the papilla could not be recognized and even determination whether or not the pollen belongs to Taxodiaceae is difficult. Accordingly, the present writer puts the Taxodiaceae pollens into one group.

Furthermore, Betulaceae excepting *Alnus* are represented in one lump. Generic determination of Betulaceae pollens is mainly based on the shape of protrusion, structure and thickness of the pollen membrane around the germinal pores, and size of pollen grain. Of the generic discrimination of Betulaceae pollens many authors have reported mainly about living pollens; but, some fossil pollens in the Tertiary sediments do not allow a clear examination of the structure of the pores, and moreover, there are some pollens which have intermediate forms of the typical forms of each genus; furthermore, the deformation and damage of fossil pollen samples make the generic discrimination difficult. Though the writer makes Betulaceae into a bundle with division in proportion to the rate of each genus, such an expression is based on the above-noted consideration and means that error of percentage values of genera occurs to some degree.

Also the reason why *Ulmus* and *Zelkova* are shown together is owing to difficulty of discrimination. JIMBO (1933) stated that the pollen membrane around the germinal pores is thicker in *Zelkova* than in *Ulmus*. But, RUDOLPH (1935) wrote as follows: "Der Pollen gleicht volkommen rezentem und alluvialfossilem *Ulmus*-Pollen. Die gleiche Gestalt und Grössenordung zeigen aber auch *Zelkowa*-Arten, so dass eine generische Unterscheidung vorläufig noch nicht möglich ist. JIMBO gibt als unterscheidendes Merkmal für die japanischen *Zelkowa*-Arten an, dass hier die Exine gegen die Keimporen hin stärker verdickt ist als bei *Ulmus*. Bei meinem Vergleichsmaterial von *Zelkowa cretica* Spach. fand ich diesen Unterscheid nicht bestätigt." If JIMBO's discrimination is true regarding recent Japanese plants, as plants in the Miocene age may differ from the recent in species, it can not always be possible to apply similar discrimination to Tertiary fossil pollens, but there may be such a case as described by RUDOLPH. Also it is not rare in present writer's experience that the discrimination of *Ulmus* and *Zelkova* by means of photographs and description is very difficult in many foreign papers. Based on the abovementioned considerations the writer represents them together in pollen diagrams.

Such a matter as described above could also be applied for *Rhus* and *Nyssa*. Namely, according to RUDOLPH who wrote in detail on the two genera, the discrimination is possible based on contour in the polar view and structure of membrane at the germinal pores; the difference of the structure of the germinal pores is well illustrated also in the figures by I. M. POLKOVSKAYA and others (1956) ; but, this discrimination is difficult in the case of fossil pollens under microscope. Accordingly, the writer dares to represent together the two genera into a bar with division which shows the frequency of their occurrence.

As will be understood from the above considerations, the representation by a bar in which different genera are united with division in proportion of their frequencies means that some mutual errors in their percentages may be included.

Percentages of herbaceous plants as Polypodiaceae, *Osmunda*, Lycopodiaceae, Nymphaeaceae etc. are shown by proportion to the total tree pollens.

VII. Results of pollen analysis in each locality

For the establishment of the standard succession of pollen floras in the Miocene sediments in Hokkaidô, it presents great difficulty that the stratigraphic positions of the Miocene sediments are not yet settled but that the correlation of the sediments is differently set down by many authors. Moreover, there is no authoritative report on fossil pollens in the Miocene sediments in Hokkaidô to be compared with and referred to.

Recently, Dr. T. TANAI (1961) has reported that the floral succession in the Miocene sediments in Japan is as follows in ascending order in age: the Ainoura-, Aniai-, Daijima- and Mitoku-type floras, but that the oldest has not been found in Hokkaidô. The present writer will describe his results of pollen analysis with checking against TANAI's results. The pollen floras are classified in the Miocene sediments in Hokkaidô by the present writer: the pollen floras of the Fukuyama, Takinoue, Kawabata and Wakkanai stages in ascending order:

1. Pollen floras of the Fukuyama stage

The floras of the Fukuyama stage is the same as the Aniai-type flora after TANAI. He gave the following floras as representatives of the Aniai-type: the flora of the Kinoko and Kayanuma formations in Southwest Hokkaidô, the Sôya coal-bearing formation in the Tempoku coal field, the Asahi coal-bearing formation in the central Ishikari region, the Nokanan coal-bearing formation in the northern Ishikari region, the Honjin-no-sawa coal-bearing formation in the Rumoe coal field and the Niikappu coal-bearing formation in the Hidaka coal field. Among these, the writer considers that of the Asahi coal-bearing formation to belong to the Daijima-type flora, and that of the Sôya coal-bearing formation to be similar to the Aniai-type flora in floral composition but to be different in stratigraphic position from the Aniai-type flora: that is, it is hgiher in stratigraphic position than the Aniai- and Daijima-type floras. Also, whether or not the floras of the Honjin-no-sawa and Niikappu coal-bearing formations are the Aniai-type could not be determined with firm confidence according to the writer's present pollen analytical data because the distribution areas of both formations are so complicated in geologic structure that the stratigraphic positions of them are not yet settled. The pollen floras of the above-mentioned formations will be described below.

1A. Kinoko area

The sampling locality is about 8 km southwest from the Kaminokuni station of the Esashi line (Figs. 1 and 5). It was reported that two coal seams (246 cm and 194 cm in thickness) exist in the formation in this locality and they were worked in the past, but when the writer visited them for sampling the mine was in ruin and no exposure of the seams could be found. So, the samples were collected from coal which was remained on the site of the old pit.

The pollen flora in the samples comprises those of *Tsuga*, *Pinus*, Taxodiaceae, *Juglans*, *Pterocarya*, *Carya*, *Alnus*, *Betula*, *Carpinus*, *Corylus*,

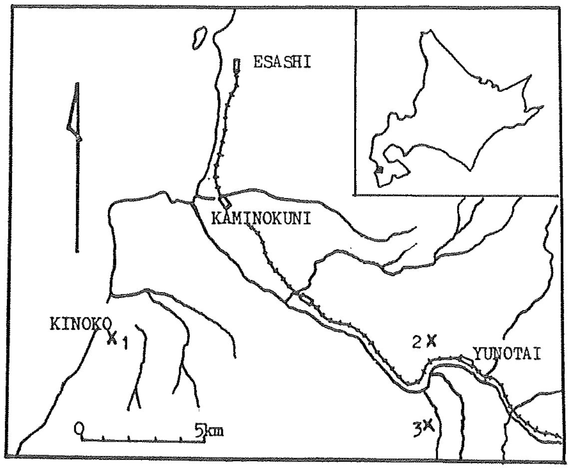


Fig. 5. Locality map of samples from the Kaminokuni and Yunotani area
1: Kinoko, 2: Garo-no-sawa, 3: Tsuratsura-zawa

Fagus, Ulmus, Zelkova, Tilia, Ericaceae and very abundant spores of Polypodiaceae and some sorts of indterminable pollens and spores. The relative abundance of them is shown in Fig. 6. As is seen from the figure, there is no very dominant genus among them which feature may be a characteristic of the present pollen flora. The absence of *Liquidambar,*

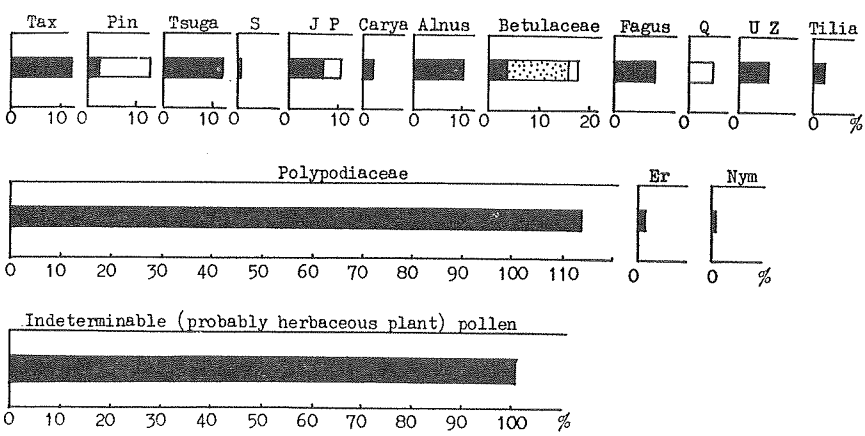


Fig. 6. Composite pollen diagram of Kinoko, Kaminokuni
Tax: Taxodiaceae, Pin: Pinaceae (black *Pinus*), S: *Salix*, JP: *Juglans* (black: *Betula*, dotted: *Carpinus*, white: others and indeterminable ones), UZ: *Ulmus* and *Zelkova*, Er: Ericaceae, Nym: Nymphaeacae

the poorness of *Quercus*, and the relatively common occurrence of *Tsuga*, *Picea*, *Juglans*, *Pterocarya* and Betulaceae are features clearly different from the Daijima-type flora.

T. TANAI (1961), investigated the flora in this formation of the same locality, reported the floristic composition as illustrated in Table 1, and determined the flora to be Aniai type. The present writer agrees

TABLE 7. Relative abundance of species in the Kaminokuni flora (after T. TANAI)

Fossil species	No specimens	Percentage
Carpinus subcordata NATHORST	189	20.8
Corylus macquarri (FORBES) HEER	125	13.7
Alnus usyuensis HUZIOKA	100	11.0
Carpinus miofangiana HU et CHANEY	68	7.5
Betula uzenensis TANAI	46	5.1
Ulmus shiragica HUZIOKA	46	5.1
Ulmus longifolia UNGER	45	5.0
Betula mioluminifera HU et CHANEY	44	4.8
Tilia subnobilis HUZIOKA	43	4.7
Acer subpictum SAPORTA	39	4.3
Tilia distans NATHORST	20	2.0
Fagus antipofi HEER	13	1.4
Glyptostrobus europaeus (BRONG.) HEER	9	1.0
Carpinus subyesoensis KONNO	9	1.0
Betula sp.	7	0.8
Populus nipponica TANAI et SUZUKI	7	0.8
Salix sp.	7	0.8
Ostrya huziokai TANAI	6	0.7
Pterocarya asymetrosa KONNO	5	0.6
Carpa miocathayensis HU et CHANEY	5	0.6
Viburnum miocenicum TANAI et SUZUKI	5	0.6
Ostrya subvirgiana TANAI et ONOE	4	0.4
Carpinus stenophylla NATHORST	3	0.3
Picea ugoana HUZIOKA	3	0.3
Thujopsis miodorabrata TANAI et SUZUKI	3	0.3
Hydrangea lanceolimba HU et CHANEY	3	0.3
Phellodendron mioamurensis TANAI et ONOE	2	0.2
Zelkova ungeri (ETTINGS.) KOVATS	2	0.2
Picea magna MACGINITIE	2	0.2
Acer ezoanum OISHI et HUZIOKA	2	0.2

Fossil species	No Specimens	Percentage
Fraxinus sp.	2	0.2
Equisetum sp.	1	0.1
Abies n-suzukii TANAI	1	0.1
Picea hiyamaensis TANAI et SUZUKI	1	0.1
Tsuga miocenica TANAI	1	0.1
Cercidiphyllum crenatum (UNGER) BROWN	1	0.1
Platanus aceroides GOEPPERT	1	0.1
Buxus protojaponica TANAI et ONOE	1	0.1
Celastrus mioangulata HU et CHANEY	1	0.1
Acer palaeorufinerve TANAI et ONOE	1	0.1
Acer protojaponicum TANAI et ONOE	1	0.1
Acer protonegundo TANAI	1	0.1
Rhododendron sp.	1	0.1
Hemitrapa cfr. *hokkaidoensis* (OKUTSU) MIKI	1	0.1
Trapa ezoana TANAI et ONOE	1	0.1
Total	908	100.0

with TANAI's opinion based on the pollen floral composition. However, there are some differences between the relative abundance values of pollens and macrofossil plants in each genus as described in following.

The following values of the relative abundance of each genus are calculated from Table 7:

Carpinus 29.6%, *Corylus* 13.7%, *Alnus* 11 %, *Betula* 10.7%,
Ulmus 10.1%, *Tilia* 6.7%, *Acer* 4.8%, *Ostrya* 1.1%,
Glyptostrobus 1.0%, *Populus* 0.8%, *Salix* 0.8%, *Pterocarya* 0.6%,
Carya 0.6%, *Picea* 0.6%, *Zelkova* 0.2%,
conifers 2.1% (*Glyptostrobus* 1.0%, *Picea* 0.6%, *Abies* 0.1%, *Tsuga* 0.1%)

Comparing the above-noted values with those of pollens (refer to the pollen diagram shown in Fig. 6), the most distinct difference between the two is seen to be the much less occurrence of conifers among the macrofossil plants. Though the writer can not say with conviction to what cause the difference is due, the following matter may be considered as the cause. That is to say, the coal-forming basin at that time was poor in non-arboreal plants as shown by the predominance of Polypodiaceae, ferns. So, the pollens of arboreal plants came flying from the high-land surrounding the basin at that time. Also macrofossils of the arboreal plants might have been supplied from the area surrounding the basin. In such cases, it is considered with much probability that pollen grains were supplied into the basin from much more remote areas than other vegetational organs were. Accordingly, the pollen flora may include elements from higher land than the flora of the macrofossil plants. Conifers which are dominant in the pollen flora may represent such an element of high-land vegetation. Besides, it must be remembered that the pollen flora is taken from coal itself but macrofossil flora from the roof of the coal seam: that is to say, sediments from which the pollen flora and the macrofossil flora occurs are not the same in the strict sense of the term. As is noted above, the difference in composition of the macrofossil flora and the pollen flora may be due to the difference in horizon of collection and in facility of transportation of the pollens and the macrofossil plants. Besides, the absence of *Acer* pollen may be due to the destruction of the pollen owing to the low resistivity of the pollen membrane to chemical or bacterial attacks as has been reported by many earlier authors. Also, the less occurrence of *Tilia* pollen in comparison with the relative abundance of its macrofossil remains may be due to the less production of pollen of *Tilia,* an entomophilous plant, as is generally stated.

At any rate, the present pollen flora represents a feature of the Aniai-type flora, especially in abundance of conifers and Betulaceae and accompaniment of Juglandaceae, Ulmaceae and *Fagus* with common frequencies; it is clearly different from the pollen floras of the Daijima-type in the feature that there is in the pollen flora no element indicating a warm climatic condition.

1B. Kayanuma coal mine

This mine is situated on the western side of the base of the Shakotan peninsula, protruding into the Japan Sea (Fig. 1). Samples for pollen analysis are taken from a coal seam in the Kayanuma coal-bearing formation which is considered to be Fukuyama stage in age although there are some disagreements as to its detailed stratigraphic position. Coal from the present mine is various in quality from non-coking sub-bituminous in the southern part of this mine to strong coking bituminous coal in the northern part where there is an intrusion of igneous rock which seems to have an effect upon the coal quality; the writer could not take out fossil pollens from the latter in good state for examination under microscope. The observations reported in this paper are derived from a coal seam at the Chazu pit, southern part of this mine.

The result of the pollen analysis of these samples is shown in Fig. 7. Though the pollen flora varies in composition through the seam from the bottom to the top, it indicates rather cool temperate climatic condition on the whole in respect to the following features: the lack of pollens of warm~

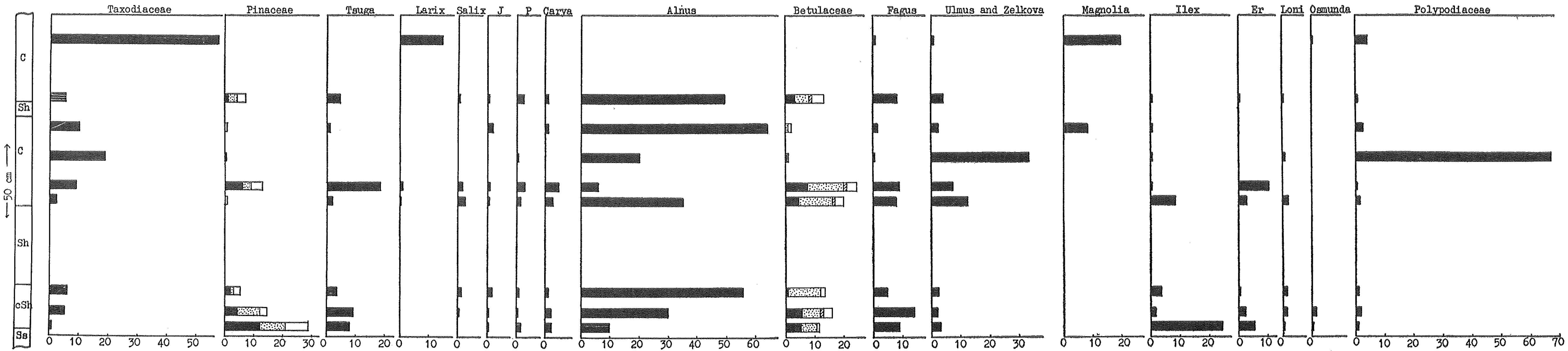


Fig. 7. Composite pollen diagram for the Kayanuma mine (Chazu pit area)

Pinaceae: (black: *Pinus*, dotted: *Picea*, white: others and indeterminable ones), J: *Juglans*, P: *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*, white: others and indeterminable ones), Er: Ericaceae, Loni: *Lonicera*, warm-temperate loving plants as *Liquidambar* or *Cinnamomum*, and the dominance of coniferous pollens as *Tsuga, Larix, Picea,* etc. Moreover, the lack of *Quercus*, a dominant element of the Daijima-type flora, and *Liquidambar* and *Rhus* etc., common elements of the same flora, represents a clear difference from that type. The main components of this pollen flora are *Alnus*, Taxodiaceae, Pinaceae, *Carpinus, Fagus, Ulmus* and *Zelkova*, and a characteristic feature of this flora is the rather high frequencies of *Magnolia, Larix* and *Ilex* at some portions of the seam. Such change in frequency is recognized of all pollens in this flora as illustrated in the pollen diagram and may have some relationship with the phenomenon that the parts containing pollens and without pollen exist in alternation in the main part of the seam. That is, such change in the quantity of pollens contained may mean that some change in environment in the coal forming basin might have occurred during the coal formation, and the change in the environment might affect the flora which existed on the coal forming basin and surrounding area. The following average values of frequency of each pollen are calculated from the pollen diagram: Pinaceae excluding *Tsuga* and *Larix* 8 per cent (*Picea* 3 per cent, *Pinus* 3 per cent), *Tsuga* 5 per cent, *Larix* 2 per cent, Taxodiaceae 14 per cent, *Pterocarya* 1 per cent, *Carya* 2 per cent, *Alnus* 31 per cent, Betulaceae excluding *Alnus* 11 per cent (*Betula* 3 per cent, *Carpinus* 6 per cent), *Fagus* 6 per cent, *Ulmus* and *Zelkova* 9 per cent, Magnoliaceae 4 per cent, *Ilex* 4 per cent, Ericaceae 3 per cent, Polypodiaceae 9 per cent; in addition, *Osmunda, Salix, Juglans, Fraxinus?, Acer, Lonicera,* Compositae, *Alangium?*, Rosaceae, *Corylus*, etc. are recognized with frequencies under 1 per cent. Such a floral composition is similar to the pollen flora of the Kinoko formation; it is shown also in the pollen floras that both of them are Aniai-type as is stated by TANAI on basis of his study of macrofossil plants. However, an unsolved problem is remaining as regards this conclusion: viz., there are some publications which report the occurrence of *Liquidambar* and *Comptonia*, characteristic members of the Daijima-type flora, from the present mine. Accordingly, in order to ascertain whether or not the flora from the present formation is an Aniai-type flora, the stratigraphic horizon must be known from where *Liquidambar* and *Comptonia* are collected.

Though macrofossil plants are not very abundant from the present formation in the present mine, the following plants were determined by TANAI and the flora to be the Aniai-type flora:

Carpinus subcordata NATHORST
Fagus antipofi HEER

Platanus aceroides GOEPPERT
Aesculus majus (NATHORST) TANAI
Hemitrapa borealis (HEER) MIKI

2. Pollen floras of the Takinoue stage

The floras of this stage are recognized in the following sediments: the Yoshioka and Kunnui formations in Southwest Hokkaidô, the Asahi coal-bearing and Takinoue formations in the Ishikari coal field, the Haboro and Tomamae coal-bearing formations in the Tomamae coal field and the Sôya coal-bearing formation in the Tempoku coal field. It is accepted that the Takinoue stage is characterized by the Daijima-type flora which indicates a temperature~warm temperate climatic condition, but the writer is of a different opinion that the flora being similar in composition with the Aniai-type flora existed in the later part of this stage in the Tempoku coal field. That is to say, the writer considers the following items to belong to the flora of the later part of this stage: the floras in the Sôya and Tomamae coal-bearing formations both of which indicate cool temperate climatic conditions. The former of them has been considered to be an Aniai-type flora or to be correlated to the flora in the Haboro coal-bearing formation. The writer showed this later part of the Takinoue stage in the Tempoku and Tomamae region under the name of Sôya-Tomamae "stage" in Fig. 1.

2A. Yunotai coal-bearing area

Samples for pollen analysis were taken from two sites which about 4 km distant from each other around Yunotai station; the two points are at Tsuratsura-zawa and Garo-no-sawa (Figs. 1 and 5). The samples were collected from a coal seam in the Yunotai coal-bearing formation which was worked in the past but the mines are in ruin at present. The formation is correlated to the Yoshioka formation which yields the Daijima-type flora according to some authors, or to a part of the Kunnui formation which is higher in stratigraphic horizon than the Yoshioka formation as stated by others.

The sample from Garo-no-sawa is so poor in preservation and quantity of contained pollens and spores that only a few grains of *Alnus* and *Zelkova*? and Polypodiaceae are seen, while the sample from Tsuratsura-zawa is rich in well preserved pollens and spores. The composition of the pollen flora in the latter is shown in the pollen diagram of Fig. 8. A characteristic feature of this flora is the overwhelming occurrence of *Alnus,* of which pollen is commonly found in all coal examined by the writer with frequent showing of overwhelming abundance in certain samples. As the present sample was taken from the upper part of the

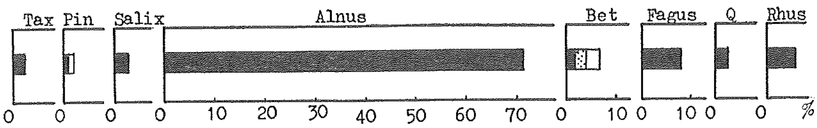


Fig. 8. Composite pollen diagram of the sample from Tsuratsura zawa, Yunotai Tax: Taxodiaceae, Pin: Pinaceae (black: *Pinus*), Q: *Quercus*, Bet: Betulaceae (black: *Betula*, dotted: *Carpinus*)

coal seam (other parts were so bad in exposure that the writer could not make any excavation), the change in composition of the pollen flora through this seam from the bottom to the top can not be observed. Such features as the absence of *Liquidambar* and the slight occurrence of *Quercus* and Taxodiaceae, make the writer presume that this pollen flora is different from that of the typical Daijima type. The accompaniment of *Rhus* is a characteristic feature. The present pollen flora is similar in composition to that of the Chatsu formation, Kunnui stage, in Okushiri island (Fig. 10) and to that of the Honjin-no-sawa coal-bearing formation in the Rumoe coal field (Fig. 33). The writer is inclined to correlate the Yunotai formation to the Kunnui formation based on the similarity of the pollen floras and to assume this pollen flora to be later in age than the typical Daijima-type flora.

2B. Wakamatsu coal mine

The sampling locality is about 15 km south of Higashisetana-machi on the Setana line (Fig. 1) ; the area neighbouring this mine is called the Kudô coal-bearing area. Samples were collected from a coal seam (110–350 cm in thickness) in the Kudô coal-bearing formation which overlies the Fukuyama formation with an unconformity and is correlated to the Yoshioka formation in the more southern district.

The results of pollen analysis of this coal seam are shown in Fig. 9. The characteristic feature of this flora is the predominance of *Fagus* and Ulmaceae and the accompaniment of *Quercus* and *Liquidambar* and Rosaceae. From the diagram of Fig. 9 the following values are calculated:

Zelkova and *Ulmus*	41 per cent	*Pterocarya*	3 per cent
Fagus	28 ,,	*Carya*	3 ,,
Juglans	5 ,,	*Tilia*	2 ,,
Carpinus	4.5 ,,	*Alnus*	2 ,,
Quercus	3.5 ,,	*Liquidambar*	1.5 ,,

On the other hand, abundant macrofossil plants occur from the roof of this coal seam. T. TANAI (1961) reported on the fossil flora in detail

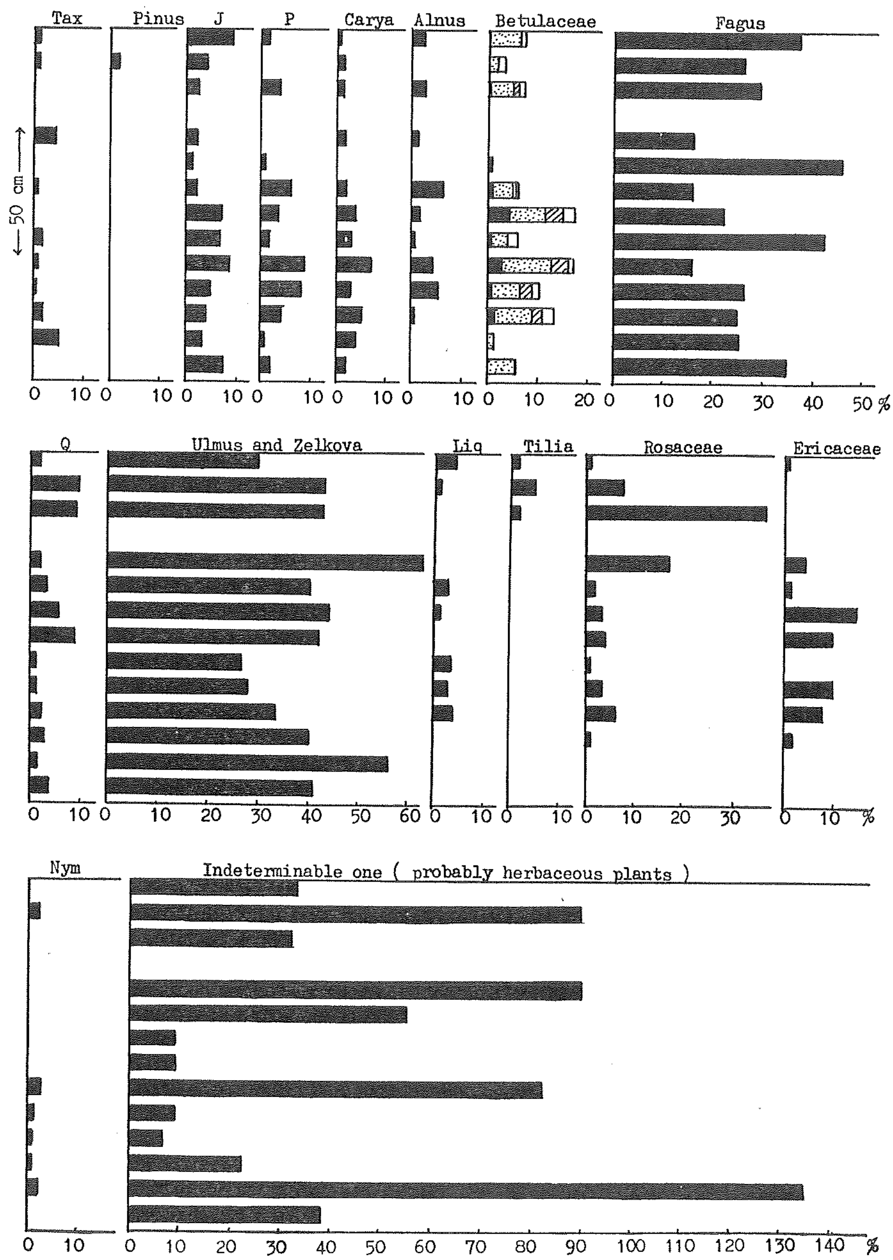


Fig. 9. Composite pollen diagram of the Wakamatsu coal mine
Tax: Taxodiaceae, J: *Juglans*, P: *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), Q: *Quercus*, Liq: *Liquidambar*, Nym: Nymphaeaceae

TABLE 8. Relative abundance of species in the Wakamatsu flora (after T. TANAI)

Fossil species	No Specimens	Percentage
Quercus sinomioceniun HU et CHANEY	98	26.7
Castanea ungeri HEER	76	20.7
Fagus antipofi HEER	32	8.7
Zelkova ungeri (ETTINGS.) KOVATS	20	5.4
Quercus subvariabilis TANAI	18	4.9
Carpinus miofangiana HU et CHANEY	14	3.8
Carpinus subcordata NATHORST	12	3.2
Acer ezoanum OISHI et HUZIOKA	11	2.9
Picea magna MACGINITIE	10	2.7
Pinus miocenica TANAI	7	1.9
Alnus protomaximowiczii TANAI	6	1.6
Abies aburaensis TANAI	5	1.3
Picea kanoi HUZIOKA	4	1.1
Carya miocathayensis HU et CHANEY	4	1.1
Alnus miojaponica TANAI	4	1.1
Acer protonegundo TANAI	4	1.1
Picea ugoana HUZIOKA	3	0.8
Myrica (Comptonia) naumanni (NATHORST) TANAI	3	0.8
Quercus miocrispula HUZIOKA	3	0.8
Acer peseudoginnala TANAI et ONOE	3	0.8
Picea miocenica TANAI	2	0.5
Picea kaneharai TANAI et ONOE	2	0.5
Metasequoia occidentalis (NEW.) CHANEY	2	0.5
Pterocarya asymetrosa KONNO	2	0.5
Keteleeria ezoana TANAI	1	
Pseudotsuga ezoana TANAI	1	
Thuja nipponica TANAI et ONOE	1	
Juglans miocathayensis HU et CHANEY	1	
Betula mioluminifera HU et CHANEY	1	
Carpinus miofangiana HU et CHANEY	1	
Carpinus subyedoensis KONNO	1	
Ulmus longifolia UNGER	1	4.8
Magnolia miocenica TANAI	1	
Rhus miosuccedanea HU et CHANEY	1	
Robinia nipponica TANAI	1	
Acer protojaponicum TANAI et ONOE	1	
Tilia distans NATHORST	1	
Camellia miocenica TANAI et ONOE	1	
Hemitrapa borealis (HEER) MIKI	1	
Fraxinus sp.	1	
Total	367	100.7

and determined this flora to be a Daijima-type flora. The floristic composition in this formation is reported by him as (his) Table 7 and the following values of the percentage of each genus are got from his table:

Quercus	32.4 per cent	*Zelkova*	5.4 per sent
Castanea	20.7 ,,	*Acer*	4.0 ,,
Fagus	8.7 ,,	*Alnus*	2.9 ,,
Carpinus	7.6 ,,	*Pinus*	1.9 ,,
Picea	5.6 ,,		

As is clearly seen from the above-stated values, it is noteworthy that the values of the percentage of each genus calculated from the occurrence of macrofossil plants difinitely differs from the values for the pollen flora. Namely, they are different in the following six features; 1) especially, while *Quercus* and *Castanea* are main components and *Fagus* and *Zelkova* are not so abundant in the macrofossils, *Quercus* and *Castanea* are not so abundant and *Fagus* and Ulmaceae (*Ulmus* and *Zelkova*) are main components in the pollen flora, 2) besides, pollen grains of Pinaceae are scarcely found (the writer could find only two grains of Pinus among about three thousand grains examined), 3) while the frequencies of *Juglans* and *Pterocarya* pollens are greatest in frequency of specimens of all samples examined by the writer in the present study, the two genera are not so prominent in the macrofossil remains, 4) *Liquidambar* is not found in macrofossil remains, 5) as it is generally said that an insect-pollinating (entomophilous) plants is poorer in pollen production than an anemophilous plant, it is presumed that the trees of *Tilia*, an entomophilous plant, were more abundant than presumed from the value of pollen frequency. Nevertheless, the frequency of macrofossils of *Tilia* is under 1 per cent: the percentage of the macrofossils of *Tilia* reaches 6.7 per cent with accompaniment of value of 2 per cent of the pollen grain at Kinoko area, and 6) though macrofossils of *Acer* are rather commonly found (4 per cent), no *Acer* pollen is recognized.

To what causes are these differences due? Though the writer can not elucidate the difference, the following points are considered as a probable causes: that is, the sampling horizons of the macrofossils and the pollens are not the same in the strict sense as the macrofossil plants are collected from the roof of the seam while the pollens are from the coal itself. Into a coal forming swamp (which existed in the present area at that time) with many herbaceous plants, many sorts of pollen were supplied from the surrounding area of the swamp where low-land or swampy plants were growing and accordingly the pollen flora in the coal comprises a mixture of pollens both from plants on the higher land surrounding the basin at the time of coal forming and from swampy plants. The coal forming process in the swamp was suddenly interrupted by the depression of the basin caused by some reason—this is represented by the sharp boundary of the coal seam and its roof. The swamp flora was killed off by such a depression and clastic material was deposited with remains of plants growing on the area surrounding the basin. Accordingly, the flora of the roof composed of the clastic material are poorer in swampy elements. Such facts as the dominance of *Quercus* and *Castanea*, rather common occurrence of conifer, and the absence of *Liquidambar* in the macrofossil flora and the rather common occurrence of *Ulmus* and *Juglans* with the accompaniment of *Liquidambar* in the pollen flora might be accounted for by the above-noted supposition (According to TANAI's opinion, the association of the above-described macrofossil plants is dominant in the slope elements and includes high-land elements). Besides, the paucity of *Acer* pollen may be due to the fact that the pollen is so easily destroyed that it is scarcely left as a fossil.

2C. Chatsu formation in Okushiri island

Samples were taken from two thin coal seams included in marine sediments of the Chatsu formation in the northern part of the island (Fig. 1). The Chatsu formation yields *Operculina* sp., *Pecten* sp., *Ostrea* cfr. *gravitesta* YOK., *Cultellus izumoensis*, *Macoma dissimilis* MART., *Acila mirabilis*, *Turritella* sp., *Vicarya japonica**, *Vicaryella* sp.*, etc. and is correlated to the Kunnui formation, middle Miocene.

Following pollen grains are recognized: Taxodiaceae, *Pinus*, *Picea*, *Tsuga*, other indeterminable Pinaceae, *Salix*, *Juglans*, *Pterocarya*, *Carya*, *Alnus*, *Betula*, *Carpinus*, *Fagus*?, *Quercus*, *Castanea*?, *Ulmus*, *Zelkova*, *Liquidambar*, *Ilex*, *Tilia*, and some other indeterminable pollens in the sample from Locality 1; Taxodiaceae, *Pinus*, *Tsuga*, *Larix*?, other indeterminable Pinaceae, *Salix*?, *Juglans*, *Carya*, *Alnus*, *Carpinus*, *Ulmus*, *Zelkova*, *Liquidambar*, *Magnolia*?, and some other indeterminable pollens from Locality 2 (the distance between Localities 1 and 2 is about 400 m). Their quantitative relationship is illustrated in Fig. 10. It is noteworthy that this flora is clearly different in composition from the Daijima-type flora which is expected to occur in this horizon in connection with the occurrence of a warm current molluscan fauna such as *Vicarya* and *Vicaryella*. That is to say, the abundant occurrence of *Quercus*, accompanied with common frequency of *Liquidambar*, *Nyssa*, *Cinnamomum*, etc. and richness in kinds of plants which are characteristic features of the

* S. UOZUMI & T. FUJIE (1961): The Cenozoic Research No. 33, p. 11.

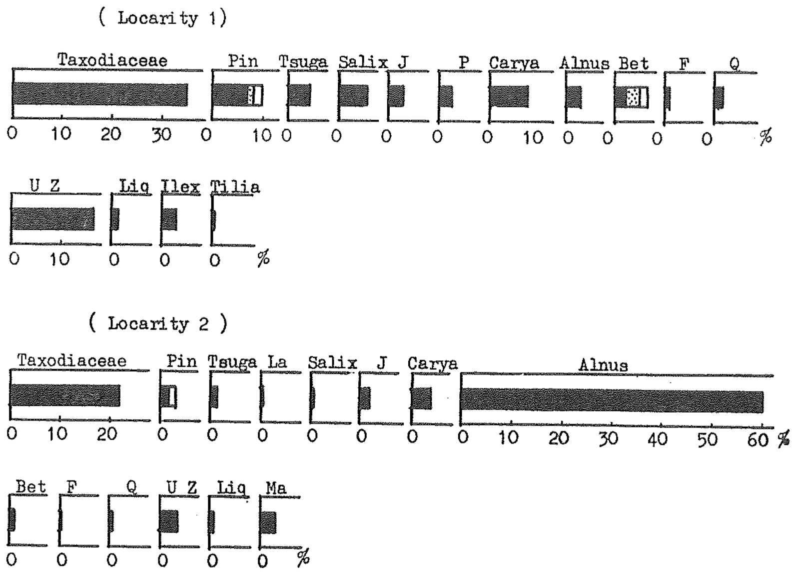


Fig. 10. Composite pollen diagrams of the Chatsu formation in Okushiri island Pin: Pinaceae (black: *Pinus*; dotted: *Picea*; white: others and indeterminable ones), La: *Larix*, J: *Juglans*, P: *Pterocarya*, Bet: Betulaceae (black: *Betula*; dotted: *Carpinus*; white: others and indeterminable ones), F: *Fagus*, Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Liq: *Liquidambar*, Ma: Magnoliaceae

Daijima-type flora are not recognized in this flora. Though the pollen analytical results of the two samples which are collected at two points, distant about 400 m from one another but not so different in stratigraphic horizon, are different in composition, the general feature of these floras are characterized by the abundance of Pinaceae, Taxodiaceae, Betulaceae (especially *Alnus*), and by the accompaniment of Juglandaceae, Ulmaceae and *Liquidambar*, though the last is scarce in number of specimens. The present pollen flora is similar in composition, especially in the abundance of *Alnus*, to the pollen floras of the Yunotai formation, the Kunnui or Yoshioka stage, and of the Honjin-no-sawa coal-bearing formation.

2D. Haboro coal-bearing formation

These localities are shown in Figs. 1 and 11. The stratigraphic succession of the Miocene in this area is as follows in ascending order: the Haranosawa, Haboro (coal-bearing), Sankebetsu, Tomamae* (coal-bearing), Chikubetsu, Kotanbetsu and Chepotsunai (or Ogawa lignite-bearing) formations. Detailed description on the stratigraphical succession is

* The writer first gives this name in the present paper.

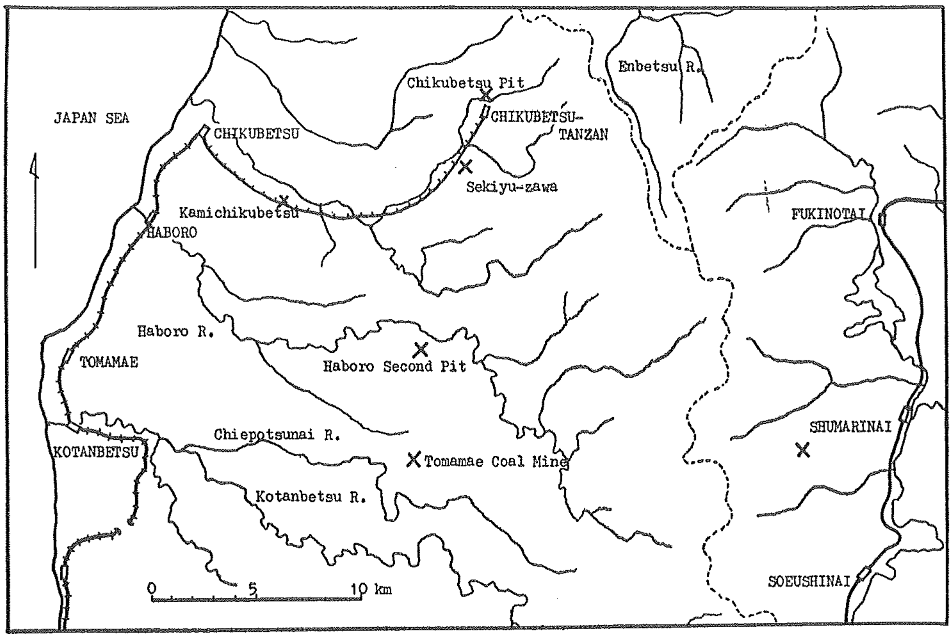


Fig. 11. Locality map of samples from the Tomamae coal field

discussed above in Chapter III and below in Chapter VIII. Though carbonaceous matter is included in the Haboro, Tomamae, Kotanbetsu and Chepotsunai formations, the main coal-bearing formation in the present area is the first. The most important one of several coal seams included in the formation is the so-called "Haboro main-seam", which is actively worked in the present mine, an important one in Hokkaidô. Coal of the seam is good in quality (sub-bituminous coal) and the seam is rather stable in thickness and is scarce in parting. The thickness of the seam is about 1 m in the Haboro second pit, however it thickens in the Chikubetsu main pit (sometimes reaches 4 m). Sample for the present study were taken from the "main seam".

