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776. PALYNOLOGICAL INVESTIGATION OF THE POSTGLACIAL DEPOSITS IN LAGOON KAHOKU-GATA, KANAZAWA, CENTRAL JAPAN*

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Abstract. The palaeovegetational and palaeoclimatic changes during the last 20,000 years in and around Lagoon Kahoku-gata, Kanazawa, Central Japan are analysed from the viewpoint of pollen analysis. The palaeoclimatic change is inferred as follows:

The last 1,500 years (Pollen Subzone A-d): mild and wet (the last 500 years . . . . . mild as climate of the present-day, 500—1,500 years . . . . . more or less warm);

1,500—5,000 years ago (Pollen Subzone A-c): cool and slightly dry (1500—3,500 years . . . . . cool or slightly cool);

5,000—8,000 years ago (Pollen Subzone A-b): warm and wet;

8,000—11,000 years ago (Pollen Subzone A-a): more or less cold and slightly wet;

11,000—12,000 years ago (Pollen Subzone B-d): cool and slightly wet;

12,000—14,000 years ago (Pollen Subzone B-c): more or less cold and slightly dry;

14,000—16,500 years ago (Pollen Subzone B-b): cold and slightly dry;

16,500—21,000 years ago (Pollen Subzone B-a): cold or slightly cold and dry.

The pollen zones from Lagoon Kahoku-gata may be correlated with the divisions in Northwestern Europe as follows:

Subzone A-d may be correlated with the Subatlantic, Subzone A-c with the Subboreal, Subzone A-b with the Atlantic, Subzone A-a with the Preboreal and the late Younger Dryas, Subzone B-d with the early Younger Dryas — Alleröd — Older Dryas, Subzone B-c with Bölling — the late Oldest Dryas, Subzone B-b with the early Oldest Dryas, and Subzone B-a with age before the Oldest Dryas respectively.

Introduction

After the last glaciation called the Würmian Glacial Age in the Middle Europe, the Weichselian Glacial Age in the Northwestern Europe, a large transgression confirmed over the world had begun. This transgression has been internationally called the Flandrian Transgression, and it has been called Yurakucho Transgression in the Japanese Islands, and also the later part of the transgression has been named the Jomonian Transgression. Though an ancient inlet called the Ko-kahoku-irie had existed during the transgressional age, the inlet had been changed a lagoon by the formation of large

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coastal sand dunes in the small regression during the stage of the middle Jomonian to the late Yayoian Age, and the environment as a lagoon has been kept since the Yayoian Age (Fuji, 1975; Fuji *et al.*, 1981). Therefore, the present writer infers that all of the deposits throughout the latest Quaternary deposits called the Postglacial deposits have been distributed beneath this lagoon. If this inference is correct and a boring will be drilled at the lagoon, all of the deposits after the last glacial age may be collected. If the deposits are obtained, palaeovegetational and palaeoclimatic changes in and around the lagoon during about 20,000 years since the last glacial age may be ascertained.

The present writer has obtained many core samples from the two drilled wells, about 15-m and about 85-m borings, and these core samples have been studied from the viewpoint of palynological investigation.

This article consists of three parts of descriptions of the stratigraphy of the Postglacial period around and in Lagoon Kahoku-gata, the palynological study on the last Quaternary deposits, and the palaeovegetational and palaeoclimatic significance during the last 20,000 years.

The present writer takes this opportunity to express his deepest gratitude to the late Dr. Naoto Kawai, former Professor of Osaka University, for his continuous encouragement and supervision. Thanks are due to Assistant Professor Tadashi Nakajima of Fukui University, and Professor Kimio Hiro'oka of Toyama University for their advice on the palaeomagnetism of the present core samples. Finally, the writer expresses his deep appreciation to the Ministry of Education of the Japanese Government for grants from the Science Expenditure Funds during the period 1977 to 1979, and also to the Japan Society for the Promotion of Science for grants during the period 1978 to 1979.

1. Topography and Geology

Lagoon Kahoku-gata is located in the central part of Ishikawa Prefecture, facing the Japan Sea of Central Japan. The coastal sand dunes which were formed during the middle and late Holocene Epoch have been distributed in front of the simple coastal region of the Japan Sea. The alluvial lowland areas around this lagoon were formed during the period since the Flandrian Transgression. This lagoon is the second largest lagoon on the Japan Sea side, and had been an old inlet called Ko-kahoku-irie during the Flandrian Transgression age. In the middle Holocene Epoch, the lagoon was changed from a marine condition to a brackish condition. The change of palaeoenvironment as mentioned above agrees chronologically with the relative small regression age. The ancient inlet was isolated from the Japan Sea by the formation of the coastal sand dunes and by a lowering of sea-level during this regression age, and changed to a lagoon (Fuji, 1975; Fuji *et al.*, 1981; Fuji, 1982a; Fuji, 1982b).

The deposits beneath the Kanazawa Plain including Lagoon Kahoku-gata are stratigraphically divided into two parts: the lower and the upper parts. The lower part is composed mainly of hard Neogene strata and loose Pleistocene deposits, and the upper one is composed of the postglacial deposits which are divided into three subparts; the alternation of coarse sand and mud layers in the lower horizon, a loose medium sand layer in the middle horizon, and a mud layer in the upper horizon. A gravel layer, about 5 m to 8 m thick and 50 mm to 100 mm in diameter of gravel, is intercalated between the lower and upper parts, and belongs to the last stage of the last glacial age.

The gravel layer is generally distributed just below the Postglacial deposits of the Holocene alluvial plain developing along the coastal area of the Japan Sea, and called the First Gravel Layer in Japan, and a key bed indicating the boundary between the Postglacial and the last glacial deposits.

2. Palynological Study

2-1) Preparation for Pollen Analyses

Pollen grains in the sediments were concentrated in the laboratory by slight modifications of the process described by Faegri and Iversen (1964).

2-2) Microscopic Examination

Pollen grains and spores mounted on slides were identified and counted by means of a mechanical stage of a microscope. The counting was continued up to more than 300 identifiable arboreal pollen grains. Determination was made with the aid of the key by Faegri and Iversen (1964) and McAndrews (1973), and also in reference to the pollen grains obtainable from the Japanese Islands. Hard-to-identify pollen grains were identified with the aid of a reference collection of about 500 slides for important trees, shrubs, and acquatic herbs of the Japanese Islands in possession of the Institute of Earth Science, Kanazawa University, a reference collection of about 9,000 slides owned by the Limnological Research Center, University of Minnesota, Minneapolis, U.S.A., and also a reference collection of about 5,000 slides owned by the Department of Quaternary Geology, Faculty of Science, University of Uppsala, Uppsala, Sweden.

