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Pollen Analytical Study on the Process of Formation of Coal Seam

(I) The peat bed of the Kushiro moor, Hokkaido, Japan

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Preface

In consideration of the origin of coal, there is a prevailing view that coal beds have been originated from peat beds; that is to say, coal consists of the same materials as peats, and was formed under swampy conditions similar to that of modern peats.

Under such a view, we expect that coal seams still preserve traces of original peat, and also would be able to identify their initial features such as the lowland moor, the highland moor, and the transition moor. Moreover, we have the possibilities of identifying it by pollen analysis and we are able to discriminate the mode of deposition of coal by studying recent peat beds.

The writer intends to make clear the process of the formation of coal seams on this ground, making a comparison with that of recent peats. The present paper dealt with the peat bed of the Kushiro moor, Hokkaido, as the first step for approaching on this problem.

In the first place, association of pollen were examined to make comparison with the peat-forming plants. Next, the attempt was maid to distinguish the original type of peat by pollen diagram. At the same time, lateral and vertical changes of facies of peat beds are traced by pollen analytical method. These effort will give us conclusion that the pollen analysis is really an effective method or not for the study of the process of peat formation.

Before proceeding further with the subject, the writer wishes to express his cordial thanks to Dr. Y. Sasa of Hokkaido University for his encouragement as well as for his many valuable suggestions and also for the revision of the manuscript. His thanks are also due to Asst. Prof. M. Tanaka of Hokkaido Gakugei University for his helpful advice as to the living plants in the Kushiro moor.
I. Vegetation in the Kushiro Moor

The Kushiro moor is located in eastern Hokkaido from 63°00'N. lat. to 43°07'N. lat. and from 144°15'E. long. to 145°27'E. long. The moor is a wide, flat and swampy plain and one of the largest moors in Hokkaido with an area of 3,000 square kilo-meters. As for the living vegetation on the surface layer of the moor and the peat-forming plants beneath the surface J. Iizuka (1954) and M. Tanaka (1958) have already described in detail.

According to them, the lowland peat occupies the bulk of the moor surface, while the highland peat and the transition peat show very limited and also isolated distribution.

The dominant plants forming these peats are as follows, though they differ slightly in respective localities:

The highland peat: Sphagnum sp., Polytricum juniperum of Bryophyta, Andromeda polifolia, Ledum palustre, Rhododendron japonicum, Chamaedaphne calyculata, and Oxyccorus quadripetalus of Ericaceae, Eriophorum vaginatum, E. gracile, Carex Middendorffii, C. Miyabei, and Moliniopsis japonica of grass, Equisetum arvense of Pteridophyta, including Empetrum nigrum.

The lowland peat: Carex Miyabei, C. limosa, Eriophorum vaginatum, and Phragmites communis belonging to Cyperaceae and Gramineae, Polypodiaceae, Lycopodiaceae, Osmudae, and Equisetum arvense of Pteridophyta, with Myrica Gale var. tomentosa, Solidago virgaerea, Lobelia sessilifolia, etc.

Among these species, the most abundant and the characteristic ones which are regarded as the indicators of each type are as follows:

The highland peat which is often called as Sphagnum peat, is marked by both Sphagnum and Heaths (Erica), while the lowland peat is known as Grass (or Carex) peat, and is characterized by Cyperaceae and Gramineae such as Carex and Phragmites, or also by Pteridophyta in most cases respectively, and the transition peat or the forest peat occasionally represents an intermediate nature of the two peats above mentioned.

Naturally, our attention will be focused on the association of the above-account species, and also on their pollens and spores for studying peat formation.

In the pollen diagram, we expect that these species play an important rôle as indicators and that their figures vary according to the composition of the dominant plants of which the peat consists.

For the next step, considerations are made to verify this idea, based on the pollen diagram.

II. Materials

The materials for the present study are collected from the following nine points (Table 1 and Fig. 1).