Though the Haboro coal-bearing formation does not yield abundant macrofossil plants so there is no report describing the fossil plants in details, the flora was determined to be Daijima-type by T. TANAI* in 1961. The following macrofossil plants are reported up to the present: *Metasequoia occidentalis, Pterocarya asymetrosa, Carya miocathayensis, Car-*

* T. TANAI reported in 1955 that the flora of the present formation is the Aniai-type, but the determination is based on not adequate specimens. With the increasing of knowledge of fossil plants, he has recently re-determinated it to be the Daijima-type flora.

pinus subcordata, Coculus heteromorpha, Acer sp., *Populus latior, Zelkova ungeri, Sophora miojaponica, Tilia* sp., *Alangium aequalifolia* etc. (after TANAI).

Already (1960) the writer has found the following pollens from the Haboro coal-bearing formation and determined the flora to be of Daijima type based on them: *Picea, Pinus, Pseudolarix, Keteleeria, Tsuga,* Taxodiaceae (*Metasequoia, Glyptostrobus, Taxodium*? and others), *Salix, Juglans, Pterocarya, Engelhardtia, Alnus, Betula, Carpinus, Ostrya*?, *Fagus, Quercus, Castanea, Ulmus, Zelkova, Morus, Myrica* Nymphaeaceae, Magnoliaceae, *Cinnamomum, Liquidambar, Rhus, Ilex, Acer, Tilia, Nyssa, Alangium, Viburnum*?, Ericaceae, Sapotaceae, *Lonicera, Typha,* Oleaceae?, Violaceae? *Symplocos*?? and several other indeterminable pollens and many sorts of spores. The quantitative relationship of them is shown in Figs.* 12 and 13. The present pollen flora is mainly composed of Taxodiaceae and *Quercus*; the former is 2–47 per cent (20 per cent on the average) in Chikubetsu pit I and 4–77 per cent of the total tree pollen (34 per cent on the average) in Haboro second pit L while the latter is 3–69 per cent (20 per cent on the average) in Chikubetsu pit I and 0–87 per cent (10** per cent on the average) in Haboro second pit L. Such abundance of *Quercus* is a characteristic feature of the Daijima-type flora. Here, it is striking that the abundance of *Quercus* is generally found in the part of good quality coal. THOMSON and PFLUG reported that *Quercus* pollens abundantly occur in brown coal in the Rhine district in Germany and the abundance is found in the so-called "hellen Schichten". And they gave the following interpretation to this fact: as the coal of this phase (hellen Schichten) is presumed to be formed in an environment of "offene Niedermoor von Everglades-Typus" which is a poor swamp in respect to tree. *Quercus* pollen, anemophilous, which were carried from the marginal land of the swamp predominated in the sediments formed in such an environment owing to the poorness in tree in this environment itself. Though TRAVERSE (1955) also referred to the abundant occurrence of *Quercus* pollen in a lignite bed (latest Oligocene) in the United States, the occurrence is in a reverse relation to that of THOMSON and PFLUG and the writer's results: that is, according to TRAVERSE's observation the

* Though the writer includes only two pollen diagrams in the present paper, they are considered to be representative of the general features of the pollen flora in the seam (refer to SATO (1960)).

** As the samples of Haboro second pit L were taken from the lower part of the seam, it does not show the feature of whole part of the seam. Consequently, this value of *Quercus* pollen which is much in the upper part (the part of good coal) is lower than the general value.

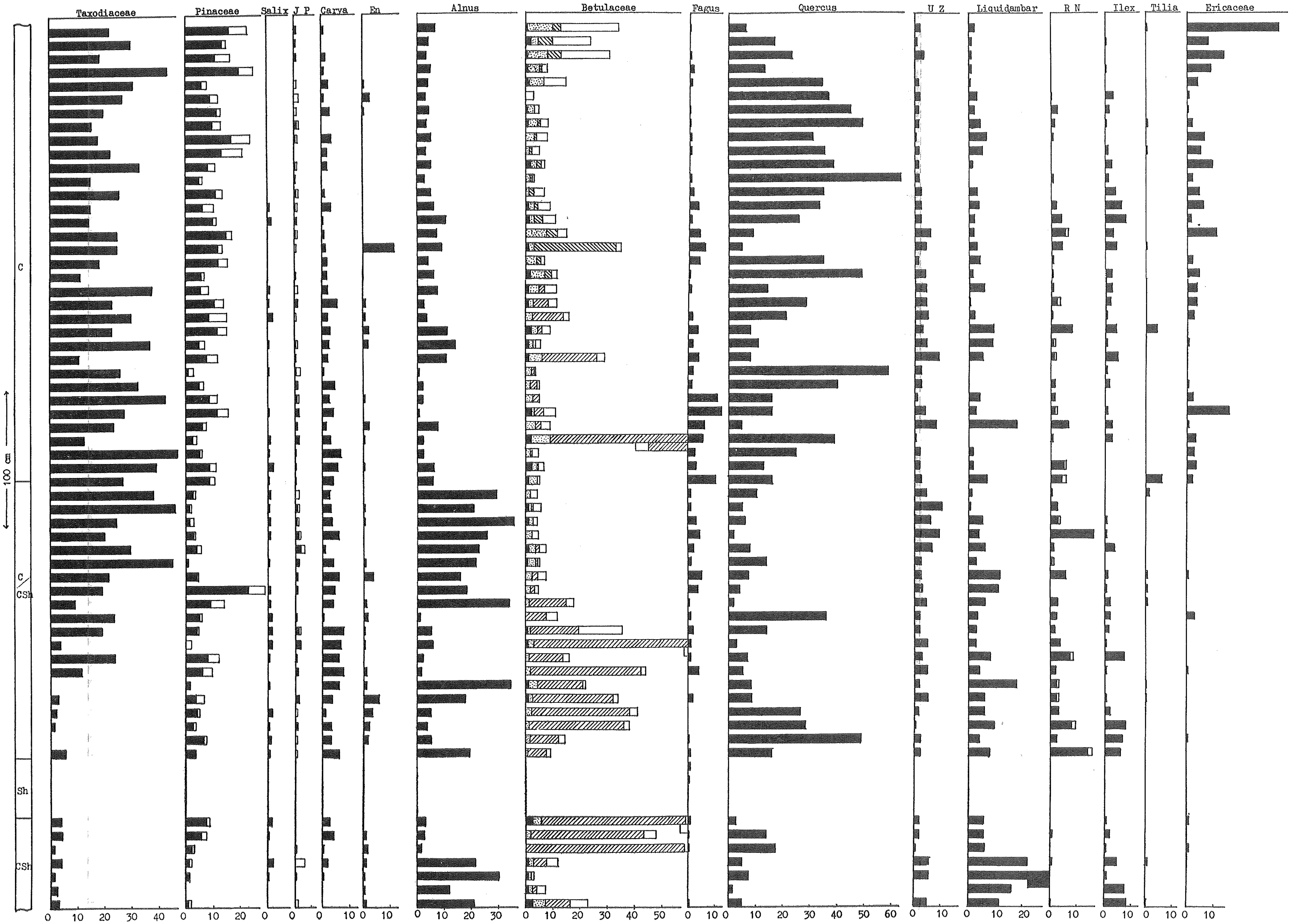


Fig. 12. Composite pollen diagram for "Main Seam" in the Haboro coal-bearing formation at Chikubetsu main pit

Pinaceae (black: *Pinus*), JP: *Juglans* (black) and *Pterocarya*, En: *Engelhardtia*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), UZ: *Ulmus* and *Zelkova*, RN: *Rhus* (black) and *Nyssa*

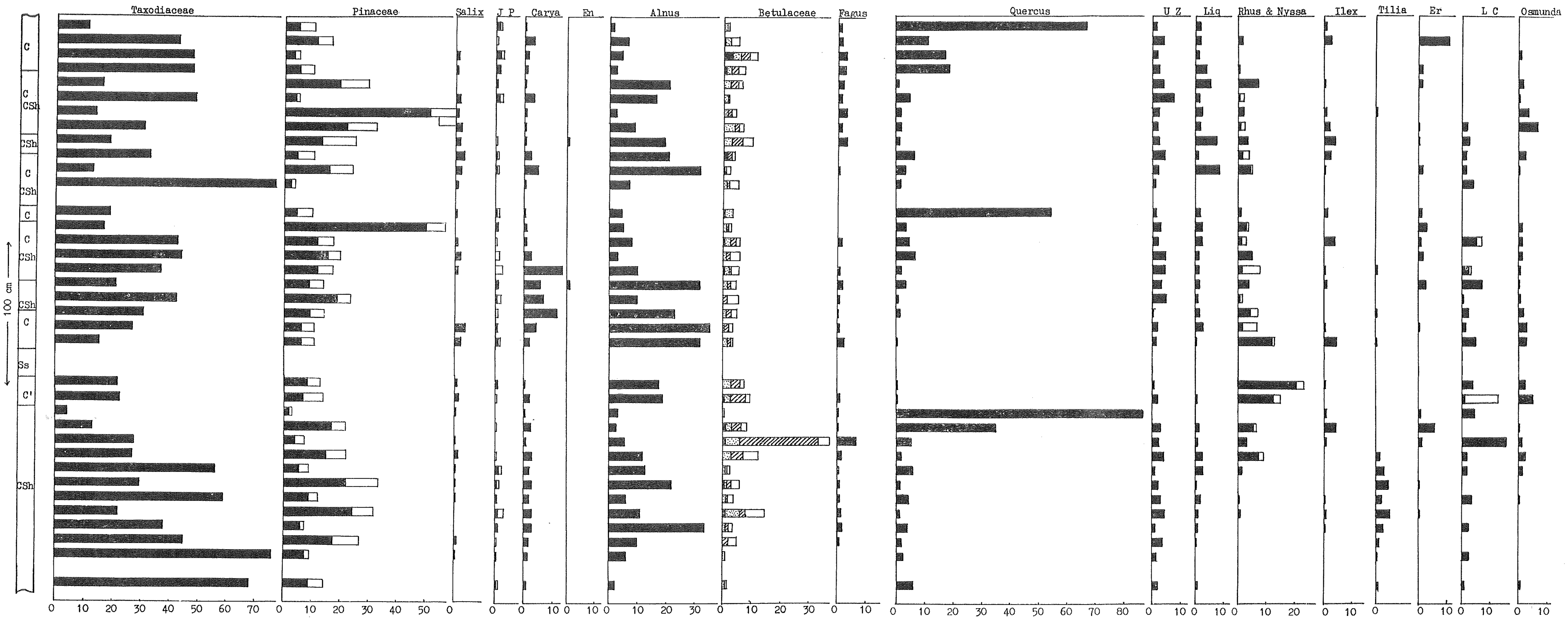


Fig. 13. Composite pollen diagrm of Haboro second pit L

Pinaceae (black: *Pinus*), JP: *Juglans* (black and *Pterocarya*), En: *Engelhardtia*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), UZ: *Ulmus* and *Zelkova*, Liq: *Liquidambar*, *Rhus* (black), Er: Ericaceae, Legminosae (black) and *Castanea* abundance of *Quercus* pollens is found only in silt and not in the part of lignite. He gave the following explanation (1955, p. 32~33) for the fact: the lignite itself was formed in a forest swamp and the silt was deposited in a phase of open water; so, *Quercus* pollen, anemophilous, is largely represented in the latter case and swamp-forest pollens are dominant in the former case; accordingly, if the "hellen Schichten" was formed in a phase of open water, TRAVERSE's conclusion is not contradictory to PFLUG's and THOMSON's views. Besides, THOMSON and PFLUG recognized two phases of brown coal: one is the bright layer with high content of *Quercus* pollen (open water or Everglades condition) and the other is the true forest-swamp type (Taxodiaceen-Cupressineen-Bruchwald, for example). Then, if one examine the pollen flora shown in the pollen diagrams of Figs. 12 and 13, he can recognized such a feature as is described above: that is, one phase represented by Taxodiaceae-*Alnus*-*Liquidambar*-*Ulmus* association and another represented by the dominance of *Quercus*. The former may represent the swamp-forest type while the latter does the "offene Niedermoor von Everglades-Typus". Accordingly, also the writer's opinion is not inconsistent with TRAVERSE's view. Whether the environment is an open water condition postulated by TRAVERSE or the Everglades-type condition depends upon various circumstance of individual basin but both are consistent in the feature of poorness in tree pollen. Further, SEARS and CLISBY (1955, p. 523) referred to the relationship of *Quercus* and *Alnus* in the study of Quaternary peat in Mexico; according to them the two genera are in a concordant relationship in that "high oak count is usually accompanied by alder, a definite moisture indicator". Presumably, the difference from the writer's observation may be resultant from difference of species of *Quercus*. Besides, *Alnus* represents a characteristic occurrence in this seam: that is, it occurs in the part of relative high ash content with an utterly reverse relationship with *Quercus*; as the relationship is well illustrated in Figs. 12 and 13, it will be noted that *Alnus* has its high frequency part in the lower part of the coal seam, while *Quercus* is predominant in the upper part as a general feature.

Pinaceae pollens, mainly *Pinus*, occur without very much fluctuation in frequency through the seam from the bottom to the top: the frequency is 3–29 per cent (9.4 per cent on the average) in Chikubetsu pit I with a trend for Pinaceae to be slightly more abundant toward the upper part of the seam; the frequency is 3–56 per cent (18 per cent on the average) in Haboro second pit L. Such occurrence without much fluctuation makes the writer presume that the pollen grains were supplied from the highland surrounding the coal forming basin at that time regardless of the change in the ecological condition in the course of the formation of the coal in the basin. Moreover, though Pinaceae pollen grains are more abundant in Haboro second pit than in Chikubetsu pit which is to the west of Haboro second pit, such a trend may mean that a high-land existed eastward of the basin; this presumption agrees with the paleogeography deduced from geological considerations.

In addition, *Corylus* also shows a peculiar occurrence: that is, its frequency abruptly increases in some parts of the seam, with the parts of great abundance recognizable in the lower part of the seam on the whole, but with a few exceptions in the upper part. Though it is noted that *Corylus* pollen grains are more abundantly found in some samples from Chikubetsu pit than from Haboro second pit, such a fact may mean a difference in some ecological condition in the coal-forming basin of the Chikubetsu pit and Haboro second pit areas. Besides, as the writer has already (1960) reported, even in the Chikubetsu pit area it is not rare that the part of great abundance in *Corylus* could not be traced laterally in the seam. Such local distribution of *Corylus* pollen grains may be due to the dwarf shape of the tree. An overwhelming abundance of *Corylus* pollen has been reported from inter-glacial deposits in Europe by many authors, but not from Tertiary deposits so far as the writer knows.

Pollen grain of *Liquidambar,* a tree generally favoring low-land, is higher in frequency in the lower part of the seam than in the upper part; 38 per cent at the maximum in the lowest part of the seam. *Liquidambar* in this formation seems to be composed of two species: one has pollen grains of larger size than the other.

Ulmus (and *Zelkova*) is roughly concordant with *Alnus* and *Liquidambar,* though the frequency is low: 3.5 per cent on the average at Chikubetsu pit I and 2.6 per cent at Haboro second pit L.

It is a problem left for the future what condition indicates the trend that the above-mentioned swampy plants like *Alnus, Ulmus* or *Liquidambar* are more abundant in the lower part of the seam than in the upper part.

Further, *Carya* and *Fagus* are commonly found with trends for the pollen of the two genera to be higher in frequency in the lower (of *Carya*) and the middle part (of *Fagus*) of the seam respectively.

Next, the occurrence of Ericaceae, acid ground loving plants, is noteworthy: its frequency increases in the upper part of the seam as is well illustrated in Fig. 12; this feature may mean that the condition of the ground in this basin became more acidic in the course of the development of the swamp. Though such a change in nature of peat toward the acidic

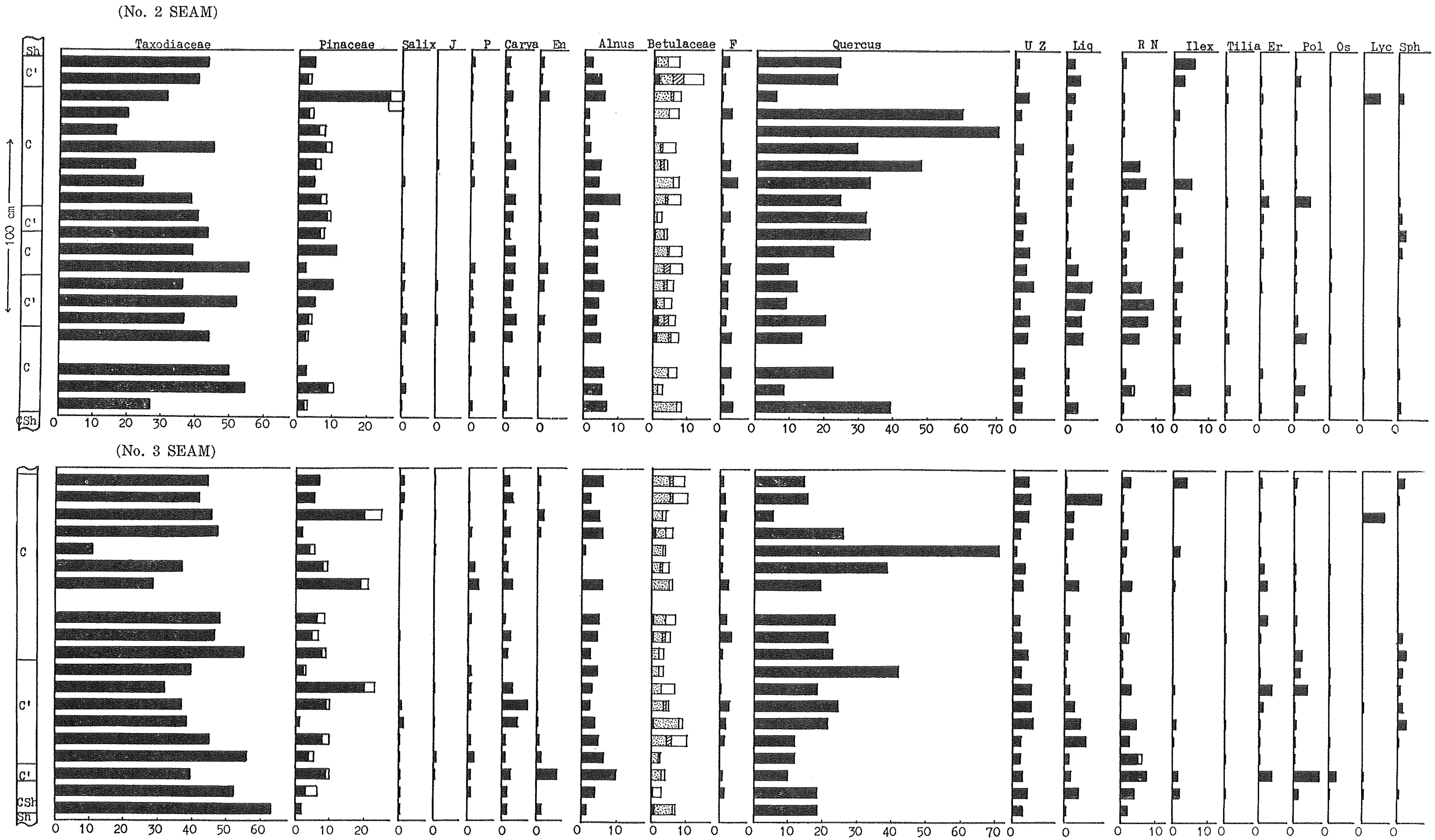


Fig. 14. Composite pollen diagram for the Asahi coal mine

Pinaceae: black portion, *Pinus*; J: *Juglans*, P: *Pterocarya*, En: *Engelhardtia*, Betulaceae (black: *Betula*; dotted: *Carpinus*; shaded: *Corylus*), UZ: *Ulmus* and *Zelkova*, Liq: *Liquidambar*, RN: *Rhus* (black) and *Nyssa* (white), Er: Ericaceae, Pol: Polypodiaceae, Os: *Osmunda*, Lyc: Lycopodiaceae Sph: *Sphagnum* condition is recognized also in Quaternary peat: lower moor→intermediate moor→higher moor, the writer does not care to express an opion for the present whether or not the above-noted occurrence of Ericaceae indicates the peat from which the present coal seam was made to grow with the course of lower→higher peat.

At any rate, the various above-described features indicate that the conditions in the coal-forming basin were never uniform in the course of the coal forming and that the environment of the basin was under temperate (—warm temperate) climatic condition and swampy condition. Though abundant occurrence of macrofossil plants is not yet found from the present area, studies on macrofossil and fossil pollens yield consistent data in the point that the flora of the Haboro coal-bearing formation is correlated to the Daijima-type flora.

2E. Asahi coal mine

This coal mine is situated at the center of the Ishikari coal field (Fig. 1).

The geologic succession of the Miocene sediments in this area is hitherto considered to be as shown in Table 8. However, the geologic

TABLE 9. Geologic succession of the Miocene in the Asahi coal mine area

Miocene	Iwamizawa formation	
	Kawabata formation	
	Takinoue group	Alternation of green sandstone and siltstone (molluscan fossil bearing)
		Alternation of sandstone and shale (Asahi coal-bearing formation)
		Black mudstone member (molluscan fossil bearing)
		Green sandstone member (molluscan fossil bearing)
Oligocene	Poronai formation	

structure in the area is so complex that many different opinions exist regarding the stratigraphic horizon of the sediments below the Kawabata formation, especially of the Asahi coal-bearing formation. The Asahi coal-bearing formation contains several coal seams of good quality of which five seams are workable, but the coal-bearing facies develops well only in the neighbourhood of the Asahi coal mine. Samples for the present study were collected from No. 2 and No. 3 seams.

The following fossil pollens and spores were recognized from these samples: *Pinus, Picea, Tsuga,* other indeterminable Pinaceae, Taxodiaceae, *Salix, Juglans, Pterocarya, Carya, Engelhardtia, Alnus, Betula, Carpinus, Corylus, Ostrya*?, *Fagus, Quercus, Castanea, Ulmus, Zelkova, Liquidambar,* Magnoliaceae, *Cinnamomum*?, *Rhus, Acer, Tilia, Nyssa, Alangium*?, *Ilex,* Ericaceae, *Viburnum* and some other indeterminable pollens and spores. Their quantitative relationship is illustrated in the pollen diagram of Fig. 14. Main components of the pollen flora are Taxodiaceae and *Quercus*: the former provides 17–56 per cent (38 per cent on the average) in No. 2 seam and 11–63 per cent (44 per cent on the average) in No. 3 seam; the latter is 6–71 per cent (27 per cent on the average) in No. 2 seam and 5–71 per cent (23 per cent on the average) in No. 3 seam. With the above two, *Pinus, Carya, Alnus, Carpinus, Fagus, Ulmus, Zelkova, Liquidambar, Rhus, Ilex,* etc. are commonly intermixed. Besides, *Picea, Tsuga, Salix, Juglans, Pterocarya, Engelhardtia, Betula, Corylus,* Magnoliaceae, *Cinnamomum*?, *Acer, Tilia, Nyssa, Alangium*?, etc. are recognized with very small frequencies. Pollens of non-arboreal plants are not numerous, but only a few examples of Ericaceae and *Lonicera* pollen and spores of Polypodiaceae, *Osmunda,* Lycopodiaceae, *Sphagnum* etc. are found. Though there is no very conspicuous change in composition of the present pollen flora through these seams from the bottom to the top, it is noteworthy that the part of high frequency in *Quercus* is found only only in the portion of good quality coal. Such a phenomenon has already been referred to in the section of the Chikubetsu main pit and Haboro second pit. The present pollen flora is characterized by the dominance of Taxodiaceae and *Quercus,* and the accompaniment of *Engelhardtia, Liquidambar, Rhus, Nyssa* and *Cinnamomum*?; it is very similar in composition to that in the Haboro coal-bearing formation, the Daijima-type flora. Also, it is similar to that of a thin coal seam in the neighbourhood of the Shinkakuta coal mine, about 10 km south from the present mine; that thin seam is considered to belong to the Takinoue formation. Accordingly, there is good reason to consider that the Asahi coal-bearing formation is in the Haboro or Takinoue stages in age in accordance with the customary opinion; but it is also noteworthy that the present pollen flora is closely similar in composition to that of the Kawabata formation as is well seen by reference to the section below on the Kawabata stage. Considering the fact that no well-developed coal-bearing facies of the Takinoue stage like that of the present area is found in the neighbourhood (while the Kawabata formation contains some coal seams in several localities in this area of which some have been worked on a small scale) and that the coal-bearing formation in the present area is separated by faults from the surrounding rocks, it is feared that the

Asahi coal-bearing formation may prove to be the coal-bearing facies of the Kawabata stage sunken by faults or that the sediments which are considered to be of the Kawabata stage are lower in stratigraphic horizon than they are considered .

On the other hand, TANAI (1961) reported the following macrofossil plants from the Asahi coal-bearing formation and determined the flora to belong to the Daijima type.

Glyptostrobus europaeus (BRON.) HEER
Metasequoia occidentalis (NEWB.) CHANEY
Betula mioluminifera HU et CHANEY
Fagus antipofi HEER
Ulmus shiragica HUZIOKA
Cocculus heteromorpha (KNOWLTON) BROWN
Cercidiphyllum crenatum (UNGER) BROWN
Platanus aceroides GOEPPERT
Aesculus majus (NATHORST) TANAI
Alangium aequalifolia (GOEPPERT) KRYSHT. et BORSUK
Kalopanax acerifolium (NATHORST) HU et CHANEY

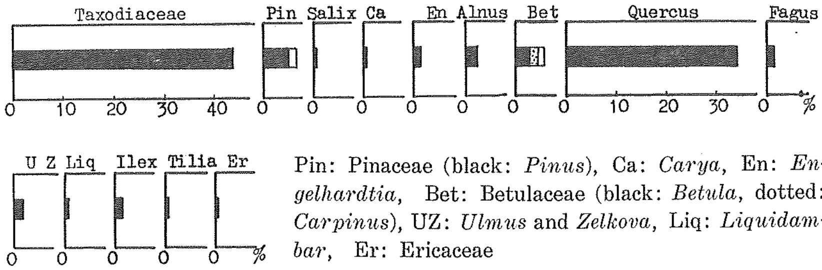
Such a difference in the evidence presented by the macrofossil plants and by the pollen flora is a problem remaining for the future.

The molluscan fauna in the lower green sandstone member in the above-noted geologic succession is so strange in composition as never to have been found from the Neogene in Hokkaidô. It is considered to be older in age than the so-called "Takinoue fauna" according to UOZUMI, while the molluscan fauna in the alternation of green sandstone and siltstone is clearly composed of the so-called "Takinoue fauna". No unconformity is recognized between these sediments which contain the two fauna (generally, clear unconformity exists at the base of the sediments of the Takinoue stage). Moreover, the well-developed coal-bearing facies is not found in the Horomui river at the place where the succession of the above-noted marine fossil-bearing sediments is well exposed.

At all events, many unsolved problems are remaining on the stratigraphic succession and horizon of the Neogene sediments in the present area owing to the complexity of the fossil evidences and geologic structure in the area.

2F. Takinoue formation in the Shinkakuta coal mine area

The source locality of the samples is a little westward of the Shinkakuta coal mine, Yûbari-gun (Fig. 1). The stratigraphic succession has already been referred to in Chapter III above. Some thin coal seams are sometimes included in the lower or basal part of the Takinoue formation.



Pin: Pinaceae (black: *Pinus*), Ca: *Carya*, En: *Engelhardtia*, Bet: Betulaceae (black: *Betula*, dotted: *Carpinus*), UZ: *Ulmus* and *Zelkova*, Liq: *Liquidambar*, Er: Ericaceae

Fig. 15. Composite pollen diagram of the Takinoue formation in the neighbourhood of the Shinkakuta coal mine

The sample for the pollen analysis is taken from a thin coal seam, about 40 cm in thickness, but the detailed occurrence of the seam could not be known owing to its poor exposure at the surface.

The result of the pollen analysis is illustrated in the pollen diagram of Fig. 15. As clearly seen from that diagram, main compositions of this pollen flora are *Quercus* (34 per cent) and Taxodiaceae (44 per cent); it is a characteristic feature that *Liquidambar* and *Engelhardtia* accompany the two, though they are comparatively less in abundance. The above-noted composition of this pollen flora is closely similar to that of the Asahi coal-bearing formation at the Asahi mine and the Haboro coal-bearing formation in the Tomamae region; it clearly represents features of the Daijima-type flora.

Recently, it is advocated by SHIMOKAWARA and TEJIMA (1961) that present coal-bearing facies may be correlated to the coal-bearing facies in the lower part of the Momijiyama formation in the Momijiyama district; the flora included in the latter is of the Aniai type. However, from the present pollen analysis, if it is true that the flora included in the Momijiyama formation in that district belongs to the Aniai-type flora, their correlation is not appropriate because the present pollen flora is not of Aniai type, but of typical Daijima type.

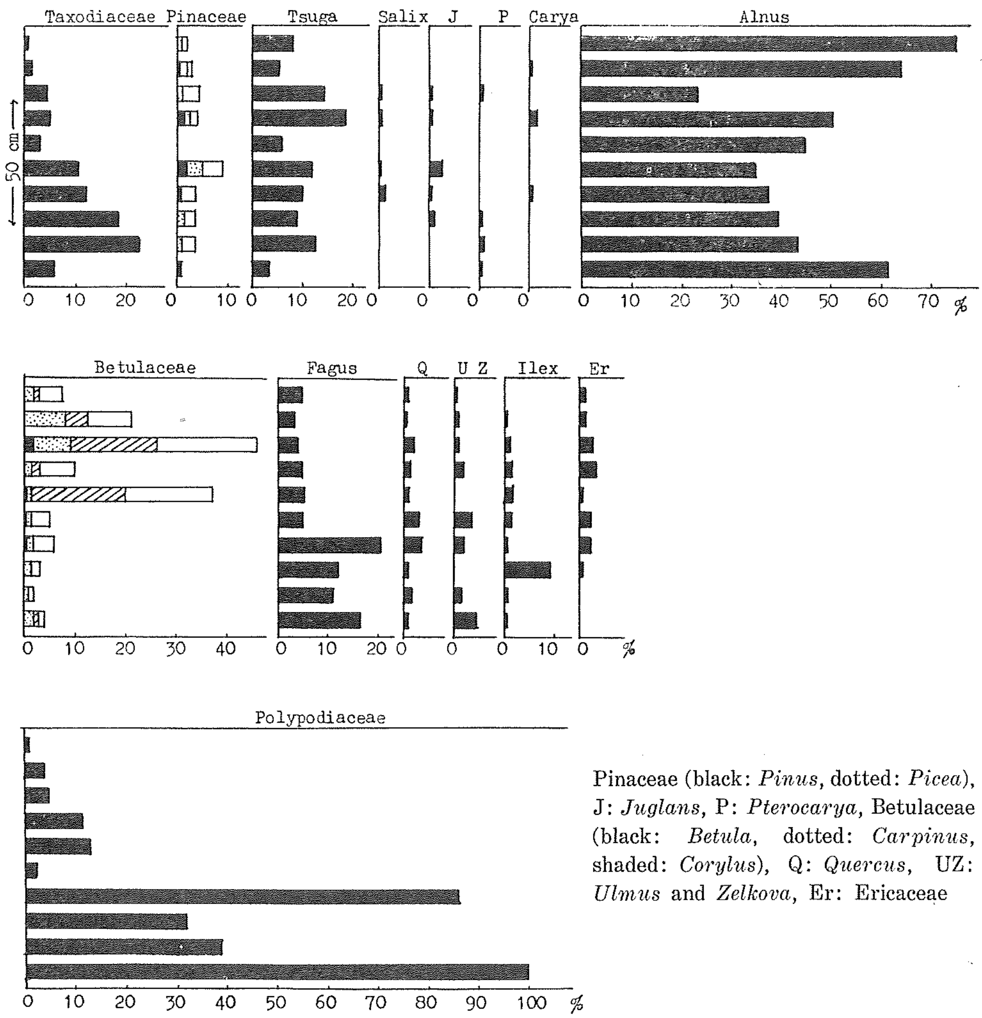
2G. Tomamae coal mine

This mine is situated on the upper stream of the Chiepotsunai river, about 13 km east from Kotanbetsu-machi on the Rumoe railway line and about 5.5 km south from the Haboro second pit (Figs. 1 and 11).

The geologic succession in this area is about the same as that in the area of the Haboro coal mine. The samples for the present study were taken from a coal seam in the Tomamae coal-bearing formation. That formation has heretofore been correlated to the Haboro coal-bearing formation, but it is recently said that the Haboro coal-bearing formation and the Sankebetsu formation may be thinning or eroded out by the

Chikubetsu formation in the present area. Though yet no official report on the matter has been published some students consider the Tomamae coal-bearing formation to be correlated to the basal part of the Chikubetsu formation. The coal seam from which samples were taken is about 1 m in thickness and was working in 1954 on a small scale. The coal is high in ash content and not good in quality. Though no macrofossil plant has been reported from the Tomamae coal-bearing formation, many samples of fossil pollen are found from the present samples in good preservation.

The pollen flora is composed of *Pinus, Picea, Tsuga,* Taxodiaceae,



Pinaceae (black: *Pinus*, dotted: *Picea*), J: *Juglans*, P: *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Er: Ericaceae

Fig. 16. Composite pollen diagram of the Tomamae coal mine

Salix, Juglans, Pterocarya, Carya, Alnus, Betula, Carpinus, Corylus, Ostrya?, Fagus, Quercus, Ulmus, Zelkova, Ilex, Ericaceae, Polypodiaceae and other indeterminable pollens and spores. The quantitative relation of their occurrence is shown in Fig. 16. As seen from the composition, *Alnus* is most abundant in number of specimens of all the samples excepting sample 8. This feature is a characteristic of this pollen flora. Such abundance of *Alnus* pollen is often recognized in the Miocene coal in Hokkaidô as seen in the present paper, but is not noted in many results of the pollen analysis of the Quaternary sediments; accordingly, this matter of *Alnus* abundance may be a characteristic feature of the low land flora of the Miocene age in company with the absence of Cyperaceae and Gramineae pollens, which are commonly found abundantly in the Quaternary sediments. Taxodiaceae, *Tsuga, Corylus* and *Fagus* accompany *Alnus* with frequencies over 5 per cent. The appearance of *Tsuga* with rather common frequency is significant; pollen grains of *Tsuga* are very scarce in frequency in the Haboro coal-bearing formation. As *Tsuya* is a plant which indicates rather low temperate climatic condition and is growing on high land, taking into consideration the absence of *Liquidambar, Nyssa* or *Cinnamomum* and little occurrence of *Quercus,* the appearance of *Tsuga* with rather common frequency may indicate that the pollen flora under a lower temperature condition than that existent at the time of the Haboro coal-bearing formation. With the above-noted pollens, *Pinus, Picea, Salix, Juglans, Pterocarya, Carya, Quercus, Ulmus, Zelkova, Ilex,* and Ericaceae occur with frequencies under 5 per cent. Taxodiaceae and *Fagus* show a tendency to decrease towards upper part of the seam. *Corylus* is more abundant in the upper part of the seam than in the lower part. Furthermore, the occurrence of Polypodiaceae spores is very characteristic and noteworthy: the spores are overwhelming in the lower part of the seam, 750 per cent of the total pollen grains at the lowest part. What does such a floral change of pollens and spores mean as to the ecological condition under which this coal seam was formed, is a problem left for future.

The general feature of the present pollen flora presents a clear difference from that in the Haboro coal-bearing formation and a similarity to that in the Sôya formation. Such a clear difference from that in the Haboro coal-bearing formation regardless of the neighbourhood to the distribution area of the typical Haboro coal-bearing formation (about 5 km distant from the Haboro second pit) seems to indicate some error of the customary correlation by which the sediments containing the present coal seam in this area are correlated to the Haboro coal-bearing formation.

The details of the correlation will be discussed in Chapter VIII.

2H. Shumarinai coal-bearing area

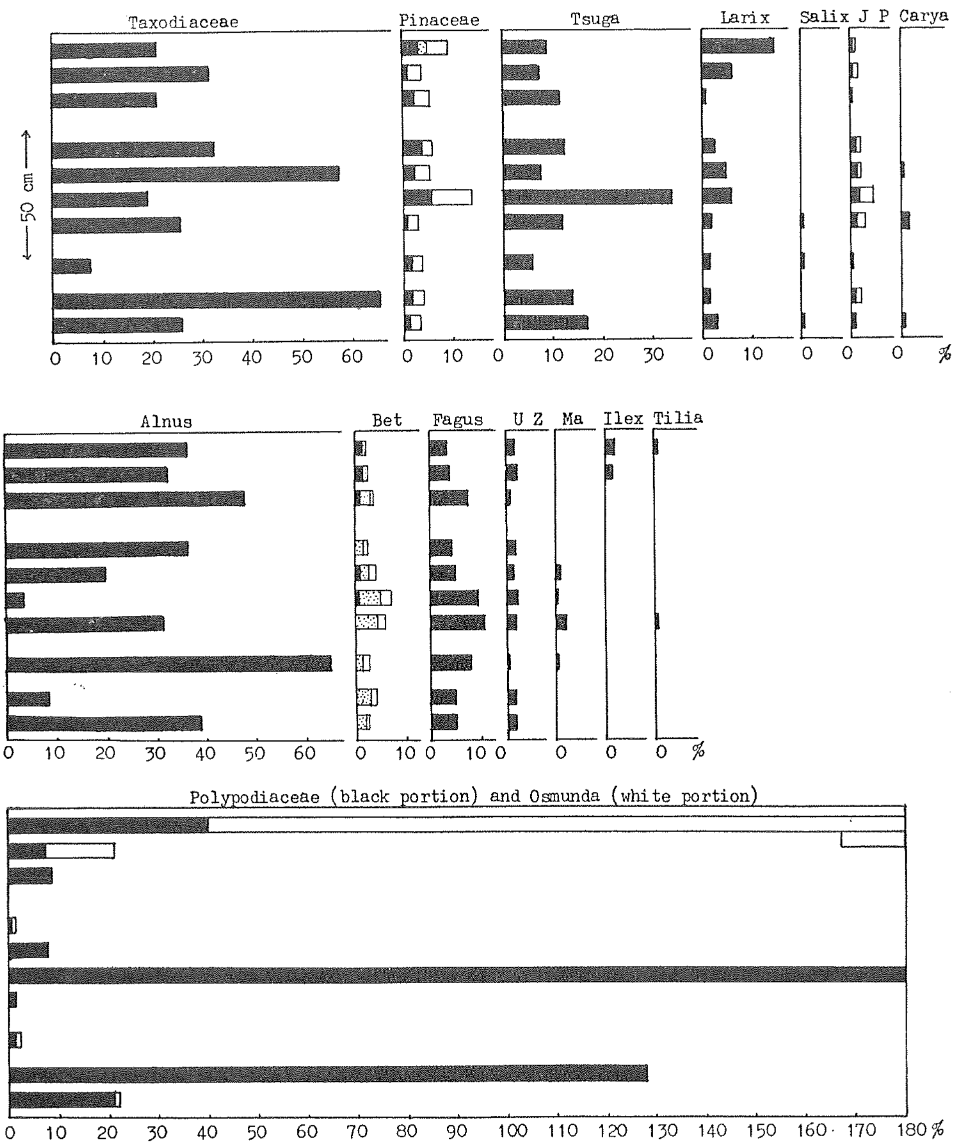


Fig. 17. Composite pollen diagram of samples from the Shumarinai district Pinaceae (black: *Pinus*, dotted: *Picea*), JP: *Juglans* (black) and *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, white: others), UZ: *Ulmus* and *Zelkova*, Ma: Magnoliaceae

The sampling locality is about 6 km southwest from the Shumarinai station on the Shinmei line (Figs. 1 and 11). The district which includes the present locality is called the Kita-uryû coal field.