2-3) Method for Interpretation of Palaeovegetation and Climatic History

The writer depends upon the pollen analyses for the reconstruction of vegetation during a glacial age. For the interpretation of the pollen spectra obtained from the 200-m core samples, he has employed two methods, namely, (1) pollen spectra of the modern samples collected from Lagoon Kahoku-gata and its vicinity, and also from various localities of some climatic zones throughout the Japanese Islands and (2) the warmth index (month-degrees). The methods are described in detail in the present writer's previous paper (1978).

2-4) Pollen Analyses of the 15-m Core Samples

(1) Location of the Boring and Samples

The boring site is situated in a reclaimed land, about −50 cm in the present altitude, near Kurotsubune of Uchinada-machi.

The 15-m core samples are composed mainly of homogeneous dark bluish grey clay. As measured by Kigoshi of Gakushuin University, the ^{14}C dating age of dark bluish grey clay in the 13.60 — 13.70 m horizon of this 15-m core is 3,220 ± 160 years B.P. (Gak-7146).

All of the core samples belong to the late Holocene deposits according to the stratigraphy of this core and ^{14}C dating.

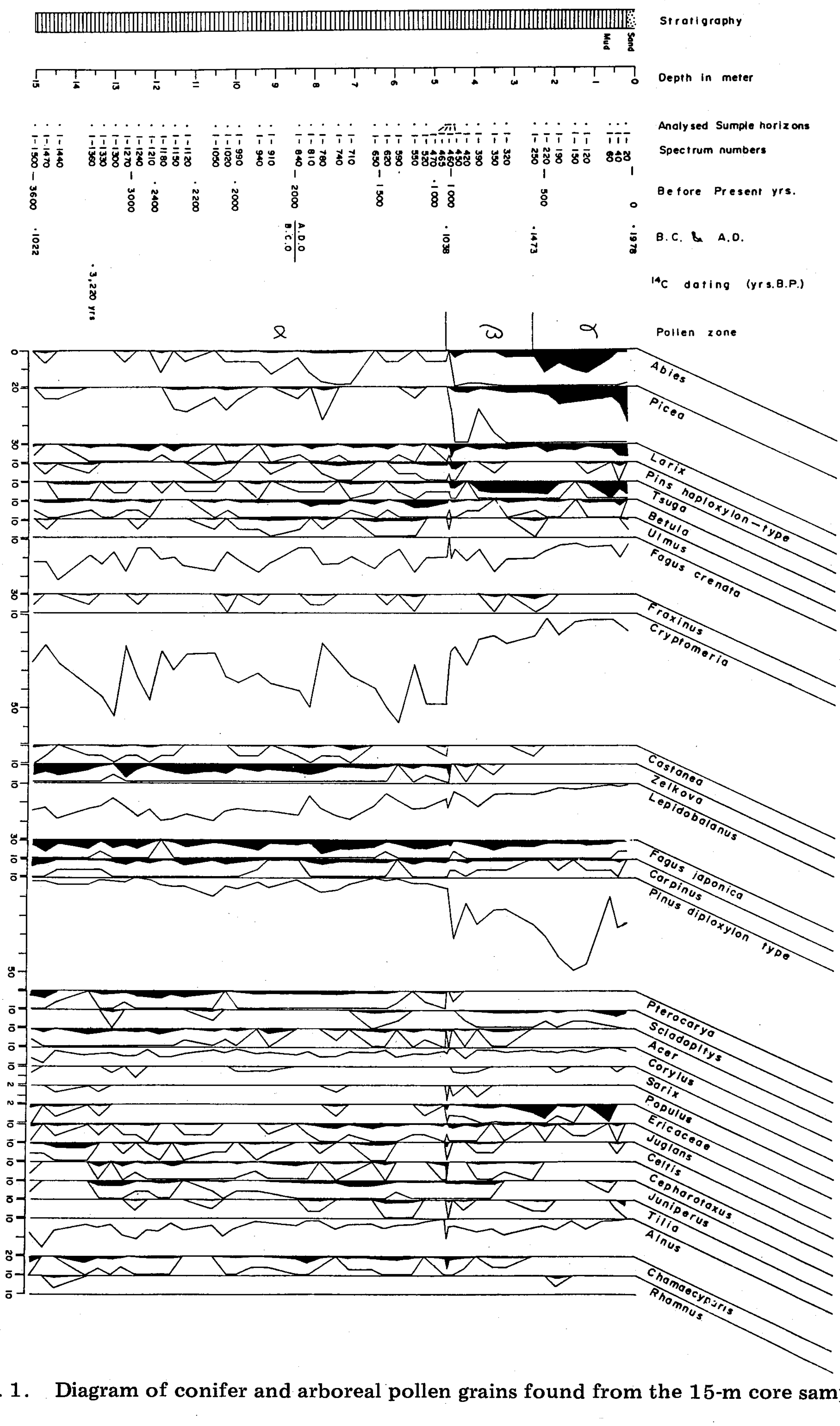
(2) Zoning of Pollen Assemblage and Palaeoclimate based on Palaeovegetation

In order to facilitate their description and discussion, the pollen diagrams are divided into some zones. These zones are based upon conspicuous changes in pollen percentages. Changes in the ratio, Total AP/Total NAP, can be described, while alternation of values of one or two pollen types may also lead to the establishment of pollen zones. Where pollen zones display the same nature characterized by assemblage of pollen grains and spores, the writer has attempted to indicate them under the same letter code in order to facilitate comparison. These pollen zones are restricted to the series of diagrams under discussion. The minor differences of the pollen assemblage in the zones are shown by subzones.

