PALYNOLOGICAL STUDY ON THE HABORO COAL SEAM OF THE HABORO COAL-BEARING FORMATION
PALYNOLOGICAL STUDIES ON NEOGENE COAL 1

By

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Introduction

For peat the pollen analysis has been made on various phases in many fundamental examinations. On the basis of such observations many interesting and useful interpretations have been reported. But for coal it can not be said that the pollen analysis method has been so much employed as for peat; it has been considered not so applicable as for peat. The purpose of the present work is to ascertain the characteristics of pollen distribution in coal seams in detail. That is to say, from the data described in the present paper the writer has tried to get some answer as to whether pollen analysis is applicable to coal in the same manner as it is to peat or not, and what consideration should be paid respectively to the cases of peat and coal in this respect. Moreover, the writer expects to find out about the usefulness of pollen analysis for the correlation of coal seams, and to gain some information on the formation of coal seams. In the present paper, the writer treats only of the pollen which shows a remarkable occurrence in connection with the formation and correlation of the particular coal seam, and moreover one which has a rather characteristic form that is not easily misidentified. On other pollens some reports will be made in other papers.

The samples studied in preparation of the present paper, were taken from the Haboro coal-bearing formation of Miocene age which is distributed with workable coal seams in the northern part of Hokkaidô, Japan. (Fig. 1)

Besides, the writer would like to make the following point: in this coal seam pollen grains were so deformed or broken that there are not a few pollen grains whose generic names cannot be determined. So, the writer felt great difficulty* to deal with these pollens quantitatively.

* Many authors, for example, ERDTMAN, POTONIE and etc. refer on such difficulty.

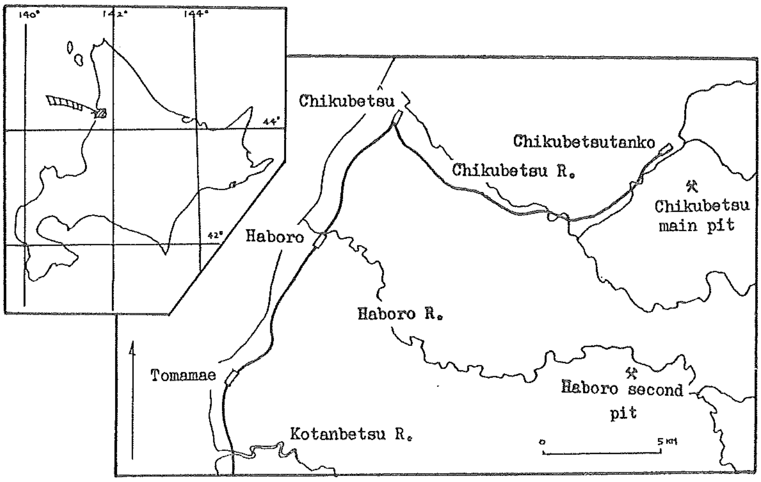


Fig. 1. Locality map.

Acknowledgment

The writer wishes to express the sincerest thanks to Professor Y. SASA, of Hokkaido University and Assistant Professor T. TANAI, of Hokkaido University, who gave kind guidances and encouragements. Grateful thanks, further, are due to Professor T. YAMAZAKI and Mr. S. TAKEOKA, of Saikyô University, who gave kind guidance at the beginning of the study. Also the writer is greatly indebted to Professor J. NAKAMURA, of Kôchi University, Mr. S. TOKUNAGA of Geological Survey of Japan and many other seniors in pollen study.

Particular thanks are due to Mr. S. HATTORI and others of the Haboro Coal-mine and Railway Company, who helped kindly in the field work.

This investigation has been partly aided by a Grant for Fundamental Scientific Research from the Ministry of Education which is most gratefully acknowledged.

On samples, their localities and method of sampling

The samples were taken from the Haboro main coal-seam in the Chikubetsu main pit and from the Haboro second pit. The order of succession, characters of rocks and the thickness of the formations in the present area are as follows;

Age	Formation	Member	
Quaternary	Alluvium		
	Diluvium		
Pliocene	Enbetsu formation (+1000 m) (marine) (Mainly tuffaceous mudstone, intercalating sandstone and diatom earth, in basal part thin "hard shale")		
	Ogawa lignite-bearing formation (0–100 m) (terrestrial) (Tuffaceous sandstone, tuffite, agglomerate, with lignite)		
Miocene	Kotanbetsu formation (+1000 m) (marine) (Frequent alternation of sandstone, mudstone and conglomerate. Rich in huge boulders.)		
	Chikubetsu formation	Mudstone member (+50 m)	(+150 m)
		Upper sandstone member (+130 m)	
		Alternation member (0–150 m)	
		Lower sandstone member (+150 m)	
	Haboro (coal-bearing) formation (250–400 m) (terrestrial) (Alternation of sandstone and shale, intercalating several coal seams with a few workable ones)		
	Haranosawa formation (200–300 m) (marine) (Alternation of tuffaceous sandstone and mudstone with tuffite (10–40 m) on top)		
Late Cretaceous	Upper Cretaceous rocks (marine) (Mainly dark gray mudstone)		

The samples are taken from the coal-seam at 10 cm interval vertically. But, this interval is problematic; there must be kept in mind the following points. Namely, pollen analysis has produced many useful and interesting results from samplings at 10 cm interval, but such a matter is for peat, and not for coal. During the time while peat changes to coal, dyhydration, compaction and compression by such actions as loads and material decay influence this process, and these cause the decrease of volume. This decrease of volume is reported from 1/3 to 1/10 by White*. So, 10 cm thickness of coal-seam may correspond to 30 to 100 cm thickness of peat. It is shown in many papers that in 0.5 to 1 m thickness of peat, considerable floristic changes are represented. So, a series of samples which are taken from 10 cm interval may not represent the detailed floristic change during deposition of that coal seam. But it is also a problematic matter whether the coal has continued under the same conditions as well as peat: the climatic during this coal formation may have not been as uniform as in case of one of those Quaternary peats.

Moreover, as a matter of fact, in such places as tunnels even sampling

* D. White: 1913, p. 89.

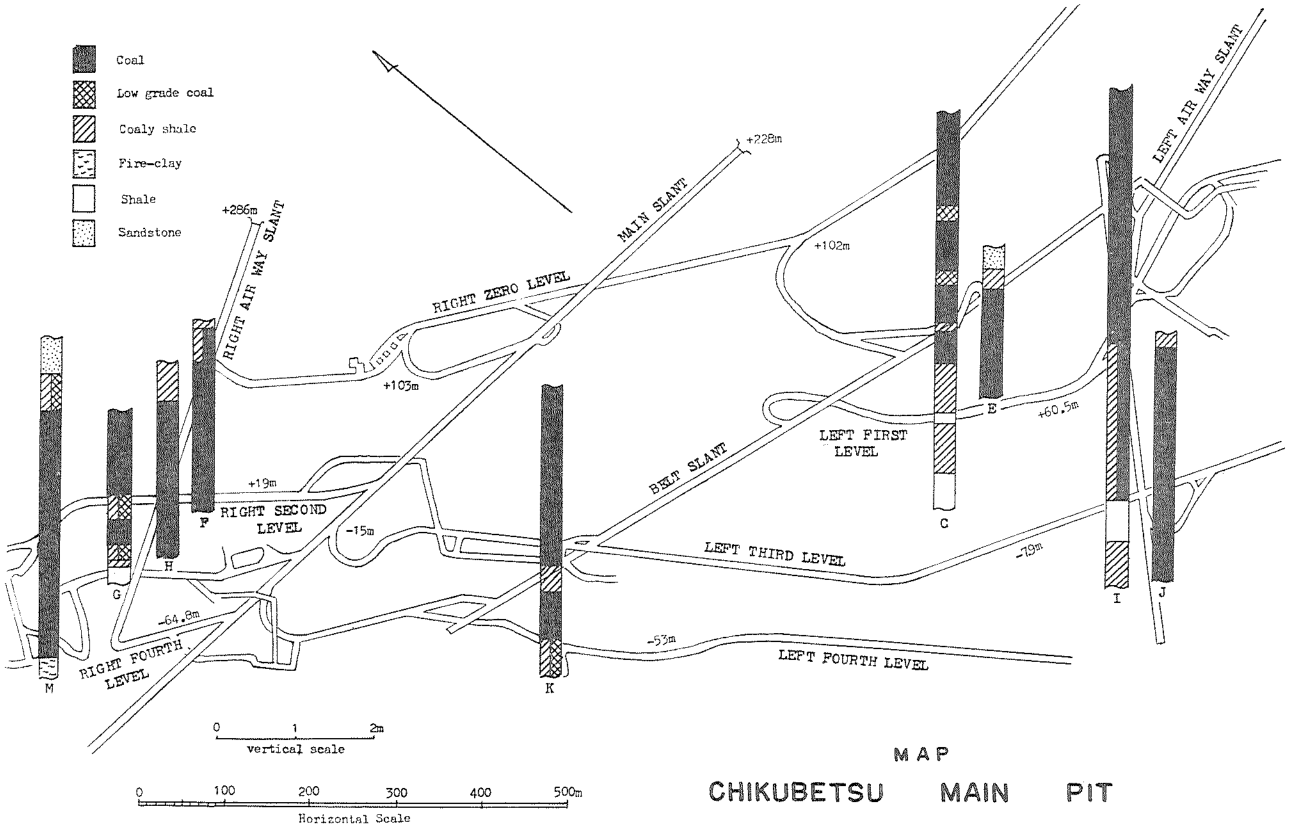


Fig. 2. Showing sampling localities and columnar sections.