The geologic succession in this area has hitherto been said to be as follows in ascending order: Cretaceous rocks, Haboro (coal-bearing), Chikubetsu, Kotanbetsu and Wakkanai (coal-bearing) formations. It is very doubtful, however, that the lower coal-bearing formation is correlated to the Haboro coal-bearing formation; the writer is convinced that the formation is correlated to the Tomamae coal-bearing formation noted above in the preceding section. Significantly, the pollen flora in the lower coal-bearing sediments from which the present samples were taken is clearly different in composition from that of the Haboro coal-bearing formation as is described in the following. The coal seam from which the samples for the present study were taken is about 1.6 m in thickness and is poor in lateral continuity; the coal is higher in ash content and also lower in quality than that of the Haboro coal-bearing formation.

As is illustrated in the pollen diagram (Fig. 17), the main components of the pollen flora are Taxodiaceae and *Alnus*: the frequency of the former is 8–66 per cent (31 per cent on the average) of the total tree pollens and the latter 4–65 per cent (32 per cent on the average). *Alnus* pollen grains are similar to those of the Tomamae coal mine in their forms and in the abundance of grains with four germinal pores. A characteristic feature is the presence of *Tsuga* with frequencies of 6–34 per cent (13 per cent on the average) with the above-noted pollens; such attendance of *Tsuga* is a point by which the present pollen flora is differentiated from that of the Haboro coal-bearing formation as has already been referred to above in the section on the Haboro coal mine. *Fagus* and *Larix* are commonly found with frequencies over 5 per cent and 2–15 per cent (4.5 per cent on the average) respectively. *Pinus, Juglans, Pterocarya, Carpinus* and *Ulmus* (and *Zelkova*) are under 5 per cent in frequencies among the tree pollens. As non-arboreal plants, spores of *Osmunda,* Polypodiaceae and Lycopodiaceae and a few pollen grains of *Lonicera* are recognized. *Osmunda* shows a characteristic occurrence being very abundant (about 150 per cent of the total tree pollens) in the uppermost part of the coal seam. Besides, Polypodiaceae shows great abundance (for examples, 600 and 130 per cent of the total tree pollens) in some parts of the seam; such great occurrence is recognized also in the Tomamae and Horonobe coal mines.

The present pollen flora differs from that of the Haboro coal-bearing formation in the absence of the representative plants of the Daijima-type flora, for examples, *Liquidambar, Cinnamomum, Quercus, Engelhardtia,* etc. On the other hand, it is very similar to the pollen flora in the coal of the Tomamae coal mine of which the coal-bearing sediments are of the Tomamae coal-bearing formation being higher in stratigraphic position than the Haboro coal-bearing formation. Presumably, the present area may be at the eastern margin of distribution of the Tomamae coal-bearing formation. Furthermore, the present pollen flora has similarity in composition to floras of the Sôya coal-bearing formation.

21. Sekiyu-zawa near Chikubetsu main pit

The sampling locality is shown in Figs. 1 and 11. The samples for pollen analysis were collected from a thin coal seam (50 cm in thickness) by K. WATANABE in 1952. The coal seam is included in member C_2 (a part of the Chikubetsu formation) according to his classification of the Chikubetsu formation, and is very poor in lateral continuity so that no coal seam is reported from any other locality of the member. When his geologic map on the present area is examined and compared with the map by MATSUNO (1961), the member seems to the writer to correspond to the Tomamae coal-bearing formation. The coal is high in ash content and very poor in pollen content.

The pollen flora found in this coal is very characteristic in overwhelming abundance of coniferous pollens as is seen in the pollen diagram (Fig. 18). Especially, the high frequency of *Tsuga* is noteworthy. Also *Alnus*

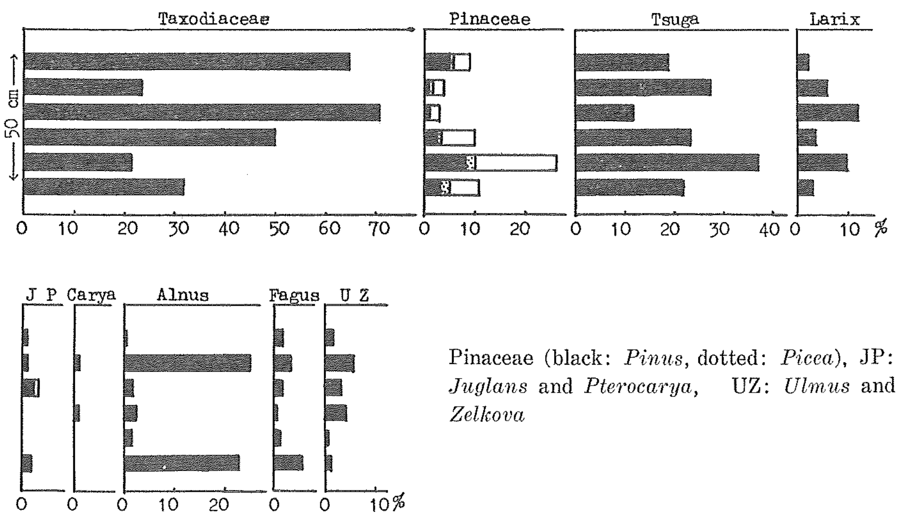


Fig. 18. Composite pollen diaglam of samples from Sekiyu-zawa

shows a rather great abundance in some parts of the seam. The present pollen flora is similar to that of the Tomamae coal mine in the features that *Alnus* and conifers are main components and the frequency of *Tsuga* is conspicuous. No pollen of warm temperate-loving plants is recognized in the present samples. Consequently, the above-suggested correlation that the sediments from which the present samples were taken correspond to the Tomamae coal-bearing formation is reasonable also on the basis of the pollen analysis. As is clearly recognized in comparison with the pollen flora of the Haboro coal-bearing formation, the present pollen flora is distinctly different in composition; this fact indicates that an abrupt change in composition of flora occurred in the period from the Haboro to the Tomamae stage.

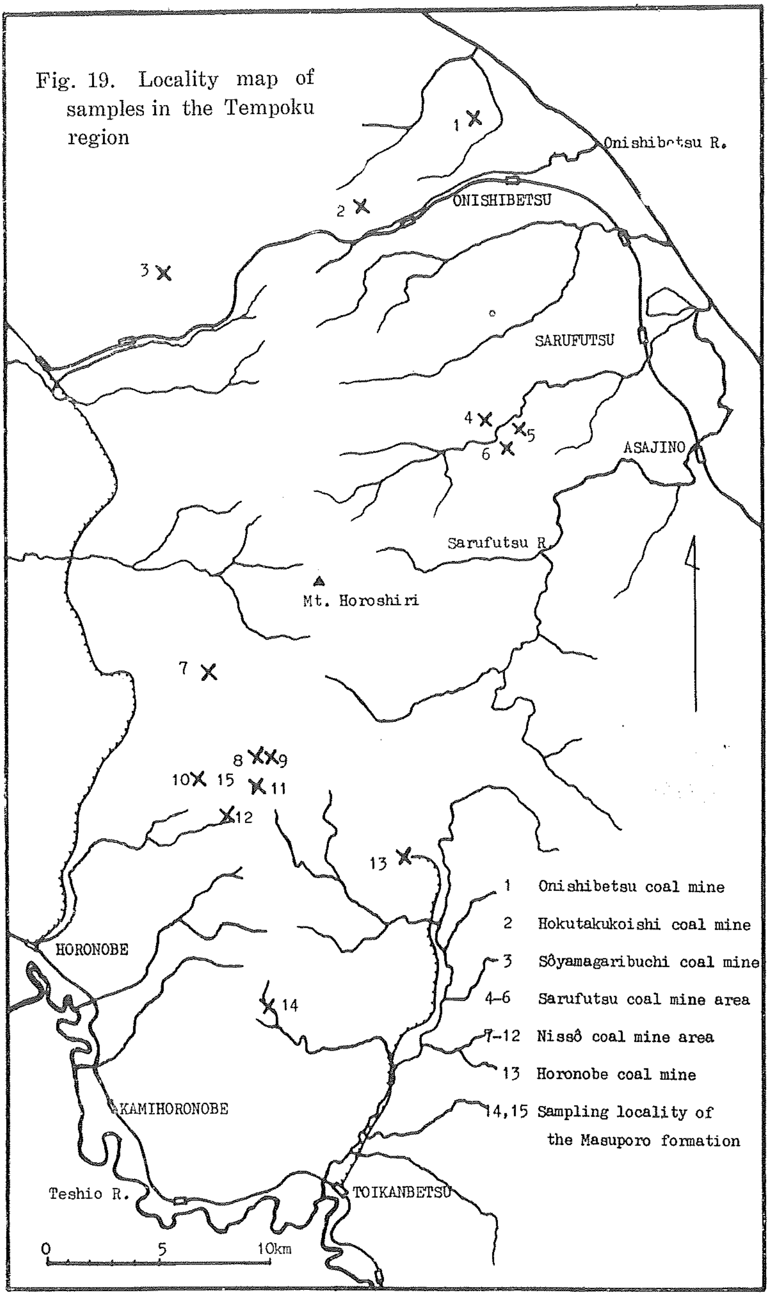
Though the writer has described above the general similarity of the present pollen flora and that of the Tomamae coal mine, they differ in the following features: 1) the present coal is poorer in pollen content than the other, 2) the present pollen flora includes much larger quantity coniferous pollens, especially *Tsuga* pollen, than the other, and 3) the pollen flora of the Tomamae coal mine is very rich in non-arboreal plants, especially in ferns like Polypodiaceae, *Osmunda* etc., but they are scarcely recognized in the pollen flora of Sekiyu-zawa. These differences may be due to the following facts: vi., 1) as the present coal is allochthonous in its origin, it is poor in pollen content and high in ash content and 2) as the coal formed in a place rather remote from the site where plants were growing, non-arboreal plant pollen is not found, but the pollens of arboreal plants which are generally distributed over very wide area are strikingly represented. But, as it is not a fact that only pollens of *Tsuga* and Taxodiaceae can fly specially for longer distance than other pollens, it can be said with confidence that *Tsuga* and other coniferous plants at any rate were rather frequent at that time.

2J. Sôya coal-bearing formation in the Tempoku coal field

The Tempoku coal field occupies the northernmost portion of Hokkaidô, is about 900 km^2 (about 20 km from east to west, about 60 km from north to south) being the largest of the Neogene coal fields in Japan in area, and it contains a great amount of Miocene brown coal.

The geologic succession of the Miocene sediments in this field is as follows in ascending order: the Magaribuchi, Sôya (coal-bearing), Onishibetsu, Masuporo, Wakkanai and Koitoi formations; the discussion on the stratigraphic horizon of them is offered in details in Chapter III and VIII. The Sôya coal-bearing formation contains coal seams over ten in number of which five or six are workable. Samples were collected from these workable seams in many localities illustrated in Fig. 19. These coal seams contain many well-preserved fossil pollens and spores, and also abundant

Fig. 19. Locality map of samples in the Tempoku region



macrofossil plants are found from the roofs of these coal seams.

The following pollens and spores are recognized in the samples: *Osmunda*, Polypodiaceae, *Sphagnum*, Lycopodiaceae, *Pinus, Picea, Tsuga, Larix,* other indeterminable Pinaceae, *Metasequoia occidentalis, Glyptostrobus,* other Taxodiaceae, *Salix, Juglans, Pterocarya, Carya, Alnus, Betula, Carpinus, Corylus, Ostrya?, Fagus, Quercus, Ulmus, Zelkova,* Nymphaeaceae, Magnoliaceae, *Ilex, Acer, Tilia,* Ericaceae, *Fraxinus?, Lonicera,* Compositae and some other indeterminable pollens and spores. Among them Taxodiaceae and Betulaceae are most dominant in number of specimens; *Alnus* is most dominant of Betulaceae and *Carpinus* is next. The present pollen floras are characterized by the dominance of Taxodiaceae and *Alnus*: the former is 13–70 per cent (generally 20–40 per cent) and the latter is 13–49 per cent (generally 20–35 per cent). In accompaniment with those two, *Carpinus, Fagus, Ulmus* and *Zelkova* are commonly found: *Carpinus* 2–35 per cent, others two 2–20 per cent. Further, *Pinus, Picea, Tsuga, Juglans, Pterocarya, Quercus, Ilex,* etc. are always recognized though their frequencies are small. Also, *Salix, Acer, Tilia,* Ericaceae, *Lonicera,* Compositae are sometimes recognized, but they are scarce in number of specimens. Further, spores of *Osmunda,* Polypodiaceae, Lycopodiaceae and *Sphagnum* are recognized. Especially Polypodiaceae seem to occur abundantly in the lower part of the coal seams as will be described below in the section on the Horonobe coal mine; its rather common occurrence is a characteristic feature of the pollen floras of the Sôya coal-bearing formation. Though this formation has hithertofore been correlated to the Haboro coal-bearing formation in the Tomamae coal field, the pollen floras in the two formations are clearly distinguished in composition from one another. Consequently, by the present writer the correlation is considered to be not appropriate. Also, study of macrofossil plants leads to the conclusion that the correlation is not appropriate.

The following macrofossil plants are reported from the Sôya coal-bearing formation:

Osmunda sp.	
Equisetum sp.	
Glyptostrobus europaeus (BRON.) HEER	(common)
Metasequoia occidentalis (NEWS.) CHANEY	(abundant)
Populus balsamoides GOEPPERT	(common)
Juglans miocathayensis HU et CHANEY	
J. japonica TANAI	
Carya miocathayensis HU et CHANEY	(common)
Pterocarya asymetrosa KONNO	

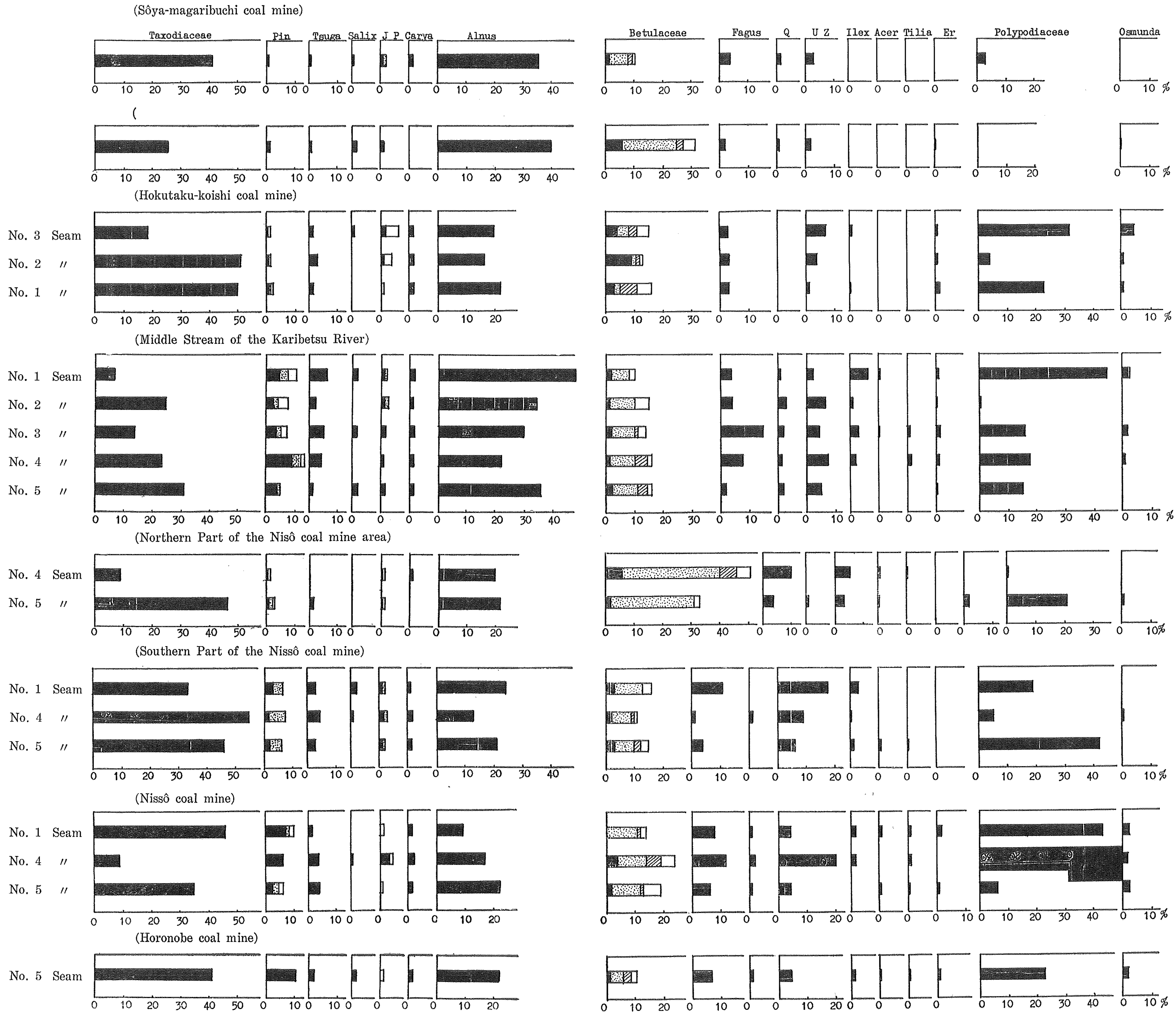


Fig. 20. Composite pollen diagrams for the Tempoku coal-field

Pin: Pinaceae (black: *Pinus*, dotted: *Picea*), JP: *Juglans* and *Pterocarya*, Petulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Er: Ericaceae

Alnus kefersteinii (GOEPPERT) UNGER
A. usyuensis HUZIOKA (common)
Betula mioluminifera HU et CHANEY (common)
Carpinus miofangiana TANAI et ONOE
C. subcordata NATHORST
Ostrya huziokai TANAI
Ulmus appendiculata HEER
Cercidiphyllum crenatum (UNGER) BROWN
Prunus miobrachypoda HU et CHANEY
Acer ezoanum OISHI et HUZIOKA
A. subpictum SAPORTA
Aesculus majus (NATHORST) TANAI
A. miochinensis HU et CHANEY
Tilia distans NATHORST
T. miohenryana HU et CHANEY
Alangium aequalifolia (GOEPPERT) KRYSHT. et BORSUK
Cornus megaphylla HU et CHANEY
Buxus protojaponica TANAI et ONOE

Based on the above listed fossils TANAI determined the flora of the Sôya coal-bearing formation to be Aniai type. Accordingly, as the Aniai-type flora is older than the Daijima-type flora, the Sôya coal-bearing formation must be lower in stratigraphic horizon than the Haboro coal-bearing formation which contains the Daijima-type flora. Surely, also the pollen flora of the Sôya coal-bearing formation is similar in some features of composition to pollen floras of the Kaminokuni area and the Kayanuma coal mine; both are the Aniai-type flora. But, the correlation that the Sôya coal-bearing formation is lower in stratigraphic horizon than the Haboro coal-bearing formation contains some unreasonable points as is described below in Chapter VIII. Thus, the writer found an interesting matter in his study: namely, he found many fossil pollen grains from the coal-bearing sediments (Tomamae coal-bearing formation) of the basal part of the traditional Chikubetsu formation in the Tomamae coal mine, Sekiyu-zawa and Shumarinai districts, and these pollen floras are similar in composition to that of the Sôya coal-bearing formation. Hitherfore, no macrofossil plant has been reported from the Chikubetsu formation and the flora of this stage has been considered to be a transitional one from Daijima-type which is recognized in the Haboro coal-bearing formation to the Mitoku-type flora which is found in the sediments of the Wakkanai stage. But, the present writer could not find any transitional character in the pollen flora, but features which indicate similarity to the Aniai-type flora. Accordingly, it is also considered enough that the flora of the Sôya coal-bearing formation corresponds to that of the Tomamae coal-bearing formation; this matter will be discussed in detail below in Chapter VIII.

The flora presumed from the pollen analysis is not very inconsistent with that presumed from macrofossil plants, but the following differences are recognized: 1) Taxodiaceae among macrofossil plants are more abundant than in pollen floras in its frequency, 2) Pinaceae which are commonly found in the pollen floras are not recognized among the macrofossil plants, 3) Polypodiaceae are abundantly found in the pollen floras, but not in macrofossils, 4) the pollen of *Populus* commonly found amongst those of macrofossils is not represented, 5) *Alnus* is higher in its frequency in pollen floras than in the macrofossil flora, 6) pollens of *Acer* and *Tilia* are scarcely found but their macrofossils are common. The main cause of these differences may be due to the following matter: viz., macrofossil plants are mostly found in roofs of coal seams, while fossil pollens are got from coal itself; that is, the occurrence of macrofossil plants is not the same as that of pollens in stratigraphic horizon. The causes of 4) and 6), however, may be due to the less remaining of fossil pollens of *Populus* and *Acer* owing to the less resistivity of their pollen membrane to chemical or bacterial attacks and less production of pollen of *Tilia*. Pollen grains of Pinaceae which are not found as macrofossils may come from far remote high-land which surrounded the old coal forming basin, for pollen grains can be carried over a great distance. The reason for lack of Polypodiaceae in macrofossils is considered to be the fact that Polypodiaceae grew in the earlier stage of the coal formation period as is presumed from their occurrence only in the lower part of coal seams as has been illustrated in the pollen diagrams of the coal mines of Tomamae, Horonobe and Shumarinai, and are almost not in existence in the time of the deposition of the sediments of the roofs; consequently, Polypodiaceae are not found as macrofossil plants in the roofs of the coal seams. Otherwise, it would be a matter of course that *Alnus*, generally a low-land loving and wet condition loving plants, would be higher in frequency in the pollen floras which are mainly composed of plants which grew on the coal forming basin, presumably under swampy condition.

2Ja. Hokutakukoishi coal mine

The Hokutakukoishi coal mine is about 1.5 km west from Koishi station on the Kitami line (Fig. 19).

Samples for pollen analysis were taken from three coal seams (Nos. 1, 2 and 3 seams) in the Sôya coal-bearing formation. The three samples are respectively averaged ones which are collected from the bottom to the top of each seam. From the coal many well-preserved fossil pollens and spores were found. Also, the following macrofossil plants have been found by T. TANAI from the Sôya coal-bearing formation in the present area:

Osmunda sp.
Equisetum sp.
Glyptostrobus europaeus (BRONG.) HEER
Metasequoia occidentalis (NEWB.) CHANEY
Populus balsamoides GOEPPERT
Juglans miocathayensis HU et CHANEY
J. japonica TANAI
Pterocarya asymetrosa KONNO
Alnus kefersteinii (GOEPPERT) UNGER
A. usyuensis HUZIOKA
Betula mioluminifera HU et CHANEY
Carpinus miofangiana TANAI et ONOE
C. subcordata NATHORST
Ulmus appendiculata HEER
Cercidiphyllum crenatum (UNGER) BROWN
Prunus miobrachypoda HU et CHANEY
Aesculus miochinensis (NATHORST) TANAI
Tilia distans NATHORST
T. miohenryana HU et CHANEY
Alangium aequalifolia (GOEPPERT) KRYSHT. et BORSUK
Buxus protojaponica TANAI et ONOE

The relative abundance of the recognized pollens in the present samples is shown in Fig. 20. Taxodiacea, mainly composed of *Metasequoia*, and *Alnus* are main components of the pollen flora. *Tsuga, Pinus, Picea, Betula, Carpinus, Corylus, Fagus, Ulmus* and *Zelkova* accompany the two main components. Furthermore, also *Salix, Juglans, Pterocarya, Carya, Ilex* and Ericaceae pollens are found with relative abundance under 2 per cent. Spores of Polypodiaceae and *Osmunda* are commonly found; especially the former occur with a great abundance in No. 1 seam and No. 3 seam. Taking into consideration that spores of Polypodiaceae show peculiar characteristic of being very dominant in the lower parts of the coal seams and are almost absent in the upper parts of them as is seen at the pollen diagrams of the Horonobe and Tomamae coal mines, the value of the relative abundance of Polypodiaceae in the present samples may not be uniform through the coal seams from the bottom to the top, but it may be very dominant in the lower part. The above-described features of the pollen flora show so close similarity to the other pollen floras in the Sôya formation in other districts of the Tempoku coal field that the pollen flora should be accepted as a key for the correlation of strata.

There is no great inconsistency in comparing the pollen flora with the macrofossil flora, yet *Populus* and *Acer* which are commonly found as fossil leaves and seeds are absent or very rare in the pollen flora; this matter was already referred to in the foregoing paragraph. Also, as *Tilia* is an insect-pollinating plant which generally produces little pollen, the scarcity of *Tilia* in this pollen flora is a matter of course.

Here, the writer will add an example of a conclusion based on pollen analytical study in conjunction with the study of macrofossil plants. That is, under microscope it was observed that a sort of Taxodiaceae pollen as is illustrated in Figs. 1~4 of Plate 13 is very dominant in specimen. On the other hand, it is known from the study of macrofossil plants by TANAI that *Metasequoia occidentalis* is extremely abundant in quality in the fossil flora in the Sôya formation in this area. So, it was concluded that the pollen grains belong to *Metasequoia occidentalis*. Generally, it is said that generic and specific determination of Taxodiaceae pollens in the Tertiary sediments is difficult, and many investigators have reported them in a lump as Taxodiaceae. But, as in the present case, if the pollen analytical study is carried out in conjunction with the study of macrofossil plants, it is hoped that it may be possible to make even a specific determination of the fossil pollens in the Tertiary sediments. At any rate, the writer is keenly feeling the necessity of the co-operation of studies on fossil pollens and macrofossil plants to get more detailed knowledge on floras in the past.

2Jb. Horonobe coal mine

The mine is about 15 km north from Toikanbetsu-machi (Fig. 19).

Samples for the pollen analysis were taken from No. 5 seam in the Sôya coal-bearing formation which contains twelve coal seams in the present area.

The following macrofossil plants have been reported by TANAI from the formation in this area:

Glyptostrobus europaeus (BRONG.) HEER
Metasequoia occidentalis (NEWB.) CHANEY
Populus balsamoides GOEPPERT
Juglans japonica TANAI
Carya miocathayensis HU et CHANEY
Alnus usyuensis HUZIOKA
Carpinus subcordata NATHORST
Ulmus appendiculata HEER

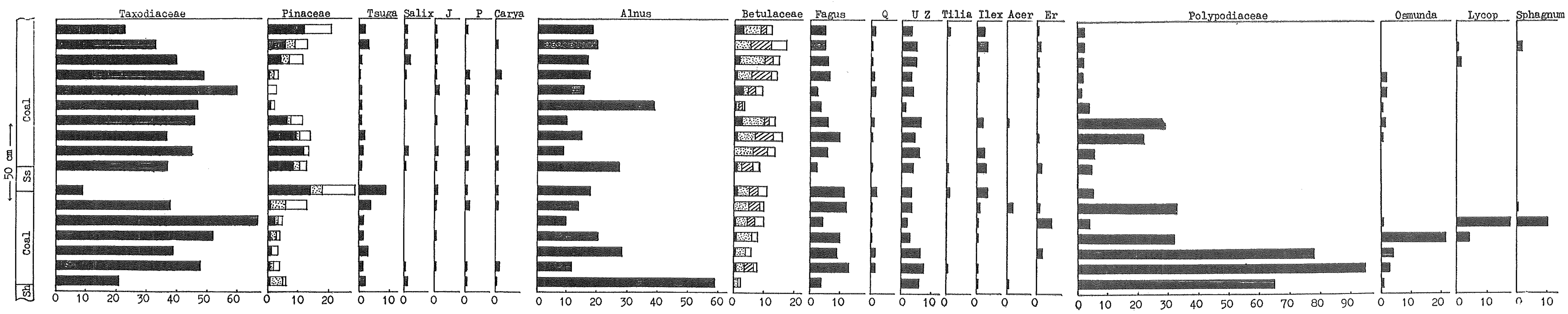


Fig. 21. Composite pollen diagram of the Horonobe coal mine

Pinaceae (black: *Pinus*, dotted: *Picea*), J: *Juglans*, P: *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Er: Ericaceae, Lycop: Lycopodiaceae

Acer ezoanum OISHI et HUZIOKA
A. subpictum SAPORTA
Cornus megaphylla HU et CHANEY

The following fossil pollens and spores were found from the samples: *Sphagnum*, Lycopodiaceae, *Osmunda*, Polypodiaceae, *Metasequoia*, *Glyptostrobus*, *Taxodium*?, *Pinus*, *Picea*, *Tsuga*, *Salix*, *Juglans*, *Pterocarya*, *Carya*, *Alnus*, *Betula*, *Carpinus*, *Corylus*, *Ostrya*?, *Fagus*, *Quercus*, *Castanea*?, *Ulmus*, *Zelkova*, Nymphaeaceae, *Ilex*, *Acer*, *Tilia*, Ericaceae and a few sorts of other indeterminable pollens and spores. The quantitative relation of these occurrence is shown in Fig. 21. This pollen flora is composed mainly of Taxodiaceae and *Alnus*: the former 41 per cent and the latter 22 per cent (on the average) of all tree pollens. *Pinus*, *Picea*, *Tsuga*, *Carpinus*, *Corylus*, *Fagus*, *Ulmus*, *Zelkova* and *Ilex* accompany the above-noted two with rather common occurrence. *Salix*, *Juglans*, *Pterocarya*, *Carya*, *Quercus*, *Tilia* and *Acer* are to be found with slight abundance (less than 3 per cent). Though *Liquidambar* pollen is found, the number of examples is only one among several hundreds of other pollen grains; it is feared that the pollen may be reworked one. Such an assemblage of pollens does not conflict with that of macrofossil plants with the exception of the absence of *Populus* and spare occurrence of *Acer* in the pollen assemblage and the absence of *Quercus* in the macrofossils. The absence or scarcity of *Populus* and *Acer* have already been referred to in the foregoing paragraph. The climatic condition presumed from this pollen assemblage is not so warm as that presumed from the flora of the Haboro coal-bearing formation, the Daijima-type. A characteristic feature of the present pollen flora is an overwhelming abundance of Polypodiaceae spores in the lower part of the coal seam, an abundance which rapidly decreases towards the upper part until almost complete lack. Also, the spores of *Osmunda* and Lycopodiaceae occur in the lower part of the seam and not in the upper part (refer to Fig. 21). Such a change in pollen assemblage may represent a change of the coal forming basin from a herbaceous-plants-dominant environment to a herbaceous-plants-inferior environment. Such a change is also found in the Tomamae coal mine.

3. Pollen floras of the Kawabata stage

The sediments of this stage in Hokkaidô are mainly marine in type and are poor in fossils except foraminiferal remains; especially, there is no report on fossil plants in these sediments; only TANAI (1961) mentioned that the flora of this stage might be temperate, the Daijima-type of Hokkaidô in general feature. His opinion is based on a small number of specimens such as *Myrica* (*Comptonia*) *naumanni*, *Carya miocatha-*

yensis, Castanea ungeri, Zelkova ungeri and *Rhus miosuccedanea,* from the Yûdoro and Horoshin formations in the Uryû district and the Naidabu formation in the northern Sorachi district, and on the consideration of macrofossil floras found from the deposits in Honshû corresponding to the present stage and marine fossils from the marine sediments of this age in Hokkaidô. These sediments, however, sometimes contain coal seams in lenticular forms. The present writer found many fossil pollens in the coal seams in the following formations: in the Masuporo formation in the neighbourhood of the Nissô-teshio mine and Toikanbetsu district of the Tempoku region and in the Kawabata formation in the neighbourhood of the Asahi coal mine of the Ishikari coal field.

3A. Masuporo formation in the Toikanbetsu area

The sampling locality is at a certain point on a tributary of the Kenashiporo river connecting with the Teshio river; it is about 9 km north from Toikanbetsu-machi (Fig. 19).

The Masuporo formation in this area is mainly composed of conglomerate, coarse—fine sandstone and siltstone; it shows an abnormal sedimentation with the mixing of coarse and fine materials. The writer found a coal seam with the thickness of 50 cm in coarse sandstone containing mudstone pebbles and showing abnormal sedimentary features. He found many fossil pollens from the coal in good preservation. As the Masuporo formation is very poor in fossil remains, especially no record of fossil plants in this formation has been reported, the writer believes that this discovery of rich pollens from this formation has an important meaning to explain the flora of that time.

Alnus is most dominant in the pollen flora (about 40 per cent of all tree pollens) with Taxodiaceae next (15–20 per cent). Ulmaceae pollens are 5–20 per cent in their frequencies and are composed of at least two kinds: one has very thickened membrane around the germinal pores (probably *Zelkova*) and the other is not so thickened (probably *Ulmus*). *Tsuga, Picea, Carpinus, Fagus* and *Quercus* occur with frequencies of 2–5 per cent of all tree pollens. *Pinus, Salix, Castanea, Juglans, Pterocarya* and *Carya* are very rare in frequency. A characteristic feature of this pollen flora is the existence of *Epilobium* pollen in the upper part of the coal seam with a frequency of about 3 per cent. The pollen grain of *Epilobium* is so characteristic as to be easily identificable, but no pollen of this genus has found among the enormous numbers of pollens in other Tertiary pollen floras so far as the writer has examined them during several years. Besides, Lycopodiaceae, Polypodiaceae, *Osmunda, Keteleeria*?, *Larix*?, *Acer, Tilia* and Nymphaeaceae are found with very low frequencies with the exception of Polypodiaceae which is abundant in the present samples like the occurrence in the Sôya coal-bearing formation. From this composition it is concluded at least that there is no element indicating warm-temperate climatic condition in this area such as is reported by K. SUZUKI (1959) on the flora of this stage in Northeast Japan or as is presumed on basis of the occurrence of the so-called *Miogypsina-Operculina* fauna from the Kunnui formation in Southwest Hokkaidô a part of which is correlated to the Masuporo formation. The the present pollen flora is similar to that in the Tomamae coal-bearing formation in the feature that *Alnus* is abundant while Taxodiaceae is not so high in frequency. Also, it is similar to the pollen floras of the Sôya coal-bearing formation on the whole. Another pollen flora was found from the Masuporo formation in the neighbourhood of the Nissô coal mine, about 11 km north from the present locality; in composition it is different from the present pollen flora. It is a problem left for the future to ascertain to what the difference is due. But, both the floras agree in the point that they do not indicate so warm climatic conditions as those of the flora in the Haboro coal-bearing formation. Now, it is very interesting that the pollen flora found from the Kawabata formation in the neighbourhood of the Asahi coal mine in the Ishikari coal field which is correlated to the Masuporo formation is clearly different in composition from the present pollen

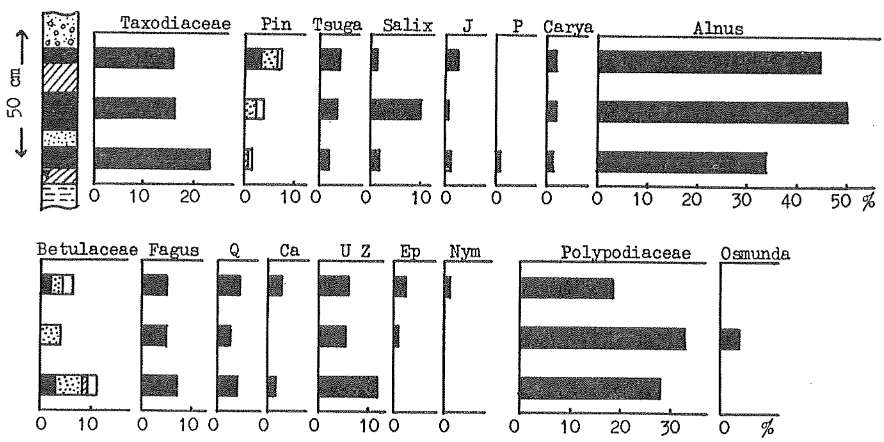


Fig. 22. Composite pollen diagram of the Masuporo formation in the Toikanbetsu area
Pin: Pinaceae (black: *Pinus*, dotted: *Picea*, white: Others and indeterminable ones), J: *Juglans*, P: *Pterocarya*, Q: *Quercus*, Ca: *Castanea*, Betulaceae (block: *Betula*, dotted: *Carpinus*, white: others and indeterminable ones), UZ: *Ulmus* and *Zelkova*, Ep: *Epilobium*, Nym: Nymphaeaceae

flora: it is closely similar to the pollen flora of the Haboro formation. This matter will be discussed below in detail.

As the Masuporo formation is very poor in fossil yields except foraminiferal remains, there is no adequate report on the climatic condition at that time, excepting that S. TSUCHIDA (1958, p. 4) has barely noted that the marine condition in which the foraminiferal fauna in this formation lived was deep and cold on basis of his study on the foraminiferal fauna at the neighbourhood of Toyotomi-machi which is near to the present sampling locality. Next, two cases are considered of the above-noted cold condition: in one case let the cold condition be considered due to the great depth of the water and in the other case due to the coldness of the water itself. If it is proved that the coldness was not due to the former fact but to the latter, i.e., to a cold current, it is induced as a matter of course that the distribution area of the Masuporo formation discussed here was under the influence of the cold current. Now, if the sedimentary condition was in deep water but not quiet as indicated by the abnormal sedimentary facies, could such concentration of light pollen grains in this thin coal seam occur under such a condition? Also, according to IWAMOTO, a specialist on foraminifera, the fauna reported by TSUCHIDA does not necessarily indicate a deep condition. At any rate, the present writer can not agree with the opinion that the sedimentary condition of the Masuporo formation in the present area occurred in deep water; accordingly the above-noted cold condition presumed from the foraminiferal fauna may be due to a cold current. So, the climatic condition in the present area of the Masuporo stage might be not so warm; the conclusion agrees with the result presumed from writer's present study.

3B. Masuporo formation in the Nissô-teshio coal mine area

The sampling locality is about 2 km west of the Nissô-teshio mine of the Tempoku coal field (Fig. 19).

The Masuporo formation in this area is composed of conglomerate, sandstone and mudstone, and is rich in such abnormal sedimentary features as intraformational folding, slumping or cross-bedding in some place and rich in facies composed of black shale in other place. The sample was taken from a thin coal seam (20 cm in thickness) in coarse-granule sandstone in this formation; the stratigraphic position of the sample is about 200 m below the base of the Wakkanai formation which overlies the Masuporo formation with a parallel unconformity*.

* The Wakkanai formation generally overlies the Masuporo formation with an unconformity in the Tempoku region, but NAGAO (1960) reported that the boundary of the two formations seems to be conformable in the neighbourhood of the Nissô mine.

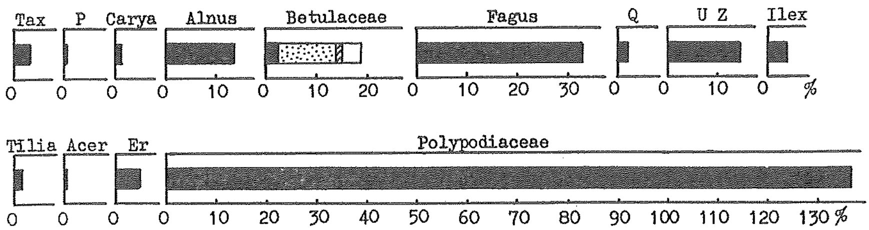


Fig. 23. Composite pollen diagram of the Masuporo formation in the Nisso-Teshio area
Tax: Taxodiaceae, P: *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*, white: others), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Er: Ericaceae

The following pollens and spores are found in the sample: *Osmunda*, Polypodiaceae, Taxodiaceae, *Pterocarya, Carya, Alnus, Betula, Carpinus, Corylus, Fagus, Quercus, Ulmus, Zelkova, Acer, Ilex, Tilia, Alangium*?, *Fraxinus*?, Ericaceae and some other indeterminable pollens. The quantitative relationship of them is illustrated in Fig. 23. *Fagus* is most dominant (33 per cent of all tree pollens), and *Alnus* (14 per cent), *Carpinus* (11 per cent) and *Ulmus* (and *Zelkova*) (15 per cent) come next in number of specimens. Besides, *Carya, Betula, Quercus, Ilex, Tilia* and Ericaceae are found with frequencies of a few per cent. Coniferous pollens are rare; especially no pollen of Pinaceae is recognized so far as the writer examined. Polypodiaceae are overwhelming in number of specimens. Other pollens and spores are scarcely found.