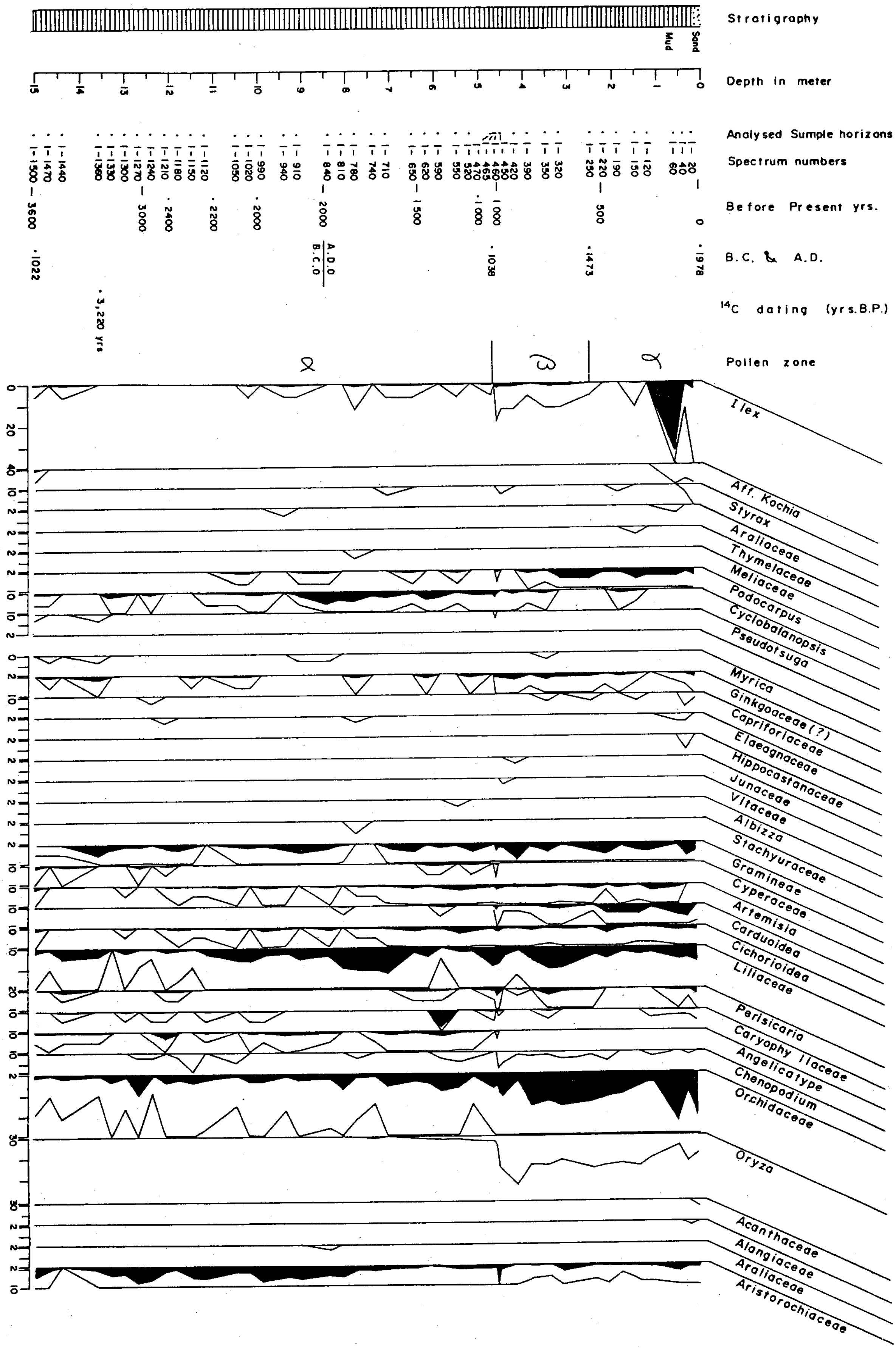
The 15-m core samples are divided into three pollen zones as Zone α, Zone β, Zone γ in an ascending order. They are described as follows:

Zone α, spectra: I-470 to I-1500; depth: 4.7 to 15 m; age: about 1,500 to 3,500 years ago.

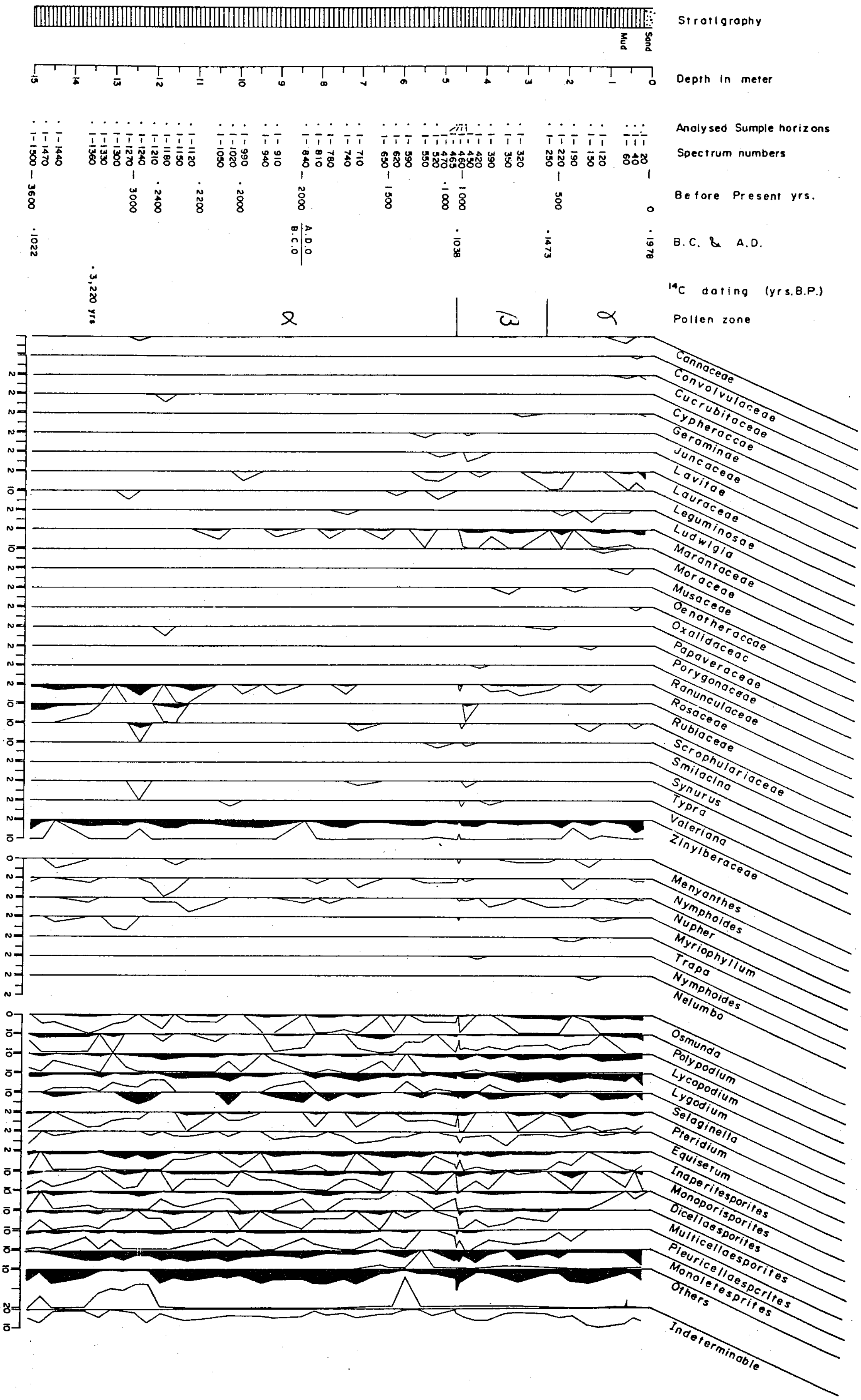
This zone is characterized by a large amplitude and a long duration of every maximum (up to about 60%) or minimum (down to ca. 17%) period in a fluctuation of pollen value of *Cryptomeria*. The percentage of arboreal pollen grains shows the highest value throughout the 15-m boring core. Such plants as *Abies*, *Picea*, and *Tsuga* growing in the Subpolar area reach only 1 to 6% in this zone. Plants adapted to the Cool Temperate climatic zone appear 7 to 24% in the fluctuation of pollen percentage. Among them, *Fagus* large-type which is inferred to be *Fagus crenata* appears about 13% on the average (1% at a minimum and 23% at a maximum). Plants growing in both climatic zones of the Cool Temperate and the Temperate (Warmth-index: 55° to 140°) reach 45 to 72% in pollen value,



Text-fig. 1. Diagram of conifer and arboreal pollen grains found from the 15-m core samples.