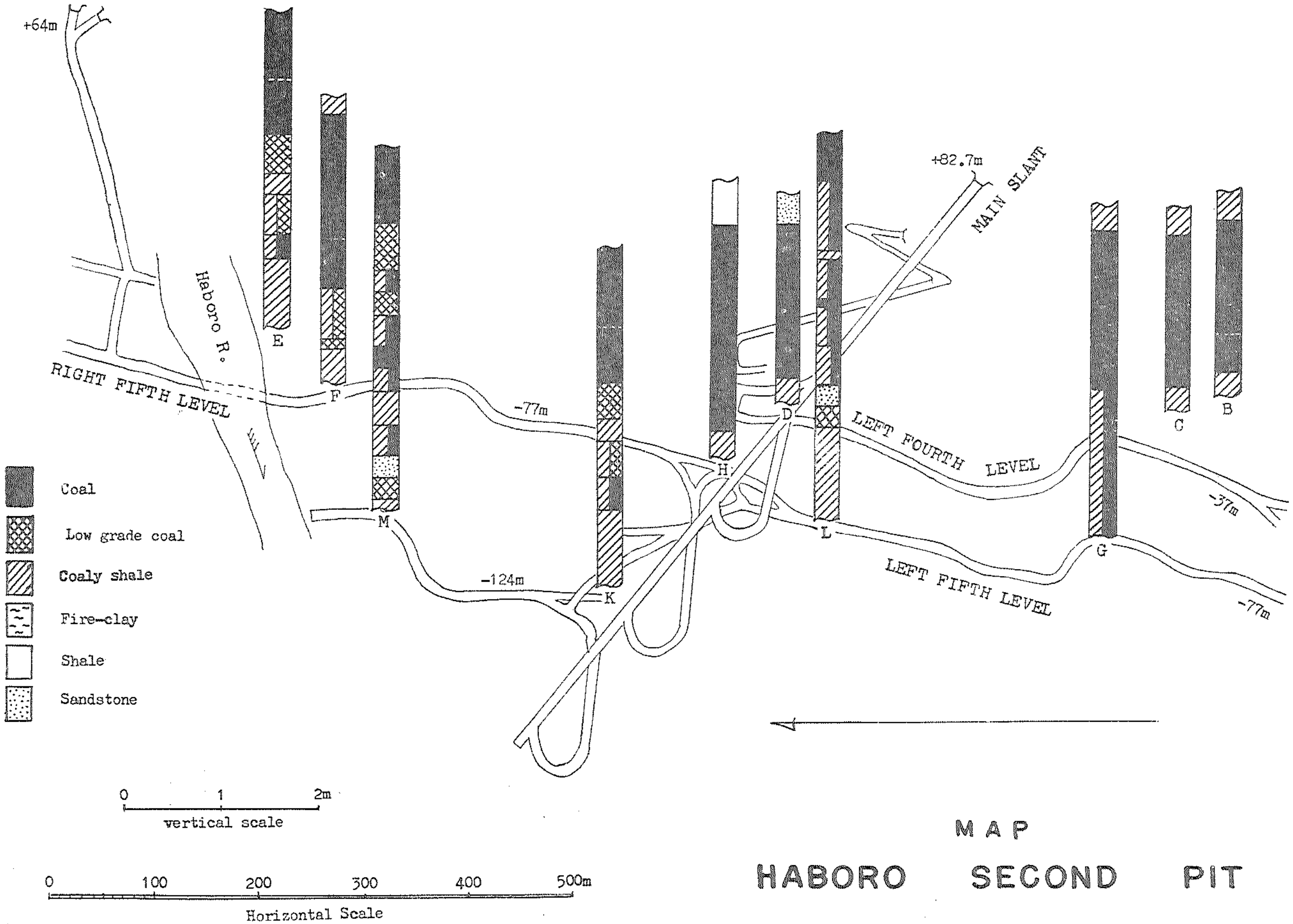


Fig. 3. Showing sampling localities and columnar sections.

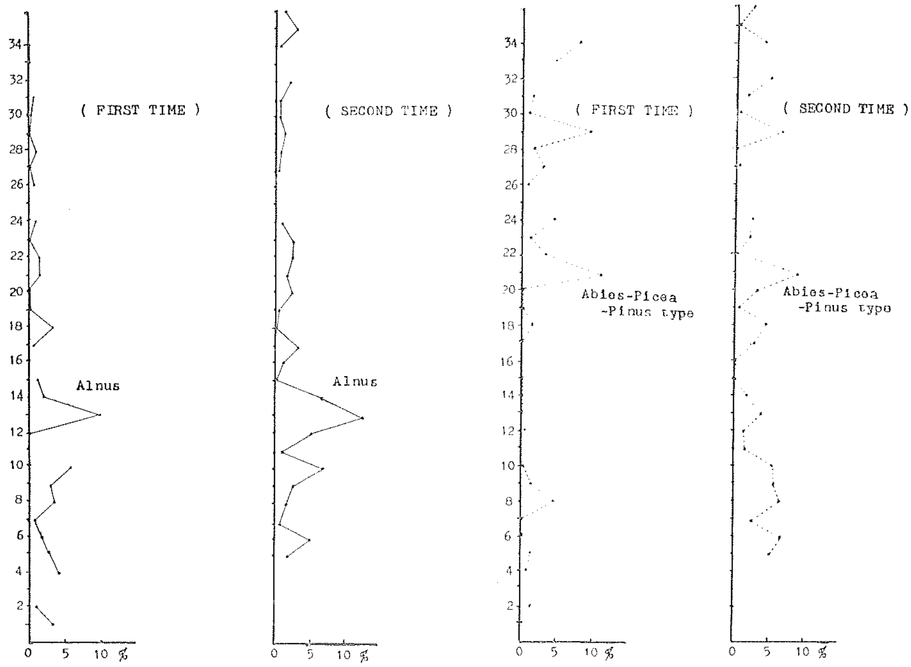


Fig. 4. Two times tests on the same sample.

at 10 cm intervals is frequently difficult. So, it must also be kept in mind that the interval may include 1–2 cm errors.

The writer has made his examination under such considerations. Fig. 6 shows 5 cm interval investigation comparing with 10 cm interval one. Though more detailed study such as examination by 1 cm sampling is necessary before this possibility may be evaluated, even from these figures it seems that general similarities are shown at even 10 cm intervals.

For caution's sake, the writer treated the same handful of samples two times respectively. Results are shown in Fig. 4. From them it is concluded that in such a volume there is not any accidental large fluctuation.

The localities where samples were taken and columnar section of the coal seam at those places are shown in Figs. 2 and 3.

Laboratory treatment

The samples were pounded finely into size to pass 30–40 mesh. It is mentioned by RAISTRICK* that, when coal is ground too fine up to 70

* A. RAISTRICK: 1934–1935 p. 142.

mesh, about 50% of all the pollen (including spores) contained in the sample may be broken, while in preparation to pass through 50–60 mesh, the most of them are not so broken.

The writer employed the treatment with 10% KOH solution after the treatment with oxidizing Schulze solution. First, 0.2–0.3 gr. of samples were put into centrifuge tubes and soaked in 5 cc Schulze solution for 36–48 hours. After this, the solution became reddish brown to brown. Next, samples were centrifuged and washed with water several times until Schulze solution was wholly removed. Then, these samples were treated with 10 cc 10% KOH solution (40–70°c) for about 30 minutes. 10% KOH solution was added to the samples after this oxidizing treatment with Schulz solution and the KOH solution soon became dark-brown to black. Then, the samples were washed with water by centrifugal machine until color of solution become clear. If samples are high in ash content, for example coaly shale, they are removed to polyethylene centrifuge tube and treated with HF (2–3 hours) to remove silicate and then washed with water several times. Finally, samples thus obtained stuck on the bottom of centrifuge tube in layers. These materials were mounted with glycerine gelatin and were ready for examination under the microscope. To draw the pollen diagram, 200 grains were counted under the microscope with a mechanical stage. In this case 200 grains included unidentified pollens. This happens because some pollens tend to be so easily broken or deformed that their identification is impossible whilst some are easily identified even under a broken condition. So, if the former pollens are excluded the later will be over-evaluated. Some samples have a great content of pollen, for instance, more than 6000 pollen grains have been found on a single coverglass (22×22 mm).

Occurrence of pollen

Pollen grain in the present coal seam are so frequently and greatly deformed that it is impossible to classify all the pollen by generic name or to apply quantitative (or statistical) dealing on all of each genus respectively. Such a matter is reported also in other paper*.

The following pollens and spores were identified: *Larix, Picea, Abies, Tsuga, Pinus, Sciadopitys, Cryptomeria- Sequoia- Metasequoia* type, *Taxodium, Glyptostrobus, Populus?, Salix, Myrica?, Engelharditia, Juglans, Pterocarya, Carya, Alnus, Betula, Carpinus, Corylus, Castanea, Fagus,*

* For example, G. ERDTMAN: (1954) pp. 215–217.

Quercus, Ulmus, Zelkova, Nymphaeaceae, *Magnolia, Liquidambar, Rhus?, Ilex, Acer?, Tilia, Myriophyllum?, Nyssa,* Ericaceae and several kinds of spores.

On the other hand, fossil leaves from the Haboro (coal-bearing) formation are not so abundant and they are poor in preservation. The following plant fossils have been found from Haboro second pit and Chikubetsu main pit area up to the present: *Metasequoia occidentalis* (NEWB.) CHANEY, *Populus latior* AL. BR., *Carpinus subcordata* NATHORST, *Ostrya sp., Zelkova Ungeri* (ETTINGS.) KOVATS, *Sophora miojaponica* HU et CHANEY, *Acer subpictum* SAPORTA, *Tilia sp., Alangium aequalifolia* (GOEP.) KRYSHT. et BORSK, etc.