The present pollen flora is different in composition from the other one found from the Masuporo formation at a point in the Toikanbetsu area, about 11 km south from the present locality, in the following features: 1) *Fagus* and *Carpinus* are higher in frequency in the former than the latter, 2) coniferous pollens in the former are very low in frequency, especially in Pinaceae, and 3) *Alnus* is less in the former than in the latter in frequency. Also, it may be recognized in comparison of the present flora with those of the Wakkanai stage, late Miocene, that the present flora has a close similarity with those of the Wakkanai stage, especially in the feature that *Fagus* and Betulaceae are very dominant and in the occurrence of *Quercus*. In addition to the above-noted matters, considering that the present pollen flora occurs from the horizon being rather near the Wakkanai formation which conformably* overlies the Masuporo formation, the present pollen flora is one of the transitional phases from the flora of the

* As referred in the preceding section there are divergent opinions on the stratigraphic relationship of both the formations.

Sôya stage to that of the Wakkanai stage. There is no report of other fossil data from the Masuporo formation in this area except foraminiferal remains as already described in the preceding section.

3C. Kawabata formation in the Asahi coal mine area

The samples were taken from a coal seam in the Kawabata formation in the catchment area of Suigenchino-sawa, in the neighbourhood of the Asahi coal mine (Fig. 1).

The geologic succession in this area has already been referred to in the section on the Asahi coal mine. The Kawabata formation in this area which is correlated to the Masuporo formation in the Tempoku region displays rythmic alternation of sandstone and shale, and sometimes contains coal seams in lenticular forms which sometimes reach 10 m in thickness but are very poor in lateral continuity. The coal is rich in vitrit. The Kawabata formation is usually poor in fossil remains except foraminifera, in particular there is no report on fossil plants in this formation. Accordingly, it can be said that the present data on fossil pollens are valuable to consider the flora of the Kawabata stage.

The pollen flora is mainly composed of Taxodiaceae (*Glyptostrobus*, *Metasequoia* and other indeterminable plants) and *Quercus*: the former 36 per cent and the latter 22 per cent on the average in frequency to the total tree pollens. *Abies, Pinus, Tsuga, Pterocarya, Carya, Engelhardtia, Carpinus, Alnus, Fagus, Ulmus, Zelkova, Liquidambar, Rhus, Lonicera*, Cornaceae etc. accompany the two with rather common occurrence. These features are shown in Fig. 24. The present pollen flora is very similar in composition to that of the Asahi coal-bearing formation: the abundance of *Quercus* in number of specimens and the existence of *Liquidambar, Rhus, Nyssa* and *Engelhardtia* are characteristic features being common with the Asahi coal-bearing formation. Such a floral composition indicates that the climatic condition of the Kawabata stage was similar to that of the stage represented by the Asahi coal-bearing formation. Though there is no report on the flora of the Kawabata formation, T. TANAI (1960) and K. SUZUKI (1959) reported on the flora of this stage. That is, the latter reported on the fossil plants which existed between the Daijima- and the Mitoku-type flora from the marine sediments of Northeast Japan a part of which corresponds to the Kawabata stage; according to K. SUZUKI, though there are some variations in composition of the association of these fossil plants, warm-temperate loving elements such as *Liquidambar, Sapindus*, ever-green oak, etc. are recognized amongst them. TANAI also referred to the flora of this stage in his study on the Nogene floras of Japan; as a representative of the flora

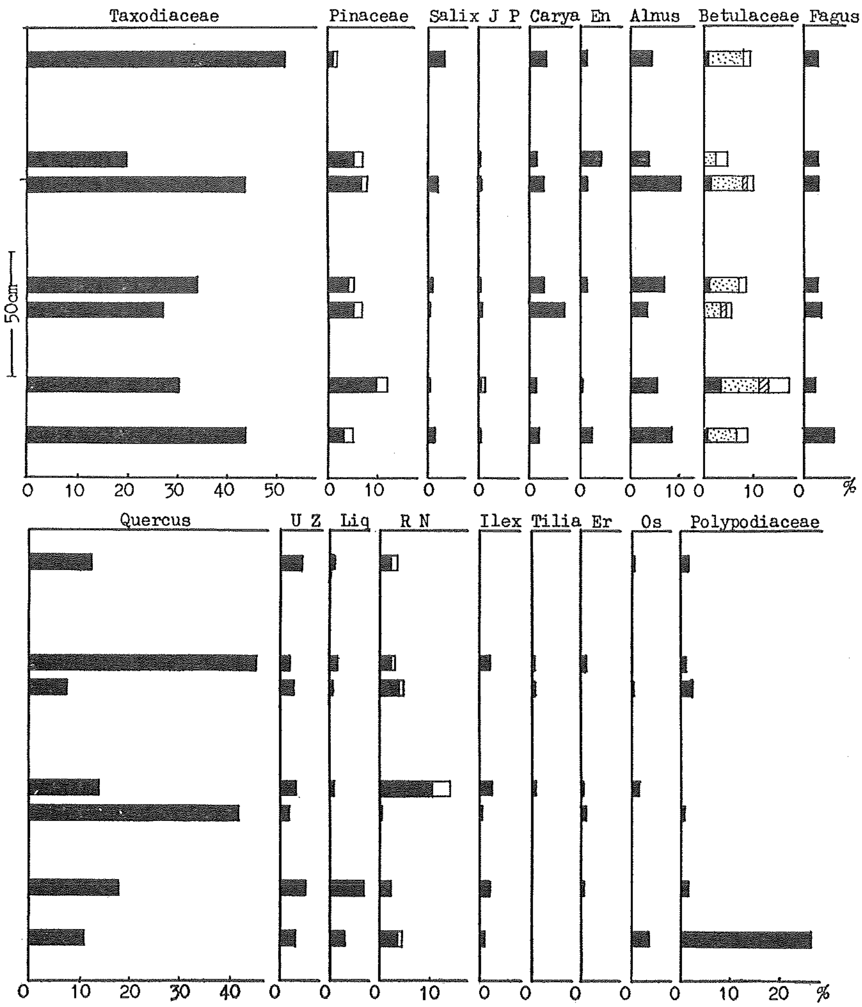


Fig. 24. Composite pollen diagram of the Kawabata formation in the neighbourhood of the Asahi coal mine
Pinaceas (black: *Pinus*), JP: *Juglans* and *Pterocarya*, En: *Engelhardtia*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*) UZ: *Ulmus* and *Zelkova*, Liq: *Liquidambar*, RN: *Rhus* (black) and *Nyssa*, Er: Ericaceae, Os: *Osmunda*

of this stage in Hokkaidô he referred to specimens in the Yûdoro and Horoshin formations in the Uryû district and the Naidabu formation in the northern Sorachi district; he said these floras belong to the Daijima-type flora in general aspect. It can not be said that the present evidence to substantiate their statements. On the other hand, though in the Tempoku region pollen floras were found from the Masuporo formation which is correlated to the Kawabata formation, the fact that the floras are clearly different in composition from the present flora attracts the writer's attention as already referred to in the preceding sections on the Masuporo formation: that is, the floras of the former are lacking in the elements of the Daijima-type pollen flora such as *Quercus, Liquidambar, Rhus, Engelhardtia* etc. This finding may mean that the climatic condition in this stage was different in the Tempoku and Ishikari regions respectively; detailed discussion on this matter will be presented below in Chapter IX.

4. Pollen floras of the Wakkanai stage

Generally the sediments of this stage are characterized by so-called "hard shale facies" which contain abundant foraminiferal and molluscan fossils, but they become terrestrial facies towards the margin of the basin where the sediments were accumulate, and contain lignite in various localities; these lignite-bearing areas are called under the names of Nakagawa, Kitauryû or Numata coal fields. Macrofossil plants are commonly found from the sediments of this stage and their assemblage is called the Mitoku-type flora, a temperate~cool temperate flora; T. TANAI (1961) reported on the floras in the following sediments as the representatives of the Mitoku-type flora in Hokkaidô: the lacustrine Taushibetsu formation in the northern part of Tokachi province, lacustrine Shanabuchi formation in the Kitami province, littoral Tachikarabetsu formation in the Kitami region and Chepotsunai (or Ogawa coal-bearing) formation in the Tomamae area; the former two are lacking in coal.

The author collected samples for pollen analysis from the Nakagawa, Numata and Tomamae coal fields and the Utanobori lignite-bearing area; the results of study of them are described in the following sections.

4A. Kamichikubetsu area

The samples were taken from a lignite bed in the Chepotsunai formation near Kamichikubetsu station, about 9 km west of the Chikubetsu coal mine. The locality is shown in Fig. 11.

The Chepotsunai formation has hithertofore been called "Ogawa lignite-bearing formation" which is correlated to the Wakkanai formation, late Miocene; it was redefined by K. MATSUNO (1960) (refer to the section on the Tomamae coal field of Chapter III on the geologic succession in the present area). The formation which is mainly composed of tuffaceous sandstone and contains tuff, sandstone and siltstone, includes a lignite bed at the present locality, but the lignite rapidly disappears northwards and southwards. The lignite bed is composed of many thin seams of lignite, siltstone and tuff, and is about 350 cm in the total thickness; a detailed

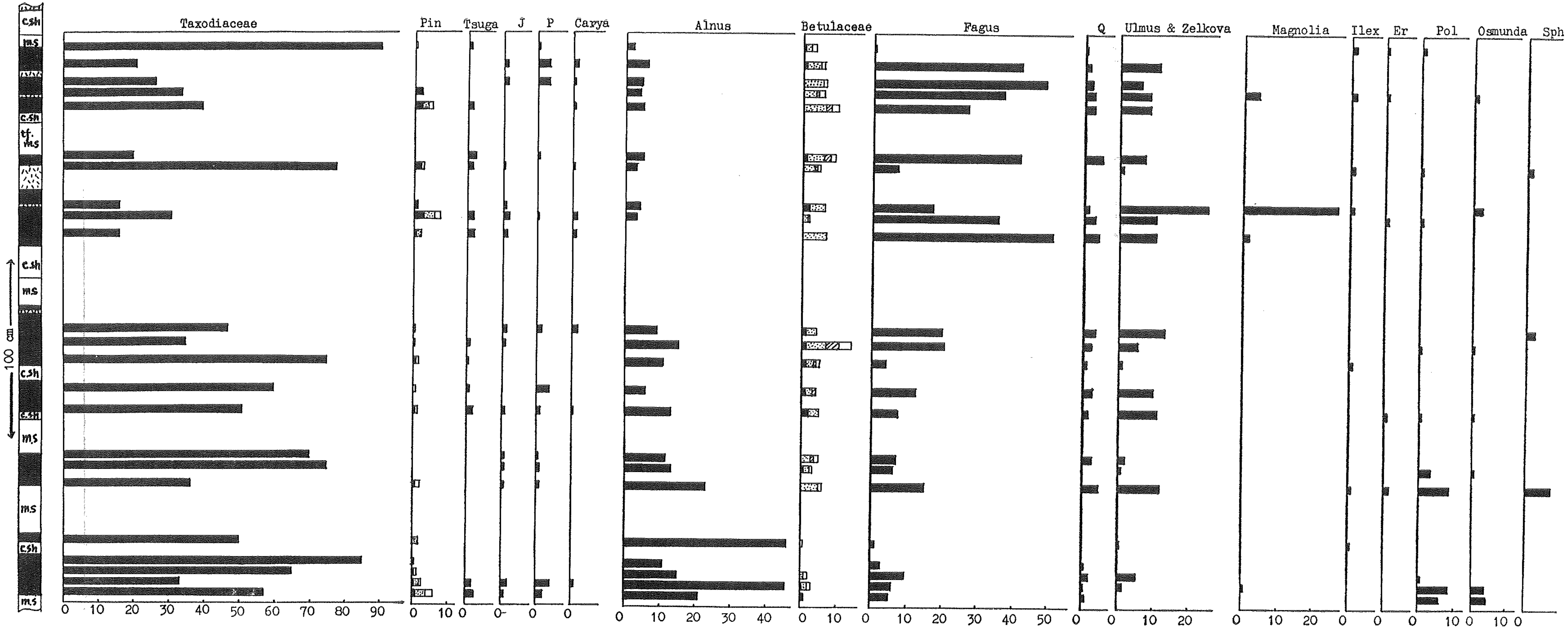


Fig. 25. Composite pollen diagram for a lignite bed in the Chiepotsunai formation at Kamichikubetsu
Pin: Pinaceae (black: *Pinus*, dotted: *Picea*, white: others and indeterminable ones), J: *Juglans*, P: *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*, white: others ane indeterminable ones), Q: *Quercus*, Er: Ericaceae, Pol: Polypodiaceae, Sph: *Sphagnum*

columnar section of the bed is illustrated in Fig. 25. The chemical procedure for taking out fossil pollens from the lignite is not the same as that for the coal which is included in the sediments being older that the Wakkanai stage, since the pollen membranes contained in the sediments of the Wakkanai stage are more easily destroyed by the chemical reagent than are those in older sediments.

The following macrofossil plants are reported from the Chepotsunai formation by K. MATSUNO (1960) : *Betula* cf. *miomaximowicziana* ENDO, *Carpinus* cf. *subcordata* NATHORST, *Carpinus* cf. *onbaraensis* OKUTSU, *Ulmus* spp., *Acer* cf. *subpictum* SAPORTA.

Following pollens and spores were found from the present samples: *Osmunda*, Polypodiaceae, *Sphagnum, Pinus, Picea, Tsuga,* indeterminable Pinaceae, *Glyptostrobus, Metasequoia,* indeterminable Taxodiaceae, *Salix, Juglans, Pterocarya, Carya, Alnus, Betula, Carpinus, Corylus, Fagus, Quercus, Ulmus, Zelkova, Liquidambar,* Magnoliaceae, *Ilex,* Ericaceae, Compositae and some other indeterminable pollens and spores. Though there is a considerable change in composition through the bed, the flora is composed mainly of Taxodiaceae and *Alnus* in the lower part and Taxodiaceae and *Fagus* in the upper part: in the lower part Taxodiaceae 33–85 per cent (57 per cent on the average), *Alnus* 6–46 per cent (19 per cent on the average), *Fagus* 1–20 per cent (9 per cent on the average), and in the upper part Taxodiaceae 16–91 per cent (37 per cent on the average), *Alnus* 2–6 per cent (4 per cent on the average), *Fagus* 7–51 per cent (31 per cent on the average) of all tree pollens. The averaged frequency values of those pollens through the whole bed are as follows: Taxodiaceae 48 per cent, *Alnus* 12 per cent, *Fagus* 19 per cent of all tree pollens. It is noteworthy that such occurrence of *Alnus* being more in the lower part of the coal seam is recognized also in the coal seams in the Haboro and Nakagawa coal bearing formations. In accompaniment wtih the above-described pollens, *Carpinus, Quercus* and *Ulmus* (and *Zelkova*) are recognized with the following percentage values: *Carpinus* 3 per cent, *Quercus* 2 per cent, *Ulmus* (and *Zelkova*) 7 per cent. Besides, *Pinus, Picea, Salix, Juglans, Pterocarya, Carya, Betula, Corylus, Ilex,* Ericaceae etc. are recognized with very low frequencies through the bed. Though only three examples in number of specimens of all pollens counted (over 4000 in numbr), *Liquidambar* pollens are found. Magnoliaceae is recognized only in some horizons in the upper part. The occurrence of Magnoliaceae and *Alnus* is similar to that of the Kayanuma coal mine already described. Polypodiaceae and *Osmunda* of non-arboreal plants are recognized with the trend to be abundant in the lower part, though the specimens are not numerous.

The present pollen flora represents a feature of the late Miocene flora in Hokkaidô: the dominance of Taxodiaceae, Betulaceae (especially *Alnus*) and *Fagus*, especially the dominance of *Fagus*. But, the present pollen flora is different from other late Miocene pollen floras in the quantitative relationship of the main components, the relative high frequency of *Ulmus* (and *Zelkova*) and the occurrence of Magnoliaceae. Such difference in composition of these floras may be due to a fact that the late Miocene sedimentary basins are subdivided into small isolated basins.

4B. Tôgeshita area

The area is about 20 km southeast from Rumoe city on the coast of the Japan sea (Fig. 1).

The geologic succession of the Miocene sediments in this area is as follows in ascending order: the Yûdoro, Tôgeshita and Mashike formations. The Tôgeshita formation overlies the Yûdoro formation with unconformity, and these Neogene sediments are underlain by the Owada coal-bearing formation (Paleogene) with unconformity, then are conformably overlain by the Rumoe formation (Pliocene).

The sample for the present study is collected from a lignite bed in the Tôgeshita formation; which in this area consists of an alternation of tuffaceous sandstone and tuffaceous mudstone in its lower part, and in the upper part, of mudstone containing plant fossils and three or four lignite beds, only a part of which was worked at the Ebishima coal mine. The same coal-bearing facies is recognized also at Kamichikubetsu, about 60 km north from the present area, and at Ogawa, about 50 km north from the present locality.

The following pollens are recognized from the sample: *Picea, Tsuga*, Taxodiaceae, *Pterocarya, Alnus, Carpinus, Corylus, Fagus, Quercus, Ulmus, Zelkova?, Ilex, Acer*, etc. Among them, *Carpinus* is most abundant in number of specimens: 77 per cent of all tree pollens; such abundance of *Carpinus*, not previously observed by the present author, is the most striking characteristic of the present pollen flora. Next, *Alnus* is commonly recognized: 16 per cent. Besids, excepting *Fagus* (2 per cent) and

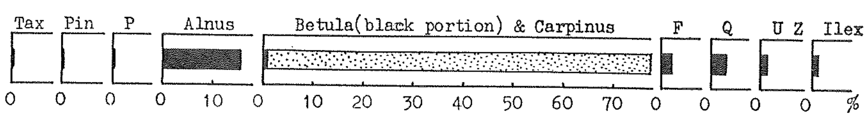


Fig. 26. Composite pollen diagram of the Tôgeshita formation
Tax: Taxodiaceae, Pin: Pinaceae, P: *Pterocarya*, F: *Fagus*, Q: *Quercus*, UZ: *Ulmus* and *Zelkova*

Quercus (2 per cent) all others occur with frequencies under 1 per cent of all tree pollens. Pollens and spores of non-arboreal plants are scarcely found. But, as the present pollen flora is one got from a piece of the the lignite, many more samples may be needed before conclusion can be reached whether the present floral composition is a general feature of the pollen flora of the Tôgeshita formation. It can be also said, however, that the present result may represent a characteristic of the upper Miocene pollen flora: though the present pollen flora is different in composition from those of the Onnenai, Kamiketobetsu, Bifuka and Kamichikubetsu areas, all of which are late Miocene in age, it is common with these in the predominance of Betulaceae which is a conspicuous characteristic of the late Miocene flora, Mitoku-type flora.

4C. Onnenai coal mine

This mine is situated about 4 km northwest of Onnenai station on the Sôya main line (Figs. 1 and 27). It has been worked in the past on a small scale, but is not in operation at present.

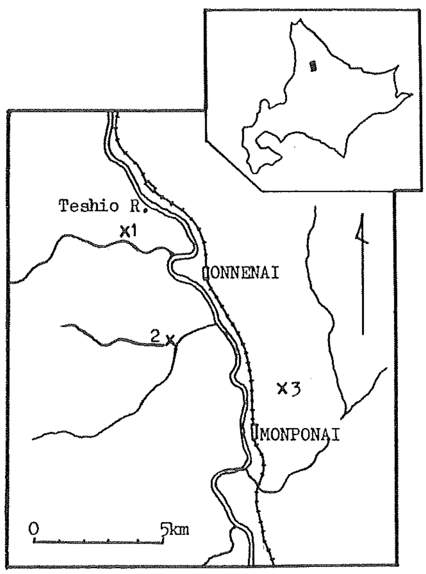


Fig. 27. Locality map of samples in the Nakagawa coal field
1: Onnenai coal mine
2: Sampling locality in Masuda-no-sawa
3: Monponai (Nakagawa) coal mine

The geologic succession in this area is as illustrated in Table 10.

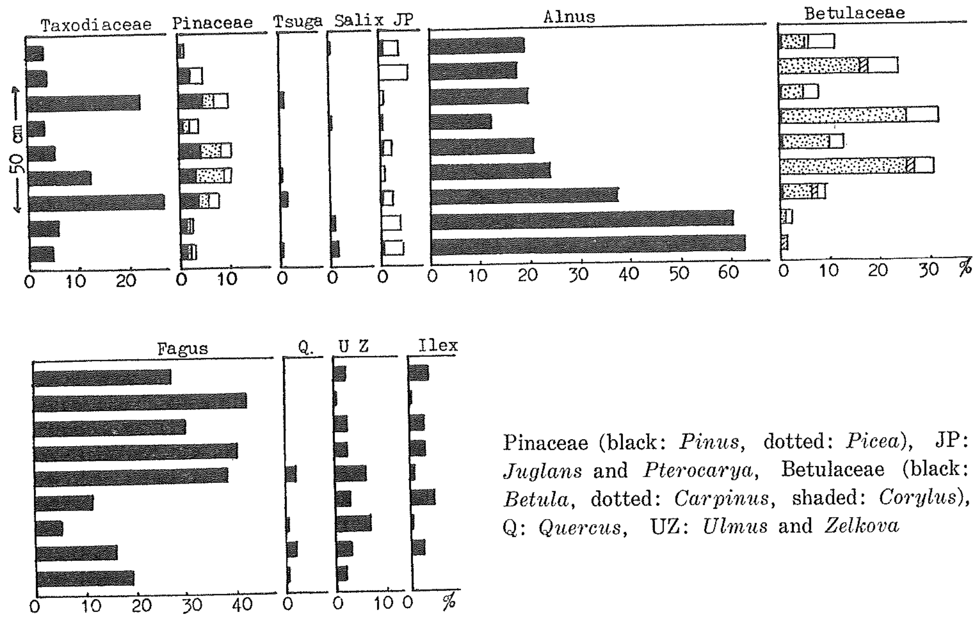
TABLE 10. Geologic succession of the Miocene sediments in the Onnenai area

	Quaternary sediments	
Miocene	Lower part of the Kawanishi formation	Upper conglomerate formation
	Lower agglomerate ?	
	Nakagawa coal-bearing formation ?	
	Cretaceous rocks	

The samples for the present study were taken from the Nakagawa coal-bearing formation which is correlated to a part of the Wakkanai formation, late Miocene; the stratigraphic relationship of the Nakagawa formation to the lower and upper strata is not yet cleared in the field owing to its poor exposure. Various arguments have been entered into on the stratigraphic position of the formation: for example, it has been correlated to the Sôya coal-bearing formation in the Tempoku region or to the Chikubetsu formation at times. Though it has been reported that three coal seams exist in this siltstone, the writer could find only one seam (No. 1 seam) in a collapsing pit. The coal is high in ash content and is so low grade in quality that the time for the oxidizing treatment by Schultze solution in order to take out fossil pollens is sufficient at five hours, which is far less than of the coal of the Sôya coal-bearing formation (1–2 days).

In the pollen flora of the present samples, *Alnus* and *Fagus* are two main components: the frequencies to the total tree pollens of the former are 13–63 per cent (31 per cent on the average) and the latter 6–43 per cent (26 per cent on the average). *Carpinus* and Taxodiaceae accompany them with frequencies of about 10 per cent on the average. Besides, *Pinus, Picea, Tsuga, Salix, Pterocarya, Quercus, Ulmus, Zelkova*, and *Ilex* are found with frequencies under 10 per cent throughout the seam. As non-arboreal plants, *Sphagnum, Osmunda* and Compositae are recognized, but they are very low in frequency (under 1 per cent). The pollen floral composition is illustrated in Fig. 28.

The above-described pollen floral composition clearly differs from that of the Sôya coal-bearing formation, especially in the features that *Fagus* and *Carpinus* are much more abundant and Taxodiaceae less so in the former than in the latter. Judging from the frequencies of *Fagus* and Betulaceae (mainly composed of *Carpinus*), the flora seems to belong to the Mitoku-type flora of late Miocene. The present pollen flora, however,



Pinaceae (black: *Pinus*, dotted: *Picea*), JP: *Juglans* and *Pterocarya*, Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*

Fig. 28. Composite pollen diagram of the Onnenai coal mine

differs in composition from that of the Tôgeshita formation of the Tôgeshita area in the feature that Betulaceae pollens are much more abundant in that than in the present pollen flora. Also, it is noteworthy that the pollen flora of the Monponai coal mine, about 9 km southeast from the present locality, of which coal-bearing sediments are considered to be equivalent in geologic age with the present ones, is different from the present pollen flora in the feature of the overwhelming abundance of Taxodiaceae. Such a clear difference makes it difficult to consider that the two floras are the same in age; presumably, they are different in stratigraphic horizon, though they both belong to the Mitoku-type flora of late Miocene.

4D. Monponai (or Nakagawa) coal mine

This mine is situated about 9 km southeast of the Onnenai mine and about 2 km northeast of Monponai station on the Sôya main line (Figs. 1 and 27).

The stratigraphic horizon of the coal-bearing sediments of this mine has not been clarified in the detail owing to the fact that the area of this mine is separated by igneous rock (andesite) from the neighbouring distribution area of sedimentary rocks; the geologic succession of the neighbouring area is as shown in Table 11. The upper conglomerate

TABLE 11. Geologic succession of the Monponai area

Miocene	Upper conglomerate formation
	?
	Nakagawa coal-bearing formation
	?
	Lower molluscan fossil bearing formation
	Cretaceous rocks

formation may change into the lower agglomerate and Kawanishi formation in the area to the west side of the Teshio river. It is said that the Nakagawa coal-bearing formation in the present mine contains two workable coal seams and many other thin coal seams. But, the author could find only one thick seam in this ruined mine; only the lower part (65 cm+) of the seam was found in a collapsing pit; from it samples were taken. The coal in the present mine is good massive lignite and it is also said that the coal is best in quality beyond other mines in the Nakagawa coal field.

The pollen flora in the coal is mainly composed of Taxodiaceae and Betulaceae; the former is 23–74 per cent (45 per cent on the average) in number of specimens and the latter 2–53 per cent (22 per cent on the average). Especially, the overwhelming dominance of Taxodiaceae is a characteristic feature of the present pollen flora; though Taxodiaceae is composed of pollen grains of large size (many grains are over 35 μ and some grains reach 50 μ in diameter) which are much larger than those of the recent Taxodiaceae pollens, it is not determined whether the large size is due to expansion caused by chemicals in treatments of pollen analysis or is the original size of those grains. Judging from the shape and size of the grains and considering the knowledge from the study of macrofossil plants that Taxodiaceae of the late Miocene age in Hokkaidô was composed of *Metasequoia, Glyptostrobus* and *Taiwania,* one may say that *Glyptostrobus* is predominant amongst Taxodiaceae in the present pollen flora. *Carpinus* is predominant of the Betulaceae in the pollen flora. Besides, there are many pollens which are similar to *Carpinus* but the membrane around germinal pores is thicker than that of *Carpinus*; these pollens may belong to *Carpinus,* but the author counted them as indeterminable pollens of Betulaceae in his pollen diagram. *Alnus* and *Fagus* are commonly found with frequencies over 5 per cent. Further, *Picea, Pinus, Tsuga, Salix, Juglans, Pterocarya, Betula, Quercus* and *Ulmus* occur with low frequencies. Also, a few grains of *Larix,* Magnoliaceae and *Ilex* pollen are recognized. Polypodiaceae occurs in the lower part of the seam, but no other non-arboreal plant is recognized except for

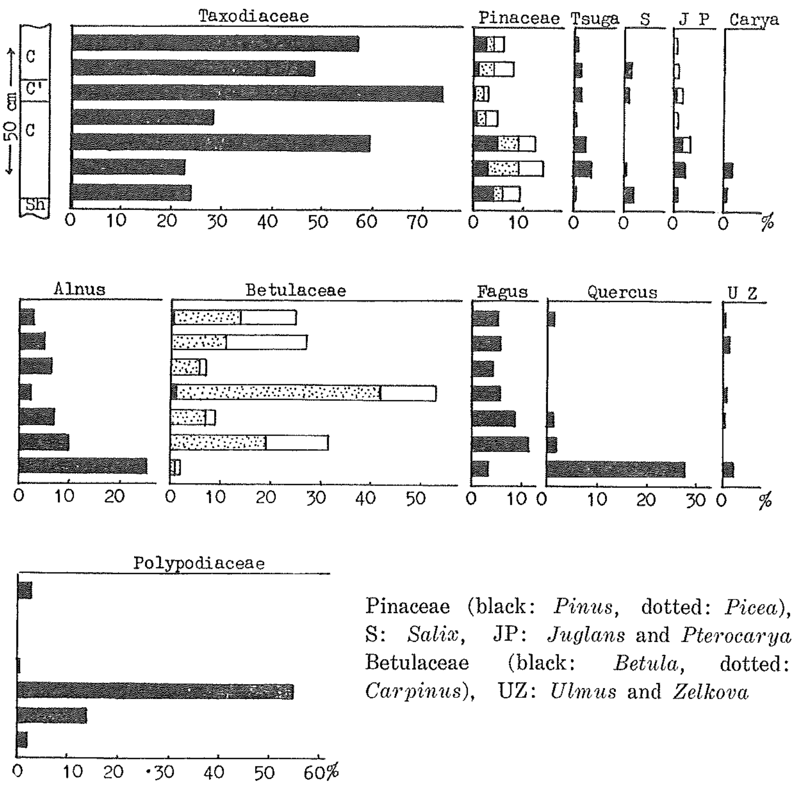


Fig. 29. Composite pollen diagram of the Monponai coal mine

a few grains of *Sphagnum* and *Osmunda*. The above-noted composition is illustrated as a pollen diagram in Fig. 29. Except the overwhelming abundance of Taxodiaceae, this flora in composition is simalr to other upper Miocene pollen floras: for example, the pollen floras of the Onnenai mine and Tôgeshita area; the abundance of Taxodiaceae may be due to a local condition. The coal-bearing horizon in the present mine, however, must be slightly different from that of the Onnenai mine in stratigraphic position, because it is difficult to assume that the flora at that time had such a difference in composition with such a short distance (about 9 km) between the two localities.

4E. Masuda-no-sawa, near Onnenai coal mine

The samples were taken from a lignite bed (60 cm in thickness) in Masuda-no-sawa, a tributary of the Ogurumanai stream which joins the Teshio river; the locality is about 5 km south from the Onnenai mine and 5 km northwest from the Monponai mine as shown in Figs. 1 and 27.

Though the geologic succession in this area is not yet clarified in detail, the stratigraphic positions of the lignite-bearing sediments of the Onnenai mine and present area are supposed to be in the following succession in ascendin order: the coal-bearing sediments of the Onnenai mine (Nakagawa coal-bearing formation), agglomerate (Futamata agglomerate) and lignite-bearing sediments of Masuda-no-sawa. This succession seems to correspond to that reported be S. IMANISHI (1955) in the Nayoro area, the neighbouring area of the present locality to the south: he reported

TABLE 12. Geologic succession in the Nayoro area

Pliocene	Kawanishi formation	
Miocene	Rokugô-no-sawa formation (contains lignite)	
	Futamata agglomerate	Urubeshi formation (contains good lignite)
	Cretaceous rocks	

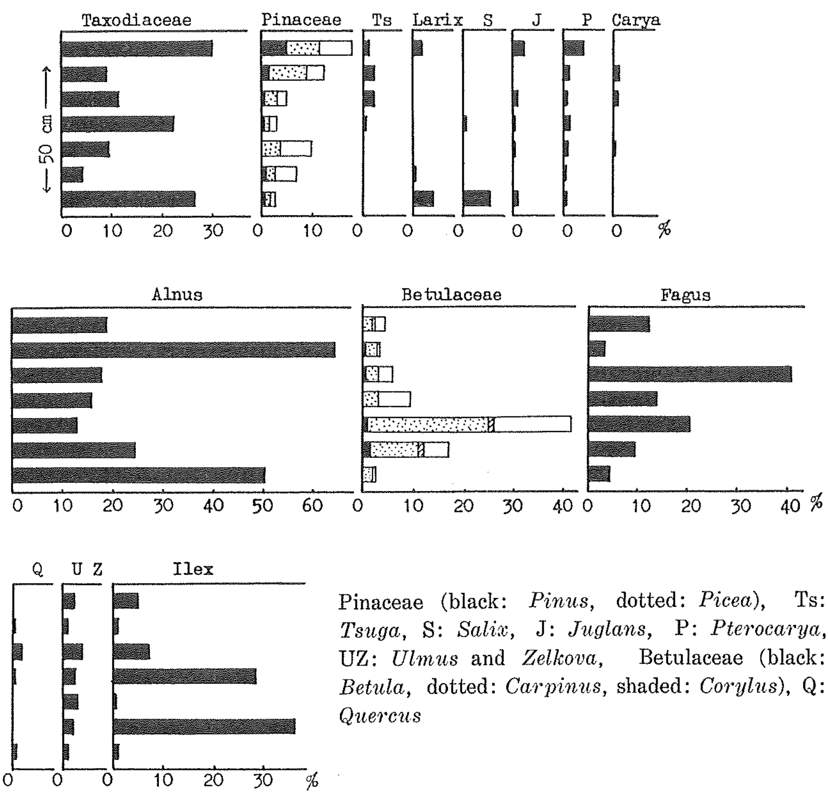


Fig. 30. Composite pollen diagram of the samples from Masuda-no-sawa

such a stratigraphic succession of the Miocene sediments in the area as shown in Table 12. The present lignite bed is contained in sandstone which overlies the agglomerate (Futamata agglomerate) and is rich in pyloclastic materials, carbonaceous fragments and conglomerate.

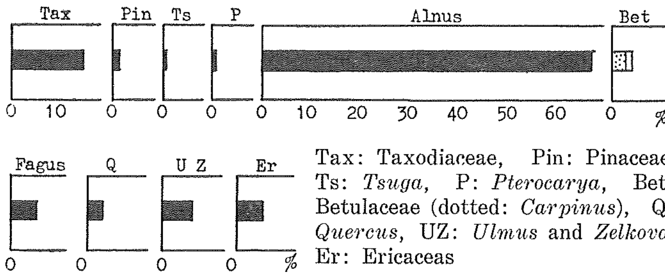
The pollen flora in the present lignite is mainly composed of Taxodiaceae, *Alnus, Carpinus, Fagus, Ilex,* etc. as shown in the pollen diagram of Fig. 30. The pollen flora is generally similar in composition to those of the Onnenai mine and others which are all late Miocene, Wakkanai stage, in age. However, it is different from them in the feature that *Ilex* is more abundant in number of specimens in the present lignite, though its frequency is not uniform through the seam from the bottom to the top but shows considerable fluctuation as is illustrated in the pollen diagram. This feature is also recognized in a sample taken from the Rokugô-no-sawa formation in the neighbourhood of Bifuka-machi, about 11 km south from the present locality (refer to Fig. 32). Presumably, the present pollen flora is one of the late Miocene age, but is slightly higher in stratigraphic position than other late Miocene pollen floras of the Nakagawa coal field described in the preceding sections. Besides, it is unexplained for what reason fossil pollen grains in the present lignite are very large in size: whether they were large in original size or the larger size is due to some post-deposition cause or to any chemical treatments used in pollen analysis.

4F. Kamiketobetsu area

The present area is situated a distance of 30 km north of the Nakagawa coal-field (Fig. 1).

In this area, the coal-bearing sediments which are correlated to the Wakkanai stage directly overlie Cretaceous rocks with unconformity. The sediments are called under the name of the "Tachikaraushinai formation" or "Shôtonbetsu formation", and contain several lignite beds some of which have been worked on a small scale. The coal is not very good in quality. The sample for the present study is taken from a lignite bed.

The pollen flora in the sample is simple in its composition as is illustrated in the pollen diagram (Fig. 31): specifically, *Alnus* occupies 66 per cent of all pollens in number of specimens accompanied by Taxodiaceae (12 per cent), *Ulmus* and *Zelkova* (6 per cent), *Quercus* (3 per cent), *Carpinus* (3 per cent), Ericaceae (3 per cent), *Pterocarya, Corylus, Pinus, Tsuga,* etc. Such a composition is similar to that of the lower part of the lignite bed of the Onnenai coal mine, especially in respect to the abundance of *Alnus*. As the abundance of *Alnus* pollen is found also in many coal seams of various ages and localities in Hokkaidô, it may indicate some ecological condition rather than climatic condition. The similarity



Tax: Taxodiaceae, Pin: Pinaceae, Ts: *Tsuga*, P: *Pterocarya*, Bet: Betulaceae (dotted: *Carpinus*), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Er: Ericaceas

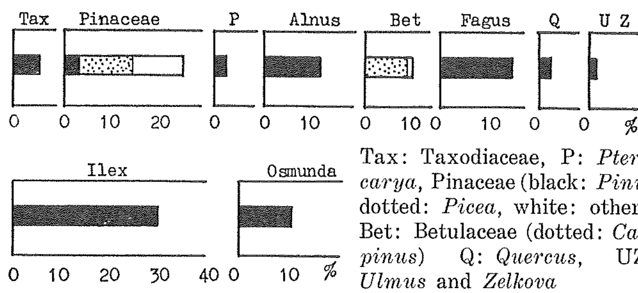
Fig. 31. Composite pollen diagram of the Kamiketobetsu area

between the present pollen flora and that of the Onnenai mine supports the idea of the same age of the two coal-bearing formations. At any rate, the predominance of Betulaceae and the common occurrence of Fagaceae and Taxodiaceae are characteristic features of the Mitoku-type flora of late Miocene.

4G. Bifuka area

The sample is taken from the lignite-bearing sediments which are of Wakkanai stage in geologic age in the neighbourhood of Bifuka-machi about 13 km south from Onnenai discussed in the preceding section.

The composition of the pollen flora in this sample is shown in Fig. 32.



Tax: Taxodiaceae, P: *Pterocarya*, Pinaceae (black: *Pinus* dotted: *Picea*, white: others) Bet: Betulaceae (dotted: *Carpinus*) Q: *Quercus*, UZ: *Ulmus* and *Zelkova*

Fig. 32. Composite pollen diagram of the Bifuka area

The common occurrence of Betulaceae and Fagaceae in the present sample indicates that the pollen flora belongs to the Mitoku type. But the relative high frequencies of Pinaceae and *Ilex* are a point different from other Mitoku-type floras. The former may suggest that the site where the lignite was formed was near to the high-land where Pinaceae were growing just like the phenomenon which was recognized in the pollen analytical result of the Chikubetsu coal mine: the frequency of Pinaceae increased towards the high-land presumed to exist at that time when the coal was formed. The relative high abundance of *Ilex* is also found in the samples collected from Masuda-no-sawa as was described above; the present lignite-bearing sediments may be correlated to those of Masuda-no-sawa and both the pollen floras may be stated to represent the youngest among the Miocene floras so far as the author has examined.

5. Pollen floras which stratigraphic horizons are unsettled

5A. Honjin-no-sawa in Rumoe coal field

As was already noted in Chapter III, many unsettled problems remain on the stratigraphic horizons of the Neogene sediments in the Uryû region owing to the complexity of its geological structure. So, much more detailed investigation may be needed to determine correctly the stratigraphic horizons of the sediments and to know the floral change during the Neogene age in this area. The present study of the Honjin-no-sawa coal-bearing formation is only a preliminary attempt to promote the study in more detail in future.

Samples for the present study were collected from a thin coal seam (about 40 cm in thickness) in the Honjin-no-sawa coal-bearing formation at a point, about 12 km north from Numata, on the river side of the Horonitachibetsu river, a tributary of the Uryû river (Fig. 1).