The specimens were treated with Alkali solvent (KOH 10%).
Table 1. List of localities of sampling of peat tested

<table>
<thead>
<tr>
<th>No. of locality</th>
<th>No. of Iizuka’s</th>
<th>Locality</th>
<th>Peat type on surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>145</td>
<td>south-east of Omnenai</td>
<td>highland</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>junction of the Hororo to the Shinkushiro river</td>
<td>lowland</td>
</tr>
<tr>
<td>3</td>
<td>139</td>
<td>west of Iwaboki-yama</td>
<td>&quot;</td>
</tr>
<tr>
<td>4</td>
<td>143</td>
<td>west of the Toya rail-road station</td>
<td>transition</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>middle of the Shinkushiro river</td>
<td>highland</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>lower of the same river</td>
<td>lowland</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>near Tsuruno</td>
<td>&quot;</td>
</tr>
<tr>
<td>8</td>
<td>143</td>
<td>near the Hokuto rail-road station</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>lower of the Akan river</td>
<td></td>
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Fig. 1 Map showing localities of the specimens for the present study in the Kushiro moor in eastern Hokkaido

All the diagrams in this paper were made with the frequency of the five elements above mentioned, namely *Sphagnum*, Ericaceae, Cyperaceae and Gramineae, Pteridophyta, and also that of forest trees were taken into consideration.

Apart from arboreal pollen, the pollen and spore grains of these elements are believed to be mostly derived from those that have grown on the spot\(^1\). Therefore this group shows to be favourable for our purpose in estimating vegetation. On the other hand, most of arboreal pollens are regarded to be foreigners that were

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\(^1\) Pollen and spore grains of grasses and Cryptogam are generally not distributed, so well when compared with a wind-pollinated tree. For example, Cyptogam pore does not fly so far owing to the position of the spore-producing organs (generally under a leaf, a pileus, etc.), and most Ericaceae pollens scatter in limited area because of zoogamous.
transported from far distant forests. Accordingly, they are less important in considering surrounding vegetation. However, in the forest (transition) peat pollens are expected to increase its frequency.

III. Pollen Diagram

The results thus obtained are shown in the pollen diagrams (Figs. 2, 3, 4, 5, 6, 7, 8, 9).

1. Comparison with the Floral Composition

It is especially important to examine whether it shows reasonable equivalency between the peat-forming plants and the pollen records obtained from the peat. The following diagrams are prepared for answer of this question.

Example 1 (No. 1) (Fig. 2)

![Diagram of pollen distribution](chart.png)

**Fig. 2** Total frequency curves of *Sphagnum* (△), *Ericaceae* (×), *Cyperaceae* and *Gramineae* (○), *Pteridophyta* (▲), and forest tree (●) at No. 1 (H: highland peat)

The pollen diagram shows that the most dominant species are *Sphagnum*, *Ericaceae*, and forest tree, while *Cyperaceae* and *Gramineae*, and *Pteridophyta* remain in small amounts, even keeping constancy.

Among the mother plants of peat, according to Lizuka, the dominant species are *Sphagnum*, *Oxyccocus* (belong to *Ericaceae*) and *Carex*.

From the facts above mentioned, we notice at once that there are little or almost no difference between the two, though there is exception in arboreal pollen, which is naturally anticipated to put out of consideration for the reason that we have described.

Example 2 (No. 8) (Fig. 3)

It meets our expectations that *Carex* is the dominant species in both pollen analysis and result obtained by Lizuka through the whole. *Alnus* tree accompanying *Carex*

1) In the pollen diagram, the total amount of *Pteridophyta* are shown excluding *Sphagnum*.
2) It may be enough to support the reason that arboreal pollen always shows usual high frequency without according to the varied types of peats as is seen in all diagrams.
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Fig. 3 Total frequency curves at No. 8, (□)Alnus (N: lowland peat) generally represents low frequency as is shown in the diagram, but at the lower horizon it increases almost parallel to the vegetal component described by Izuka. A fact which draws our particular attention is that Pteridophyta as well as Carex shows a high rate of the frequency\(^1\). The same tendency is always seen also in the other diagrams of respective localities, and therefore it will be realized that it characterizes the lowland peats.

Example 3 (No. 5) (Fig. 4)

Fig. 4 Total frequency curves at No. 5 (Z: transition peat)

In comparing both results obtained excepting forest trees, we find that there is no great difference in composition, but with a slight discrepancy in marking boundary of its horizon. The discrepancy, however, derived probably from our point is not accord precisely with that of Izuka’s.

The above stated results have surpassed all our expectations, with few exceptions (of tree and Pteridophyta). Thus we arrive at the conclusion that pollen analysis is entirely an available method for the present purpose of finding the dominant mother

\(^1\) Generally speaking, spores of members of Pteridophyta are overestimated probably because of their enormous production and of their position of the spore-producing organs, and of their strong resistance to a chemical reagent, while grass pollens are said to be apt to decay before fossilization.
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plants of peats.
The same conclusion will be made by the other points.