The pollens which show the most interesting occurrence of the recognized specimens are *Alnus* and *Quercus*. On these pollen grains the

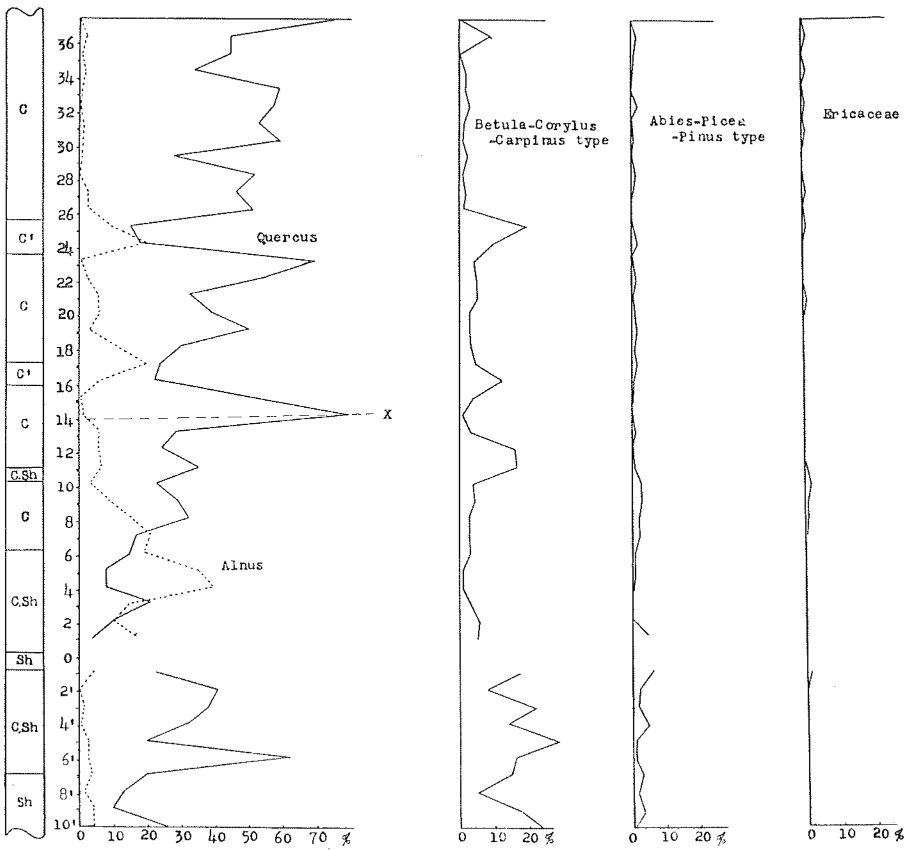


Fig. 5. CHIKUBETSU MAIN PIT C.

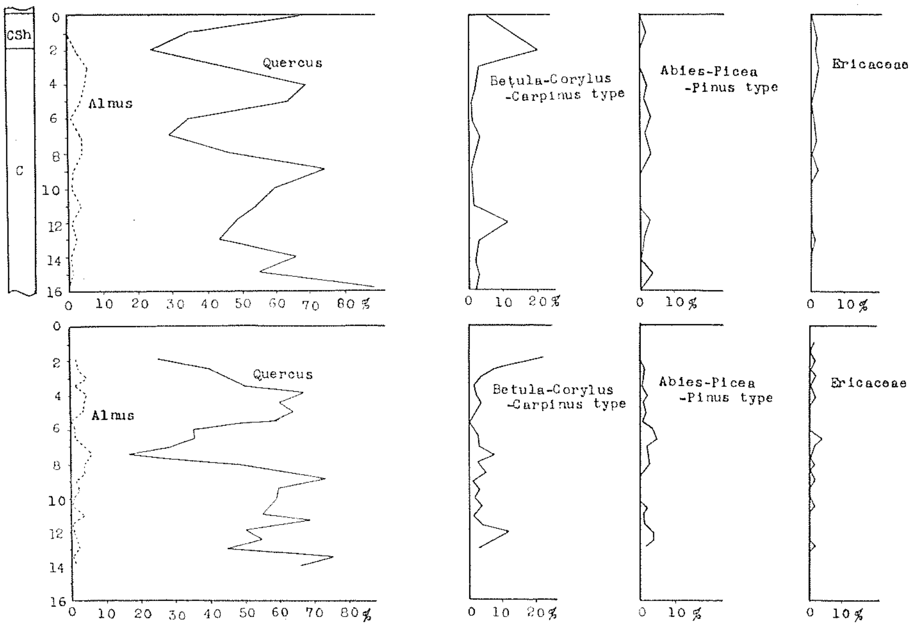


Fig. 6. CHIKUBETSU MAIN PIT E (upper by 10 cm intervals sampling, lower by 5 cm interval sampling).

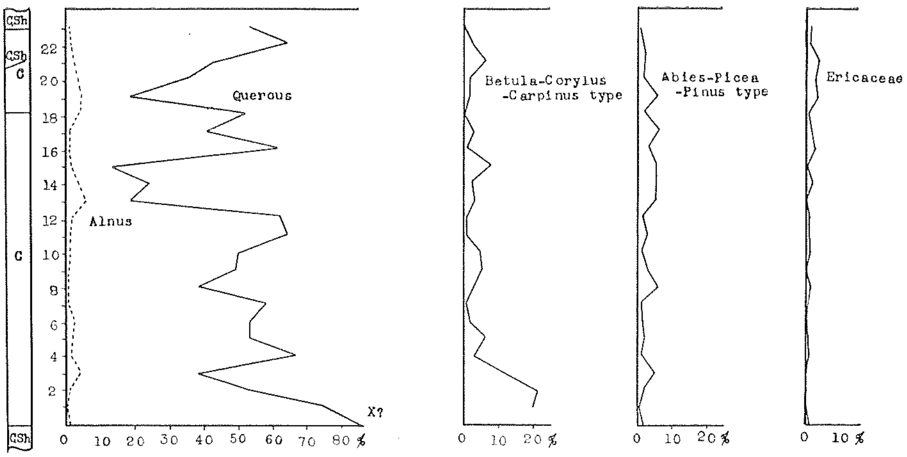


Fig. 7. CHIKUBETSU MAIN PIT F

following facts were observed:

1) Alnus occurs dominantly towards the substratum of the coal seam.
2) The dominant part of *Quercus* and that of *Alnus* show a reverse relationship. Especially, this relationship occurs suddenly at the lower part of the present coal seam. This characteristic part is presented in figures by letter x.
3) The quality of coal tends to become better upwards from the part at which the above-described alteration occurs.

The above-mentioned characteristics are recognized through all the localities. In such figures as Figs. 6, 7, and 9, which are made on the samples taken from the upper part of the coal seam, the facts described

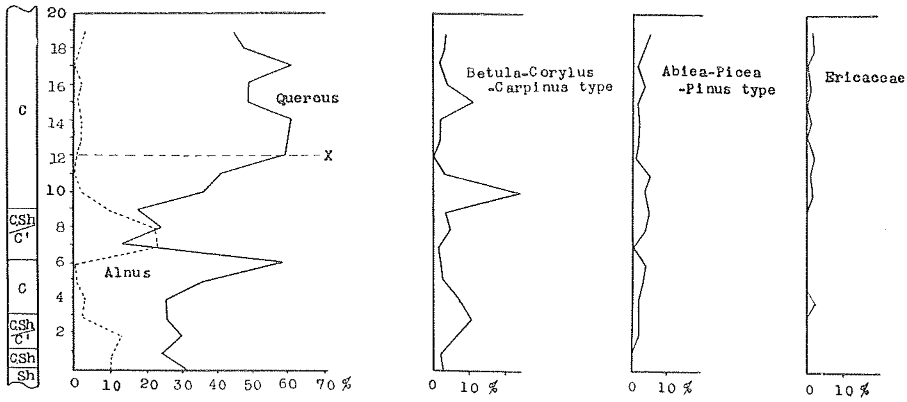


Fig. 8. CHIKUBETSU MAIN PIT G.

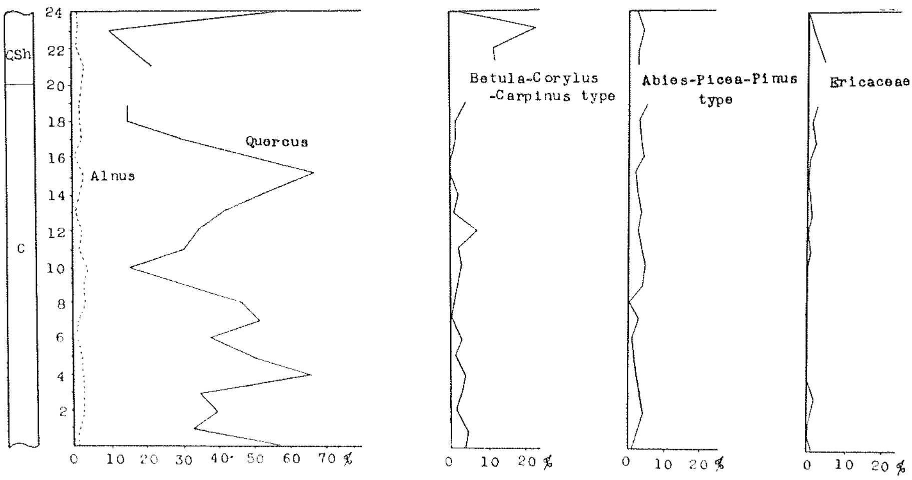


Fig. 9. CHIKUBETSU MAIN PIT H.

in 1), 2) and 3) can not be found or only the *Quercus* dominant part appears. If more downwards sampling is done, the above-described relationships shall be found.

Next, it is a remarkable features that Ericaceae pollen always occurs in the upper part of the coal seam though in small quantity, while in the lower part it rarely occurs.

Pinus-Picea-Abies-type pollens (most Pinus) are found commonly through all parts of the coal seam in all localities though not very abundantly, and they do not show any certain trend.

The occurrences of *Betula, Carpinus, Myrica* and *Corylus*-type pollens are shown together as a curve in the Figs. 3–21, though some may dispute this dealing manner of representation which such different several genus are shown together. The reason for which the writer deals so are these pollen are not so abundant [except *Corylus*] and appear to have not so significant meaning in the present coal seam. The most remarkable feature is the part of high frequency such as shown in Figs. 5, 6, 8, 10 and 13. These high frequency parts are composed mainly of *Corylus*. This remarkable occurrence is not recognized in all localities, but it appears to occur rather at randum. However, that these parts are found in the Chikubetsu main pit area only may have some meaning and more observations are needed on this point.

The above-described features are the proper characters of the present coal seam and especially the feature of occurrence of *Alnus* and *Quercus*, and Ericaceae pollen may be useful for correlation of the present coal seam.

Consideration

Now, what do the above-described features mean?

Firstly, in connection with the *Alnus* and *Quercus* occurrence the following paragraph quoted from a paper* by H. GODWIN that reports on pollen analysis of a bog in England which shows a succession: salt marsh → brackish water and willow-alder carr → oak wood, is very interesting:

"......Namely, though young to mature salt marsh with abundant Graminaceae, alder-willow scrub with abundant fern undergrowth, young ash-oak wood progressively killing out the earlier scrub until finally pure oak wood is indicated by the high value of the pollen.....the tree pollen also reflects the same succession, especially the very marked increase in

* H. GODWIN: 1934 p. 327.