Text-fig. 2. **Diagram of arboreal and non-arboreal pollen grains found from the 15-m core samples.**



Text-fig. 3. Diagram of non-arboreal pollen grains and spores found from the 15-m core samples.

which is the highest percentage throughout the 15-m core samples. Most of the highest value is taken by *Cryptomeria.* Plants growing in the middle part of the Cool Temperate zone and the Warm Temperate zone (70° to 140°) have a pollen value of 12 to 37%, which is lower than those of Pollen Zones β and γ. Plants of both climatic areas of the South Warm Temperate and Subtropical zones (Warmth-index: 100° to 180°) reach 8% at a maximum value, which is lower than those of Pollen Zones β and γ. The pollen percentage of *Fagus crenata*-type shows a negative interrelation to that of *Cryptomeria.*

On the basis of the above-mentioned description, the palaeoclimate during the sedimentation of the deposits of this zone may have been the same as the climate in the present Cool Temperate area.

Zone β, spectra: I-320 to I-460; depth: 2.5 to 4.7 m; age: about 500 to 1,500 years ago.

This zone is characterized by a large percentage of non-arboreal pollen grains, pollen value of which is about 50%. Boreal conifers growing in the Subpolar and/or Subalpine zones appear as follows; *Abies*: 0 to 4%, *Picea*: 0 to 3%, *Tsuga*: 1 to 7%. Cool Temperate plants of this zone show a value higher than that of Zone γ. Some changes are recognized in the percentage of pollen assemblages. Namely, plants adapted to the Cool Temperate and Temperate zones record a drastic decrease from 64% to 22% because of a drastic decrease (from 49% to 12%) of *Cryptomeria*, especially remarkable at 4.6 m to 4.7 m in depth. In contrast to the above-mentioned phenomenon, plants of the middle area of the Cool Temperate zone and the Warm Temperate zone increase gradually from 32% to 50% due to an increase (6% to 23%) of *Pinus diploxylon*-type. Warm Temperate and Subtropical plants show a pollen percentage (2% to 8%) which is the same as that of Zone γ.

According to palaeovegetation mentioned above, the palaeoclimate during the age of Zone β may have been more or less warm in comparison with the present climate.

Zone γ, spectra: I-20 to I-250; depth: 0 to 2.5 m; age: the present-day to about 500 years ago.

In this zone, arboreal pollen grains occupy about 43% to 63%, being higher than the value of nonarboreal pollen grains. As *Abies* and *Picea* pollen grains are respectively 2% to 12% and 3% to 18%. Subpolar plants show the highest value (21% to 35%) over this zone. Plants growing in the Cool Temperate zone have a low value, which is 4% to 8% in the total percentage. On the other hand plants growing in the Cool Temperate and Warm Temperate zones show the lowest value throughout all of the zones. However, plants growing in the middle area of the Cool Temperate zone and the Warm Temperate zone reach the highest percentage over the boring core samples due to an increase (25% to 49%) of *Pinus diploxylon*-type. Among them, *Ilex* pollen percentage shows a large amplitude, e.g., from 0% to 35%. Warm Temperate and Subtropical plants show a 3 to 7% value in this zone. The percentage of *Oryza* pollen grains records a drastic increase.

Judging from the above-mentioned description, the palaeoclimate during this zone may have been warm as the present climate.

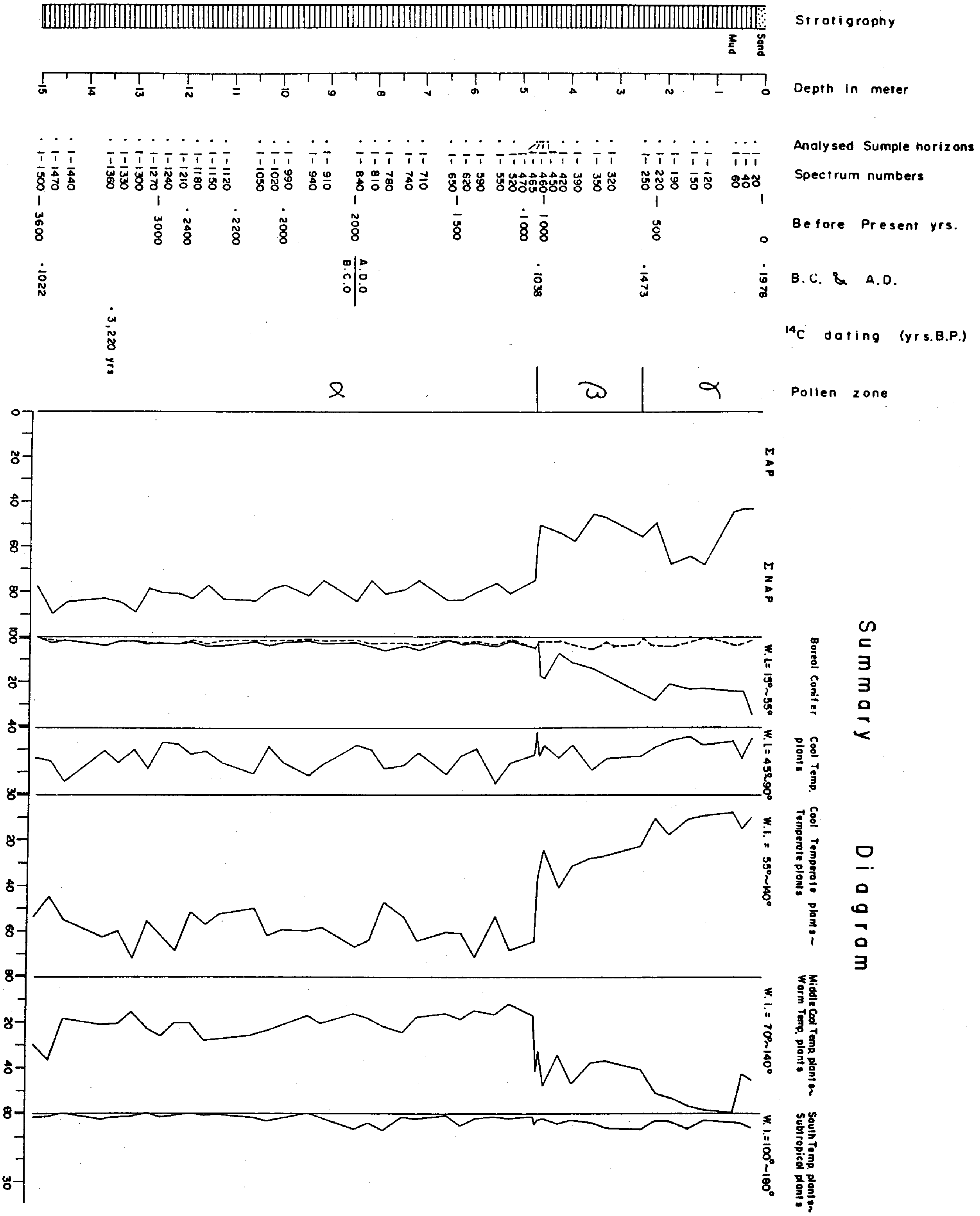
Nakai, Mori and Ohta (1982) studied the stable carbon isotopic composition ratio ($^{13}C/^{12}C$) of sedimentary organic materials in the 15-m core. Judging from the isotopic and pollen analyses, the change of climate on the basis of the pollen analysis is a close agreement to the change of the isotopic composition in a pattern of change.