The geologic succession in this area was already described in Chapter III. The stratigraphic horizon of the Honjin-no-sawa coal-bearing formation is not yet settled; the name is given for the coal-bearing facies in the Horoshin group but it is feared that some coal-bearing facies of various stratigraphic horizons are now called under this name.

The following fossil pollens and spores are recognized from the present samples: *Osmunda*, Polypodiaceae, *Pinus*, *Tsuga*, other Pinaceae, Taxodiaceae, *Salix*, *Juglans*, *Pterocarya*, *Carya*, *Alnus*, *Betula*, *Carpinus*, *Fagus*, *Quercus*, *Ulmus*, *Zelkova*, *Liquidambar*, *Ilex*, *Acer*, Nymphaeaceae and some other indeterminable pollens and spores. As will be seen in the pollen diagram (Fig. 33), the present pollen flora is characterized by the overwhelming dominance of *Alnus* in number of specimens, occurrence of *Tsuga*, *Quercus* and *Liquidambar* and abundance of *Osmunda* and Polypodiaceae. The flora is closely similar in composition to that of the Tomamae coal-bearing formation, especially in the overwhelming abundance of *Alnus* and Polypodiaceae and occurrence of *Tsuga*, but also it is different from that in the occurrence of *Liquidambar* and *Quercus*.

On the other hand, T. TANAI (1961) reported the following macro-fossil plants from this formation and determined the flora to be of Aniai type:

Metasequoia occidentalis (NEWB.) CHANEY
Salix varians GOEPPERT

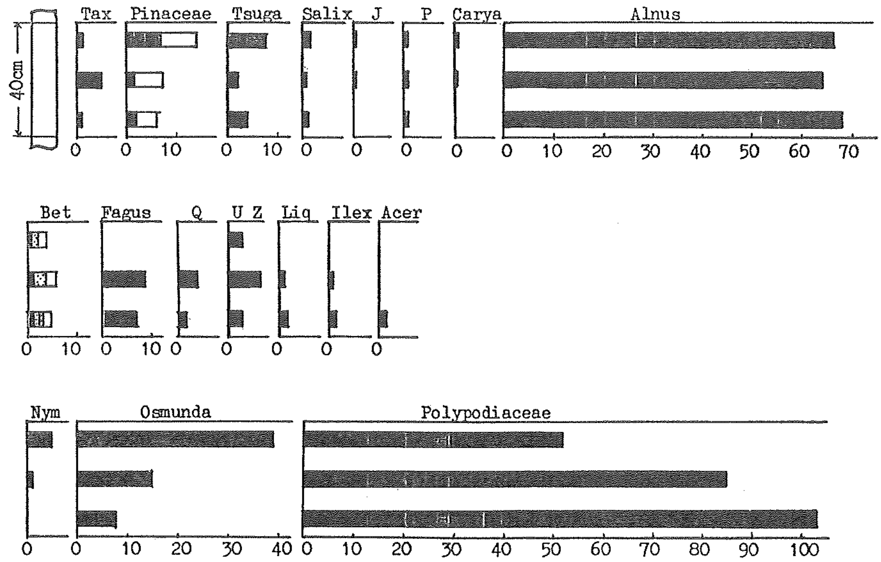


Fig. 33. Composite pollen diagram of the Honjin-no-sawa coal-bearing formation Tax: Taxodiaceae, Pinaceae (black: *Pinus*), J: *Juglans*, P: *Pterocarya*, Bet: Betulaceae (black: *Betula*, dotted: *Carpinus*), Q: *Quercus*, UZ: *Ulmus* and *Zelkova*, Liq: *Liquidambar*, Nym: Nymphaeaceae

Betula uzenensis TANAI
Carpinus subcordata NATHORST
Cercidiphyllum crenatum (UNGER) BROWN
Hydrangea lanceolimba HU et CHANEY
Aesculus majus (NATHORST) TANAI
Alangium aequalifolia (GOEPPERT) KRYSHT. et BORSUK

However, the present writer is in disagreement with TANAI's determination, because *Quercus* and *Liquidambar* which are usually not found in the Aniai-type flora in Hokkaidô are recognized in the present samples: if the present pollen flora is the Aniai type, it is unexplicable that the present pollen flora which was situated far north from the Aniai-type floras, a cool temperate loving flora, in Southwest Hokkaidô contains such temperature climatic condition loving plants as *Quercus* or *Liquidambar* which were not recognized in the latter. Then, if the present flora is not of Aniai type, of what age is it? Also, the present flora is quite unlike that of the Haboro coal-bearing formation, the Daijima-type flora. So far as the writer examined, the present pollen flora has the most similarity to that of the Tomamae coal-bearing formation with the exception that *Quercus* and *Liquidambar* are recognized in the former but not in the latter. The difference may be due to the following matter: in the post-Haboro stage, a barrier with EW trend was in existence at the boundary of the Uryû and Tomamae basin, and the former was under influence of a warm current coming from the south while the latter and more northern area were under influence of a cold current, so that the flora in the former indicates warmer condition than that in the latter. The existence of such a barrier was presumed also from the study on molluscan faunas of Hokkaidô (S. UOZUMI, 1962). But, the above-suggested correlation that the present flora corresponds to that of the Tomamae coal-bearing formation is a preliminary one and much more data will be needed before definite conclusion can be reached.

5B. Hidaka coal field

As was already noted in Chapter III, coal-bearing sediments are intermittently recognized in the basal part of the Miocene sediments in this field. The sediments are called under several local names, for example, the Hobetsu, Kenomai or Noya coal-bearing formations or coal-bearing members of the Sakae and Furanui formations. The sediments have hitherto been correlated to the Takinoue formation mainly on the basis of marine molluscan fossils contained in the sediments near the above-noted coal-bearing sediments. The fossils are correlated to the so-called "Takinoue fauna" or "Yatsuo-Kadonosawa fauna" which is contained in the Takinoue formation in the Ishikari coal field. But, when careful examination is made of some reports on these fossils, the correlation is never completely settled. For example, IMAI and SUMI (1957, pp. 19–22) stated as follows: "when we examine these molluscan fossils from the viewpoint of the correlation of strata and the determination of age, these species occurred from the Sakae formation are complex in its composition through the formation from the lower to the upper part. Namely, many species from the lower and middle parts of the sandstone member of the formation are common with the Takinoue fauna of Hokkaidô and the Kadonosawa fauna of Northeast Japan, which are middle Miocene in age, and no characteristic species of the Pliocene and Oligocene stage is recognized. On the other hand, the upper part of the sandstone member contains some species which are common with the Momijiyama, Poronai and Asagai faunas, which are Oligocene in age, and the fauna clearly differs in composition from the lower part.....it is difficult to determine to which formations the Sakae formation is correlated.....it sems correct to the authors that the Sakae formaion is early Miocene in age." Besides, YOSHIDA, MATSUNO, SATO and YAMAGUCHI (1959, pp. 31–32) described as follows: "Among these (molluscan fossils in the Furanui formation)

Nuculana kongiensis OTSUKA, ...*Cerithidea* sp. etc. are the main compositional elements of the so-called 'Yatsuo-Kadonosawa fauna', middle Miocene, and the fauna of the Furanui formation corresponds to the fauna. But, it is noteworthy that *Vicarya, Vicaryella, Batillaria* and *Cerithium* which are the most conspicuous compositional elements of the Yatsuo-Kadonosawa fauna are absent in the fauna of the Furanui formation. Otherwise, the present fauna is different in composition in each

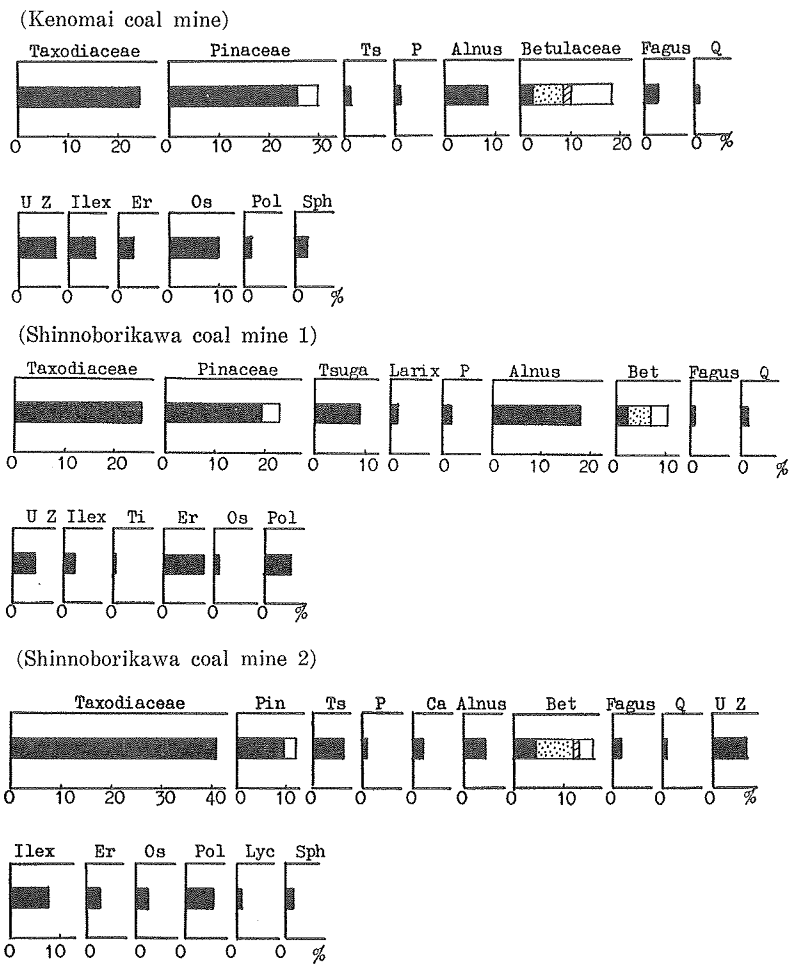


Fig. 34. Composite pollen diagram of the Hidaka coal field
Pin: Pinaceae (black: *Pinus*), Ts: *Tsuga*, P: *Pterocarya*, Bet: Betulaceae (black: *Betula*, dotted: *Carpinus*, shaded: *Corylus*), UZ: *Ulmus* and *Zelkova*, Ti: *Tilia*, Er: Ericaceae, Os: *Osmunda*, Pol: Polypodiaceae, Lyc: Lycopodiaceae, Sph: *Sphagnum*

locality in the region (the Biu district). As is described above, many species of the molluscan fossil fauna in the Furanui formation is common with the so-called 'Takinoue fauna' and there is no doubt that the present fauna is correlated to the so-called 'Yatsuo-Kadonosawa fauna', middle Miocene." However, the Sakae formation which is determined to be early Miocene is correlated to the Furanui formation of middle Miocene. As seen from such an example, the correlation of the Neogene sediments is not yet settled from the view-point of the molluscan fossils.

Now, if the formation which contains coal-bearing facies is of the Takinoue stage in age, the pollen flora of the coal-bearing facies must be similar to that of the Takinoue formation in the Ishikari coal field. But, the pollen flora of the former is clearly different in composition from the latter. That is, as is seen in the pollen diagram of Fig. 34, the pollen floras in this region are mainly composed of Taxodiaceae and Pinaceae and are lacking in *Quercus* or *Liquidambar* etc. which are a characteristic element of the Daijima-type flora in Hokkaidô. It is noteworthy that *Tsuga* is commonly recognized. *Alnus, Betula, Carpinus, Ulmus, Zelkova, Ilex* and Ericaceae occur with common frequencies (5–10 per cent). In addition to the above-mentioned pollens *Pterocarya, Carya, Corylus, Fagus* and *Tilia* appear with a few per cent. Spores of *Osmunda,* Polypodiaceae, Lycopodiaceae and *Sphagnum* are recognized but they are not very high in frequency. Such a floral composition does not indicate so warm climatic condition as that of the Haboro or Asahi pollen floras of the Takinoue stage, but indicates rather a cool temperature condtion. Especially, the lack of *Quercus,* a main component of the pollen floras of the Haboro and Asahi coal-bearing formations, is the most conspicuous difference from these floras. It may be difficult to consider that such a clear difference in floral composition is owing to the difference of local conditions in the same age. Presumably the present pollen floras are different in geologic horizon from the Haboro and Asahi pollen floras. Then, at what geologic horizon are the present pollen floras situated? A cool temperate pollen flora, the Aniai-type, is found in the Fukuyama group of the Kaminokuni and Kayanuma areas, which is lower in stratigraphic horizon than the Haboro-Asahi pollen flora. T. TANAI determined the flora in the Neogene sediments (Niikappu coal-bearing formation) in the Niikappu district to be the Aniai-type but with some question due to insufficiency of specimens. On the other hand, a cool temperate flora is recognized by the writer's pollen analytical investigation from the Tomamae coal-bearing formation which is higher in stratigraphic horizon than the Haboro coal-bearing formaton, but the flora has not yet been found in any horizon above the

Takinoue formation in the southern part of central Hokkaidô.

Taking into consideration the complexity in molluscan fossils and also the above-mentioned matter, it will be seen that much more data and investigation are necessary before the stratigraphic horizon of the Neogene coal-bearing sediments in the Hidaka region can be definitely determined. The present writer's pollen analytical study report in this paper is not one by which the problem can be explained, but is rather one which only suggests the existence of unsettled problem in the correlation in this region.

VIII. Stratigraphic horizon of the Soya coal-bearing formation

The Sôya coal-bearing formation, the main coal measure in the Tempoku coal field, has been hitherto thought by various authors to be of the same age as the Haboro coal-bearing formation, middle Miocene, in the Tomamae coal field. However, very recently, it has been questioned by a few authors whether or not the correlation is true. The formation contains many coal seams which are worked in many coal mines; many well-preserved examples of fossil pollen and spores as well as leaves are found from these seams. Therefore, these fossils should reveal the flora assemblage in the formation and at the same time give some suggestions of the stratigraphic horizon of the formation which is important if one wishes to consider the floral change during the early Neogene period; this is one objective of the present paper. Opinions on whether or not Sôya- coal-bearing formation is equivalent to the Haboro coal-bearing formation are found in many papers by various authors. Equivalence is still generally accepted up to the present. The correlation is based mainly on the result of the research by K. HUZIOKA* on macrofossil plants: in his paper he reached the conclusion that both the floras of the Sôya and Haboro formations are warm-temperate type and belong to the Daijima-type flora. Recently, S. NAGAO (1960, pp. 9–10) expressed his opinion that elements of Aniai-type flora are found in the flora from the Sôya formation. According to the current opinion of HUZIOKA the Aniai-type flora is slightly lower in stratigraphical horizon and cooler in its constituents than the Daijima-type flora.

The correlation of the formations in the Tempoku and Tomamae coal fields has hitherto been considered as follows (Table 13). Recently K. MATSUNO has made the following tentative correlation of the two fields mostly based on his stratigraphical study of the Neogene series in Hok-

* HUZIOKA, K. (1949): Doctor of Science thesis presented to Hokkaidô University (MS).

TABLE 13. Correlation of the formations of the Tempoku and Tomamae coal fields hitherto current

	(Tempoku coal field)	(Tomamae coal field)
Pliocene	Koitoi formation	Enbetsu formation
Miocene	Wakkanai formation	Shosanbetsu formation
		Ogawa (coal-bearing) formation
	Masuporo formation	Kotanbetsu formation
	Onishibetsu formation	Chikubetsu formation
	Sôya (coal-bearing) formation	Haboro (coal-bearing) formation
	Magaribuchi formation	Haranosawa formation

TABLE 14. Tentative correlation of the Miocene sediments in the Tempoku and Tomamae coal fields by K. MATSUNO

	(Tempoku coal field)	(Tomamae coal field)
Up. Miocene	Koitoi formation	Enbetsu formation
	Wakkanai formation	Chepotsunai formation
Mid. Miocene	Masuporo formation	Kotanbetsu formation
	Onishibetsu formation	Chikubetsu formation
Low. Miocene	Sôya formation	Sankebetsu formation
	Magaribuchi formation	
		Haboro formation
		Pankezawa formation

kaidô (Table 14). As is shown in Table 14, the correlation according to which the Haboro formation is older than the Sôya formation is different from the current opinion; this conclusion seems to be based on the old opinions of TANAI (1955) that the flora of the Haboro formation is Aniai type and of HUZIOKA (1949) that the flora of the Sôya formation is Daijima type. But, very recently (1961) TANAI has formed the opinion that the Haboro flora is warm-temperate~temperate and corresponds to the Daijima-type flora on basis of his recent study of macrofossil plants. The present writer has also recognized the existence of *Liquidambar, Nyssa, Cinnamomum?* and abundant *Quercus*, a typical feature of the Daijima-type flora, in fossil pollens in the Haboro formation. Moreover, it is said by TANAI that the macrofossil plants in the Sôya formation do not indicate a warm-temperate climatic condition. Also by the writer's pollen analytical investigation it is recognized that the pollen flora in the Sôya formation clearly differs in composition from that in the Haboro formation.

Accordingly, MATSUNO's correlation should be corrected. Furthermore, MATSUNO newly proposed the Sankebetsu formation for the lower half of the traditional Chikubetsu formation: namely, he separated the Chikubetsu formation and kept the name of the Chikubetsu formation only for its upper half. Because he recognized an unconformity between the two formations and he found also a difference in fossil content in both the formations. His description (1960, pp. 16–17) on the Sankebetsu formation is as follows: "These molluscan fossils contained in the Sankebetsu formation are composed of elements which occur from the late Oligocene to Miocene sediments, and moreover, the formation contains *Lithophaga* spp. indicating a warm-temperate climatic condition and *Turritella s.-hataii* NOMURA which is a member of the so-called *Vicarya* fauna. *Nonion pompilioides* (FICHTER & MOLL.) and *Elphidium takinouense* ASANO (MS) are found in a core sample and in field specimens taken from the neighbourhood of the Chikubetsu coal mine." And he concluded as follows: "From the above-described matter, though it can not be said with sureness, the faunal composition of this formation is correlated with the Takinoue formation or the Kadonosawa formation..." But, as he noted, the fauna is not a typical Takinoue fauna, and even *Lithophaga* spp. and *Turritella s.-hataii* NOMURA with which MATSUNO determined the climatic condition of the Sankebetsu stage to be warm-temperate are found only from one locality by him (MATSUNO 1960, Table 2, p. 15). Moreover, *Nonion pompilioides* (FICHTER & MOLL.) is reported by S. TSUCHIDA (1957–58) to occur from the Kawabata to Takikawa stages but not only from the Chikubetsu stage. Also, there is an opinion* that the element indicating a warm condition is only found from the lowest part of the Sankebetsu formation. Considering the above-mentioned facts, the reasons by which MATSUNO distinguished the Sankebetsu formation from the Chikubetsu formation as one formed under a warm condition may not be a positive reason. He also did not offer reasons why the terrestrial Sôya formation is correlated to the marine Sankebetsu formation. For the reasons described above, the writer is not in agreement with MATSUNO's correlation at least with respect to the lower part of the Neogene sediments.

T. TANAI (1961) has recently reported in his study of the Neogene floral change in Japan that the flora in the Sôya and Haboro formations are of the Aniai and Daijima types respectively; accordingly, the Sôya formation is lower in stratigraphical position than the Haboro formation according to his opinion. In addition to this, if a correlation between the

* UOZUMI's (a specialist of molluscan fossils of Tertiary) oral communication.

Onishibetsu and the Chikubetsu formations (at least, of the upper part of the two formations) is correct, the Haboro formation must take its stratigraphical position between the Sôya and Onishibetsu formations in the Tempoku coal field according to TANAI's opinion. However, there is no coal-bearing facies between them, but the Sôya formation is directly overlain by marine sediments of the Onishibetsu formation with a distinct unconformity. Accordingly, the two alternatives to a correlation of the two coal fields as is shown in Fig. 34 are considered.

If the stratigraphical relation is as illustrated at Case 1 in Fig. 35

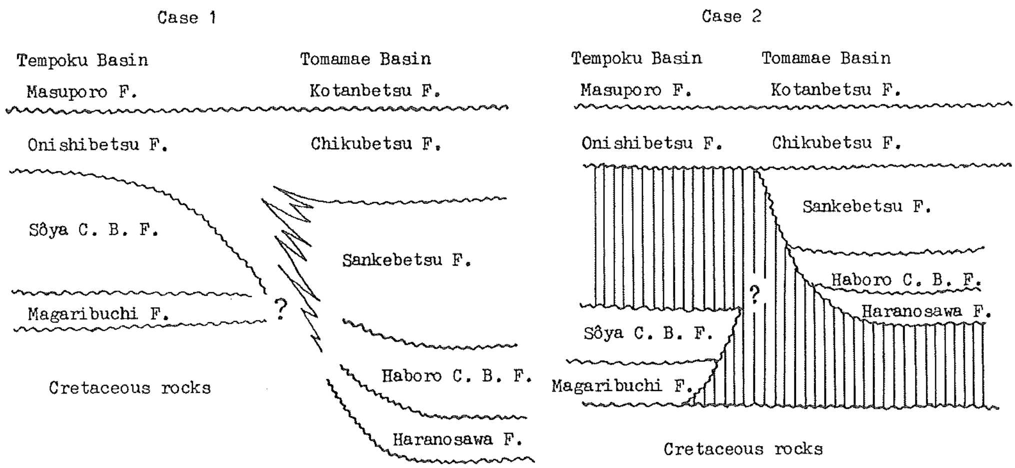


Fig. 35. Diagramatic stratigraphic relationshiy of the Tempoku and Tomamae basins

(namely, the Sankebetsu formation and the terrestrial facies of the Haboro formation change into the lower part of the marine Onishibetsu formation), any evidence representing a warm condition must be found in the lower part of the Onishibetsu formation, but it has not been found. Furthermore, the Onishibetsu formation is only 100 m$\pm$ in thickness which is too thin to be correlated to the sediments from the Haboro to Chikubetsu formation (about 1300 m in thickness), for it is not usual that a marine facies thickens towards terrestrial facies like this.

Besides, also a stratigraphical relation as illustrated at Case 2 in the figure is assumed. In this case, the unconformity between the Sôya and Onishibetsu formations represents a long period of erosion without sediments which corresponds to the Haboro and Sankebetsu formations. If so, it must be concluded that in two adjacent basins the lower coal-bearing formation (Sôya formation) is in existence and the upper one (Haboro formation) is completely eroded out in one basin (Tempoku coal field); whilst the upper exists and the lower does not at all in the other basin (Tomamae coal field). Though the writer can not speak positively that such a case is never assumed, is such a supposition very low in possibility? S. TSUCHIDA (1957, pp. 157–158) concluded from his foraminiferal study that this central basin of Hokkaidô was almost uniform in its form all through the Miocene age and there was no great unconformity which eroded out over one formation during the time; in fact such a large unconformity has not yet been reported*.

Otherwise, it may also be assumed that the warm temperate~temperate flora in the Tomamae coal field changed into the cool temperate flora in the Tempoku coal field. But, it seems to the writer unreasonable that such a sharp change in floral composition as found of the floras of the Sôya and Haboro formations could have occurred in such a distance as that between the Tomamae and Tempoku regions.

Moreover, in the southern part of Karafuto which is not so far distant from the Tempoku coal field, no coal-bearing sediment is observed in the lower part of the Miocene sediments**.

Taking into consideration the facts above-mentioned, the writer could not agree with the opinion that the flora of the Sôya formation is of Aniai type of early Miocene; accordingly, the Sôya formation is lower in stratigraphic horizon than the Haboro formation which contains the Daijima-type flora.

The writer had a chance to examine the fossil pollens in the coal of the Tomamae coal mine and the Shumarinai coal-bearing area as above described. It had previously been considered that the sediments containing the coal is correlable to the Haboro coal-bearing formation; but that of the Tomamae coal mine is now recently determined (HATTORI, S.: 1961, pp. 223–229) to be higher in stratigraphic horizon than the Haboro formation and to be a basal part of the Chikubetsu formation; as to the other (of the Shumarinai district) it is also probable that it belongs to the same horizon as that of the Tomamae coal mine based on its coal quality and the lateral discontinuity of the coal seams and the geological structure of the neighbourhood of the district. Difference in the geological horizons of these coal-bearing sediments and the Haboro coal-bearing formation is

* At Kiyokawa in Embetsu-machi, Teshiro-gun, the Wakkanai formation is directly underlain by Cretaceous rocks without the Magaribuchi-Masuporo formations. But, in the neighbourhood of this locality the lacking sediments are presumed to be thin in thickness; so, the unconformity does not represent very much erosion.

** SASA, Y. & KOIWAI, T. (1960): Geological Map of Karafuto.

proved also by pollen analytical studies of them as is described above in the preceding chapters. Particularly, the similarity of the pollen floras of the Tomamae coal mine and Shumarinai area to that of the Sôya formation leads the author to the conclusion of that the Tomamae and Sôya formations are of the same age, although no positive data are available on macrofossil plants in the Tomamae formation. On the other hand, it is also noteworthy that a coal-bearing facies which may be correlated to these coal-bearing sediments is reported by S. HATTORI (1961): that is, he reported the Chikubetsu coal-bearing member with unconformities between the marine Chikubetsu and Sankebetsu formations in the Chikubetsu coal mine area with the following geologic succession (Table 15). Another geological succession illustrated in Table 16 was reported by K. TSUSHIMA and others (1958) of the Tappu district, adjacent area to the south of the

TABLE 15. Geologic succession of the Miocene in the Haboro mine area

Kotanbetsu formation	
Chikubetsu formation	Yonkyô mudstone member
	Hidarizawa fossil-bearing member
	Chikubetsu coal-bearing member
Sankebetsu formation	Gokyô alternation member
	Futamata fossil-bearing member
Haboro coal-bearing formation	

TABLE 16. Geologic succession of the Miocene in the Tappu district

	Kotanbetsu formation	
Miocene	Neiraku formation	Chikubetsu formation
		Arakizawa coal-bearing formation
		Jûgosenzawa formation
Oligocene	Tappu formation	

Tomamae coal field. On the correlation of the Arakizawa formation to the Haboro formation and the Jûgosenzawa to the Haranosawa formation, however, FUJII* has already reported a suspicion based on his investigation of fossil content and rock facies. According to his description, the coal in the Arakizawa formation is dicontinuous laterally and not very good quality. Besides, MATSUNO, a collaborator in preparation of the

* A graduation thesis offered to Hokkaidô University in 1952 (MS).

TABLE 17. A correlation of the Miocene sediments in the Tappu and Haboro coal mine areas by MATSUNO (1960)

Tappu area	Haboro mine area
Kotanbetsu formation	Kotanbetsu formation
Chikubetsu formation	Chikubetsu formation
Arakizawa coal-bearing formation	
Jûgosenzawa formation	(coal-bearing member)
	Sankebetsu formation
	Haboro formation
	Pankezawa formation

Geologic Map of Tappu, has recently reported a correlation shown in Table 17 (MATSUNO, K. & KINO, K.: 1960), p. 28). Furthermore, MATSUNO* reported a coal-bearing facies in the basal part of the Chikubetsu formation under the name of Tomamae coal-bearing member in the Sanke district, area neighbouring to the Chikubetsu mine.

Taking into consideration these above-mentioned facts, the coal-bearing sediments between the Chikubetsu and Sankebetsu formations are

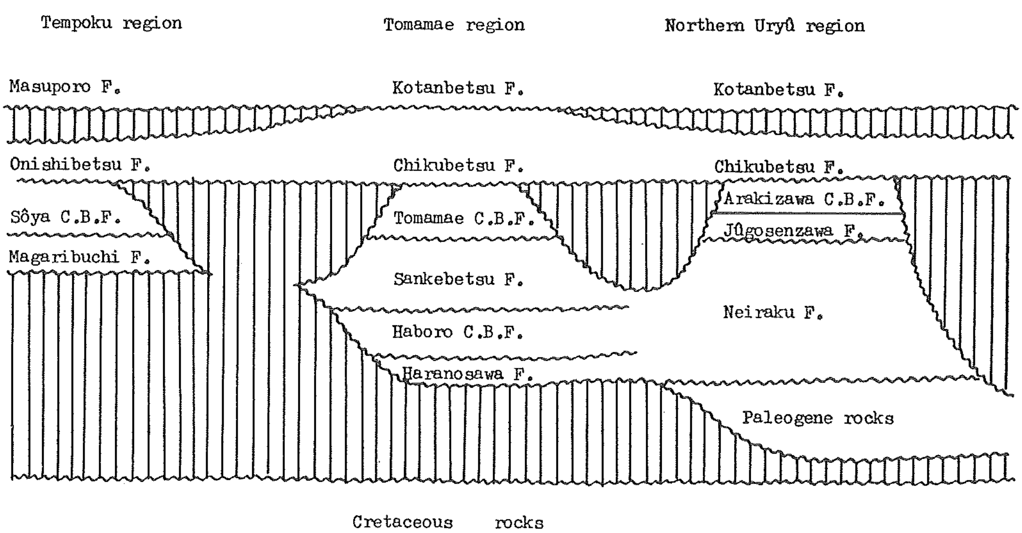


Fig. 36. Schematic stratigraphic relation of the lower half of the Neogene sediments in the Tempoku, Tomamae and Northern Uryu regions

* MATSUNO employed this name in Table 4 of p. 28 of Explanatory Text of the Geologic Map of Chikubetsu-tankô, but a clear definition is not given.

not locally found in the Tomamae district, but they do have a considerably wide areal distribution. The writer proposes the name "Tomamae coal-bearing formation", not member, for these coal-bearing sediments based on the above-mentioned matters.

From the considerations given above, the writer is of the belief that it is most reasonable to correlate the Sôya formation to this Tomamae coal-bearing formation. Probably, the transgression in the Chikubetsu stage might be wider in its areal extent than the distribution area of the Sankebetsu and Haboro formations; this is also illustrated in the map on the distribution area of the Haboro, Sankebetsu and Chikubetsu formations by MATSUNO and KINO (1960, Fig. 11, p. 29). Accordingly the Sôya formation which usually underlies the Onishibetsu (=Chikubetsu) formation may represent a precursor of this transgression. The writer's opinion on the stratigraphical horizon of the Sôya formation is represented in Fig. 36; the flora of the Sôya formation is similar to the Aniai-type in its floral composition, but is different in geologic age.

IX. Miocene floral change presumed from pollen fossils in Hokkaido

Miocene sediments in Hokkaidô are subdivided into the following stages in ascending order: the Fukuyama, Yoshioka*, Kunnui and Yakumo stages in Southwest Hokkaidô, and the Takinoue, Kawabata and Wakkanai stages in central Hokkaidô**. Though there are various different opinions on the correlation of the sediments of these stages in the two regions, the writer divides the Miocene sediments in Hokkaidô into the following stages on basis of this division: the Fukuyama, Takinoue, Kawabata and Wakkanai stages in ascending order. Already studies of the Neogene floras in Japan have been carried on by several authors; especially, T. TANAI has very recently (1961) reported on the Neogene floras in Japan and described the Neogene floras in Hokkaidô in considerable detail. He classified the Miocene floras into the following four in ascending order of age: the Ainoura, Aniai, Daijima and Mitoku type floras; among them the first did not exist in Hokkaidô according to TANAI. In the present chapter the writer describes the Miocene pollen floras in Hokkaidô together with checking against TANAI's floras based on macrofossil plants.

1. Floras of the Fukuyama stage

* Someone consider this stage to be the lower part of the Kunnui stage.

** Recently some authors consider the Momijiyama formation to be the lowest sediments of the Miocene in the southern part of central Hokkaidô.

The sediments of this stage in Hokkaidô are composed of abundant pyroclastic material; they contain carbonaceous matter in scattered areal distribution in which abundant fossil pollens and spores are found with macrofossil plants existing in accompaniment. The assemblage of these plant fossils is called under the name of Aniai-type flora, which indicates a cool-temperate climatic condition. TANAI (1961) gave the following floras as representative of the Aniai-type flora in Hokkaidô viz.: the floras in the Fukuyama formation in the Kaminokuni coal-bearing area, the Kayanuma coal-bearing formation of the Kayanuma coal mine, the Sôya coal-bearing formation in the Tempoku coal field, the Nokanan coal-bearing formation and the Asahi coal-bearing formation in the Ishikari coal field, the Honjin-no-sawa coal-bearing formation in the Rumoe coal field and the Niikappu coal-bearing formation in the Hidaka coal field. Of these, the writer has examined the pollen floras excepting in the Nokanan coal-bearing formation. The pollen floras in the Kaminokuni coal-bearing area and the Kayanuma coal mine are composed of *Osmunda*, Polypodiaceae, Lycopodiaceae, *Pinus, Picea, Tsuga, Larix,* other indeterminable Pinaceae, Taxodiaceae, *Salix, Juglans, Pterocarya, Carya, Alnus, Betula, Carpinus, Corylus, Ostrya*?, *Fagus, Quercus, Ulmus, Zelkova,* Magnoliaceae, *Ilex, Acer, Tilia,* Ericaceae, *Fraxinus*?, Nymphaeaceae, *Lonicera,* Rosaceae and some other indeterminable pollens and spores as described in detail above in chapter VII. Of these, Pinaceae, Taxodiaceae, Betulaceae, especially *Alnus* and *Carpinus* of Betulaceae, *Fagus, Ulmus, Zelkova* etc. are relatively abundant in number of specimens. There is, however, no such overwhelming abundant element as *Alnus* or Taxodiaceae in the floras of the Sôya coal-bearing formation. Besides, *Juglans, Pterocarya, Carya, Ilex,* etc. are commonly found whilst others are scarce in number of specimen. But, spores of Polypodiaceae are very abundant in number of specimen. The above-summarized statement is well in agreement with conclusions based on macrofossil plants on the whole, and represents a character of the Aniai-type flora. To quote, TANAI (1961, p. 136) gave the following features as the characteristics of the Aniai-type flora: "The Aniai-type flora consisted mainly of deciduous broad-leaved trees, as grown in temperate regions and also commonly includes many coniferous trees. Among the broad-leaved trees, these belonging to Betulacea, Ulmaceae and Aceraceae are plentiful in number of specimens and species. Especially, the family Betulaceae is most dominant, represented by temperate genera such as *Betula, Carpinus, Alnus, Corylus* and *Ostrya*. The family Ulmaceae is represented by such genera as *Ulmus* and *Zelkova*; the fossil leaves of *Zelkova* are very abundant in number. Beside them, the temperate genera such as *Juglans, Pterocarya, Populus, Cercidiphyllum, Alangium* and *Tilia* are also commonly found in this type flora. It is one of the striking characters that fossil leaves belonging to the genera *Quercus* and *Castanea* are nearly absent in the Aniai-type flora, though the remains of beech are very abundant. Among the conifers the family Taxodiaceae is dominant in number of specimens; in particular, the foliar shoots and cones of *Metasequoia* and *Glyptostrobus* are abundant, while those of *Taxodium* and *Sequoia* are rather rare. Though the fossil remains of Pinaceae are not so common in this type flora, fossil cone-scales or seeds of *Abies* and *Picea* are found." This description is well applicable also to the pollen flora except for the fact that examples of Aceraceae, *Populus* and *Cericidiphyllum* are very rare or absent in the pollen flora. But, the scarcity or absence of the pollens of Aceraceae and *Populus* may be due to the weak resistance of the pollen membranes to bacterial or chemical attacks as is generally said.

Besides, the author made pollen analytical study of the Asahi coal-bearing formation, of which the pollen flora was found closely similar to that in the Haboro coal-bearing formation, a Daijima-type flora, in such features as the overwhelming dominance of *Quercus* and the accompaniment of *Liquidambar, Cinnamomum, Nyssa, Engelhardtia, Rhus* etc. Also, regarding the flora of the Honjin-no-sawa coal-bearing formation, the author based on the occurrence of *Liquidambar* and *Quercus* and various considerations on its pollen floral composition can not agree with TANAI's opinion; the author inclines to consider the flora to be younger than the Daijima-type flora and to correspond to the flora of the Sôya-Tomamae coal-bearing formation. Further, though the flora of the main coal-bearing formation in the Hidaka coal field is considered to indicate a cool-temperate climatic condition, the writer can not reach a conclusion at the present whether the flora is Aniai-type or a flora of the upper Takinoue stage.

At any rate, respecting the flora in the Kaminokuni and Kayanuma area, a typical Aniai-type flora in Hokkaidô, the result based on study of macrofossil plants is in good agreement with the conclusions derived from the fossil pollens.

2. Floras of the Takinoue stage

2A. Floras of the early Takinoue stage

The sediments of this stage in Hokkaidô are represented by the Takinoue fauna and the Daijima-type flora. The Yoshioka and a part of the Kunnui formation in Southwest Hokkaidô, the Haboro (coal-bearing) and Sankebetsu formations in the Tomamae coal field, and the Takinoue formation in the Ishikari coal field are generally considered to belong to this stage. The sediments of this stage contain carbonaceous matter in their basal part in various localities in Hokkaidô, though the coal-bearing facies is not so large in scale as that of the Paleogene, and they contain a characteristic fossil flora called under the name of Daijima-type flora. The flora is characterized by the following features as stated by T. TANAI (1961, p. 149) : "the coniferous trees were comparatively rare whilst the ever-green trees were abundant in number of species and specimens, though local differences in floristic composition are more or less found. This flora, of course, includes many deciduous trees, but the ever-green trees commonly occupy more than 40 per cent of the total species of this flora, occasionally attaining about 80 per cent. Among the broad-leaved trees the remains Fagaceae, Juglandaceae, Hamamelidaceae, Lauraceae, Legmniosae, Aceraceae are very abundant in number of species and specimens, especially, the family Fagaceae is most dominant. It is one of the most common characters in the Daijima-type flora that *Quercus*, *Castanea* and others of Fagaceae are very abundant in number of species and specimens. The remains of Betulaceae and Ulmaceae such as *Alnus*, *Carpinus*, *Ulmus*, *Zelkova* etc. are also commonly found....."

Among specimens on which the present writer made his pollen analytical investigation, he considered the following to belong to the Daijima-type flora: the pollen floras in the Haboro coal-bearing formation of the Chikubetsu coal mine area, the Asahi coal-bearing formation of the Asahi coal mine, the Takinoue formation in the neighbourhood of the Shinkakuta coal mine and the Kudô coal-bearing formation of the Wakamatsu coal mine.

From these pollen floras the following are recognized: *Sphagnum*, *Osmunda*, Polypodiaceae, Gleicheniaceae, Lycopodiaceae, *Pinus*, *Abies*, *Picea*, *Pseudolarix*, *Keteleeria*?, *Tsuga*, *Metasequoia*, other Taxodiaceae, *Sciadopitys*?, *Salix*, *Juglans*, *Pterocarya*, *Carya*, *Engelhardtia*, *Alnus*, *Betula*, *Carpinus*, *Corylus*, *Ostrya*?, *Castanea*, *Fagus*, *Quercus*, *Ulmus*, *Zelkova*, *Liquidambar*, Legminosae, Magnoliaceae, *Cinnamomum*?, *Rhus*, *Acer*, *Nyssa*, *Ilex*, *Tilia*, *Alangium*, *Viburnam* Ericaceae, Sapotaceae, Compositae, Nuymphaeaceae, Rosaceae?, *Lonicera* *Typha*, Oleaceae?, Violaceae?, *Symplocos*??, and some other spores and pollens. Of these, Taxodiaceae and *Quercus* are main components of this pollen flora which feature is well recognized in the pollen floras of the Haboro, Asahi and Takinoue formations. Such abundance of coniferous plants comprising Taxodiaceae and Pinaceae in these formations as is seen in Figs. 12, 13 and 14 seems to be inconsistent with the above-mentioned general features of the Daijima-type flora, but TANAI reported such a fact as a special one which is found only in the Daijima-type flora in Hokkaidô. Consequently, the feature of the abundance of coniferous pollens in number of specimens is not in contradiction with the result of the study on macrofossil plants. *Pinus, Carya, Alnus, Fagus, Ulmus, Zelkova, Rhus* and *Liquidambar* occur in company with the above-noted two with relatively common frequency. With richness in variety of kind of plants, the most characteristic feature of the pollen flora in this stage is the abundance of *Quercus* and the attendance of *Liquidambar, Engelhardtia, Rhus, Nyssa,* Sapotaceae, etc.