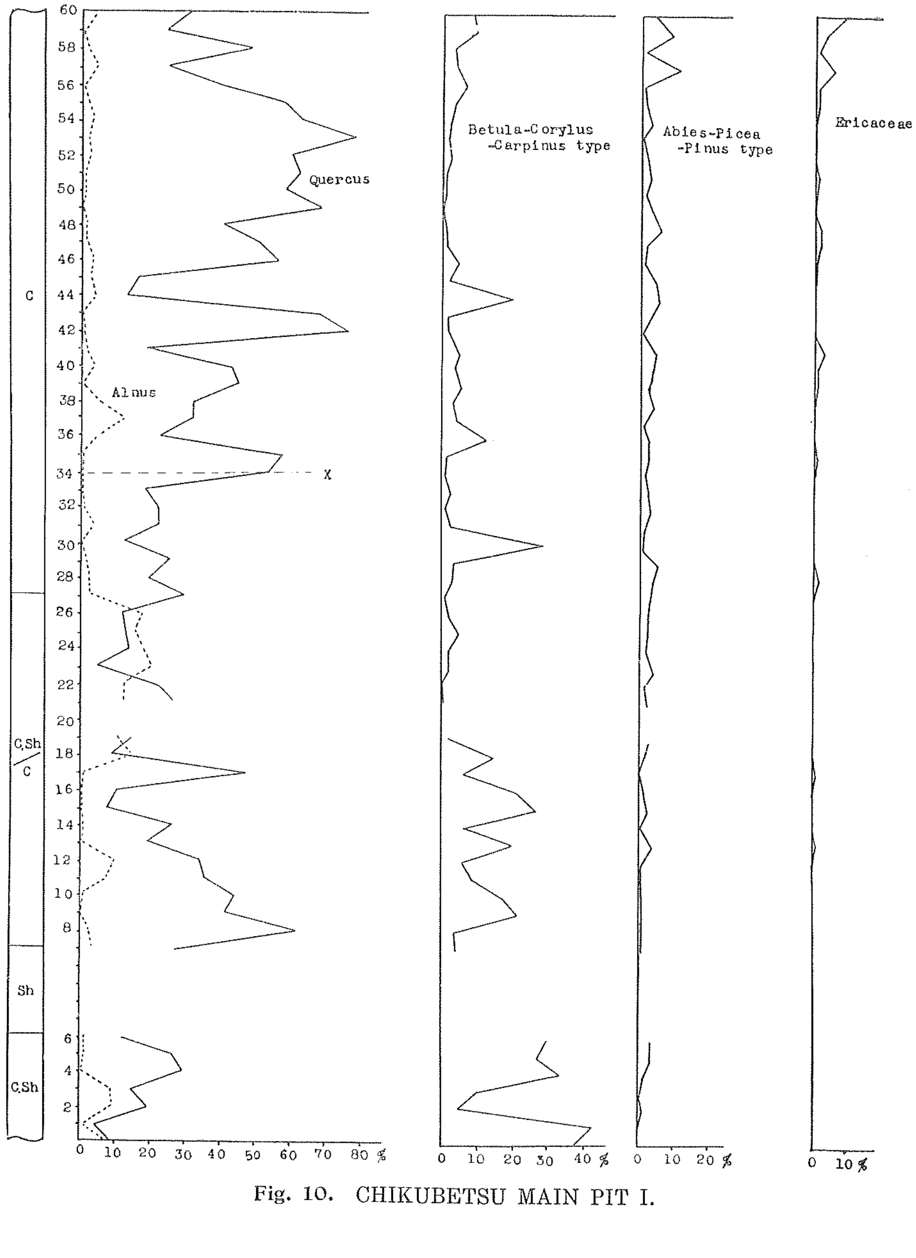


Fig. 10. CHIKUBETSU MAIN PIT I.

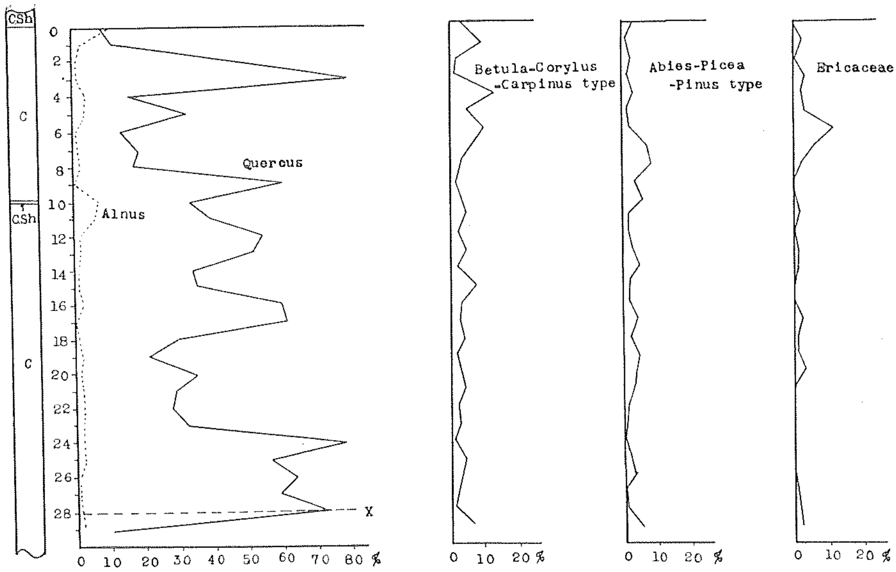


Fig. 11. CHIKUBETSU MAIN PIT J.

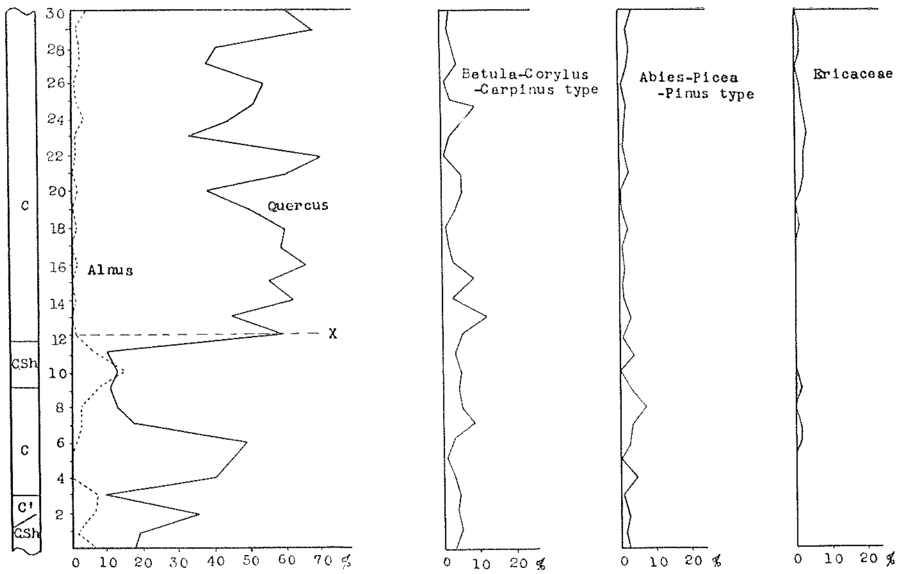


Fig. 12. CHIKUBETSU MAIN PIT K.

Quercus pollen and corresponding decrease in *Alnus*. The same inversion in the relative importance of these trees is frequently shown from the base upwards through the fen beds and progressive building up of peat above the water table by the natural 'reaction' of the prisere......"

The writer does not mean that this feature can be applied directly to the present coal seam (for example, in the present coal seam fern does not occur very abundantly). But a similarity on the noteworthy reverse relationship between *Alnus* and *Quercus* may make one consider some connection between the two cases. Moreover, the change is confined in the lower part at both cases, and quality of coal become better upwards from the part where this change occurs as if corresponded to the phrase "through young to mature salt marsh".

It is also remarkable that the occurrence of pollen of Ericaceae which prefer the acid soil condition and commonly grow on bogs, was mainly recognized in the upper part of the present coal seam. The feature appears to correspond to a succession of alkali→acid soil condition which is produced in such a bog as is described in the above-mentioned paragraph

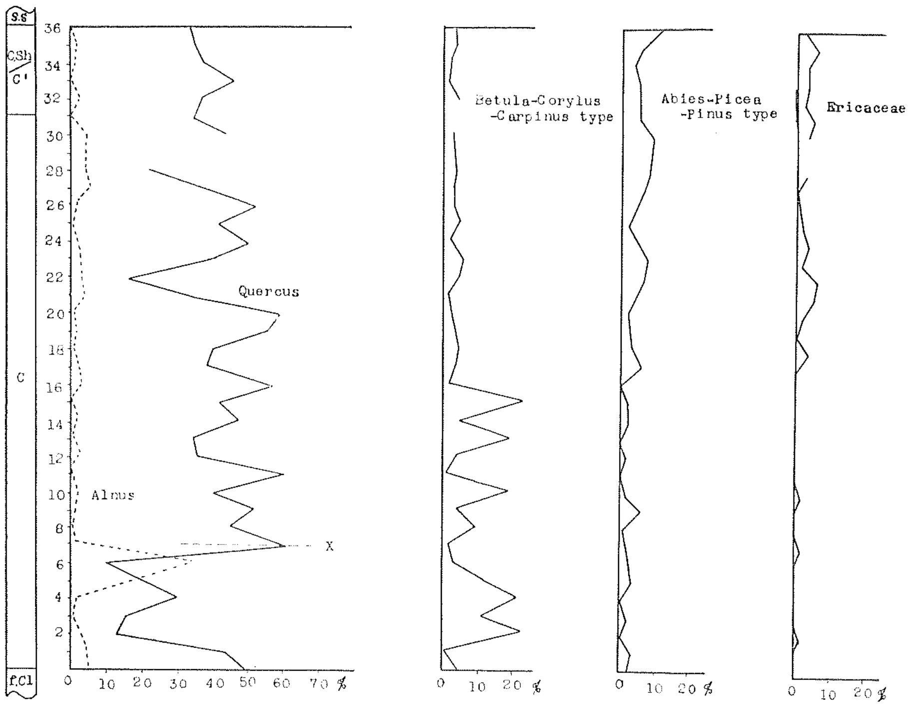


Fig. 13. CHIKUBETSU MAIN PIT M.