2. Comparison with the Known Peat Types
The above mentioned conclusion is useful to apply to make a comparison of pollen record with the present peat type.

1) Highland peat (No. 1) (Fig. 2)
Apart from arboreal pollen, the predominant species are both *Sphagnum* and Ericaceae, while others are very small in amount. Therefore we can easily identify the diagram as that of the highland peat.

2) Lowland peat (No. 8) (Fig. 3)
The diagram is characterized by the predominancy of both Cyperaceae and Gramineae, and Pteridophyta.
As has already been stated, it is noteworthy that in the place of *Sphagnum* (belongs to Pteridophyta), Pteridophyta has always high frequency in the lowland peats. So we look upon all the diagrams marked by Cyperaceae and Gramineae, and Pteridophyta as equivalent to that of the lowland peat.

3) Transition peat (No. 5) (Fig. 4)
According to Iizuka, the upper layer of the section consists of the transition peat type. In the diagram, the layer which is marked by the three elements such as Pteridophyta, Cyperaceae and Gramineae, and *Sphagnum*, shows an intermediate nature between the other highland and lowland peats, and therefore it is regarded as the diagram of the transition peat.

In this way, the main types of peats are quite easy to distinguish from each other with the pollen record. The result is based not only upon the records at the three points, but also upon consideration of those for the others.

3. Successive Sequence of the Peat Formation
It is well known that a bed of peat is a composite formation, consisting of layers of very different dominant plants, accumulated under varied conditions.

We now intend to know whether the alternation of the varied layers—the types of peats—is in regular sequence.

All the sections are marked with the abbreviation, N (lowland peat), Z (transition peat) and H (highland peat) showing the three types, according to the result already described.

Observing the successive changes through the sections, it is obvious that the alternations were orderly carried in a normal sequence which proceeds from the lowland peat stage, through the transition stage to the highland peat stage, and repeats again with an initial stage of the lowland peat (or after passing through the transition stage), and even if it started with the other type, the sequence goes on in the same fashion.

This shows that the peat layers were formed under a normal condition, and the physical (wet or dry, undulation, etc.) and chemical (acidity, nutrition, etc.) conditions under which the original plants grew with difference in each localities since the early stages of the peat accumulation.

4. Lateral Change of a Layer of Peat

As mentioned before, the topmost peat layers on the Kushiro moor are composed of
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the three fundamental types. From the outline of the distribution of these peats, it is not difficult to infer that a type of peat changes laterally and alters into the other types. But it is not to infer as to how to change it beneath the surface.

The materials at No. 9 were employed with the object of clarifying it.

When a layer of the highland peat is traced laterally as shown in Figure 10, it will be found that the layer is really lenicular, thinning out at either end, and closely covered with peats of the other types. Consequently, we suppose that the highland peat here built up a gentle dome bog, and later the top was gradually covered with transition and lowland peat layers.

IV. Summary

There is a reliable view that some type of coals are originated in similar manner as that of peat. Under this point of view, we expect to find in coal similar depositional process exhibiting that once they were layed down as peat and moreover to find out composition of vegetal matter by means of pollen analysis.

On this basis we try to infer the process of coal formation in a comparison with that of the recent peat.

Thus the writer dealt experimentally with the recent peat in the Kushiro moor, where the plants on the surface and partly beneath of the ground have already investigated in detail.

The sampling localities are shown in Table 1 and Figure 1.

The results of pollen analysis are shown in Figs. 2, 3, 4, ……9. There will be summarized as follows:

1) The pollen record accord mostly with the main composition of the mother plants of the peat (Figs. 2, 3, 4). Accordingly it is obvious that pollen analysis is an useful method for our purpose of knowing the original plants.

Arboreal pollen which always keeps a comparatively high percentage, however, should be put out of consideration.

2) The main types of peats are easily distinguished with the diagram (Figs. 2, 3, 4).

3) The highland peats are characterized by the increase curve of both Sphagnum and Ericaceae, while the lowland peats also show dominance of both Cyperaceae and Gramineae, and Pteridophyta. Pteridophyta which appears with high frequency only in the diagram is a species peculiar to the lowland peat. The transition peat represents an intermediate nature between the above two types.

Such a fact is comformable with the above result.

4) The successive changes during the peat forming were carried in a normal sequence. It proceeds from the lowland, through the transition to the highland, and again repeats the same process or after passing through the transition (Fig. 10).

V. Literatures


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