The pollen floras of the Takinoue and Haboro coal-bearing formations are typical ones of this type. Besides, though the pollen flora from the Wakamatsu coal mine is said by TANAI to be typical Daijima type from study of macrofossil plants, the pollen flora in the coal seam is different in its composition from macrofossil flora: that is, *Quercus* and *Castanea* are the most dominant elements in number of specimens amongst the macrofossil flora, whilst *Fagus* and *Ulmus* and *Zelkova* are most dominant in the pollen flora and *Quercus* is only about 5 per cent in frequency of the total tree pollens. Such a difference may be due to some item in environment of the basin as was already discussed in the section (2B) of Chapter VII. But, even though such a difference exists, the occurrence of pollens of *Quercus, Castanea* and *Liquidambar* etc. indicates that the climatic condition was warm; this pollen flora shows clear difference from that of the Kinoko area (refer to section 1A of Chapter VII) which is a typical Aniai-type flora in Hokkaidô. Consequently, the pollen flora of the Wakamatsu coal mine may represent a Daijima type. Also, the pollen flora in the Asahi coal-bearing formation is closely similar in composition to that of the Haboro formation. There is an alternative as to the stratigraphical horizon of the Asahi coal-bearing formation; namely, some scholars correlated the formation to the Haboro coal-bearing formation whilst others consider it to be lower in stratigraphical horizon than that formation. The problem is not settled on account of the complexity of the geologic structure and occurrence of molluscan fossil as is described in the section (2E) of Chapter VII. Furthermore, as the pollen flora of the Asahi coal-bearing formation is closely similar to that of the Kawabata formation in the neighbourhood of the Asahi mine, it is also probable that the coal-bearing sediments may be of the Kawabata formation; at any rate, the pollen flora has the composition of the Daijima-type flora. Next, the coal-bearing sediments in the Hidaka coal field have hitherto been considered to be correlated to the Takinoue formation and consequently were expected to yield the Daijima-type flora; however, the pollen floras of the sediments are clearly different from the Daijima-type flora in the lacking of *Quercus, Liquidambar, Engelhardtia, Rhus* etc. Also, TANAI reported the flora in the coal-bearing sediments of the Niikappu district of Hidaka region to be the Aniai-type flora with qualification of some suspicion. But, since the geologic structure and the fossil occurrence are so complicated, it is left for the future to determine to what age the flora belongs.

At all events, the pollen floras of the early portion of this stage are richest in variety of plants and indicate the warmest climatic condition in the Miocene age. There is not great difference between the conclusions based on macrofossil plants and pollens except in the case of the Asahi coal-bearing formation.

2B. Floras of the later Takinoue stage

The above-described lacustrine or terrestrial sediments of the lower part of the Takinoue stage are overlain by marine sediments which are called under the names of Kunnui formation in Southwest Hokkaidô, Tomamae-Chikubetsu formations in the Tomamae coal field and Sôya-Onishibetsu formations in the Tempoku coal field. The sediments are composed mainly of marine sediments characterized by the so-called Takinoue fauna in the central-southern part of the Sôya-Hidaka basin, by the so-called Chikubetsu fauna in the northern part of the basin, and by the so-called *Miogypsina-Operculina* fauna in Southwest Hokkaidô. But, these sediments sometimes contain also carbonaceous matter, especially, though it is not large in scale, such coal-bearing facies are found in several localities under the Chikubetsu formation in the Tomamae coal field as to have been worth working on a small scale in some localities. The writer proposes to call the coal-bearing sediments under the name of "Tomamae coal-bearing formation". These were found many well-preserved fossil pollens and spores from the coal-bearing formation; the pollen floras is utterly lacking in warm temperate loving plants such as *Liquidambar, Cinnamomum, Nyssa,* Sapotaceae etc. and is clearly different in composition from that of the Haboro coal-bearing formation. Also, the writer found a closely similar pollen flora from the coal-bearing sediments which are distributed in the neigbourhood of Shumarinai and are probably correlable to the Tomamae coal-bearing formation. Now, it is noteworthy that the above-noted pollen floras are closely similar in composition to that of the Sôya coal-bearing formation. Namely, these pollen floras are characterized by the following features: 1) the predominance of Taxodiaceae and Betulaceae, especially *Alnus* being most dominant in number of specimens among Betulaceae with *Carpinus* next; 2) the utterly lacking of such warm temperate loving plants as *Liquidambar, Cinnamomum, Nyssa,* Sapotaceae etc.; 3) the accompaniment of *Tsuga, Fagus, Zelkova, Ulmus* etc. with rather common occurrence and 4) the relatively abundant occurrence of Polypodiaceae in number of specimens. On the other hand, the flora of the Sôya coal-bearing formation is determined to be of Aniai type by T. TANAI (1961) whose work was based on macrofossil plants; namely, the flora is older in age than the Takinoue stage. Surely, also the pollen flora in the formation is very similar in composition to the floras of the Kaminokuni and Kayanuma areas, both of which are Aniai-type flora. But, the writer considers that it is more reasonable to correlate the Sôya coal-bearing formation to the Tomamae formation based on the above-described similarity in composition of their pollen floras and various considerations as were described above in Chapter VIII. Consequently, it is concluded that a cool-temperate flora similar to the Aniai-type flora was distributed in the Tomamae-Tempoku region in the middle Miocene age after the Haboro stage. Now, though the data on the macrofossil plants of the flora of this age are scarce, the flora has been generally presumed to be a transitional one from the Daijima-type of middle Miocene to the Mitoku-type flora of late Miocene: hitherto it has been said* that the elements of the Daijima-type flora mixed in this flora. However, so far as the writer experienced the floras of this stage (of the Sôya-Tomamae coal-bearing formation), in the Tempoku-Tomamae region they do not show any transitional feature and are sharply different in composition from the flora of the Haboro coal-bearing formation, which is an example of the Daijima-type flora. That is, the change in floral composition seems to have happened rather rapidly after the Haboro stage (or substage) in this region. On the other hand, the pollen floras got from the Kunnui formation in Okushiri Island and from the Yunotai formation** in the Yunotai area of Southwest Hokkaidô are both rich in *Alnus* or Taxodiaceae and poor in characteristic elements of the Daijima-type flora such as *Quercus, Liquidambar,* etc. Granted that a pollen flora got from carbonaceous materials in the marine sediments can not be treated in the same as in terrestrial sediments, it is presumed that some change in floral composition might exist after the flourishing of the Daijima-type flora also in Southwest Hokkaidô. Furthermore, it is assumed as a hypothesis

* For example, the reports by K. SUZUKI (1959) on the Miocene flora in Northeast Japan and by T. TANAI (1961) pp. 166–169.

** There are two different opinions on the stratigraphic horizon of this formation: the formation is correlated to the Yoshioka formation which yields the Daijima-type flora according to someone, while others correlate it to the Kunnui formation which is higher in stratigraphic position than the Yoshioka formation.

that the floras in the Honjin-no-sawa coal-bearing formation in the Uryû district and the floras of the Miocene coal-bearing sediments in the Hidaka coal field which do not include the Daijima-type flora may be of the age under present discussion.

Next, it attracts the writer's attention that the floras now under discussion show some difference in composition in the Tomamae-Tempoku region and that to its southward. Namely, the former reflect a cooler climatic condition of their environment at time of formation than the latter. A similar regional difference in fossil composition is reported of marine molluscan fossils of this age: the middle Miocene marine sediments in the Tomamae-Tempoku region yield the so-called Chikubetsu fauna, a cold current fauna, while the sediments of the area to the south and from Southwest Hokkaidô are represented by the so-called Takinoue and *Miogypsina-Operculina* fauna respectively, both warm current fauna. To account for the difference, UOZUMI (1962) proposed the existence of a barrier situated at the boundary of the Uryû and Tomamae basins (about 44°N.) with an east-west trend: that is sedimentary basins at that time were divided into a northern part (Tomamae-Tempoku region) and a southern part by the barrier; a cold current existed and the cold current fauna (so-called Chikubetsu fauna) lived in the former while a warm current fauna (so-called Takinoue and *Miogypsina-Operculina* faunas) existed in the latter. So far as is presumed from the present available evidence, also the writer would recognize the existence of such a barrier, and presume also that the flora at that age was influenced by the two currents and that different influence of the cold and warm currents yielded the difference in the floral composition in the two regions.

At any rate, the general features of the Takinoue stage may be summarized as follows: the early flora of this stage is represented by the Daijima-type flora which indicates a warm temperate~temperate climatic condition, represents the warmest climatic condition in the Miocene age and is characterized by abundant variety in kind of plants. Then, the flora was subjected to a change in composition from the Daijima type to a flora which indicates lower temperature than the Daijima type does; especially, the change was so rapid in the Tomamae-Tempoku region that the flora became one which is closely similar to the Aniai type, a cool temperate flora, while the change in the southern region might not have been as clear as in the Tomamae-Tempoku region. Regarding such a matter, it is interesting that a pollen flora closely similar to the Daijima type in composition is found in the Kawabata formation in the central part of the Ishikari coal field; as it is the problem remains for the future whether the above-noted change in floral composition existed in the Kawabata stage in the Ishikari region or not.

3. Floras of the Kawabata stage

The Kawabata stage is represented by a peculiar sedimentary facies which is recognized from the northern to the southern end along the western side of Hidaka range with sediments of huge volume. The sediments of this stage are generally composed of coarse material which includes sometimes huge boulders or of black shale, and is characterized by abnormal sedimentation or rythmic alternation of sandstone and shale; the deposits are considered to be a product of the molasse-type deposition. These deposits are very poor in fossil material except foraminiferal remains; though thin coal seams are sometimes contained in discontinuous form in the deposits, there is no report on fossil plants of this stage. The writer, however, could find many well-preserved fossil pollens and spores from some coal seams in the Tempoku coal field which is correlated to the Kawabata formation, though samples for the present study are taken at only three localities: one is in the neighbourhood of the Asahi mine in the Ishikari coal field whilst the others are in the neighbourhod of the Nissô mine in the Tempoku coal field. Though it can not be said that the data are sufficient to justify positive conclusions in regard to the flora of the stage, it is certain that the data are valuable as a only clue at present for presumption about the flora.

Now, it is interesting that the pollen floras of these two formations are clearly different in composition. The pollen flora from the Kawabata formation is characterized by the dominance of *Quercus* and the accompaniment of *Liquidambar, Rhus, Nyssa, Engelhardtia, Cinnamomum*?, etc. and is considered to indicate a warm temperate~temperate climatic condition. The other floras from the Masuporo formation in the Tempoku region are characterized by the dominance of Betulaceae, especially *Alnus*, and *Fagus*, and by poorness in *Quercus*; they are lacking in *Liquidambar, Nyssa, Rhus, Engelhardtia*, etc. and are considered to indicate a rather cool temperate climatic condition.

There are no evidence available from other studies to prove such difference of flora in the northern and southern parts of the Sôya-Hidaka basin in the Kawabata stage except on the foraminifera owing to the poorness of fossil materials of this stage. Only TSUCHIDA (1957–58) referred to some conditions in a wide area from the northernmost to the southernmost parts of the Sôya-Hidaka basin of this stage based on his study of foraminiferal faunas. Namely, his opinion was as follows: the foraminiferal fauna of this stage was very simple in composition through the basin from the northern to the southern parts and it is presumed from the fauna that the depositional environment of these sediments of this stage, even if they are composed of coarse materials which show an abnormal sedimentation, was in cold and deep water in disagreement with the customary opinion that the sediments composed of the coarse material were deposited in shallow water. But, if his sampling localities were examined in detail, the following matter will be noticed: although the sampling localities in the Tempoku-Tomamae region cover the area occupied by the above-described black shale facies and the facies represented by coarse materials and abnormal sedimentation, the sampling localities in the Ishikari region are biassed to the area where the black shale facies is dominant and there is no reference to the eastern area occupied by coarse material. Accordingly, it is not appropriate to compare the foraminiferal faunas of the two regions on available evidence: that is, even if the foraminiferal faunas in the black shale facies indicate an environment of cold and deep water, the fact does not necessarily indicate that the coldness is due to a cold current, because the cause of the coldness is considered to be due to the deepness of the water or to the cold current. Consequently, the data presented by TSUCHIDA do not neglect the following presumption: in the Kawabata stage, the Tempoku region was under influence of a cold current and the resultant climatic condition was rather cool, while the Ishikari region was under influence of warm current. If one hypothesizes like this, it is not necessary to assume that such coarse sediments of the Masuporo formation as contains huge boulders or coal seems were deposited in deep water. Is it more reasonable to assume that such sediments composed of coarse material are deposited in deep water? Also, the difference of the pollen floras in the Tempoku and Ishikari regions which are newly recognized by the writer is interpreted by the above-noted hypothesis. Further, it is presumed also from the molluscan faunas and the pollen floras that such difference in temperature of sea water in Tempoku-Tomamae and Ishikari regions was in existence in the preceding Chikubetsu stage. Besides, though the data are not very abundant, K. SUZUKI (1959) reported that in Northeast Japan many subtropical or warm-temperate loving plants (macrofossils) were found in marine sediments part of which corresponds to the Kawabata stage.

In summary, the writer maintains that the floras of the Kawabata stage of Hokkaidô were different in composition in the Tempoku and Ishikari regions: the former was mainly composed of Polypodiaceae, Betulaceae, Fagaceae, Ulmaceae etc. which indicate a cool temperate climatic condition, while the latter was mainly composed of Taxodiaceae, *Quercus*, included warm temperate~temperate loving plants and indicates a warm temperate~temperate climatic condition like that reflected by the Daijima-type flora.

4. The flora of the Wakkanai stage

Generally, this stage is represented in Hokkaidô by the sediments of a peculiar rock-facies, so-called "hard shale", and abundant foraminiferal and molluscan fossils are contained in the sediments. Besides, pyroclastic materials sometimes as an agglomerate of huge volume like that at the boundary of the Tomamae and Tempoku basins, are recognized mainly in the lower part of the sediments; coal-bearing facies are found in various localities and stratigraphic horizons in the marginal facies of the sediments.

Though the coal-bearing sediments of this stage do not well develop in the central and southern part of Hokkaidô, they are frequently found in many localities in the northern part, some of which have been worked, even though they were on a small scale: for example, the Utanobori area of Esashi-gun, the Nakagawa coal field of Nakagawa-gun, the Tôgeshita and Fukinotai areas in the Uryû region, etc. The coal is low grade lignite and contains many well-preserved fossil pollens and spores.

The writer investigated these pollen floras of the Utanobori area, three points in the Nakagawa coal field, Kamichikubetsu and Tôgeshita areas. The fossil pollen floras of these localities are composed mainly of Taxodiaceae, Betulaceae, especially *Alnus* and *Carpinus* among Betulaceae, *Fagus* and *Ulmus* (and *Zelkova*) as a whole. Besides, *Pinus, Picea, Tsuga, Salix, Juglans, Pterocarya, Carya, Quercus*, Magnoliaceae, *Ilex, Tilia, Acer*, etc. are recognized. But, it is noted that these pollen floras are mutually different in composition.

On the other hand, TANAI (1961) stated on the late Miocene flora, the Mitoku-type flora, as follows: "The Mitoku-type flora consists mainly of temperate deciduous broad-leaved trees, accompanied by several ever-green trees; it also commonly contains conifers. As shown in Table 6, the broad-leaved trees of this type include a large number of Juglandaceae, Betulaceae, Fagaceae, Ulmaceae and Aceraceae; especially, *Castanea, Quercus* (deciduous oaks), *Fagus, Alnus, Betula, Carpinus, Ulmus, Zelkova, Acer*, etc. are most abundant in number of species or specimens..... Mixed with many temperate zone trees, there are frequently found several warm or warm-temperate broad-leaved trees such as *Liquidambar, Ilex, Cinnamomum, Buxus*, ever-green oaks, *Smilax* and others in this type flora includes several exotic broad-leaved trees such as *Carya, Liriodendron, Sassafras, Liquidambar* and *Catalpa*, which are relics from the

Daijima-type flora of the previous stage.....The Mitoku-type flora commonly contains coniferous trees.....However, these conifers are far less in number of specimens than the broad-leaved trees in this type flora..... Furthermore, the Mitoku-type flora has somewhat local or regional difference in floristic composition; especially the difference between Hokkaidô and Honshû....." (T. TANAI: 1961, pp. 169–174). Furthermore, "Thus, late Miocene flora of Hokkaidô shows a different floristic composition from the Mitoku-type flora of Honshû: the former consists mainly of northern deciduous trees, with very few southern warm or exotic elements..... Such a difference of floristic composition between Honshû and Hokkaidô may be due to regional distribution of forest and the existence of climatic zones in Late Miocene time....." (T. TANAI: 1961, p. 184)

That is to say, also TANAI recognized a regional difference in composition of the late Miocene flora. However, the regional difference of flora described by him is so large in scale such as to cover Honshû and Hokkaidô, and is not the same in scale as is discussed by the writer in this paper.

Then, to what cause is such difference due? Again, TANAI (1961, p. 241) referred to the cause as follows: "In late Miocene time, the physiographic conditions were probably more complicated than in the previous age, due to regional uplift or subsidence. Accordingly, the floristic composition of each flora is somewhat or partly very different respectively in each of their localities.....Such floral change in Late Miocene time was probably due to regional differentiation of crustal movements which prevailed in Japan and to a lowering of temperature." The writer is of the opinion at present that the complicated physiographic condition at that time resulted in not only the regional differences of flora on such large scale as that between Honshû and Hokkaidô, but on such a small scale as intra-Hokkaidô.

At any rate, though there are some discrepancies between the conclusions derived from fossil plants and those from fossil pollens, for example, *Acer* is abundantly found in macrofossil plants while it is scarce in pollen flora in number of specimens, the conclusion based on fossil pollens agrees well with that from macrofossil plants as a whole.

X. Summary

1) In respect to Tertiary fossil pollens, there is no uniform nomenclature which is common to all countries. In Japan, nomenclature on Tertiary pollens used by some authors is not clearly defined: that is, it is sometimes ambiguous whether they adopt the natural classification of

plants or artificial classifications. The writer considers the nomenclature proposed by A. TRAVERSE to be most reasonable for the study of Tertiary fossil pollen floras.

2) Though it has been said hitherto that various precautions are necessary in chemical treatments for pollen analysis, the writer further reports in this paper that careful attention must be paid to identification of fossil pollens after HF treatment because the treatment causes shrinkage in volume of fossil pollens.

3) It is possible to some degree roughly in proportion to elaboration in sampling to know the depositional environment of the sediments from which samples are taken. For example, in the Chikubetsu coal mine area the writer found two types of pollen associations, one is Taxodiaceae-*Alnus-Liquidambar-Ulmus* association and the other is represented by the dominance of *Quercus*; the former, a rather lowland vegetation, is found mainly in the lower part of the seam and the latter, the so-called "offene Niedermoor von Everglades-Typus", is found in the upper part which is good in quality. Such variation of pollen associations in one coal seam which was also reported from the brown coal of Germany shows a feature of the growing of the coal-forming basin. Furthermore, it is also found as a fact that the increase in frequency of Pinaceae pollens which are supposed to come flying from the surrounding highland is related to the distance from the high land. Besides, some coal seams in the Sôya-Tomamae coal-bearing formation are characterized by the dominance of Polypodiaceae spores in their lower parts; this fact means these coal-forming basins began with an environment in which herbaceous plants were dominant.

4) On the whole, floras presumed from fossil pollens agree with those from macrofossil plants with only a few discrepancies.

5) Though the Miocene floral change in Hokkaidô is said to be as follows based on macrofossil plants: the Aniai-type flora (cool temperate flora), the Daijima-type flora (warm temperate~temperate flora), the Mitoku-type flora (temperate~cool temperate flora), the conclusions from the present pollen analytical study are approximately in agreement with this sequence. In the present paper, however, the writer has tried to put emphasis on the matter of the existence of a flora between the Daijima-type and Mitoku-type floras as clarified by the pollen analytical study better than before. That is, the Daijima-type flora suffered rapid change in its composition and changed into an Aniai-type like flora in the northern part of Hokkaidô (Tomamae—Tempoku region), while in the central and southern parts the change was not so clear as in the northern part. Such

opposition of the different floras may be due to influences by different currents which were divided by a barrier presumed to exist at about 44°N.L.; the existence of such a barrier was also suggested by UOZUMI (1962) from his study of molluscan fossils. In the next, Kawabata, stage (there has been no report of the flora of this stage), the flora in the northern part was transitional in composition from the Aniai-type like flora to the Mitoku-type flora, while the central and southern parts are presumed to be represented by a Daijima-type like flora. Besides, it is presumed from the present study that the regional difference in floristic composition of the late Miocene floras (the Mitoku-type flora) existed within Hokkaidô.

6) On the correlation of the Miocene sediments, the Sôya coal-bearing formation which has been correlated to the Haboro coal-bearing formation or to still older sediments is considered by the writer to be more reasonably correlated to the Tomamae coal-bearing formation which is higher in stratigraphic position than the Haboro coal-bearing formation; such a correlation, if it is proven to be correct, may change old considerations on the history during the Miocene age. Besides, the Asahi coal-bearing formation on the stratigraphic position of which various discussions have been entered into by many authors is considered to be correlated to the Haboro coal-bearing formation.

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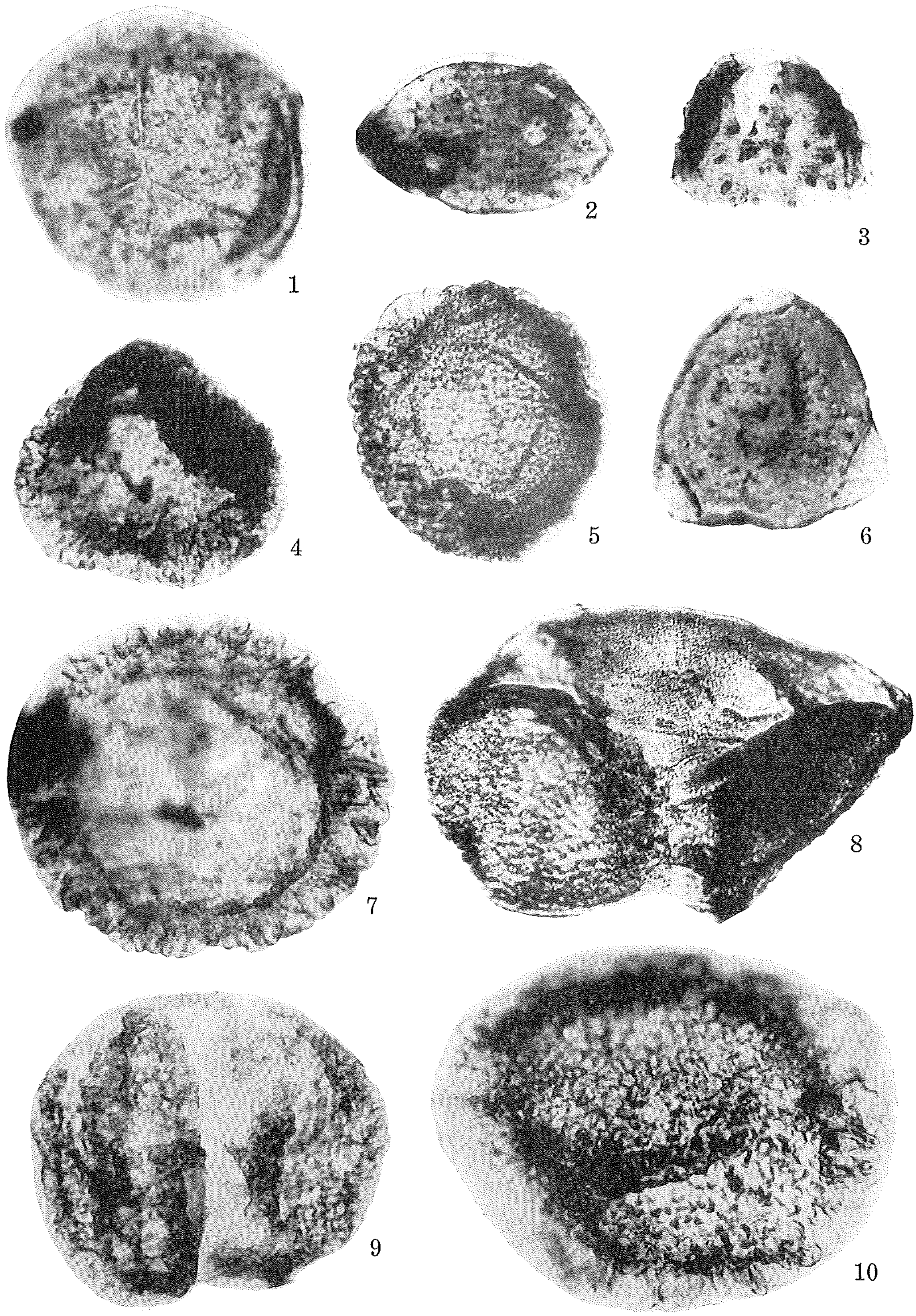
Explanation of Plate 1

Explanation of Plate 1

		(Size μ)	(Locality)
1.	*Osmunda*	62 × 58	Kayanuma coal mine
2.	*Lonicera*	53 × 33	〃
3.	Compositae	40 × 35	〃
4.	*Tsuga*	57 × 40	〃
5.	*Tsuga*	73 × 65	Kinoko, Kaminokuni-mura
6.	*Lonicera*	52 × 50	Kayanuma coal mine
7.	*Tsuga*	79 × 75	〃
8.	*Picea*	114 × 80	Kinoko, Kaminokuni-mura
9.	*Pinus*	73 × 65	Kayanuma coal mine
10.	*Tsuga*	95 × 75	〃

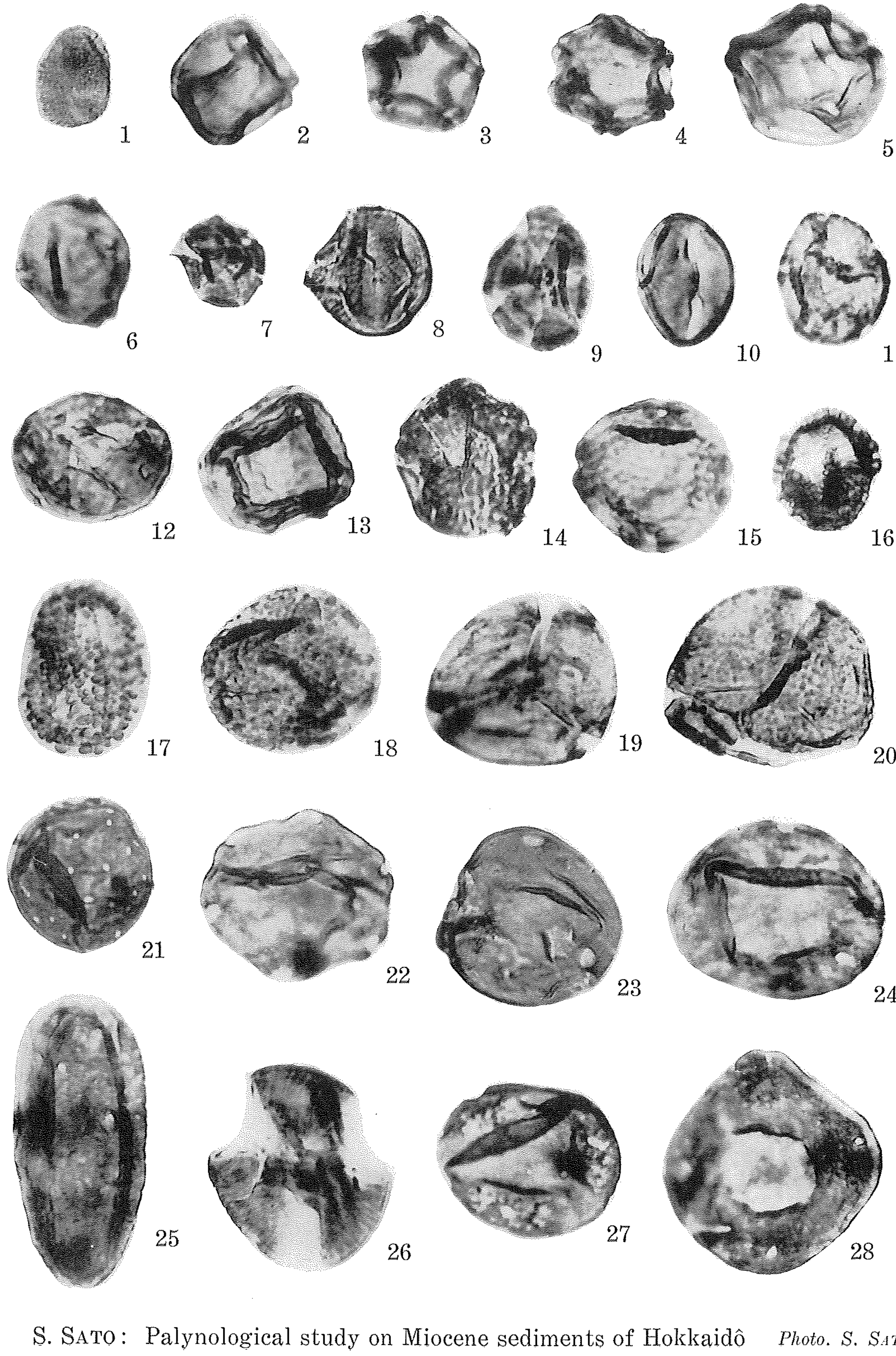


S. SATO: Palynological study on Miocene sediments of Hokkaidô *Photo. S. SATO*

Explanation of Plate 2

Explanation of Plate 2

		(Size μ)	(Locality)
1.	*Salix*	21 × 16	Kayanuma coal mine
2.	*Alnus*	28 × 26	〃
3.	*Alnus*	27 × 25	〃
4.	*Alnus*	28 × 25	〃
5.	*Alnus*	34 × 30	〃
6.	*Carpinus*	28 × 25	〃
7.	Rosaceae	25 × 21	Kiniko, Kaminokuni-mura
8.	Rosaceae	33 × 30	〃
9.	Rosaceae	30 × 23	Kayanuma coal mine
10.	*Fraxinus* ?	28 × 21	〃
11.	*Ulmus*	28 × 23	〃
12.	*Zelkova*	33 × 28	〃
13.	*Zelkova*	30 × 25	〃
14.	*Zelkova*	39 × 37	Kinoko, Kaminokuni-mura
15.	*Zelkova*	34 × 32	Kayanuma coal mine
16.	*Ilex*	26 × 23	〃
17.	*Ilex*	36 × 25	〃
18.	*Fagus*	38 × 34	〃
19.	*Fagus*	40 × 36	〃
20.	*Fagus*	45 × 38	〃
21.	Chenopodiaceae	39 × 37	Kinoko, Kaminokuni-mura
22.	*Pterocarya*	40 × 35	Kayanuma coal mine
23.	*Carya*	47 × 40	Kinoko, Kaminokuni-mura
24.	*Carya*	47 × 38	Kayanuma coal mine
25.	Magnoliaceae	60 × 28	〃
26.	*Acer*	44 × 37	〃
27.	*Carya*	40 × 33	〃
28.	*Carya*	46 × 42	〃

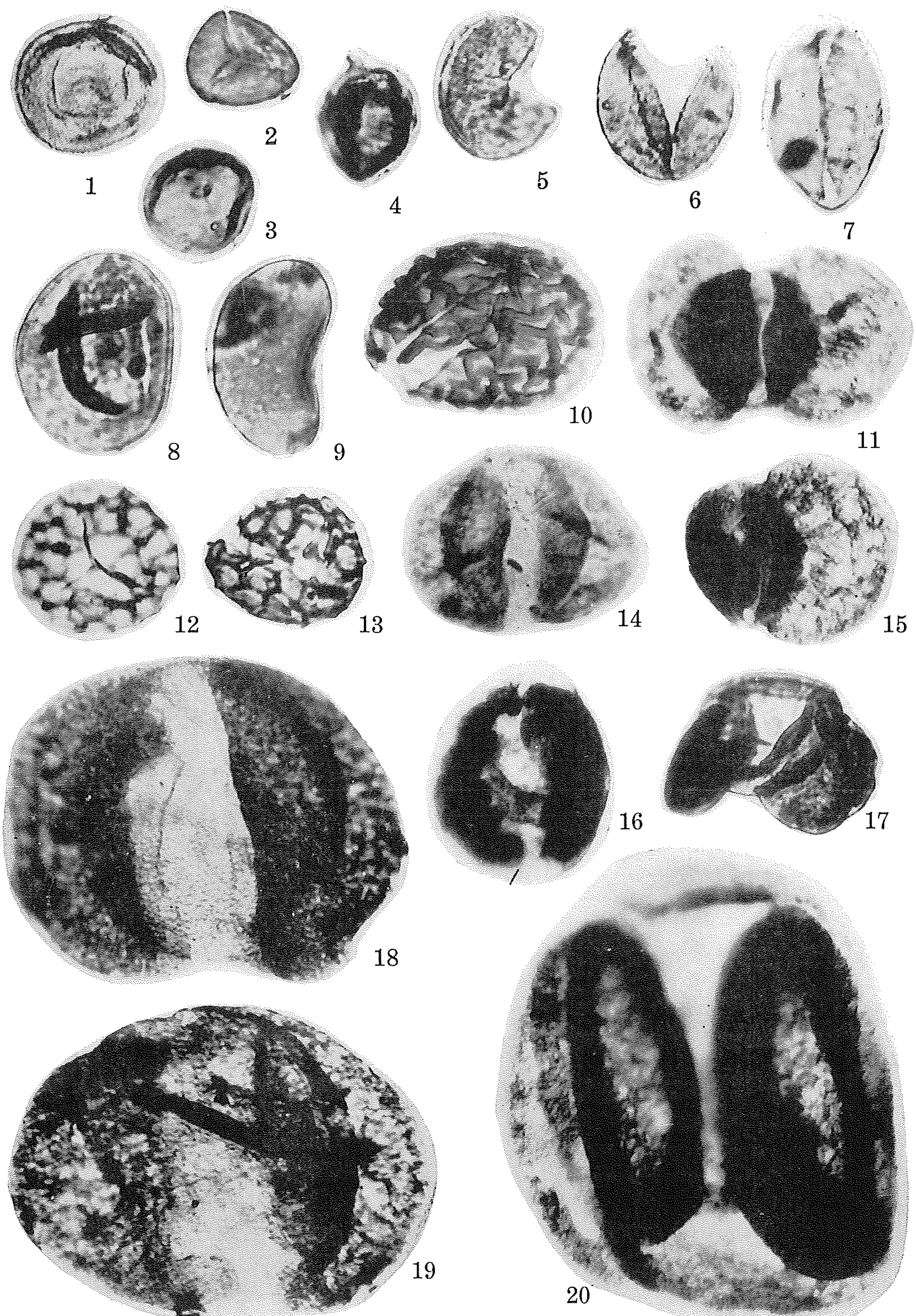


S. SATO: Palynological study on Miocene sediments of Hokkaidô *Photo. S. SATO*

Explanation of
Plate 3

Explanation of Plate 3

		(Size μ)	(Locality)
1.	*Sequoia* ?	30 × 30	Haboro second pit
2.	*Sphagnum*	24 × 20	Asahi coal mine
3.	*Metasequoia*	27 × 21	Haboro second pit
4.	*Metasequoia*	24 × 21	Asahi coal mine
5.	Taxodiaceae	30 × 25	〃
6.	*Glyptostrobus* ?	33 × 29	〃
7.	cf. *Cycas* or *Ginkgo*	38 × 24	〃
8.	Polypodiaceae	43 × 33	〃
9.	Polypodiaceae	41 × 24	〃
10.	Indeterminable spore	48 × 37	Chikubetsu main pit
11.	*Podocarpus*	58 × 30	Haboro sedond pit
12.	Lycopodiaceae	40 × 36	〃
13.	Lycopodiaceae	35 × 28	Asahi coal mine
14.	*Pinus*	53 × 40	Haboro second pit
15.	*Podocarpus*	40 × 43	〃
16.	*Pinus*	45 × 38	〃
17.	*Pinus*	47 × 33	〃
18.	*Picea*	113 × 97	〃
19.	*Abies* ?	88 × 65	Asahi coal mine
20.	*Abies* or *Keteleeria*	95 × 83	Haboro second pit

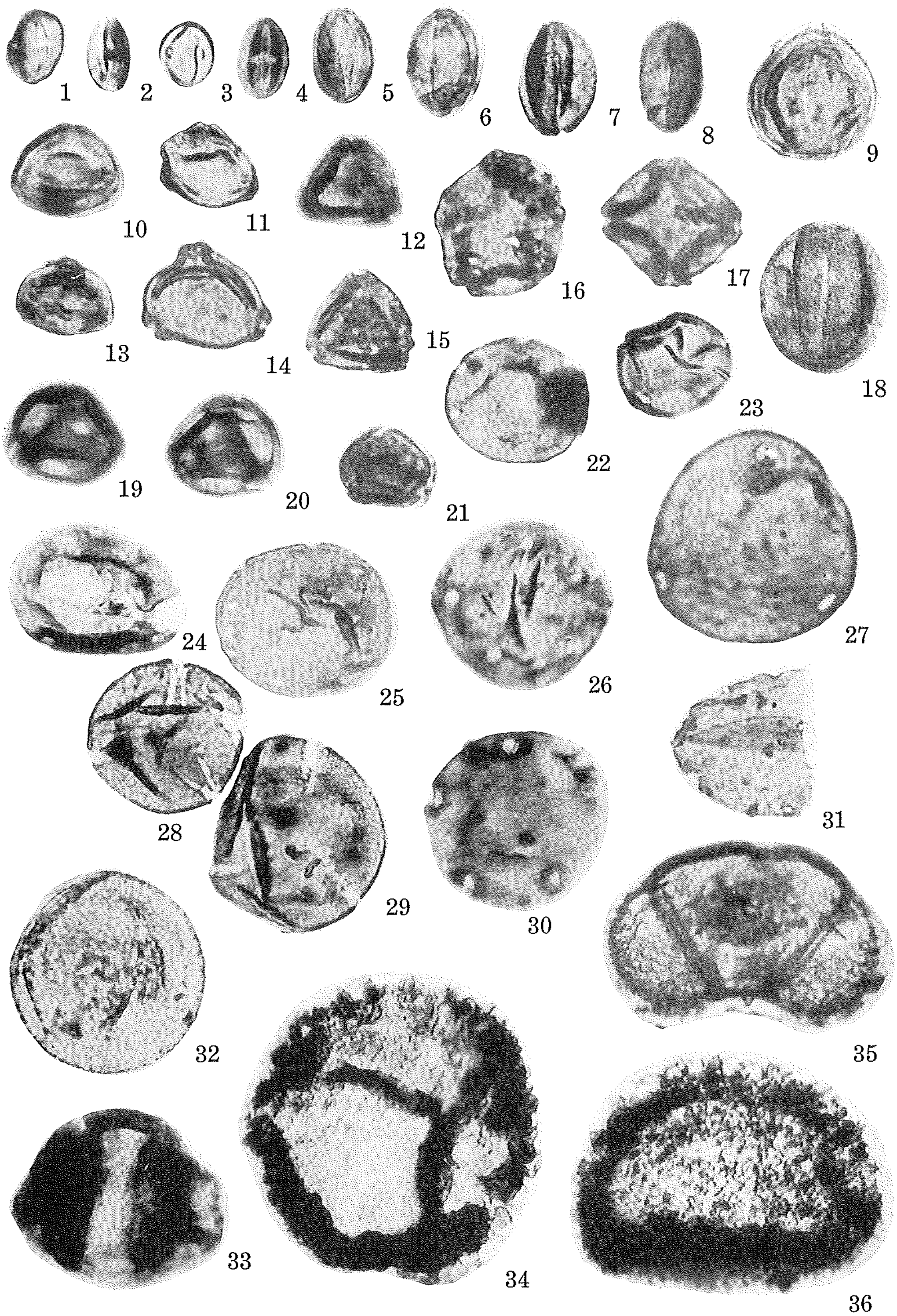


S. SATO: Palynological study on Miocene sediments of Hokkaidô *Photo. S. Sato*

Explanation of
Plate 4

Explanation of Plate 4

		(Size μ)	(Locality)
1.	*Castanea*	16 × 13	Haboro second pit
2.	*Castanea* ?	18 × 10	〃
3.	*Castanea*	15 × 13	Wakamatsu coal mine
4.	*Castanea*	18 × 12	Haboro second pit
5.	*Quercus*	21 × 15	〃
6.	*Quercus*	23 × 16	〃
7.	*Quercus*	26 × 18	Asahi coal mine
8.	*Quercus*	28 × 16	Haboro second pit
9.	*Quercus*	31 × 30	Wakamatsu coal mine
10.	*Corylus*	24 × 20	Chikubetsu main pit
11.	*Corylus*	24 × 18	Wakamatsu coal mine
12.	*Corylus* or *Myrica*	23 × 22	Chikubetsu main pit
13.	*Betula* ?	23 × 18	Haboro second pit
14.	*Betula*	28 × 23	Wakamatsu coal mine
15.	*Carpinus* ?	23 × 22	Asahi coal mine
16.	*Alnus*	30 × 28	〃
17.	*Alnus*	32 × 28	〃
18.	*Qusrcus*	34 × 28	〃
19.	*Engelhardtia*	26 × 23	Haboro second pit
20.	*Engelhardtia*	26 × 23	〃
21.	*Engelhardtia*	21 × 17	Asahi coal mine
22.	*Pterocarya* ?	30 × 28	〃
23.	*Alnus*	30 × 27	Wakamatsu coal mine
24.	*Carya*	37 × 29	Asahi coal mine
25.	*Juglans*	40 × 34	Haboro second pit
26.	*Juglans*	42 × 40	〃
27.	*Carya*	41 × 41	〃
28.	*Fagus*	37 × 35	Wakamatsu coal mine
29.	*Fagus*	51 × 45	〃
30.	*Pterocarya*	43 × 39	Chikubetsu main pit
31.	*Juglans*	32 × 30+	Asahi coal mine
32.	*Fagus*	47 × 45	Wakamatsu coal mine
33.	*Pinus*	44 × 29	Haboro second pit
34.	*Tsuga*	66 × 62	〃
35.	*Pinus*	66 × 38	Wakamatsu coal mine
36.	*Tsuga*	72 × 53	Asahi coal mine