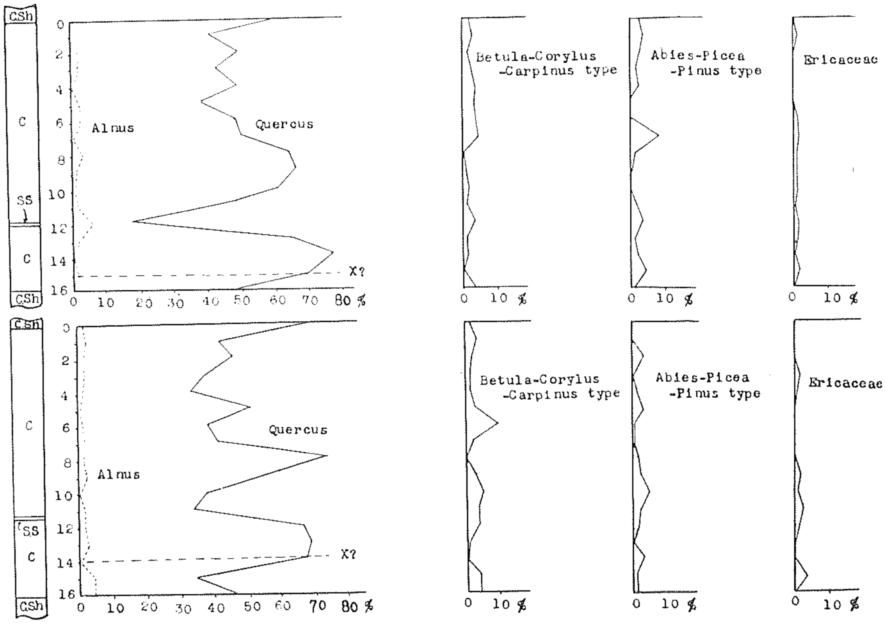


Fig. 14. HABORO SECOND PIT B (upper diagram)
// C (lower diagram)

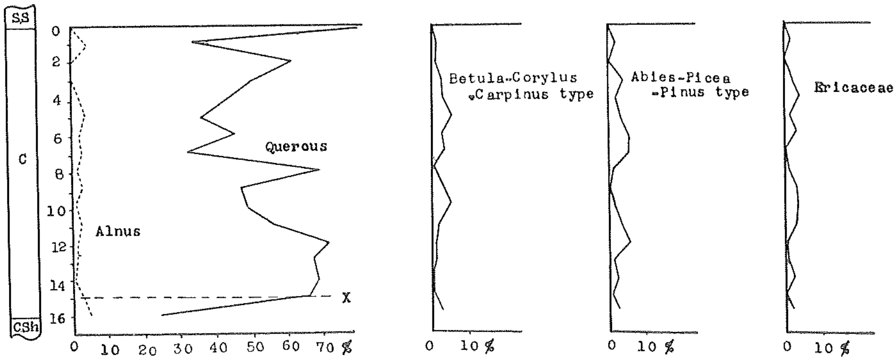


Fig. 15. HABORO SECOND PIT D.

as "progressive building up of peat above the water table." In addition, the following statement* is interesting in respect of Ericaceae: "they thrive best in acid soil, for which a continual mulch of dead (oak) leaves is helpful."

It appears to the writer that the above-described aspects are not

* GRAVE:, A. H.: 1952 p. 198.

accidental, but an inevitable phase in relation to the growth of peat which produced the Haboro main coal seam *in situ*. To state it from a different angle, if this coal originated alloctonously, why are the aspects of occur-

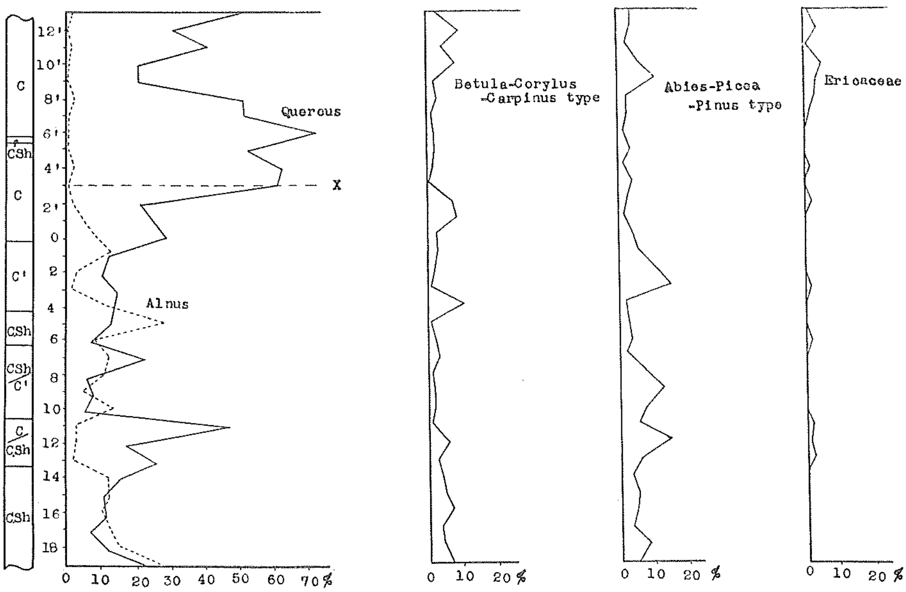


Fig. 16. HABORO SECOND PIT E.

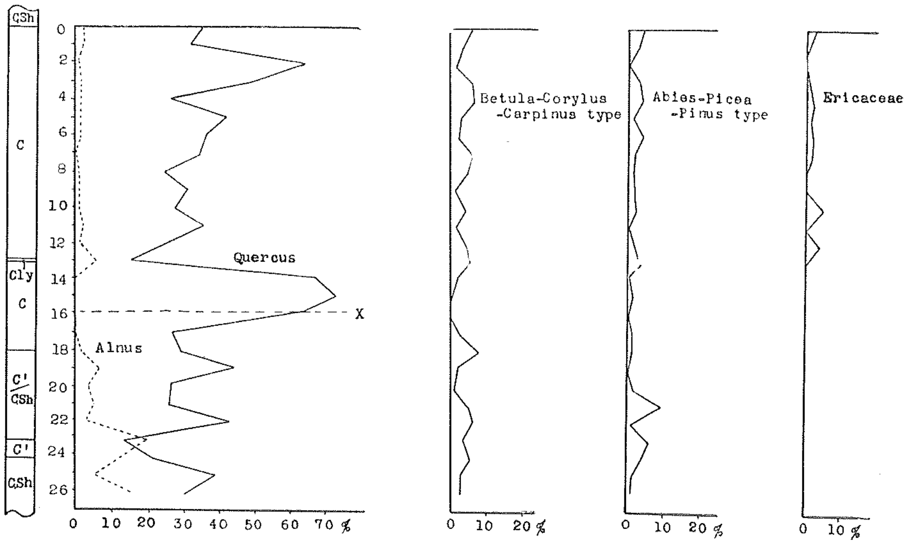


Fig. 17. HABORO SECOND PIT F.

rence of *Alnus, Quercus* and Ericaceae, which all are closely related to the ecological conditions of the peat swamp, similar through all the sampling localities? On the other side why does not such similarity occur through all sampling localities of *Betula-Carpinus-Corylus* type pollens which were not so closely related to peat swamp caused to form the present coal? Namely, if materials which originated alloctonously were transported into

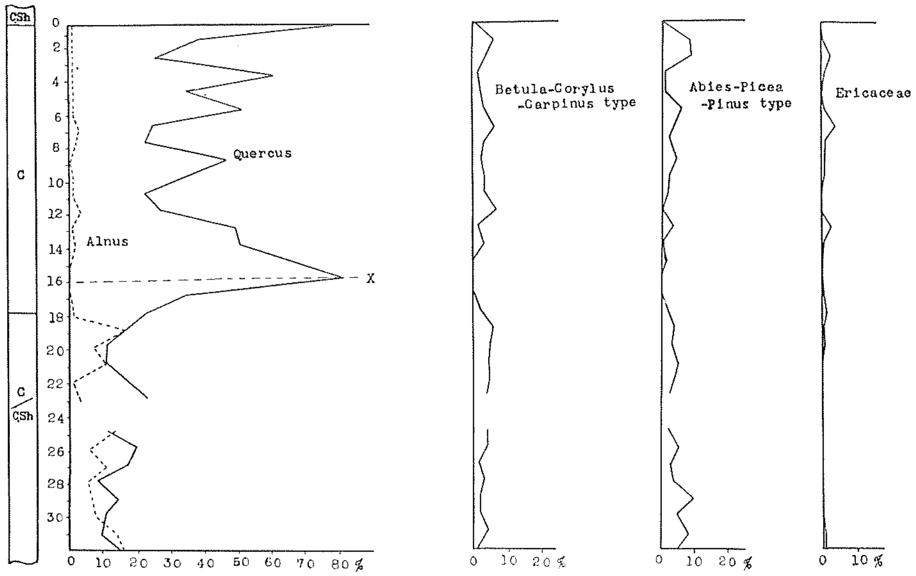


Fig. 18. HABORO SECOND PIT G.