The frequency of pollen grains of *Oryza* (rice plant) found in Zone γ shows a value larger than those of Zones α and β. This phenomenon reveals the remarkable development of rice-cultivation around Lagoon Kahoku-gata during the time of Zone γ, and this inference is supported by many old documents and pieces of archaeological evidence.

2-5) Pollen Analyses of the 85-m Core Samples

(1) Locality of the Boring and Samples

The 85-m boring site is situated in the bottom of Lagoon Kahoku-gata near Bridge Konan-ohashi, Tsubata, northwest Kanazawa, and about −100 cm in the present altitude. The



Text-fig. 4. Summary diagram of the palynological analysis of the 15-m core samples.

writer can divide the 85-m core samples into seven parts. Fuji, the present writer, calls them Layers A to G in a descending order. They are described as follows (Fuji, 1982b):

Layer A: This layer is distributed locally in a deltaic area near the mouths of the Tsubata, Morimoto and Asano Rivers flowing into Lagoon Kahoku-gata. The layer is composed of loose brown coarse-grained sand. It is about 2 — 5 m thick.

Layer B: This is composed mainly of homogeneous loose dark bluish grey silt intercalated with thin (2 m thick) loose dark bluish grey mud (about 18 to 20 m deep). This layer is about 26 m thick (−2 to −28 m below the present sea-level).

Layer C: This is composed mainly of loose dark yellowish brown silty sand and medium-grained sand, and about 10 m thick (−28 to −37 m below the present sea-level).

Layer D: This is composed of alternation of loose brown-colored sand and dark bluish grey mud or silt, and about 25 m thick (−37 to −62 m below the present sea-level).

Layer E: This is composed of brown-colored gravels, kinds of which are sandstone, homogeneous hard mudstone, hornblende andesite, and pyroxyne andesite, etc. The gravel is 5 to 10 cm in diameter. It is about 4 m thick, and −62 to −66 m in the present altitude.

Layer F: This layer is composed of alternation of dark bluish grey clayey silt and dark bluish grey silty mud. This is about 16 m thick, and −66 to −82 m below the present sea-level.

Layer G: This layer is composed of brown medium- and coarse-grained sand, and −82 to −85 m below the present sea-level.

Layer E to G belong to the latest Pleistocene deposits according to stratigraphy and ^{14}C dating on this core sample (Fuji, 1982a, 1982b).

(2) Zoning of Pollen Assemblage and Palaeoclimate based on Palaeovegetation

The 85-m core samples are divided into two pollen zones as Zones A and B, and eight pollen subzones as Subzones A-d, A-c, ... A-a, B-d, B-c, ... B-a in a descending order as described below. The present palynological study of the 85-m core samples has been made in order to discover, in detail, changes of palaeovegetation and palaeoclimate during the sedimentation of the 85-m core samples.

Zone A, spectra: 0.82 to 39.70; depth: 0 m to 40 m; age: about 10,000 years ago to the present-day.

Zone A is characterized by a dominant percentage of plants growing in the middle area of the Cool Temperate and Warm Temperate zones, and A-a, A-b, A-c, and A-d in an ascending order.

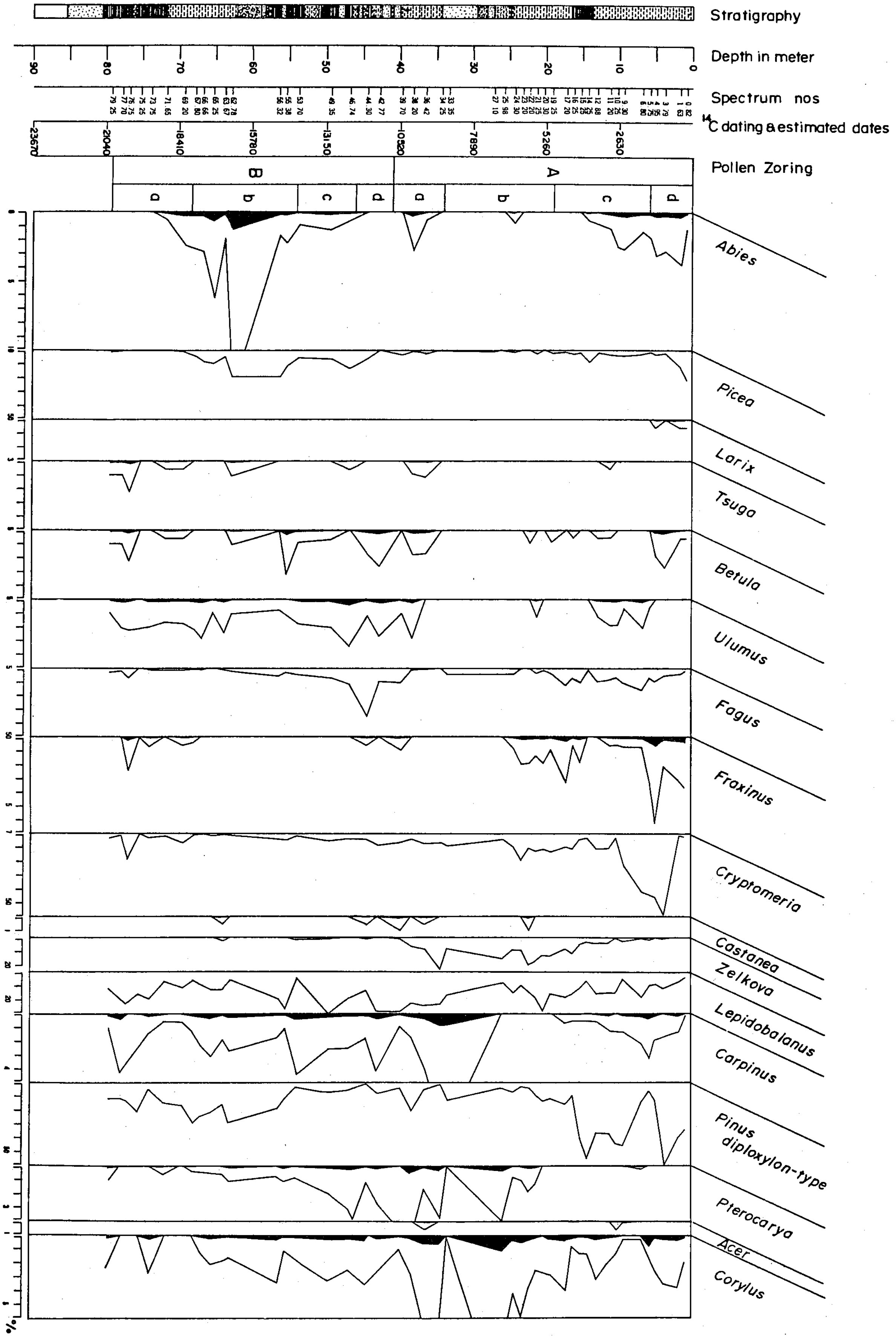
Subzone A-d, spectra: 0.82 to 4.95; depth: 0 m to 5 m; age: 1,500 years ago to the present.