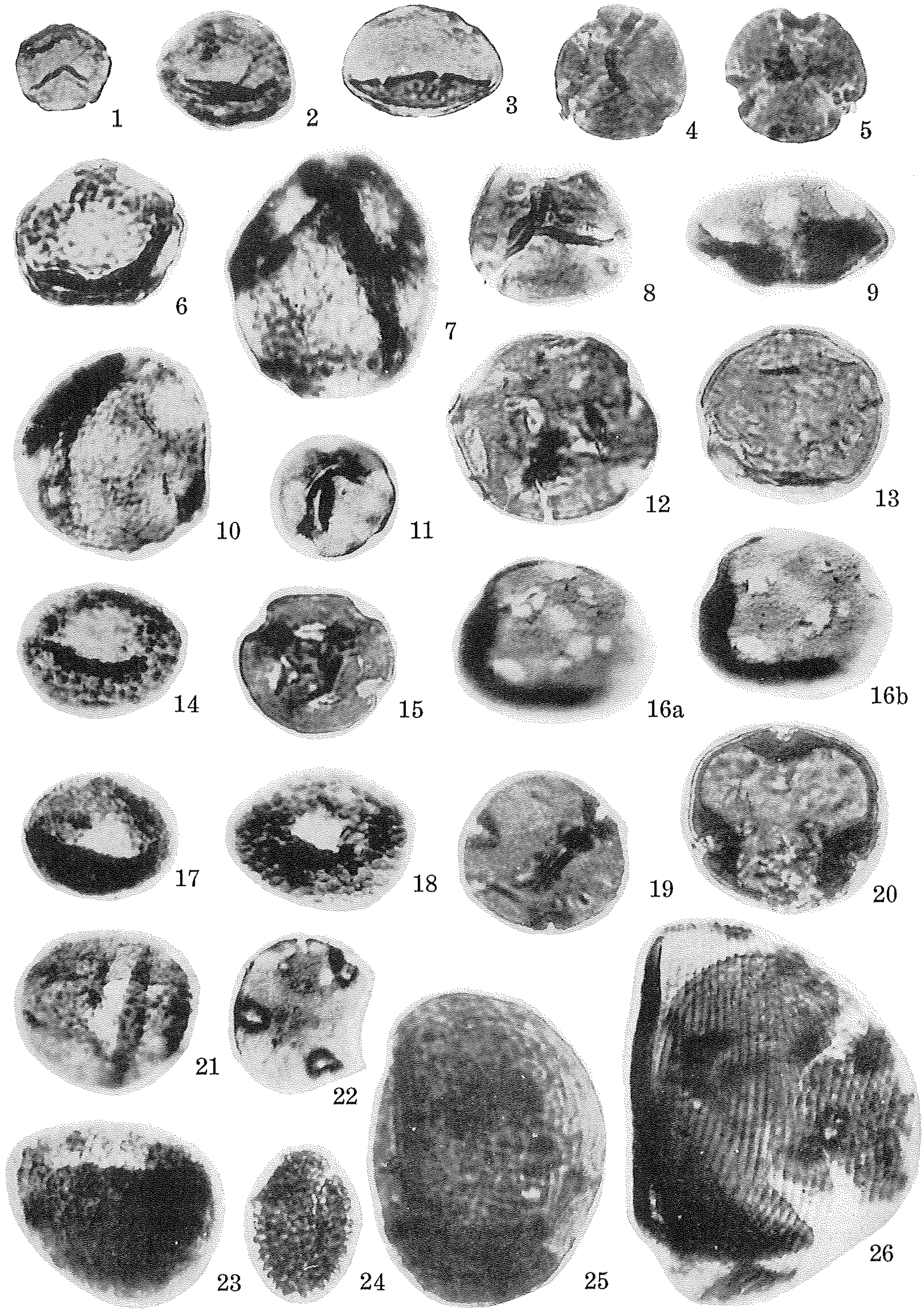


S. SATO: Palynological study on Miocene sediments of Hokkaidô *Photo. S. SATO*

Explanation of
Plate 5

Explanation of Plate 5

		(Size μ)	(Locality)
1.	*Ulmus*	22 × 20	Wakamatsu coal mine
2.	*Ulmus*	29 × 24	Haboro second pit
3.	*Ulmus*	36 × 26	Wakamatsu coal mine
4.	*Rhus*	29 × 28	Asahi coal mine
5.	*Rhus*	31 × 28	〃
6.	*Zelkova*	35 × 31	〃
7.	*Zelkova*	57 × 45	〃
8.	*Rhus*	33 × 31+	〃
9.	*Liquidambar*	43 × 24	Haboro second pit
10.	*Zelkova*	43 × 38	Asahi coal mine
11.	*Liquidambar*	24 × 25	〃
12.	*Liquidambar*	43 × 40	〃
13.	*Liquidambar*	40 × 37	Wakamatsu coal mine
14.	*Cinnamomum* ?	35 × 26	Chikubetsu main pit
15.	*Liquidambar*	33 × 29	Asahi coal mine
16 a, b	*Liquidambar*	42 × 37	Haboro second pit
17.	*Cinnamomum* ?	33 × 26	Chikubetsu main pit
18.	*Cinnamomum* ?	41 × 32	〃
19.	*Tilia*	33 × 32	Asahi coal mine
20.	*Tilia*	43 × 42	Wakamatsu coal mine
21.	*Cinnamomum* ?	38 × 35	Chikubetsu main pit
22.	*Tilia*	32 × 31	Asahi coal mine
23.	*Cinnamomum* ?	48 × 39	Chikubetsu main pit
24.	*Ilex*	32 × 22	Asahi coal mine
25.	Magnoliaceae	63 × 50	〃
26.	Magnoliaceae	83 × 60	〃

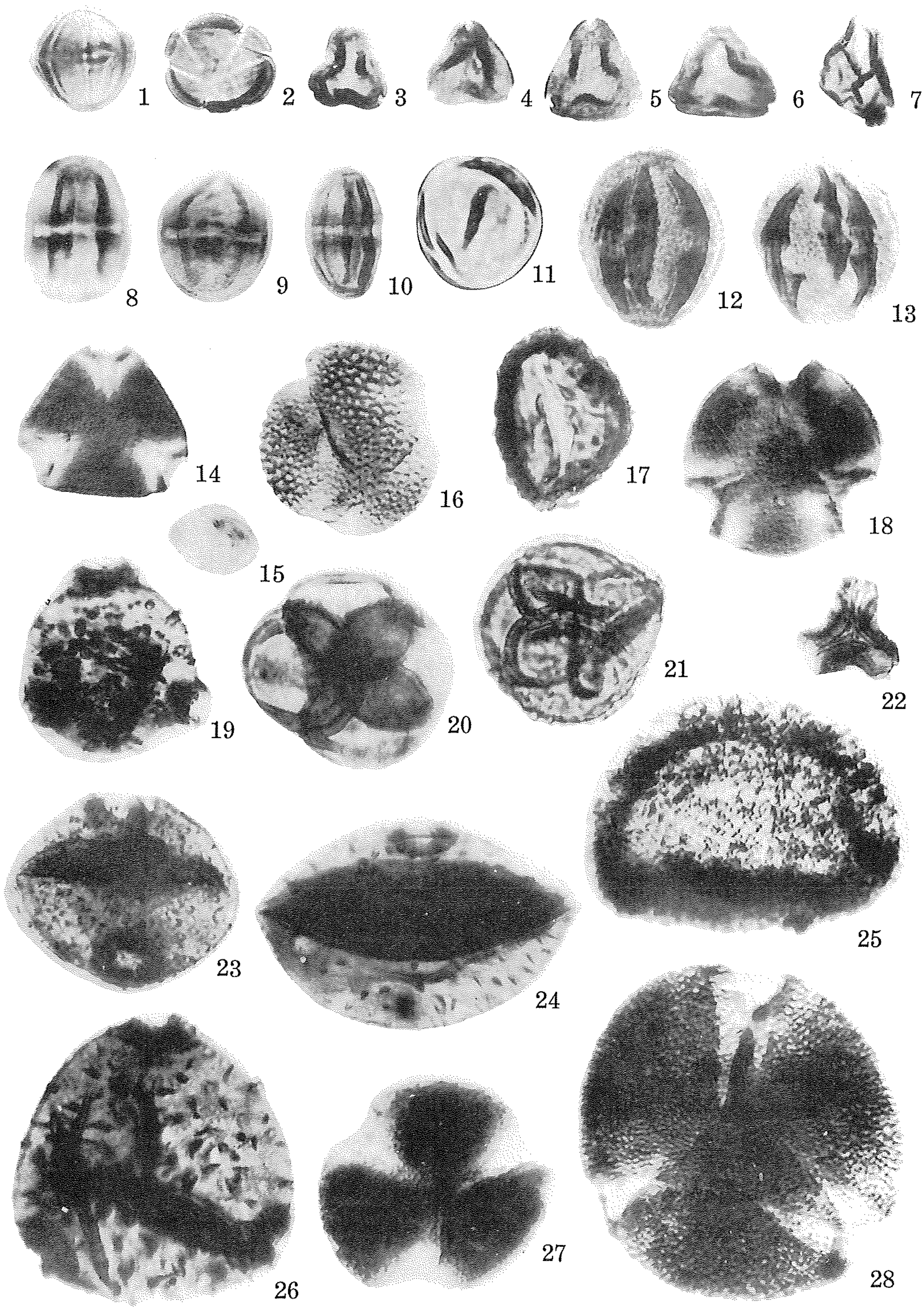


S. SATO: Palynological study on Miocene sediments of Hokkaidô *Photo. S. SATO*

Explanation of Plate 6

Explanation of Plate 6

		(Size μ)	(Locality)
1.	Rosaceae	25 × 24	Wakamatsu coal mine
2.	Rosaceae	25 × 23	〃
3.	*Myrica* ?	19 × 16	Chikubetsu main pit
4.	*Myrica* or *Corylus*	28 × 20	〃
5.	*Myrica* ?	23 × 20	〃
6.	*Myrica* ?	23 × 21	〃
7.	*Symplocos* ??	23 × 15	〃
8.	Sapotaceae	31 × 22	Haboro second pit
9.	Sapotaceae	29 × 23	〃
10.	Sapotaceae	28 × 17	〃
11.	Indeterminable pollen	30 × 28	Wakamatsu coal mine
12.	Cornaceae	39 × 32	Asahi coal mine
13.	Cornaceae	39 × 33	Haboro second pit
14.	*Nyssa*	35 × 33	Chikubetsu main pit
15.	*Morus*	20 × 15	Haboro secone pit
16.	Oleaceae ?	40 × 37	〃
17.	Comsositae	40 × 30	Wakamatsu coal mine
18.	Violaceae ?	46 × 43	Chikubetsu main pit
19.	*Lonicera*	43 × 39	Asahi coal mine
20.	Ericaceae	45 × 43	〃
21.	Ericaceae	40 × 40	Wakamatsu coal mine
22.	Indeterminable spore	22 × 22	Asahi coal mine
23.	*Lonicera*	48 × 40	〃
24.	*Lonicera*	67 × 45	Haboro second pit
25.	*Tsuga*	72 × 53	Asahi coal mine
26.	*Lonicera*	63 × 63	〃
27.	*Alangium*	50 × 48	Chikubetsu main pit
28.	Indeterminable pollen	76 × 70	Asahi coal mine



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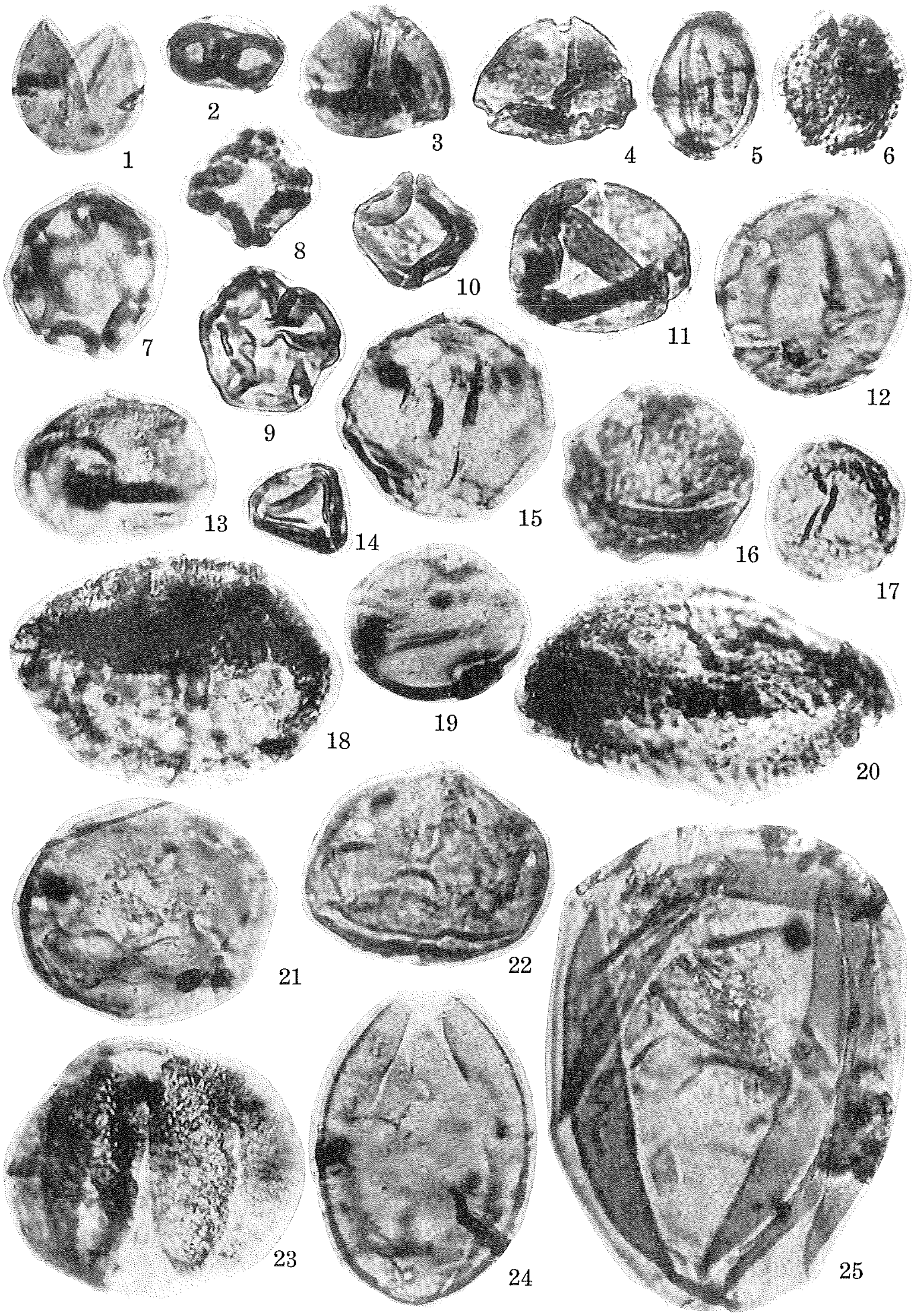
Explanation of
Plate 7

Explanation of Plate 7

		(Size μ)	(Locality)
1.	Taxodiaceae	29 × 25	Okushiri island
2.	*Alnus*	25 × 17	Yunotai area
3.	*Rhus*	30 × 28	〃
4.	*Rhus* ?	35 × 29	〃
5.	*Quercus*	30 × 23	Okushiri island
6.	*Ilex*	30 × 27	〃
7.	*Alnus*	35 × 31	〃
8.	*Alnus*	29 × 27	Yunotai area
9.	*Alnus*	32 × 30	〃
10.	*Alnus*	28 × 26	〃
11.	*Fagus*	40 × 35	〃
12.	*Carya*	43 × 40	Okushiri island
13.	*Liquidambar*	38 × 30	〃
14.	*Alnus*	22 × 20	Yunotai area
15.	*Juglans*	45 × 43	Okushiri island
16.	*Zelkova*	43 × 35	Yunotai area
17.	*Ulmus*	30 × 28	Okushiri island
18.	*Tsuga*	70 × 48	〃
19.	*Tilia*	38 × 32	〃
20.	*Tsuga*	80 × 47	Yunotai area
21.	*Juglans*	53 × 45	Okushiri island
22.	*Carya*	53 × 41	Yunotai area
23.	*Pinus*	62 × 52	Okushiri island
24.	Magnoliaceae	67 × 45	〃
25.	*Larix*	110 × 78	〃



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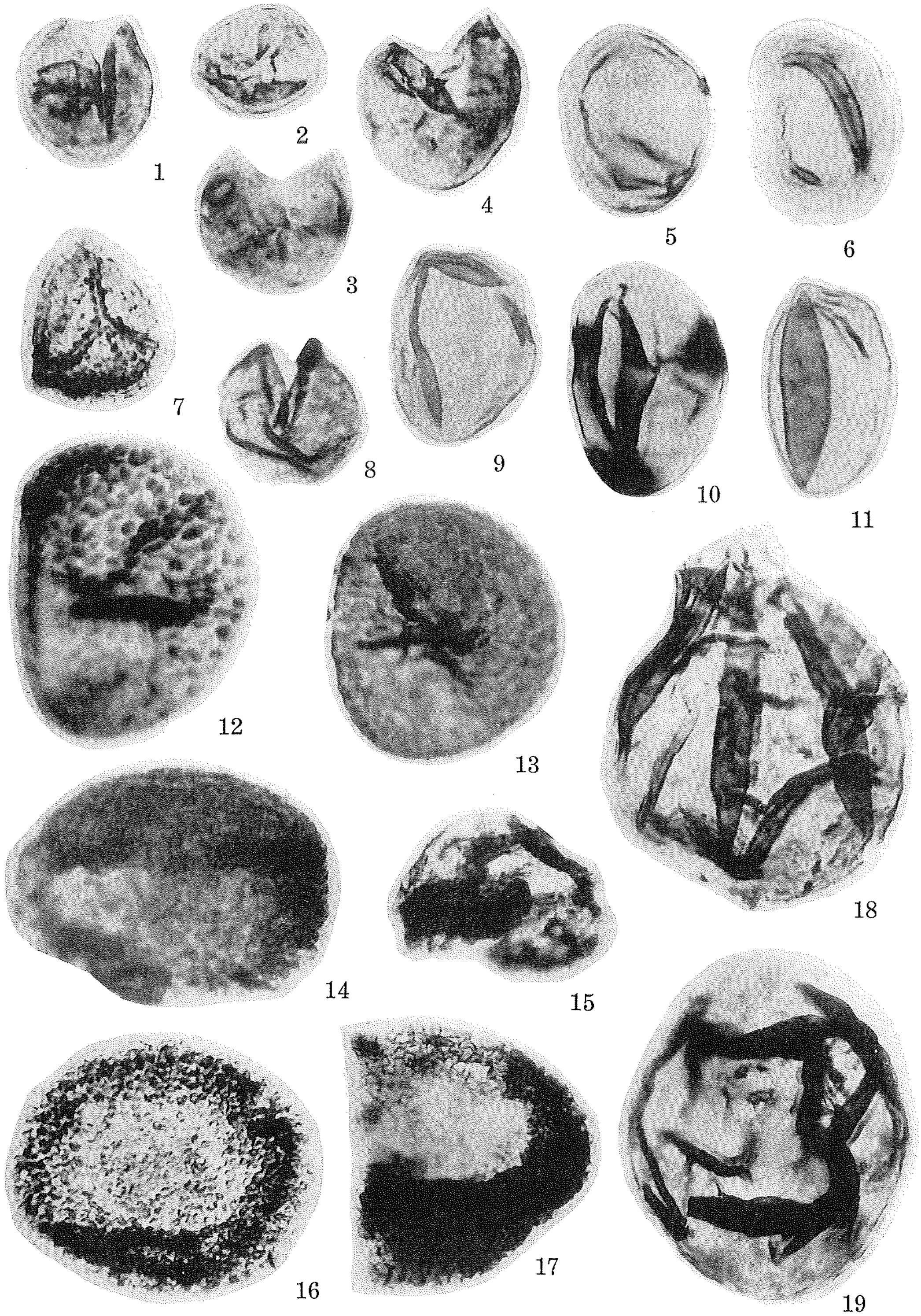
Explanation of
Plate 8

Explanation of Plate 8

		(Size μ)	(Locality)
1.	Taxodiaceae	33 × 29	Shumarinai arca
2.	*Metasequoia*	26 × 21	〃
3.	Taxodiaceae	32 × 30	Tomamae coal mine
4.	Taxodiaceae	40 × 35	Shumarinai area
5.	Polypodiaceae	38 × 30	Tomamae coal mine
6.	Polypodiaceae	42 × 32	〃
7.	Indeterminable spore	39 × 32	Shumarinai area
8.	Taxodiaceae	32 × 27	〃
9.	Polypodiaceae	40 × 30	Tomamae coal mine
10.	Polypodiaceae	48 × 33	Shumarinai area
11.	Polypodiaceae	44 × 26	Tomamae coal mine
12.	Polypodiaceae	66 × 50	Shumarinai area
13.	Polypodiaceae	54 × 48	Tomamae coal mine
14.	*Tsuga*	66 × 50	〃
15.	*Pinus*	45 × 35	Shumarinai area
16.	*Tsuga*	68 × 58	〃
17.	*Tsuga*	57 × 51+	〃
18.	*Larix*	80 × 65	〃
19.	*Larix*	73 × 60	〃



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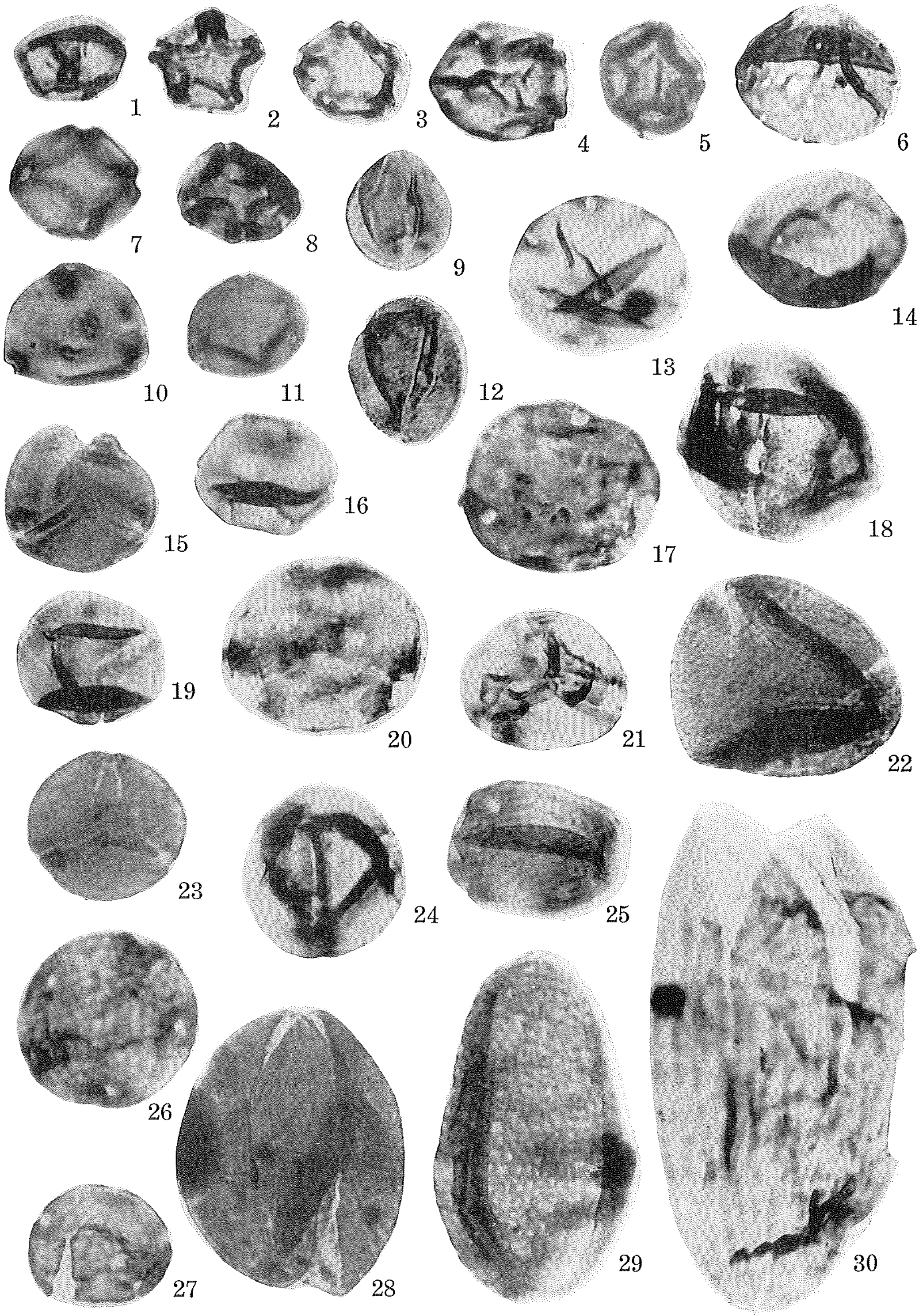
Explanation of Plate 9

Explanation of Plate 9

		(Size μ)	(Locality)
1.	*Alnus*	22 × 18	Shumarinai area
2.	*Alnus*	23 × 21	Tomamae coal mine
3.	*Alnus*	28 × 25	Shumarinai area
4.	*Alnus*	30 × 25	〃
5.	*Alnus*	24 × 21	Tomamae coal mine
6.	*Juglans*	35 × 30	Shumarinai area
7.	*Alnus*	28 × 24	〃
8.	*Alnus*	27 × 22	Tomamae coal mine
9.	*Quercus*?	25 × 23	〃
10.	*Carpinus*?	30 × 27	〃
11.	*Corylus*	27 × 23	〃
12.	*Quercus*	30 × 25	〃
13.	*Pterocarya*	38 × 32	Shumarinai area
14.	*Juglans*	38 × 29	〃
15.	*Fagus*	31 × 30	Tomamae coal mine
16.	*Pterocarya*	29 × 24	Shumarinai area
17.	*Carya*	42 × 37	〃
18.	*Fagus*	44 × 40	〃
19.	*Fagus*	33 × 28	〃
20.	*Fagus*	40 × 37	〃
21.	*Fagus*	35 × 29	〃
22.	*Fagus*	49 × 43	Tomamae coal mine
23.	*Fagus*	33 × 30	〃
24.	*Fagus*	44 × 40	Shumarinai area
25.	*Zelkova*	38 × 25	Tomamae coal mine
26.	*Zelkova*	38 × 37	〃
27.	*Ulmus*	30 × 25	〃
28.	Magnoliaceae	60 × 48	Tomamae coal mine
29.	Magnoliaceae	72 × 42	〃
30.	Magnoliaceae	105 × 53	Shumarinai area



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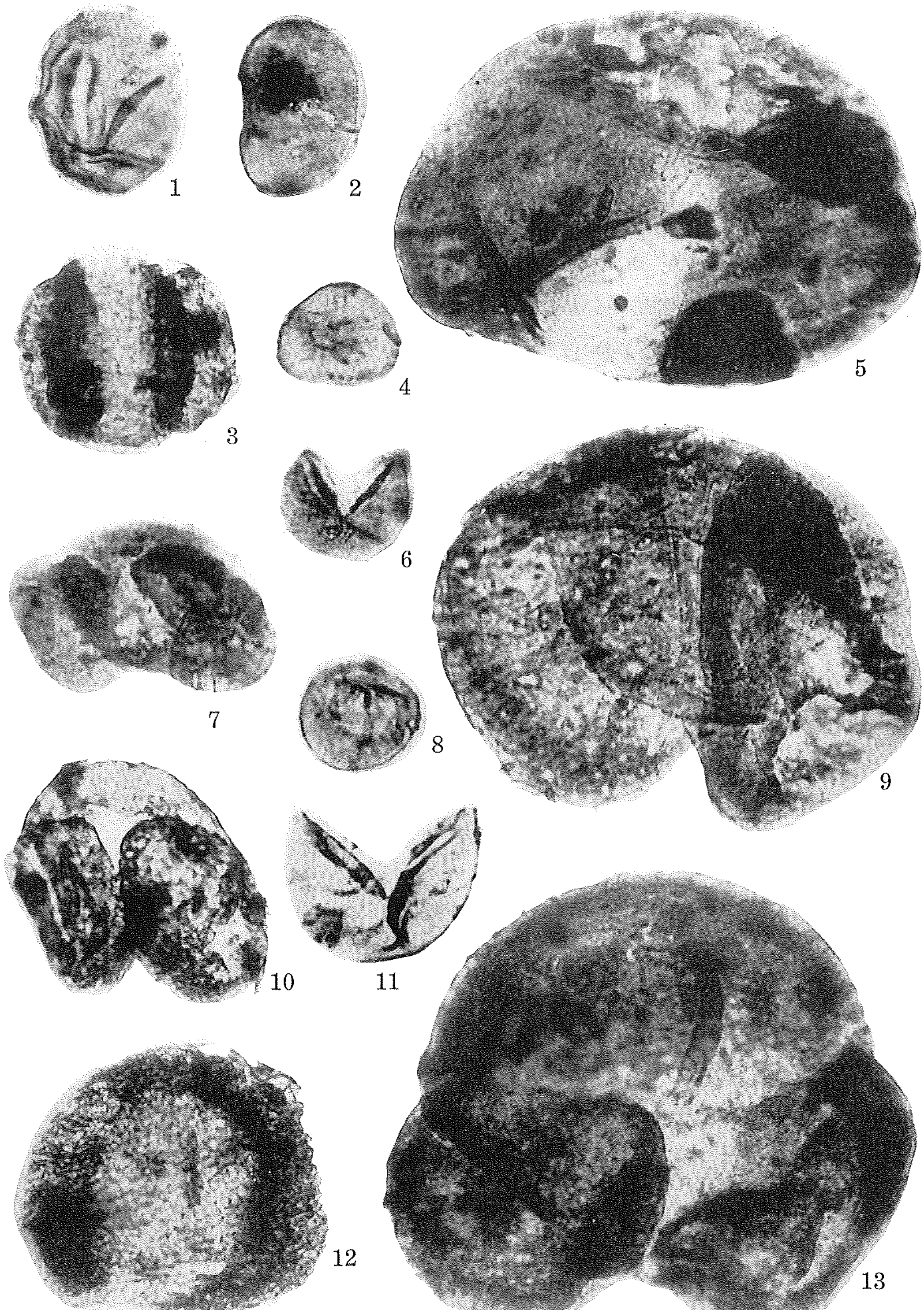
Explanation of
Plate 10

Explanation of Plate 10

		(Size μ)	(Locality)
1.	Polypodiaceae	40 × 30	Horonobe coal mine
2.	Polypodiaceae	38 × 26	〃
3.	*Pinus*	45 × 43	〃
4.	*Sphagnum*	26 × 23	〃
5.	*Picea*	110 × 79	〃
6.	Taxodiaceae	28 × 26	〃
7.	*Pinus*	55 × 33	〃
8.	*Metasequoia*	25 × 24	〃
9.	*Picea* ?	100 × 80	〃
10.	*Pinus*	60 × 45	〃
11.	Taxodiaceae	40 × 40	〃
12.	*Tsuga*	64 × 59	〃
13.	*Abies* or *Keteleeria*	105 × 95	〃



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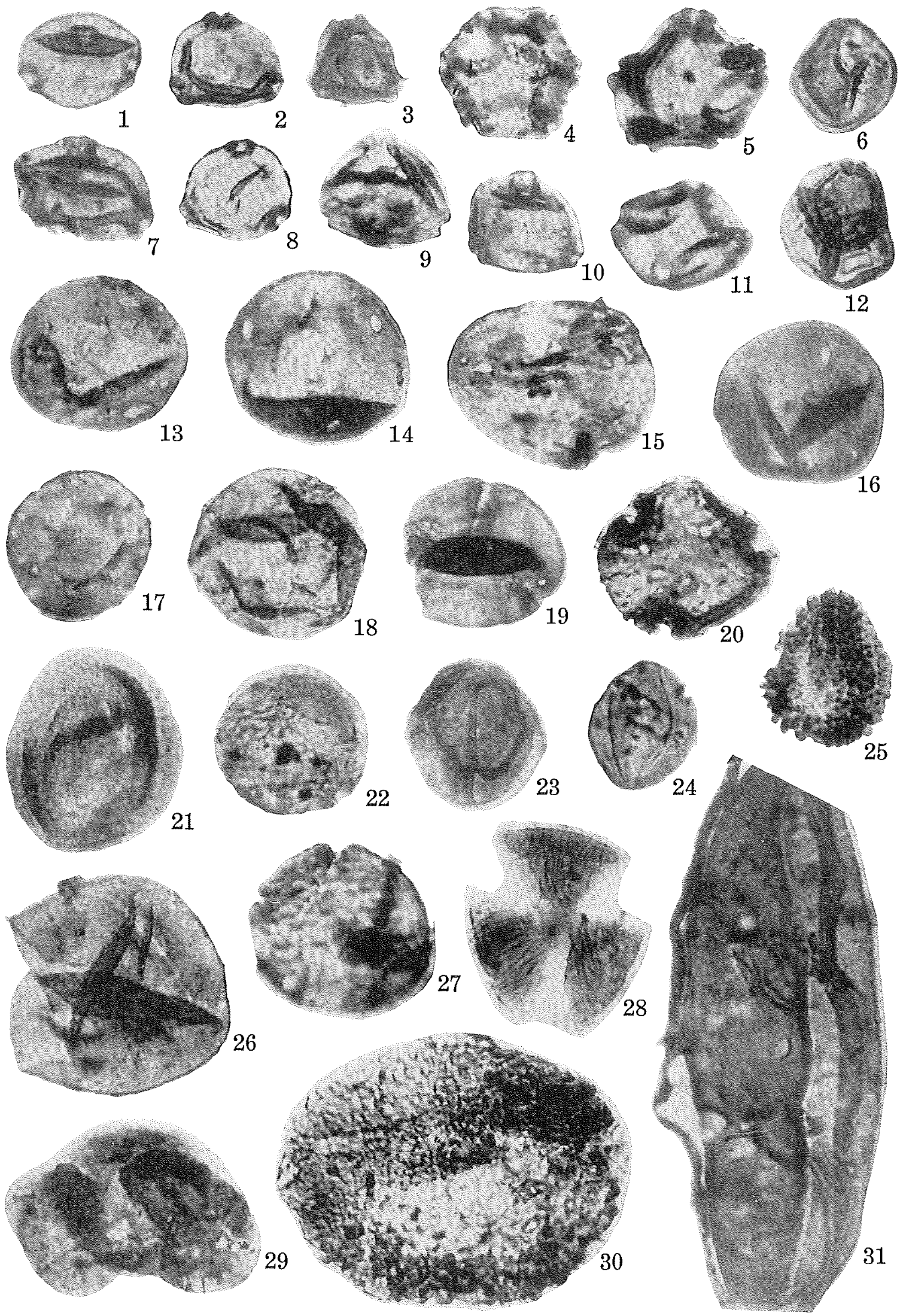
Explanation of Plate 11

Explanation of Plate 11

		(Size μ)	(Locality)
1.	*Carpinus*	27 × 21	Horonobe coal mine
2.	*Carpinus*	24 × 21	〃
3.	*Betula*	20 × 20	〃
4.	*Alnus*	30 × 28	〃
5.	*Alnus*	34 × 31	〃
6.	*Fraxinus* ?	25 × 23	〃
7.	*Betula*	33 × 23	〃
8.	*Carpinus*	25 × 22	〃
9.	*Corylus* ?	28 × 24	〃
10.	*Corylus*	28 × 22	〃
11.	*Alnus*	31 × 23	〃
12.	Ericaceae	28 × 25	〃
13.	*Carya*	38 × 34	〃
14.	*Carya*	42 × 38	〃
15.	*Carya*	46 × 38	〃
16.	*Carya*	37 × 35	〃
17.	*Juglans* ?	33 × 30	〃
18.	*Fagus*	37 × 36	〃
19.	*Fagus*	35+ × 33	〃
20.	*Tilia*	37 × 34	〃
21.	*Fagus*	45 × 38	〃
22.	*Ulmus*	34 × 30	〃
23.	*Quercus* ?	33 × 31	〃
24.	*Quercus*	27 × 23	〃
25.	*Ilex*	33 × 29	〃
26.	*Fagus*	53+ × 48	〃
27.	*Zelkova*	40 × 39	〃
28.	*Acer* ?	41 × 36	〃
29.	*Pinus*	55 × 33	〃
30.	*Tsuga*	78 × 55	〃
31.	Magnoliaceae	115+ × 48	〃