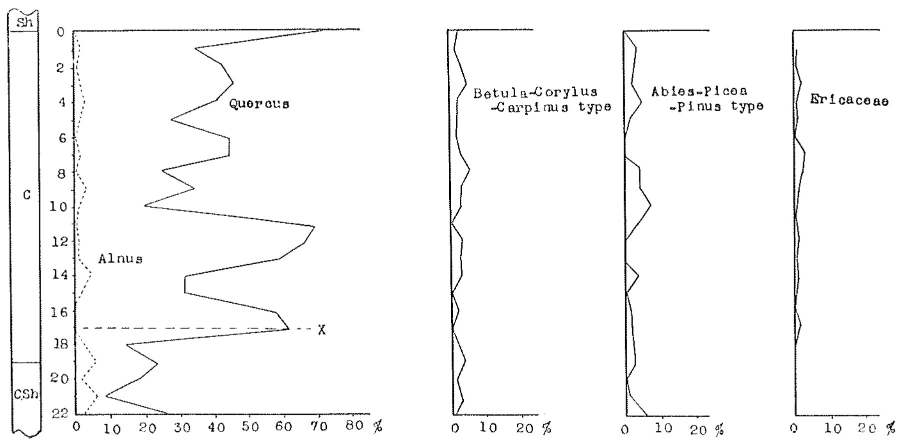


Fig. 19. HABORO SECOND PIT H.

the present basin by water it would seem water which transported the pollen grains into this basin produced the different distribution in compliance with the kind of pollen, and that is very unreasonable. If one considers the formation of the present coal to have been *in situ*, it is explained that the *Corylus* might be grown locally in the peat swamp which formed the present coal seam and the pollen of *Corylus* showed the locally great occurrence owing to its dwarf bush form; that appears more reasonable. Though, before the writer forms a conclusion on the origin of the present coal seam, more studies are needed on the occurrence of all the sorts of vegetation and other detailed observations are needed on the coal seam; even on the basis of the above-noted matters it is reasonable to think that the present coal originated *in situ*.

As regards *Pinus-*, *Picea-Abies* type pollen: as the greater part of these pollens were probably transported by wind from the surrounding high lands and have no connection with the swamp conditions, their occurrence may not be very great and does not show any certain trend.

In addition to the above-described matters, another matter is observed: clusters of pollen grains are sometimes found under the microscope. The existence of these clusters means that these pollen grains were not transported by (any water) current to the site of deposition, but fell

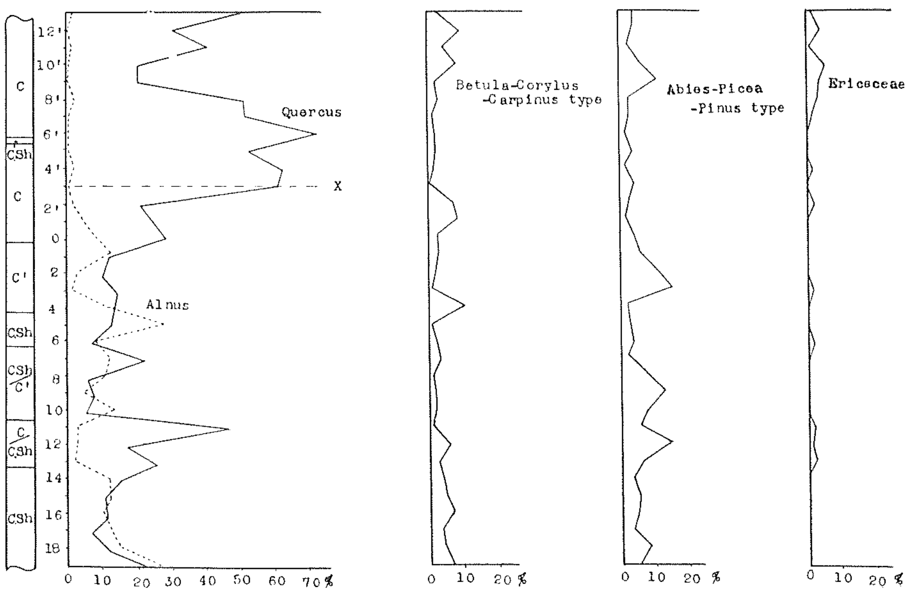


Fig. 20. HABORO SECOND PIT K.

into the stagnant water in the swamp, for if these clusters had been transported by currents they might have been resolved into separate pollen grains. Consequently, the common existence of clusters of pollen grains appears to strengthen the presumption of the formation *in situ* of the present coal seam.

Next, commonly at the Quaternary peat beds of several decacentimeters the meaning of the changes of vegetations in them are reduced mainly from the climatic side. Though these thickness correspond to the much less thickness in the present coal (as mentioned in the paragraph: on samples, their localities and method of sampling) the writer could not find any meaning from the fluctuation of vegetation of vegetation in such a thickness. Consequently, the trends which the writer has discussed in the present paper may be controlled by factors of much larger scale than those effecting the Quaternary peats. In other words, still more studies from other points of view may be needed for the explanation of the formation of the Tertiary coal. But, the writer does not at all neglect that some Quaternary peats may correspond to Tertiary coal in respect

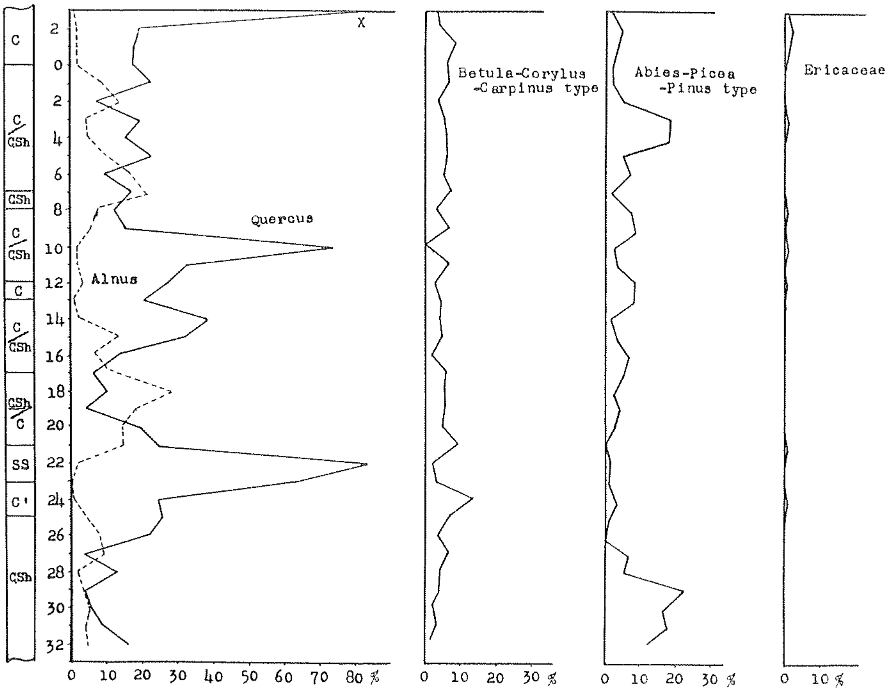


Fig. 21. HABORO SECOND PIT L.

to the mode of formation.

Though the writer can not refer to climatic effects from the present data, but has discussed the formation of the present coal seam principally from the edaphic side much more study is needed on whether or not climatic effects are reflected in the fluctuation of the vegetation. It is, however, concluded that the climatic environment of this area might be temperate to warm-temperate considering from the floristic composition and component; especially from the existences of *Liquidambar*, *Nyssa*, *Glyptostrobus*, *Taxodium*, *Ilex*, etc.

Besides, to find the general trend of the floristic change of one coal basin, sampling at one point in the basin is not sufficient; for example, if one samples at only the one points as in Figs. 8 and 13 and make it the representation of this whole coal seam, he may be unable to find the real distribution of *Corylus* and over-evaluate its occurrence and disregard the meaning of the slight occurrence of *Ericaceae*.

Conclusion

The following conclusions are reached from the above-described matters:

(1) It seems that correlation of the coal seam by the pollen analysis method possible to some extent at the present case.

(2) Though farther studies based on sampling at more close interval are necessary, it seems that pollen analysis at 10 cm interval (vertically) sampling is satisfactory to show the general floristic change.

(3) The rapid decrease of *Alnus* pollen is accompanied by the rapid increase of *Quercus* pollen at the lower part of the present coal seam, and upwards from this part the quality of coal tend to become better.

(4) It is more probable that the coal seam (Haboro main coal-seam) originates in situ.

(5) The flora judged on the basis of pollen grains seems to indicate temperate to warm-temperate climatic environment.

Bibliography

ASHLEY, G. H. (1907): The maximum rate of deposition of Coal. *Econ. Geol. vol. 2.*

DARRAH, W. C. (1941): Observations on the Vegetable constituentes of Coal. *Econ. Geol. vol. 36.*

DAWSON, I. W. (1866) : On the Conditions of the Deposition of Coal. *Quar. Jour. Geol. Soc. vol. 22.*

ERDTMAN, G. (1924) : Studies in the micropalaeontology of post-Glacial deposits in northern Scotland and the Scotch Isles, with especial reference to the history of the woodland. *Jour. Linn. Soc. vol. 46.*

——— (1947) : Suggestions for the classification of fossil and recent pollen grains and spores. *Sven. Bot. Tidsk. vol. 41, No. 1.*

——— (1952) : Pollen Morphology and Plant Taxonomy. I. Angiosperms. *Chronica Botanica Comp. U. S. A.*

——— (1954) : An Introduction to Pollen analysis. *Chronica Botanica Comp. U. S. A.*

FAEGRI, K. & IVERSEN, T. (1950) : Text-book of Modern Pollen Anaglysis.