Arboreal grains show up with a total pollen value of 61% to 72%, which is higher than the percentage of non-arboreal pollen grains. Boreal conifers reach about 15% on the average (3% at a minimum and 24% at a maximum), which is influenced by an increase of *Abies*, *Picea*, and *Larix*. Plants growing in the Cool Temperate zone are 11% to 75%, which is influenced by an increase of *Cryptomeria*. Plants growing in the middle part of the Cool Temperate and the Warm Temperate zones show a high percent, 11% to 62%. Among them, *Pinus*'s and *Corylus*'s percentages are respectively 3 to 48% and 2 to 8%. *Oryza* pollen grains are found to be 8.1 to 23%.

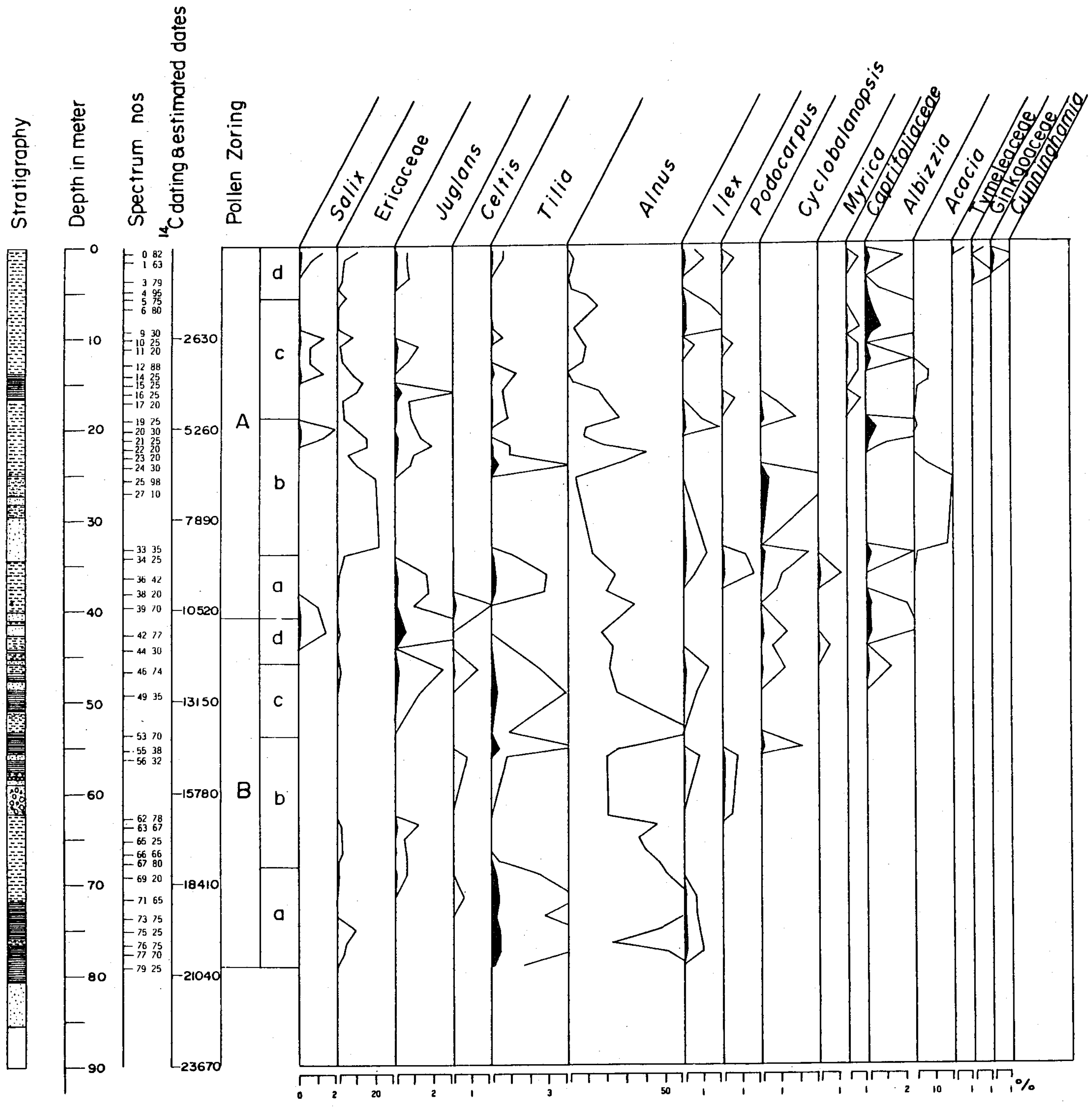
Judging from the above-mentioned pollen assemblage, it is inferred that the palaeoclimate since about 1,500 years ago may have been mild and wet.

Subzone A-c, spectra: 5.75 to 17.70; depth: 5 m to 19 m; age: 1,500 to 5,000 years ago.