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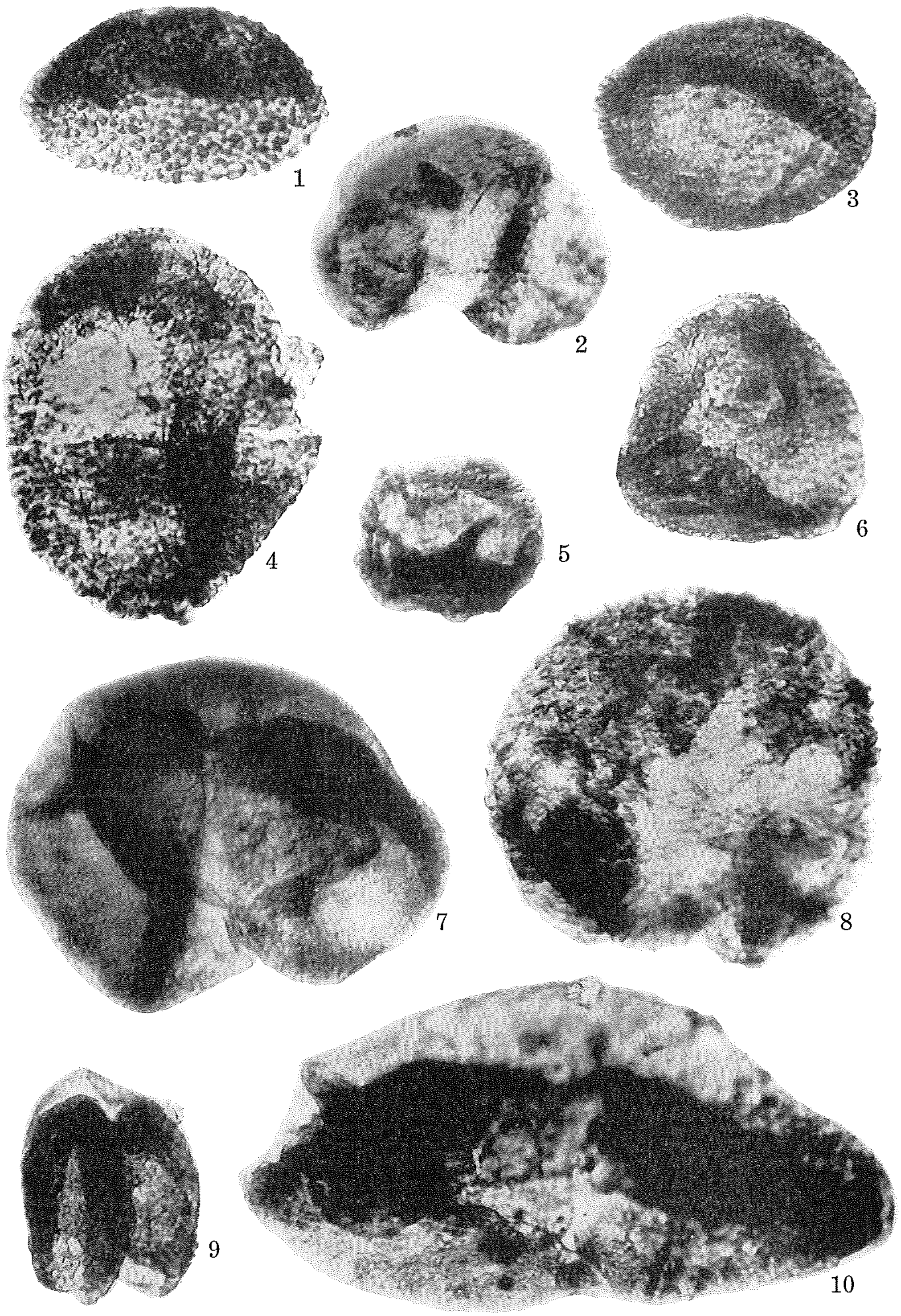
Explanation of Plate 12

Explanation of Plate 12

		(Size μ)	(Locality)
1.	*Osmunda*	63 × 38	Hokutakukoishi coal mine
2.	*Pinus*	61 × 50	〃
3.	*Tsuga*	60 × 45	〃
4.	*Tsuga*	83 × 67	〃
5.	*Tsuga*	41 × 36	〃
6.	*Tsuga*	52 × 51	〃
7.	*Picea*	94 × 77	〃
8.	*Tsuga*	95 × 85	〃
9.	*Pinus*	49 × 43	〃
10.	*Picea*	113 × 68	〃



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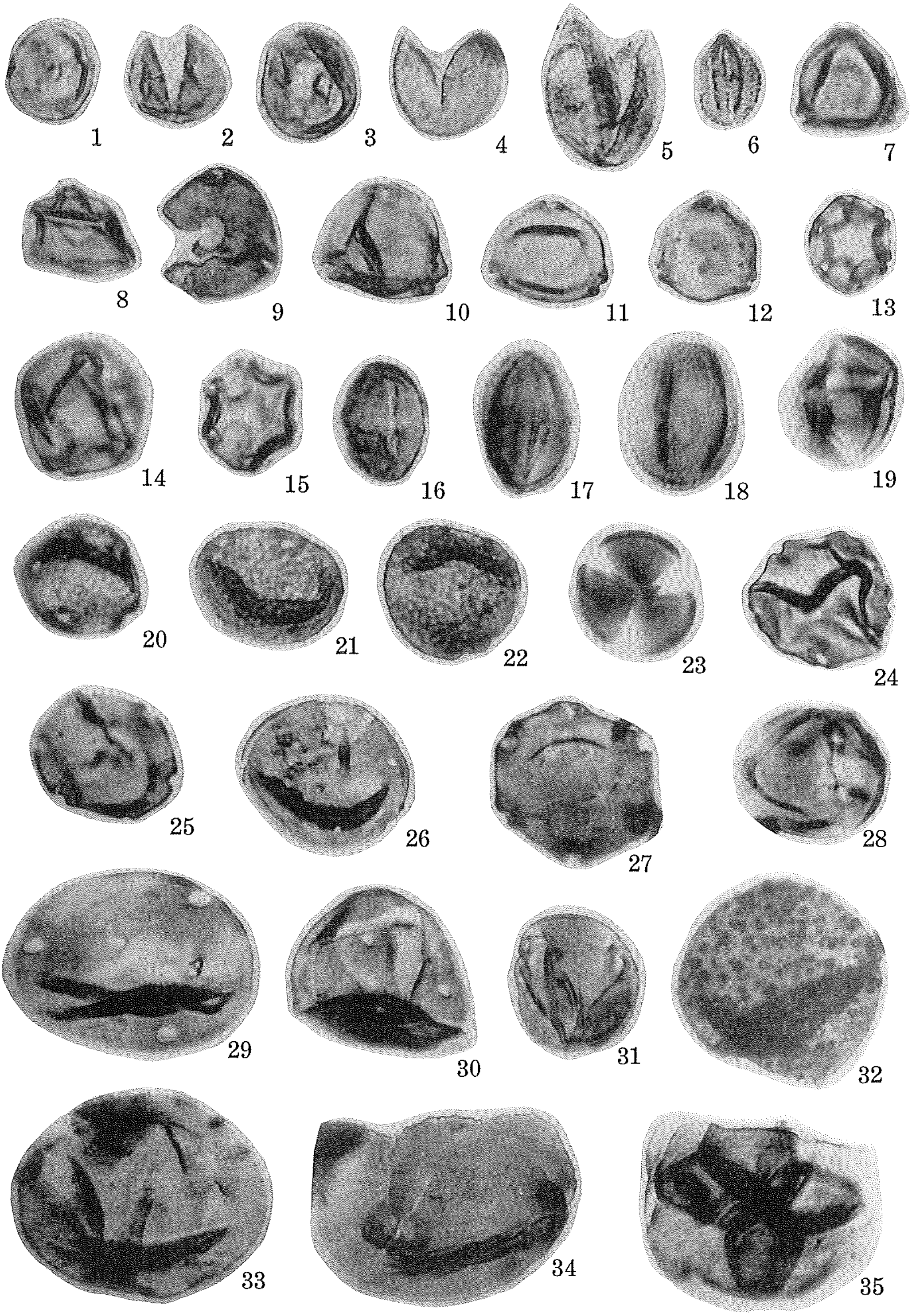
Explanation of Plate 13

Explanation of Plate 13

		(Size μ)	(Locality)
1.	*Metasequoia occidentalis* (NEWBERRY) CHANEY	20 × 18	Hokutakukoishi coal mine
2.	〃	20 × 19	〃
3.	〃	25 × 20	〃
4.	〃	24 × 23	〃
5.	*Glyptostrobus* ?	33 × 25	〃
6.	*Salix*	19 × 13	〃
7.	*Betula*	23 × 22	〃
8.	*Betula*	25 × 18	Onishibetsu coal mine
9.	*Carpinus* ?	28 × 27	Hokutakukoishi coal mine
10.	*Carpinus* ?	27 × 24	〃
11.	*Carpinus*	27 × 22	Onishibetsu coal mine
12.	*Carpinus*	23 × 23	〃
13.	*Alnus*	21 × 13	Hokutakukoishi coal mine
14.	*Alnus*	30 × 27	〃
15.	*Alnus*	24 × 20	〃
16.	*Quercus*	24 × 19	〃
17.	*Quercus*	31 × 21	〃
18.	*Quercus*	33 × 25	〃
19.	*Fraxinus* ?	28 × 25	〃
20.	*Ulmus*	26 × 23	〃
21.	*Ulmus* or *Zelkova*	31 × 25	〃
22.	*Ulmus* or *Zelkova*	29 × 27	〃
23.	*Acer* ?	28 × 25	〃
24.	*Pterocarya*	30 × 28	〃
25.	*Pterocarya*	30 × 25	〃
26.	*Juglans*	35 × 31	〃
27.	*Pterocarya*	36 × 31	〃
28.	*Fagus*	32 × 29	Onishibetsu coal mine
29.	*Carya*	50 × 39	Hokutakukoishi coal mine
30.	*Carya*	40 × 33	〃
31.	*Fagus* or *Rhus*	30 × 24	〃
32.	*Lonicera*	41 × 41	〃
33.	*Fagus*	52 × 43	〃
34.	*Fagus*	57 × 38+	〃
35.	Ericaceae	51 × 39+	〃



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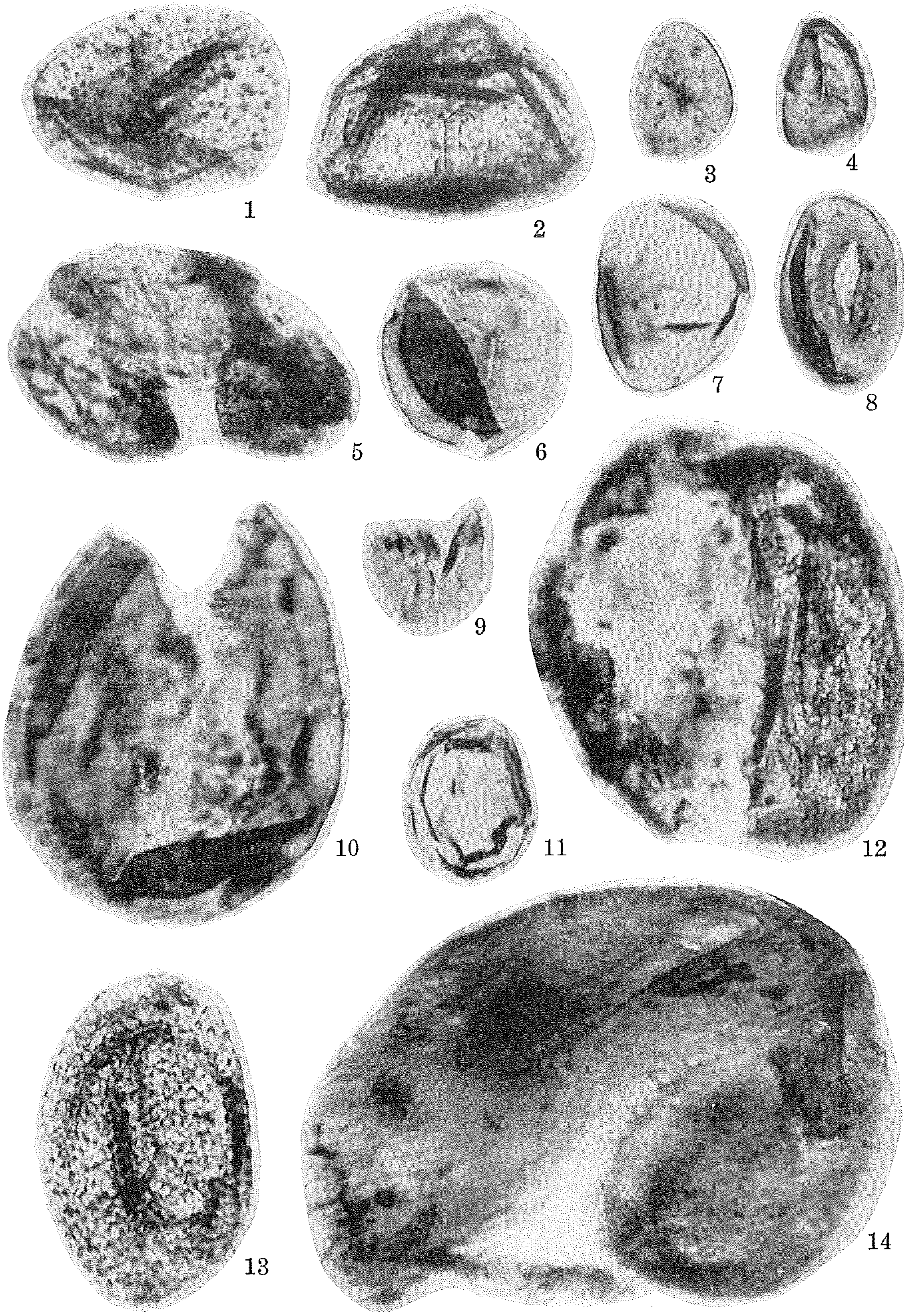
Explanation of
Plate 14

Explanation of Plate 14

		(Size μ)	(Locality)
1.	*Osmuda*	52 × 39	Honjin-no-sawa, Uryû
2.	*Osmuda*	58 × 45	〃
3.	*Sphagnum*	30 × 22	〃
4.	*Sphagnum*	28 × 20	〃
5.	*Pinus*	73 × 43	〃
6.	Polypodiaceae ?	40 × 38	〃
7.	Polypodiaceae	43 × 34	〃
8.	Polypodiaceae	42 × 25	〃
9.	*Larix*	92 × 75	〃
10.	Taxodiaceae	29 × 25	〃
11.	Polypodiaceae	35 × 26	〃
12.	*Picea*	98 × 68	〃
13.	*Osmunda*	70 × 45	〃
14.	*Picea*	105 × 87	〃



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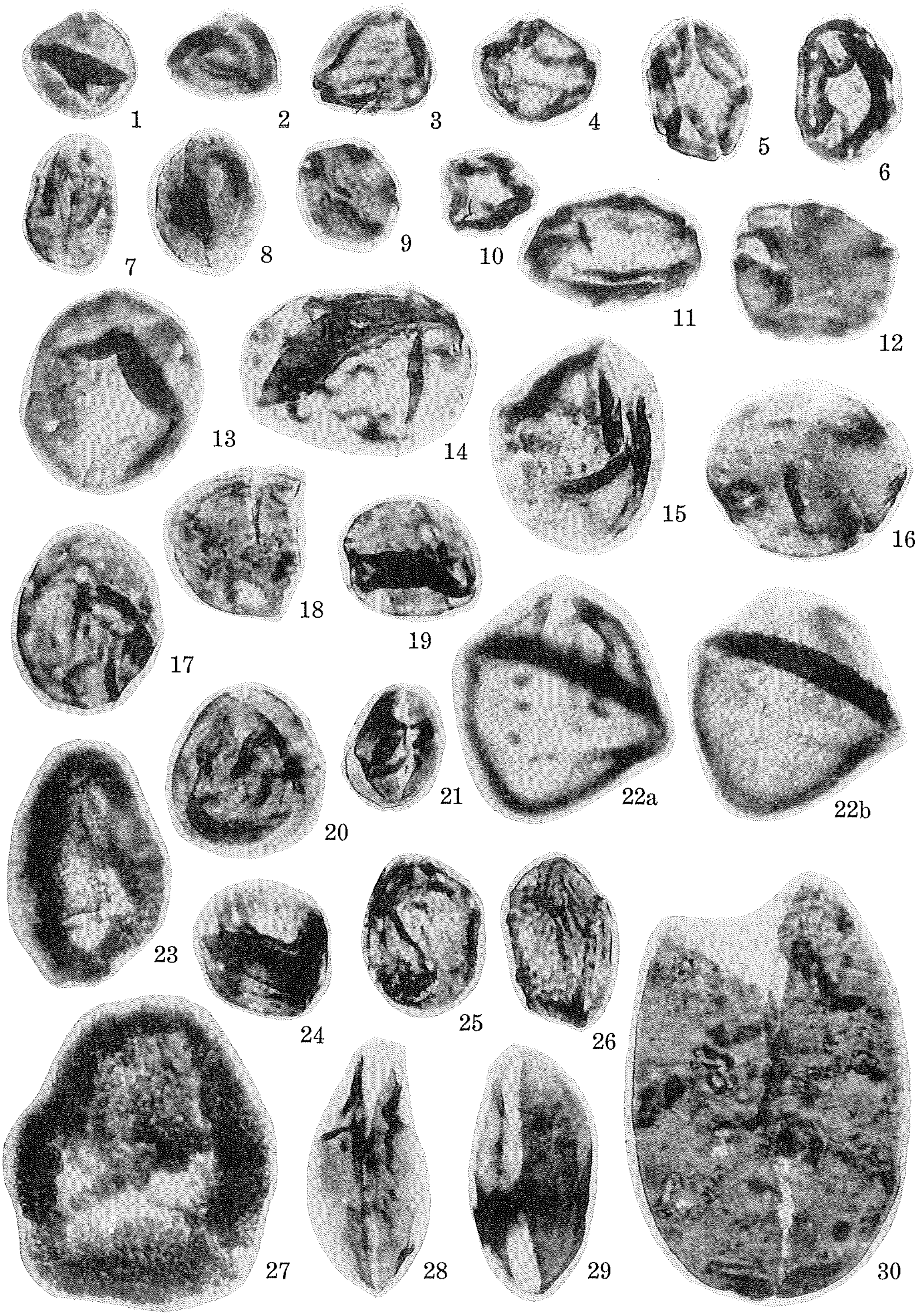
Explanation of Plate 15

Explanation of Plate 15

		(Size μ)	(Locality)
1.	*Carpinus*	23 × 23	Honjin-no-sawa, Uryû
2.	*Corylus*	23 × 19	〃
3.	*Carpinus* ?	26 × 23	〃
4.	*Alnus*	26 × 23	〃
5.	*Alnus*	31 × 23	〃
6.	*Alnus*	32 × 23	〃
7.	*Quercus*	27 × 18	〃
8.	*Quercus*	34 × 35	〃
9.	*Pterocarya*	25 × 20	〃
10.	*Alnus*	21 × 18	〃
11.	*Pterocarya*	38 × 25	〃
12.	*Pterocarya*	35 × 30	〃
13.	*Carya*	43 × 35	〃
14.	*Juglans*	50 × 37	〃
15.	*Fagus*	44 × 36	〃
16.	*Fagus*	43 × 37	〃
17.	*Juglans*	40 × 31	〃
18.	*Fagus*	32 × 29+	〃
19.	*Fagus*	30 × 25	〃
20.	*Liquidambar*	35 × 31	〃
21.	*Fraxinus* ?	27 × 20	〃
22 a, b	Indeterminable pollen	51 × 48	〃
23.	*Tsuga*	52 × 33	〃
24.	*Zelkova*	30 × 28	〃
25.	*Ulmus* or *Zelkova*	32 × 24	〃
26.	*Ulmus* or *Zelkova*	35 × 22	〃
27.	*Tsuga*	67 × 55	〃
28.	Magnoliaceae ?	52 × 24	〃
29.	Magnoliaceae ?	52 × 26	〃
30.	Magnoliaceae ?	92+ × 36	〃



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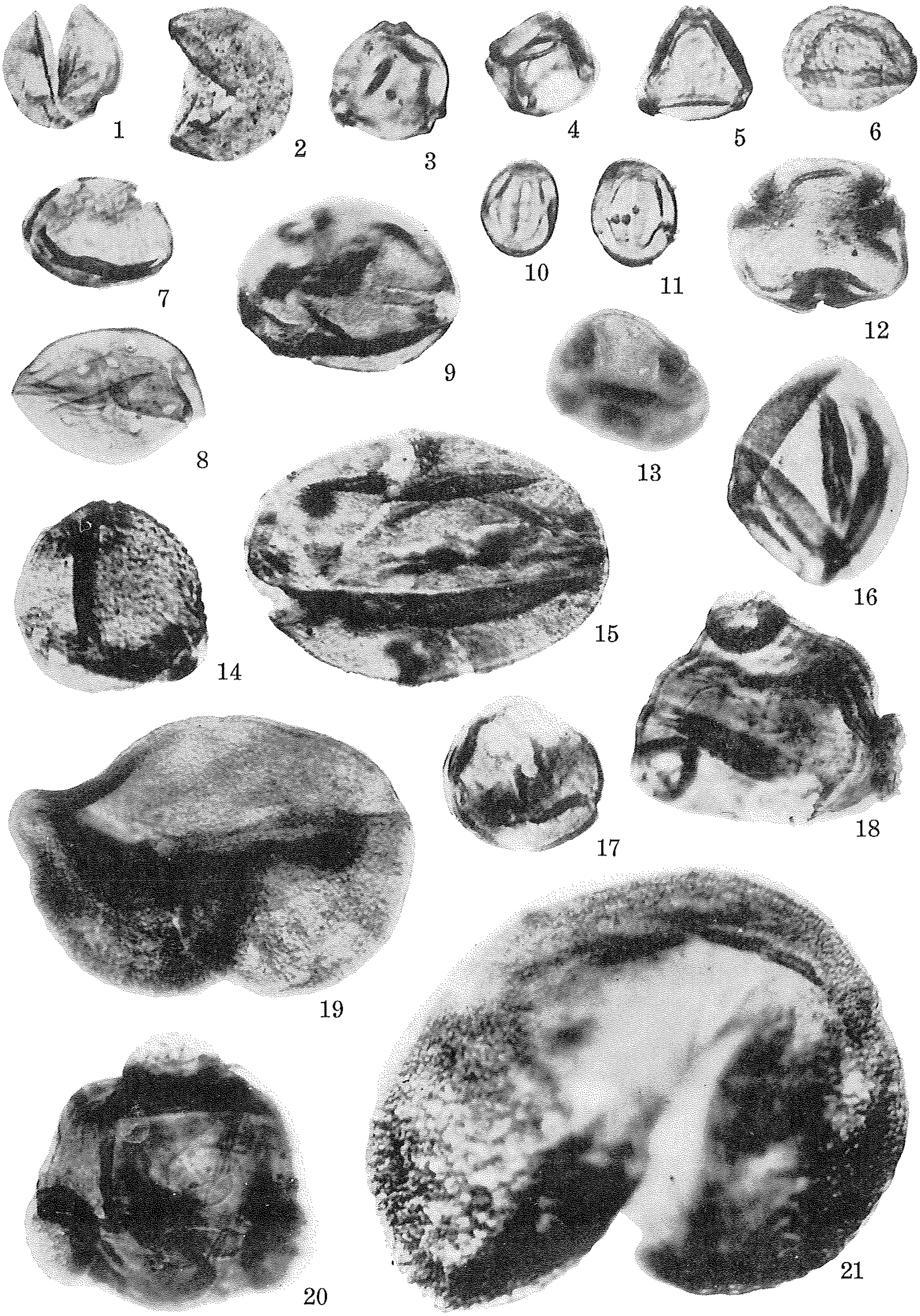
Explanation of Plate 16

Explanation of Plate 16

		(Size μ)	(Locality)
1.	Taxodiaceae	28 × 23	Nissô-teshio coal mine (Masuporo formation)
2.	Taxodiaceae	26 × 23	Toikanbetsu area (Masuporo formation)
3.	*Carpinus*	26 × 25	〃
4.	*Alnus*	24 × 22	Nissô-teshio coal mine (Masuporo formation)
5.	*Betula*	24 × 23	〃
6.	*Ulmus*	29 × 23	Toikanbetsu area (Masuporo formation)
7.	*Ulmus*	31 × 23	Nissô-teshio coal mine (Masuporo formation)
8.	*Juglans*	42 × 28	Toikanbetsu area (Masuporo formation)
9.	*Fagus*	45 × 36	Nissô-teshio coal mine (Masuporo formation)
10.	Indeterminable pollen	21 × 16	Toikanbetsu area (Masuporo formation)
11.	Indeterminable pollen	23 × 18	〃
12.	*Tilia*	40 × 35	〃
13.	*Tilia*	37 × 26	〃
14.	*Fagus*	40 × 38	Nissô-teshio coal mine (Masuporo formation)
15.	*Fagus* ?	75 × 52	〃
16.	*Fagus*	48 × 37	Toikanbetsu area (Masuporo formation)
17.	*Liquidambar*	33 × 30	Nissô-teshio coal mine (Masuporo formation)
18.	*Epilobium*	58 × 50	Toikanbetsu area (Masuporo formation)
19.	*Picea*	87 × 61	〃
20.	*Epilobium*	64 × 63	〃
21.	*Picea*	115 × 90	〃



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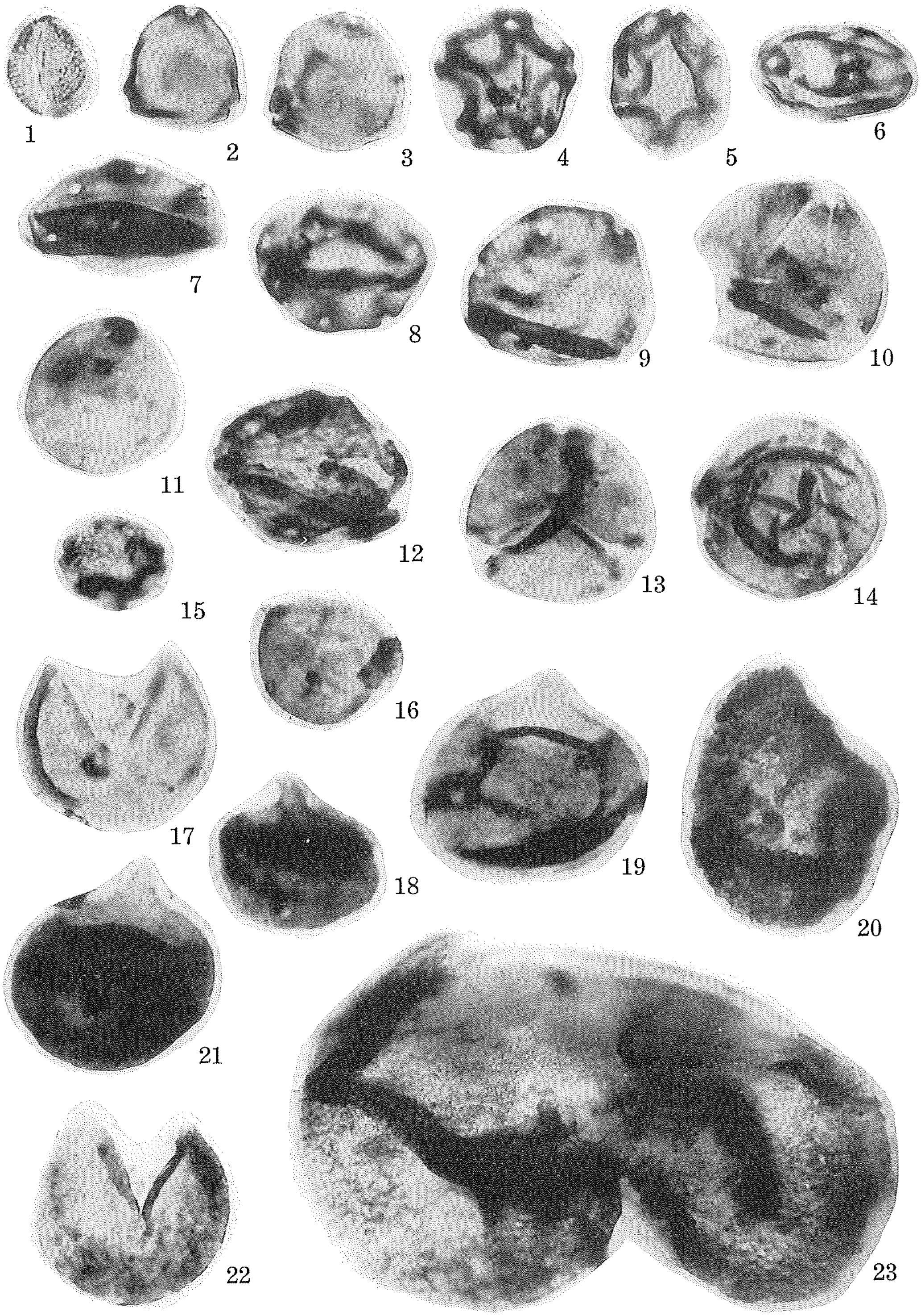
Explanation of Plate 17

Explanation of Plate 17

		(Size μ)	(Locality)
1.	*Salix*	21 × 18	Onnenai coal mine
2.	*Carpinus*	26 × 24	〃
3.	*Carpinus*	29 × 29	〃
4.	*Alnus*	30 × 29	〃
5.	*Alnus*	30 × 23	〃
6.	*Alnus*	33 × 20	〃
7.	*Pterocarya*	40 × 23	〃
8.	*Pterocarya*	35 × 28	〃
9.	*Pterocarya*	38 × 33	〃
10.	*Fagus*	40 × 38+	〃
11.	*Carya*	33 × 30	〃
12.	*Zelkova*	42 × 33	〃
13.	*Fagus*	38 × 38	〃
14.	*Fagus*	38 × 37	〃
15.	*Ulmus*	24 × 19	〃
16.	*Sphagnum*	29 × 28	Monponai coal mine
17.	*Glyptostrobus* or *Cryptomeria*	38 × 37	Onnenai coal mine
18.	*Metasequoia*	35 × 26	Monponai coal mine
19.	*Glyptostrobus*	48 × 47	〃
20.	*Tsuga*	55 × 42	Onnenai coal mine
21.	*Glyptostrobus* or *Cryptomeria*	43 × 38	Monponai coal mine
22.	*Glyptostrobus* or *Cryptomeria*	43 × 40	〃
23.	*Picea*	125 × 78	Onnenai coal mine



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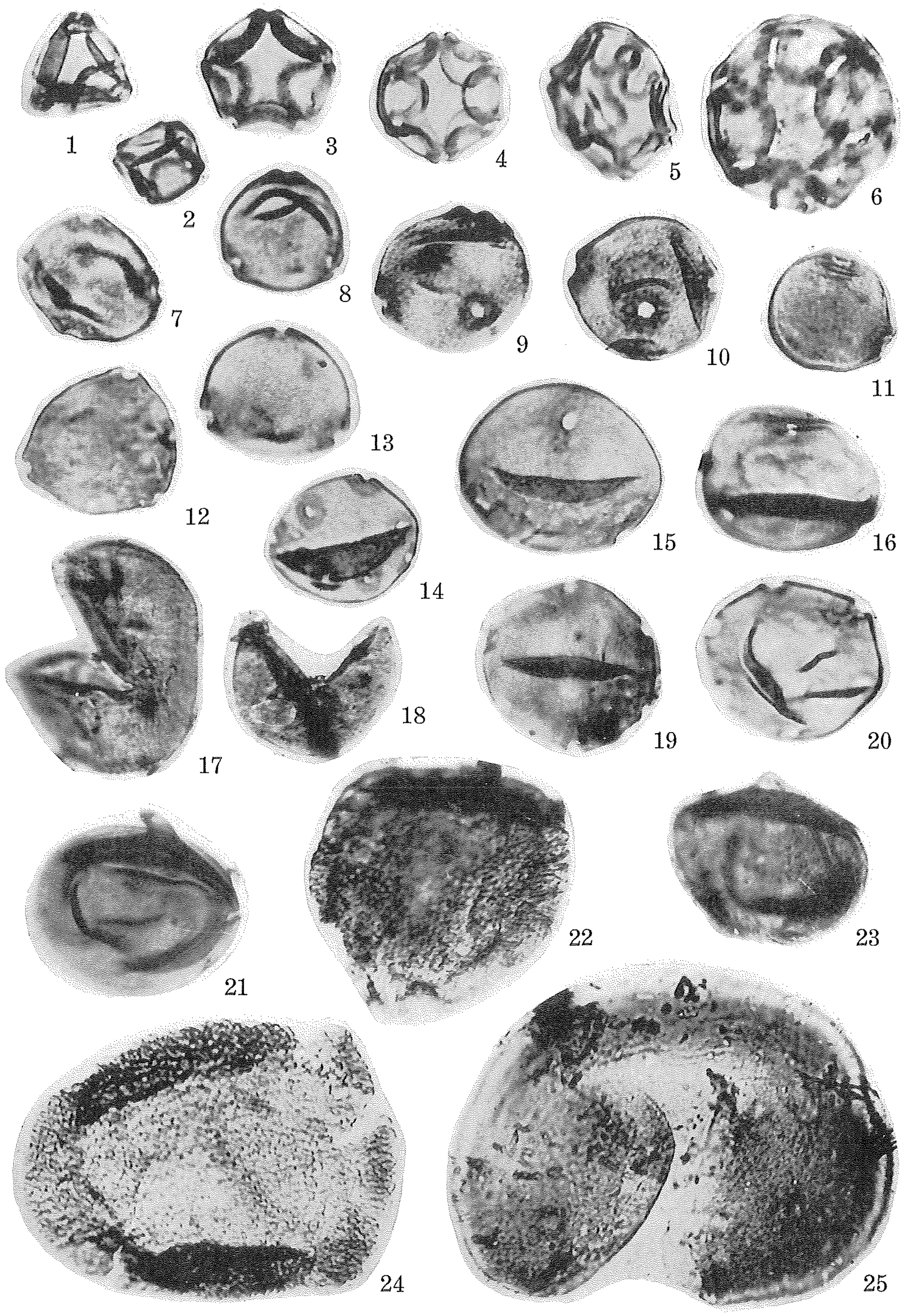
Explanation of Plate 18

Explanation of Plate 18

		(Size μ)	(Locality)
1.	*Betula*	23 × 22	Tôgeshita area
2.	*Alnus*	20 × 18	〃
3.	*Alnus*	28 × 27	〃
4.	*Alnus*	28 × 27	〃
5.	*Alnus*	34 × 28	〃
6.	*Alnus*	45 × 43	Onnenai coal mine
7.	*Carpinus*	30 × 25	Tôgeshita area
8.	*Carpinus*	29 × 28	〃
9.	*Carpinus*	32 × 29	〃
10.	*Carpinus*	33 × 29	〃
11.	*Carpinus*	27 × 26	〃
12.	*Carpinus*	35 × 33	Masuda-no-sawa, Onnenai
13.	*Carpinus*	32 × 28	Tôgeshita area
14.	*Pterocarya*	33 × 28	〃
15.	*Carya*	43 × 36	〃
16.	*Carya*	39 × 32	Kamichikubetsu area
17.	*Glyptostrobus* or *Cryptomeria*	48 × 38	Masuda-no-sawa, Onnenai
18.	*Metasequoia* ?	35 × 33	Kamichikubetsu area
19.	*Pterocarya*	37 × 35	〃
20.	*Pterocarya*	39 × 34	Tôgeshita area
21.	*Sequoia* or *Cryptomeria*	44 × 37	Kamicikubetsu area
22.	*Tsuga*	55 × 55	〃
23.	*Glyptostrobus*	43 × 36	〃
24.	*Tsuga*	82 × 60	Tôgeshita area
25.	*Picea*	122 ×107	Masuda-no-sawa, Onnenai



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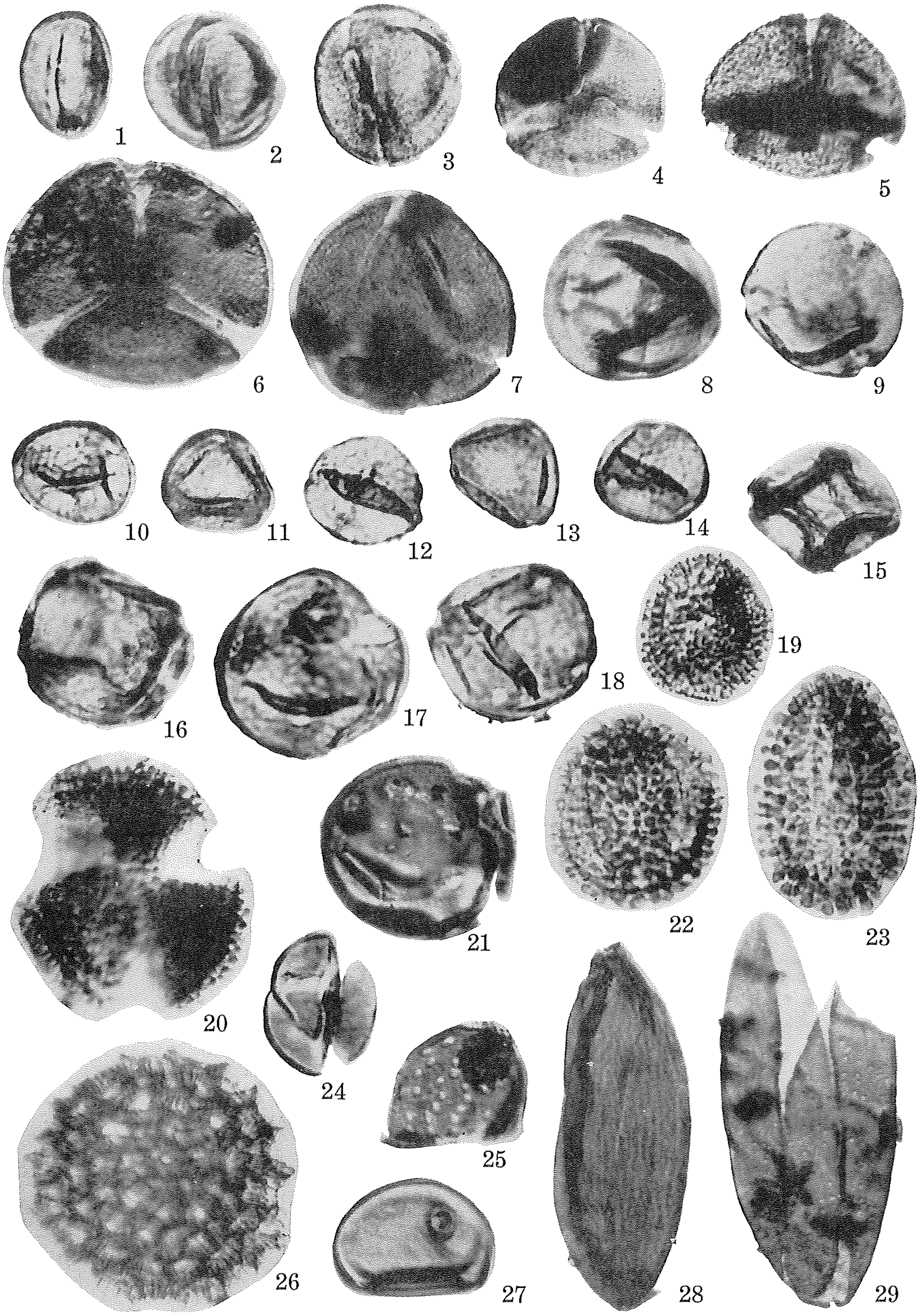
Explanation of
Plate 19

Explanation of Plate 19

		(Size μ)	(Locality)
1.	*Quercus*	28 × 19	Tôgeshita area
2.	*Quercus*	30 × 28	〃
3.	*Fagus*	35 × 33	〃
4.	*Fagus*	37 × 34	〃
5.	*Fagus*	43 × 35	Kamichikubetsu area
6.	*Fagus*	53 × 47	Masuda-no-sawa, Onnenai
7.	*Fagus*	48 × 44	〃
8.	*Fagus*	38 × 33	Kamichikubetsu area
9.	*Fagus*	35 × 32	Tôgeshita area
10.	*Ulmus*	27 × 22	〃
11.	*Ulmus*	23 × 22	Kamichikubetsu area
12.	*Ulmus*	26 × 23	Tôgeshita area
13.	*Ulmus*	27 × 22	〃
14.	*Ulmus*	27 × 22	〃
15.	*Zelkova*	32 × 28	Kamichikubetsu area
16.	*Zelkova*	36 × 32	〃
17.	*Zelkova*	41 × 38	Tôgeshita area
18.	*Zelkova*	36 × 32	〃
19.	*Ilex*	31 × 27	〃
20.	*Ilex*	55 × 48	Masuda-no-sawa, Onnenai
21.	*Liquidambar*	40 × 40	Kamichikubetsu area
22.	*Ilex*	44 × 38	Masuda-no-sawa, Onnenai
23.	*Ilex*	53 × 35	〃
24.	Indeterminable pollen	31 × 27	Kamichikubetsu area
25.	Chenopodiaceae	31+× 27	〃
26.	Compositae	57 × 57	〃
27.	Gramineae	34 × 25	〃
28.	Magnoliaceae	78 × 28	〃
29.	Magnoliaceae	85 × 37	〃



S. SATO: Palynological study on Miocene sediments of Hokkaidô *Photo. S. SATO*