GODWIN, H. & M. E. (1933) : Pollen analysis of fenland peats at St. Germans near King's Lynn. *Geol. Mag. vol. 70.*

GODWIN, H. (1934) : Pollen Analysis. Problems and Potentialities I. Technique and Interpretation. II. General Applications of Pollen Analysis. *New Phyt. vol. 33.*

GRAVES, A. H. (1952) : Illustrated guide to trees and shrubs. *Harper Brother New York & London.*

HECK, H. L. (1927) : Die tertiäre Kieselgur und Braunkohle von Buern im Voglsberg und ihre Flora. I. Teil. Geologische Untersuchungen der Kieselgur und Braunkohle von Beern und ihre Mikroflora. *Not. ver Erdkunde U. D. Hess. Landesanst.*

IKUSE, M. (1956) : Pollen Grains of Japan. *Hirokawa-Shoten, Tokyo.*

JIMBO, T. (1933) : The diagnoses of the pollen of forest trees. *Sci. Rep. Tôhoku Univ. Ser 4, vol. 8.*

KIRCHHEIMEN, F. (1935) : Die Korrosion des pollens. *Beih. Bot. Cent. Abt. A. vol. 53.*

MEINKE, H. (1927) : Atlas und Bestimmungsschlüssel zun pollenanalytik. *Bot. Archiv. vol. 19.*

MOORE, E. S. (1940) : Coal. *Wiley, U. S. A.*

NAKAMURA, J. (1943) : Diagnostic Characters of Pollen Grains. *Sci. Rep. Tôhoku Imp. Univ. Ser. 4, vol. 17.*

——— (1951) : Fossil Pollens in the Nahari Lignite *Res. Rep. Kôchi Univ. vol. 1.*

NAKAMURA, J. & KATTO, J. (1953) : Stratigraphical and palynological studies of the Shimane coal field. *Rep. Kôchi Univ. vol. 1, No. 29.*

NAKAMURA, J. & KATTO, J. (1954) : Palynological Studies of Cenozoic Formations, II. The Cenozoic formation of Saida in Kagawa and Mam in Kôchi Prefecture, Shikoku. *Bull. Soc. Plant. Ecol. vol. 3, No. 4.*

OKAZAKI, Y. (1957) : Palynological and Stratigraphical Studies on the Paleogene coals in the Kushiro Coal Field, Eastern Hokkaidô. (Part I) Geology of the Beppo Formation and its Pollenanalysis. *Jour. Hokkaido Gakugei Univ. vol. 8, No. 1.*

POPE, M. (1952) : Pollen Morphology as an Index to Plant Relationship. 1. Morphology of Pollen. *Bot. Gaz. vol. 80.*

POTONIE, R. (1931) : Pollenformen aus tertiären Braunkohlen. *Jb. Preuss. Geol. L-A. Berlin Bd. 52.*

——— (1934) : Zur Mikrobatanik der Kohlen und ihere Verwandten. *Arbeiten aus dem Institute für Paläobotanik und Petrographie der Bremensteine. Bd. 4.*

RAISTRICK, A. (1834) : The Correlation of Coal Seams by Microspore-content. Part 1—The seams of Northumberland. *Trans. Inst. Min. Eng. vol. 88.*

SCHOPE, J. M. (1948) : Variable Coalification: the processes involved in Coal formation.

Econ. Geol. vol. 43, No. 3.
SEARS, P. B. (1930): Common fossil pollen of the Erie Basin, *Bot. Gaz. vol. 89.*
——— (1955): Palynology in Southern North America. *Bull. Geol. Soc. Amer. vol. 66, No. 5.*
SOHMA, K. (1956): Zur Pollenflora einer Miozänen Braunkohle in Sendai. *Ecol. Rev. vol. 14, No. 2.*
SIMADA, M. (1953): The Pollen analyses of some lignite beds in the north-eastern provinces of Japan. *Bull. Soc. Plant. Ecology vol. 3, No. 3.*
TAKAHASHI, K. (1957): Pollen und Sporen aus der Onga Formation in Kokura Kohlenfeld, Nordkyûshu, *Jour. Min. Inst. Kyûshû vol. 25, No. 8.*
——— (1957): Pollen und Sporen aus den Hauptflözen im Miike und Asakura Kohlenfeld und ihre Stratigraphische Bedeutung. *Jour. Mon. Inst. Kyûshû vol. 19, No. 12.*
TAKAHASHI, K. (1954): Palynological Studies of Coal-field (1). On the Mogami and Okitama in Yamagata Pref. *Bull. Soc. Plant Ecology vol. 3, No. 4.*
TOKUNAGA, S. (1955): Pollenanalyses of the known Coal seam in the Bibai Area, Sorachi District, Ishikari Coal field, Hokkaidô. *Bull. Geol. Surv. Jap. vol. 6, No. 9.*
——— (1956): Palynological Study on Japanese Coal. I. Method of Pollenanalysis on Japanese Coal. Rep. *Geol. Surv. Jap. No. 177.*
TRAVERSE, A. (1955): Pollen Analysis of the Brandon Lignite of Vermost. *Rep. Inverstigation Bureau of Mines No. 5151.*
WHITE, D. (1913): The Origin of Coal. *Wash. Government Print. Office.*
WODEHOUS, D. (1935): Pollen Grains. *Mac. Graw Hill New York & London.*
YAMAZAKI, T. (1933): Forms of Pollens and Spores. *Bull. Kyôto Univ. Forest, No. 5.*
——— (1951): Studies on the Changes of the Forests and the Climate in Southern Sagalien and Hokkaidô, based on Pollen Analysis. *Bull. Kyôto Univ. Forest, No. 21.*
YAMAZAKI, T. & SASA, Y. (1938): Natural geographical transition of North Japan, since Tertiary epoch, based on pollen analysis. *Mem. Jap. Acad. vol. 13, No. 3.*

Explanation of Figures

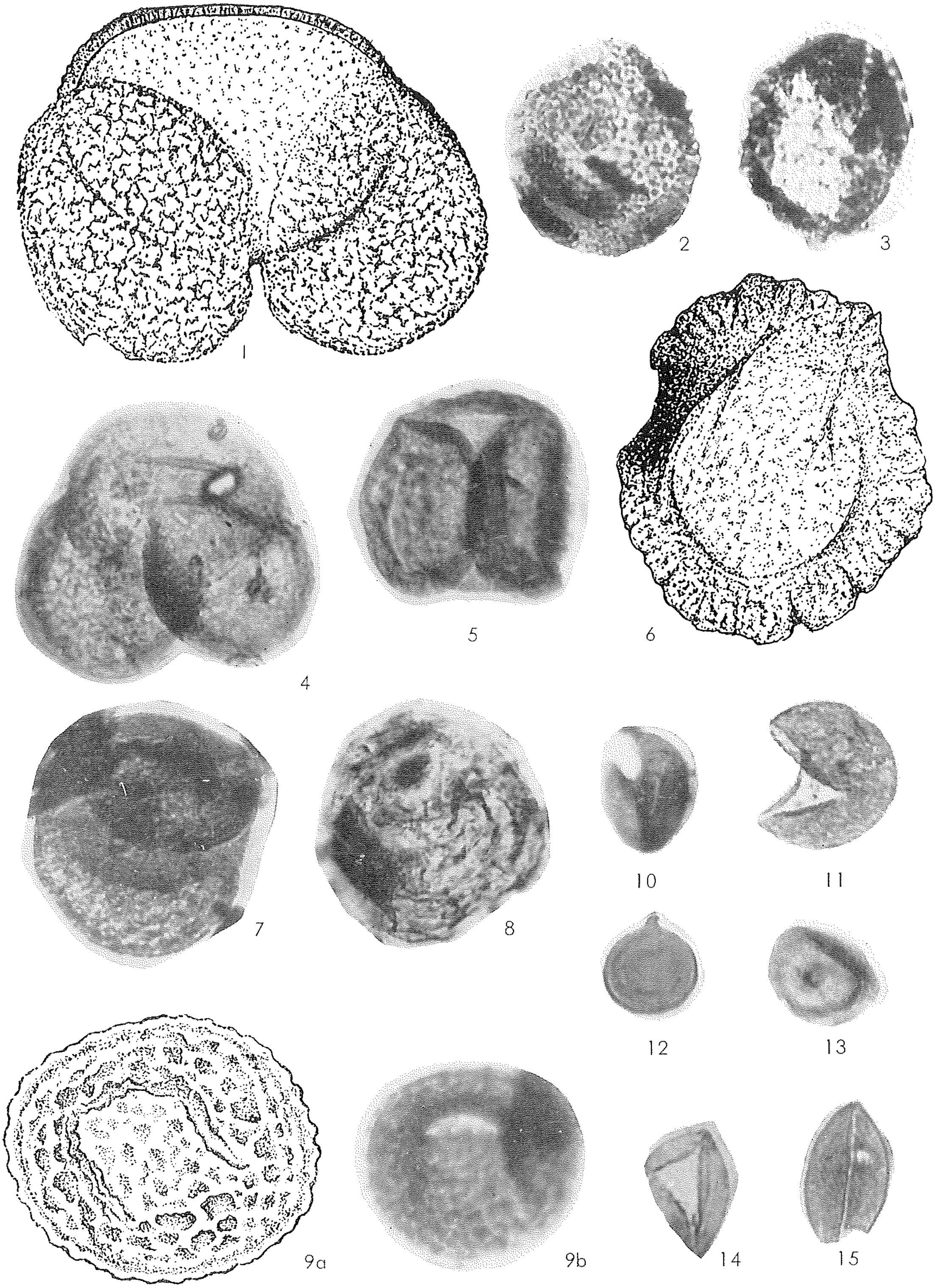
Ordinates show sample numbers.
Abscissas show the percentage of total pollen.
------ X: the horizons from which *Quercus* occurs abundantly upwards and *Alnus* shows rather much occurrence downwards. (refer to the paragraph "occurrence of pollen")

Explanation of Plate I

Explanation of Plate I

		size (μ)	locality
1.	*Abies*	96×72	Chikubetsu main pit
2.	*Tsuga*	48×42	do.
3.	*Tsuga*	53×43	Haboro second pit
4.	*Pinus*	75×71	do.
5.	*Pinus*	46×45	do.
6.	*Tsuga*	72×63	Chikubetsu main pit
7.	*Pinus*	58×50	Haboro second pit
8.	*Larix*	58	Chikubetsu main pit
9a, 9b.	*Sciadopitys*	53×46	Haboro second pit
10.	Taxodiaceae	26×22	do.
11.	*Taxodium*	37×35	do.
12.	*Sequoia-Metasequoia* type	27×22	do.
13.	*Sequoia-Metasequoia* type	22	do.
14.	*Glyptostrobus*	33×20	do.
15.	*Glyptostrobus* ?	35×20	do.