Arboreal pollen grains have a large percentage, 65% to 88%, which is the highest one throughout the 85-m core samples under the influence of an increase of *Abies* (about 3%) and *Picea* (1.5 to 8%). Plants adapted to the Cool Temperate and Temperate zones show 14% to 45% due to an increase of *Cryptomeria* pollen grains, though *Zelkova* pollen grains decrease from about 16% to 1%. Plants of the middle Cool Temperate and the Warm Temperate zones reach 30% to 70%. Plants growing in the Warm Temperate



Text-fig. 5: **Diagram of conifer and arboreal pollen grains found from the 85-m core samples.**



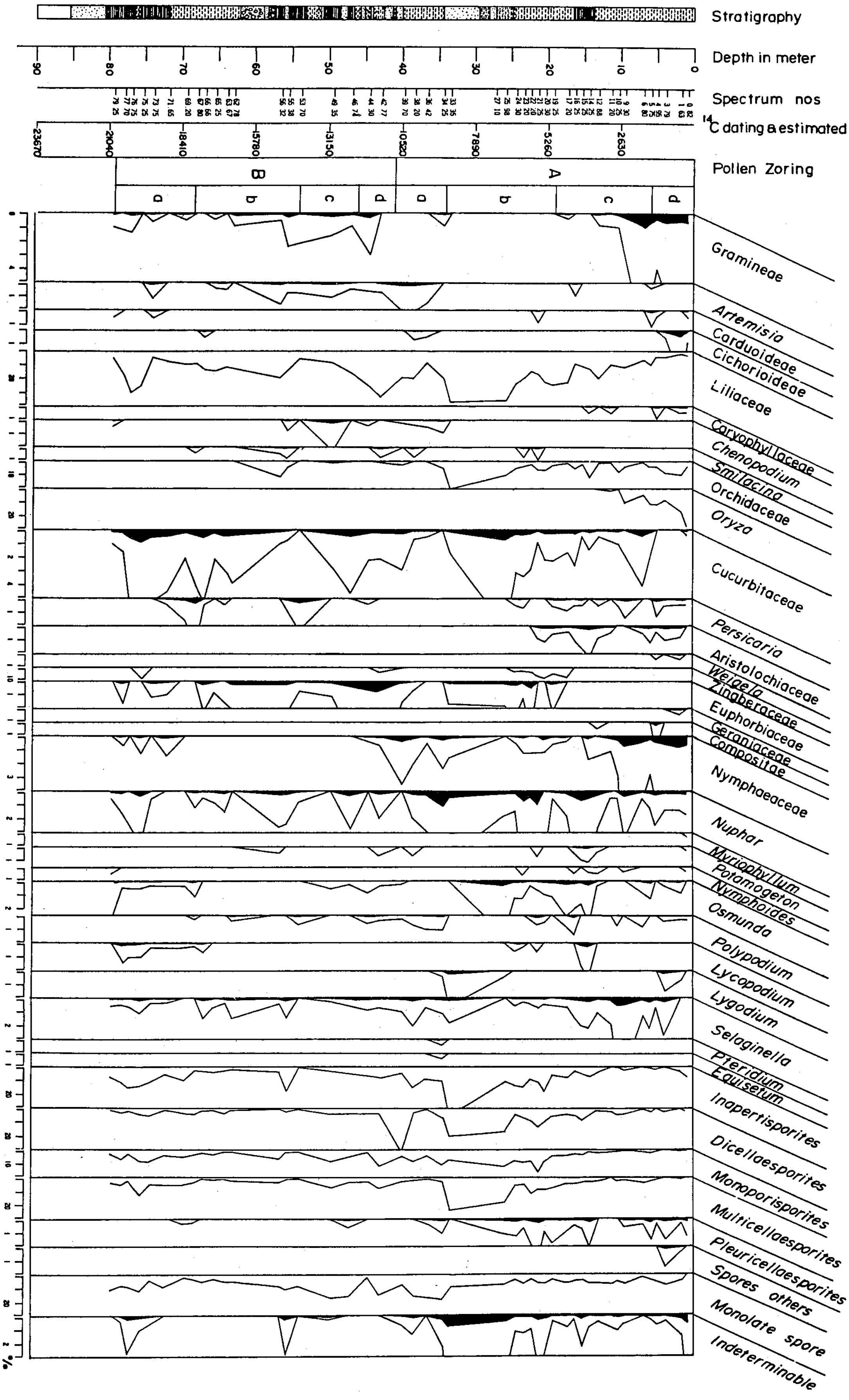
Text-fig. 6. Diagram of arboreal pollen grains found from the 85-m core samples.

and the Subtropical zones are 1% to 9%, which is a decrease as compared to Subzone A-b. *Oryza* pollen grains are found in an upper horizon from this subzone, and the percentage of these grains is 0.5% to 10.2%.

On the basis of the result mentioned above, the palaeoclimate is inferred to have been cooler than those of the present-day, Subzones A-d and A-b.

Subzone A-b, spectra: 19.25 to 33.45; depth: 19 m to 34 m; age: 5,000 to 8,000 years ago.

Arboreal pollen grains have a value of 39% to 73%, lower than those of the other subzones. Therefore, non-arboreal pollen grains increase. Such boreal conifers as *Abies*, *Picea*, *Tsuga*, and *Larix* decrease to 0% or 2.5%, and



Text-fig. 7. Diagram of non-arboreal pollen grains and spores found from the 85-m core samples.

the percentages of their conifers show the lowest value throughout all of the eight subzones. Cool Temperate plants decrease. Plants growing in the Cool Temperate and the Warm Temperate zones show such a high percentage as 28% to 55% because of an increase of *Zelkova* (9% to 20%), *Lepidobalanus* (8% to 28%), and *Cryptomeria* (4% to 20%). Middle Cool Temperate and Warm Temperate plants reach a high value (36% to 58%) of pollen grains due to an increase of *Corylus* (12%). Plants adapting to the Warm Temperate and Subtropical zones have the highest percentage throughout all of the eight subzones.

Judging from the above-mentioned palynological results, the palaeoclimate during the age of this subzone may have been the warmest over the 85-m core samples.

Subzone A-a, spectra: 34.75 to 39.70; depth: 34 m to 41 m; age: 8,000 to 11,000 years ago.

Arboreal pollen grains show a high percentage of 71% to 87%, and non-arboreal pollen grains have a low percentage. Plants growing in the Subpolar zone reach to a value of about 4.6% at a maximum, which is low. Cool Temperate plants decrease from 11% to 3%. This phenomenon is influenced by a decrease (from 10% to 0%) of *Fagus*. In contrast to this decrease, plants of the Cool Temperate and the Warm Temperate zones increase from 32% of the Subzone B-d to 72% of this Subzone A-a. This increase is influenced by an increase of *Zelkova* (1% to 24%) and *Lepidobalanus* (25% on the average). Warm Temperate and Subtropical plants reach 1% to 7%.

Judging from the above-mentioned pollen assemblage, it is inferred that the palaeoclimate during the Subzone A-a may have been more or less cold.

Subzone B-d, spectra: 42.77 to 44.30; depth: 41 m to 46 m; age: 11,000 to 12,000 years ago.

Arboreal pollen grains are 51% to 62%, and occupy a value more than that of non-arboreal pollen grains. Plants growing in the Subpolar zone are few. Among them, *Abies*, *Tsuga*, and *Larix* pollen grains are lacking, and only 6% of *Picea* grains are included. Cool Temperate plants show a high percentage (15% to 38%); that is, *Betula* grains reach 1.8% to 2.7%, *Ulmus* 1.2% to 2.7%, and *Fagus* 10% to 35%. Plants of the Cool Temperate and Warm Temperate zones increase gradually in contrast to the lower horizon as Subzone B-c. Plants growing in the middle part of the Cool Temperate and Warm Temperate zones are 33% to 40%. The Warm Temperate and Subtropical plants increase from a lower subzone to this subzone; that is, *Myrica* pollen grains are 0.6% on the average, and *Cyclobalanopsis* grains 0.6% to 1.5%.