Plate I

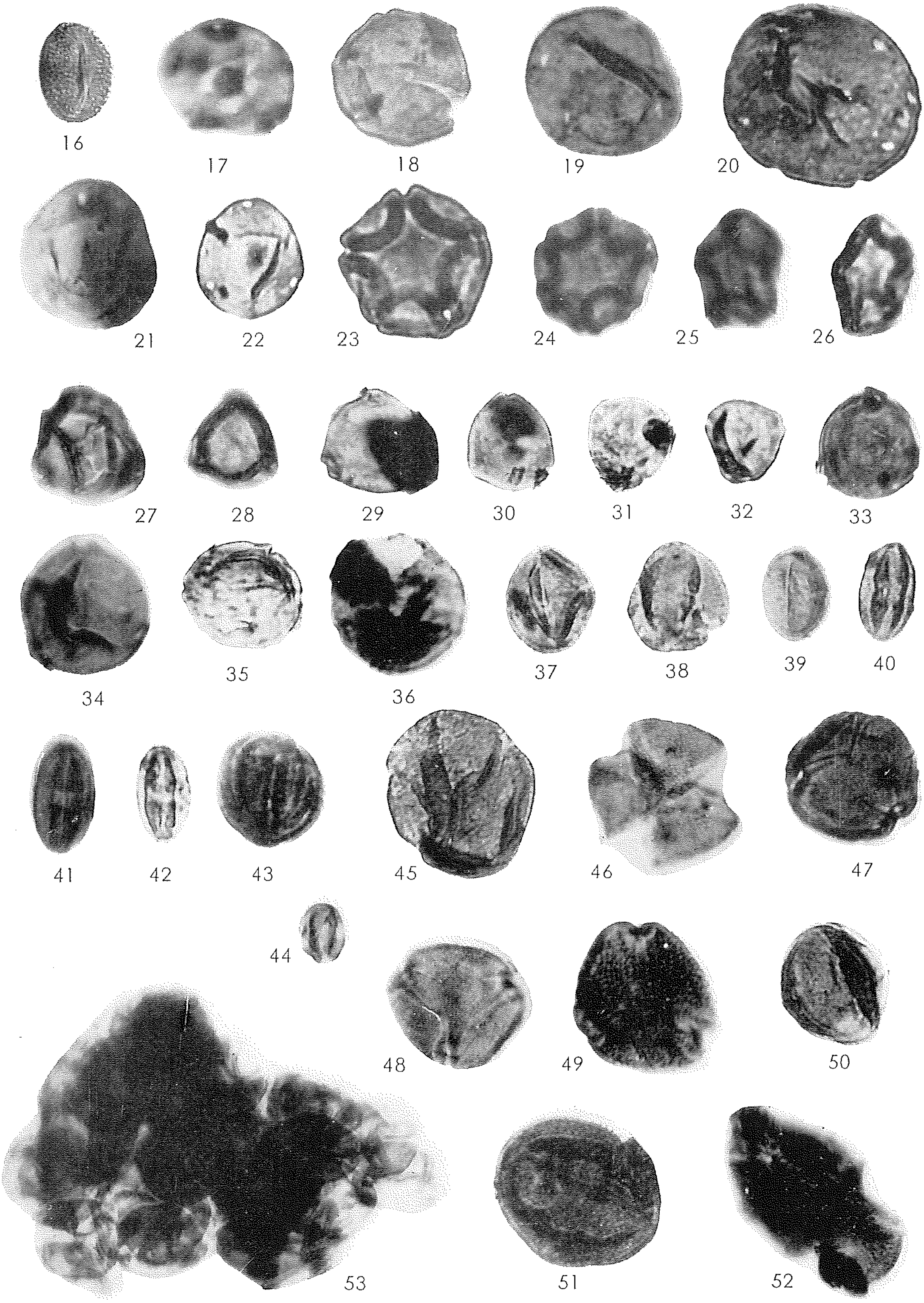


S. Satô Photo.

Explanation of Plate II

Explanation of Plate II

		size (μ)	locality
16.	*Salix*	24×18	Haboro second pit
17.	*Pterocarya*	31×26	do.
18.	*Pterocarya*	30	Chikubetsu main pit
19.	*Juglans*	36×32	Haboro second pit
20.	*Juglans*	40×34	do.
21.	*Carya*	32	do.
22.	*Carya*	30	Chikubetsu main pit
23.	*Alnus*	28	Haboro second pit
24.	*Alnus*	28	do.
25.	*Alnus*	22×20	do.
26.	*Alnus*	29×27	Chikubetsu main pit
27.	*Betula*	26	Haboro second pit
28.	*Betula*	21	do.
29.	*Betula*	25	Chikubetsu main pit
30.	*Corylus*	25×23	do.
31.	*Corylus*	25	do.
32.	*Corylus*	21	do.
33.	*Corylus*?	26	Haboro second pit
34.	*Carpinus*	31×27	do.
35.	*Carpinus*	30×28	Chikubetsu main pit
36.	*Carpinus*	35×34	do.
37.	*Quercus*	25×21	do.
38.	*Quercus*	24×23	do.
39.	*Quercus*	29×18	do.
40.	*Quercus* ?	24×14	Haboro second pit
41.	*Quercus* ?	28×15	do.
42.	*Quercus* ?	25×14	Chikubetsu main pit
43.	*Quercus* ?	22×20	Haboro second pit
44.	*Castanea*	15×12	do.
45.	*Fagus*	40×35	do.
46.	*Fagus* ?	36	do.
47.	*Fagus* ?	33	do.
48.	*Nyssa* ?	31×28	do.
49.	*Nyssa*	30	do.
50.	*Nyssa* ?	34×29	Chikubetsu main pit
51.	*Nyssa*	43×35	Haboro second pit
52.	*Nyssa*	45×33	Chikubetsu main pit
53.	Clump of *Alnus*		Haboro second pit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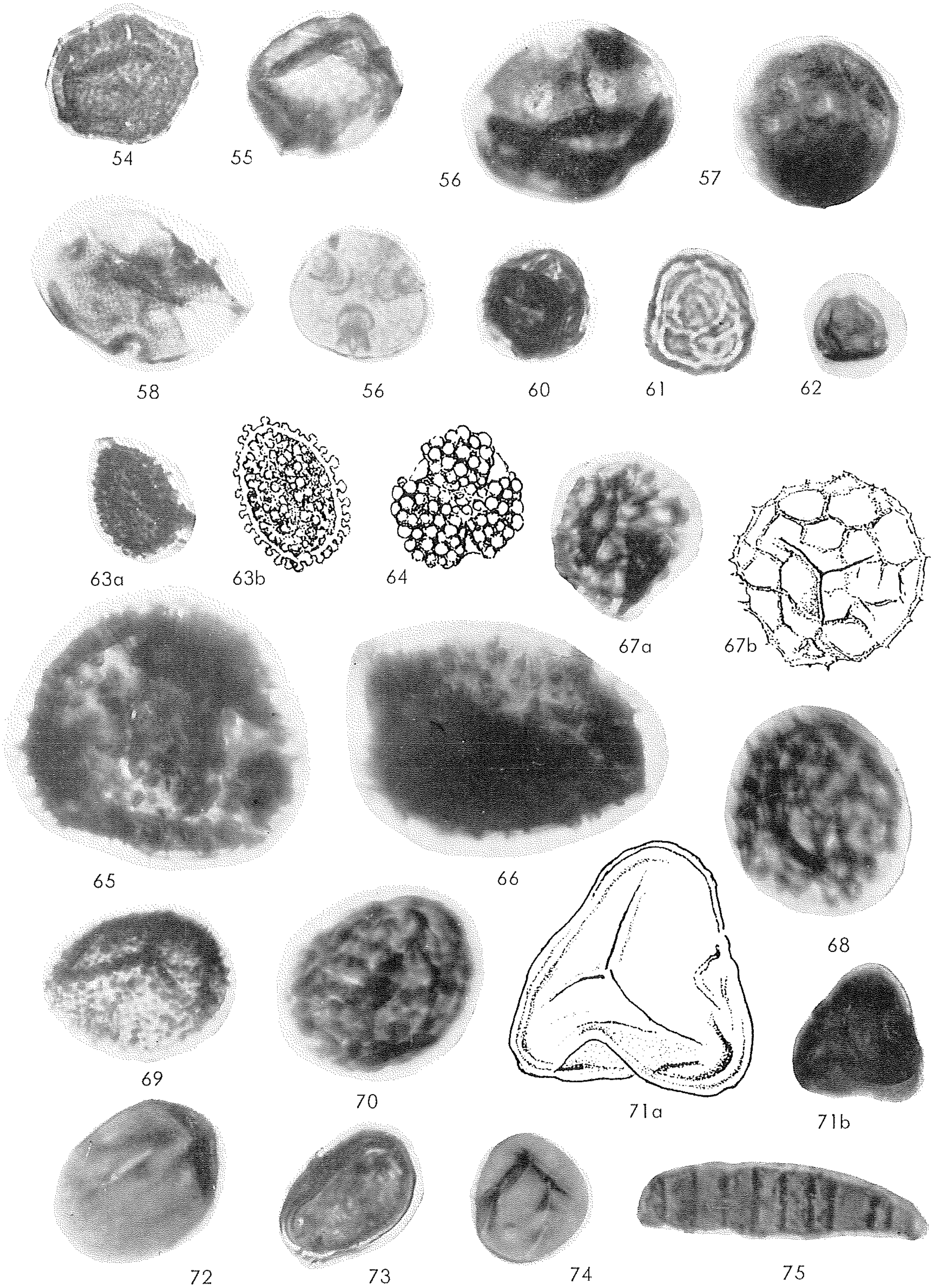
S. SATÔ Photo.

Explanation of Plate III

Explanation of Plate III

		size (μ)	locality
54.	*Ulmus*	34×28	Haboro second pit
55.	*Ulmus*	33×32	do.
56.	*Liquidambar*	46×37	do.
57.	*Liquidambar*	37	do.
58.	*Tilia*	40×32	do.
59.	*Tilia*	32	Chikubetsu main pit
60.	Ericaceae	27×25	do.
61.	Ericaceae	25×23	do.
62.	cf. *Engelhardtia*	19	Haboro second pit
63a, b.	*Ilex*	28×20	do.
64.	*Ilex*	29	Chikubetsu main pit
65.	Nympheraceae	67×60	Haboro second pit
66.	Nympheraceae	63×44	do.
67a, b.	Lycopodiaceae	35	do.
68.	*Lycopodiaceae*	43×40	do.
69.	*Osmunda* ?	42×32	do.
70.	Lycopodiaceae or Lygodiaceae	42×32	do.
71a, b.	Cyatheaceae	48	do.
72.	Polypodiaceae	38×32	do.
73.	Polypodiaceae	36×24	do.
74.	Undeterminable pollen	33	do.
75.	Fungus (*Septonema*)	67	Chikubetsu main pit

Plate III



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