As mentioned above, this subzone is characterized by the abundance of plants growing in the Cool Temperate zone, and the middle area of the Cool Temperate and the Warm Temperate zones. Also, Warm Temperate and Subtropical plants increase gradually from the lower horizon of this subzone.

The palaeoclimate during the age of the sedimentation of deposits of Subzone B-d had been a cool condition.

Subzone B-c, spectra: 46.74 to 53.70; depth: 46 m to 54 m; age: 12,000 to 14,000 years ago.

Arboreal pollen grains show a high percentage (74% to 90%) throughout the 85-m core samples, and in contrast, non-arboreal pollen grains are very rare. Subpolar plants increase to about 10% on the average. Plants growing in the Cool Temperate and Warm Temperate zones increase to about 25% on the average (12% at a minimum and 39% at a maximum) owing to an increase (31% to 44%) of *Lepidobalanus*. Middle Cool Temperate and Warm Temperate plants decrease from about 62% on the average (77% at a maximum) of Subzone B-b to about 40% of this subzone. This decrease results from a decrease of *Alnus* pollen grains from 67% in lower Subzone B-b to 22% in this subzone. Warm Temperate and Subtropical plants increase, though the increase is a small percentage.

The palaeoclimate at the time of this Subzone B-c may have been a more or less cold condition.

Subzone B-b, spectra: 55.38 to 67.80; depth:

54 m to 68.2 m; age: 14,000 to 16,500 years age.

This subzone is characterized by the abundance of conifers, and by the absence of Subtropical and Warm Temperate plants. Accordingly, Subpolar plants are about 70% on the average, which is influenced by a high value of *Abies* (12% to 18%) and *Picea* (5% to 20%). Cool Temperate plants appear about 4% on the average (1% at a minimum and 7% at a maximum) except *Alnus*. Cool Temperate and Warm Temperate plants change from 10% to 30% in Subzone B-b. The percentage of plants growing in the middle area of the Cool Temperate and Warm Temperate zones shows a high value (46% to 77%), which is influenced by *Alnus* pollen grains (20% to 47%).

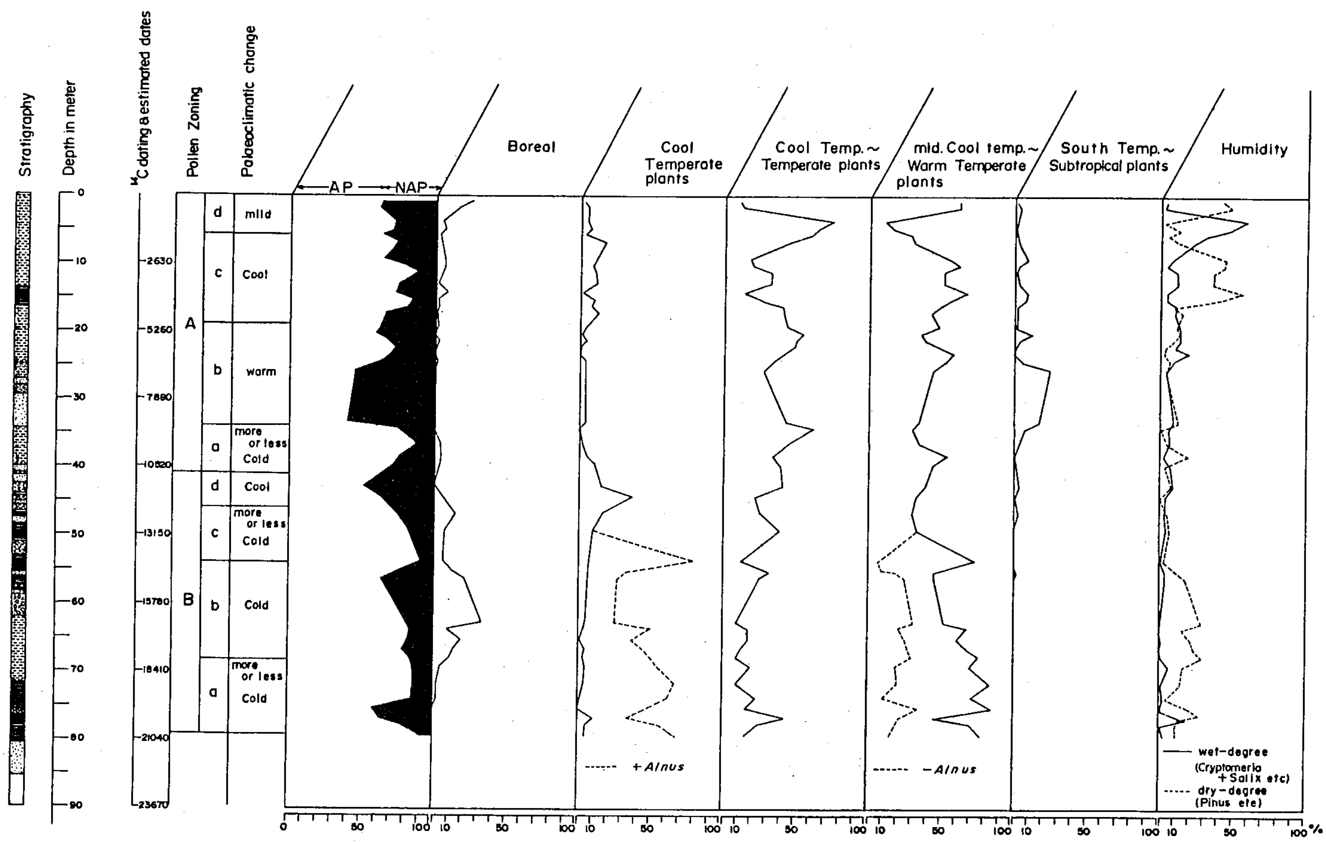
The palaeoclimate in the stage of Subzone B-b may have been a cold condition.

Subzone B-a, spectra: 69.20 to 79.25; depth: 68.2 m to 79.25 m; age: 16,500 to 21,000 years ago.

This subzone is characterized by the abundance of conifers, and by the absence of Subtropical and Warm Temperate plants. Cool Temperate plants appear about 5% on the average (11% at a maximum). Plants growing in the Cool Temperate and Warm Temperate zones show the lowest percentage throughout all of the eight subzones by the influence of the low values of *Cryptomeria* and *Zelkova.* Plants of the middle part of the Cool Temperate and Warm Temperate zones reach 46% (at a minimum) to 85% (at a maximum), which are higher than those of the other subzone in the 85-m core samples.

Judging from the above-mentioned description, the palaeoclimate of Subzone B-a is inferred as having been cold or slightly cold.

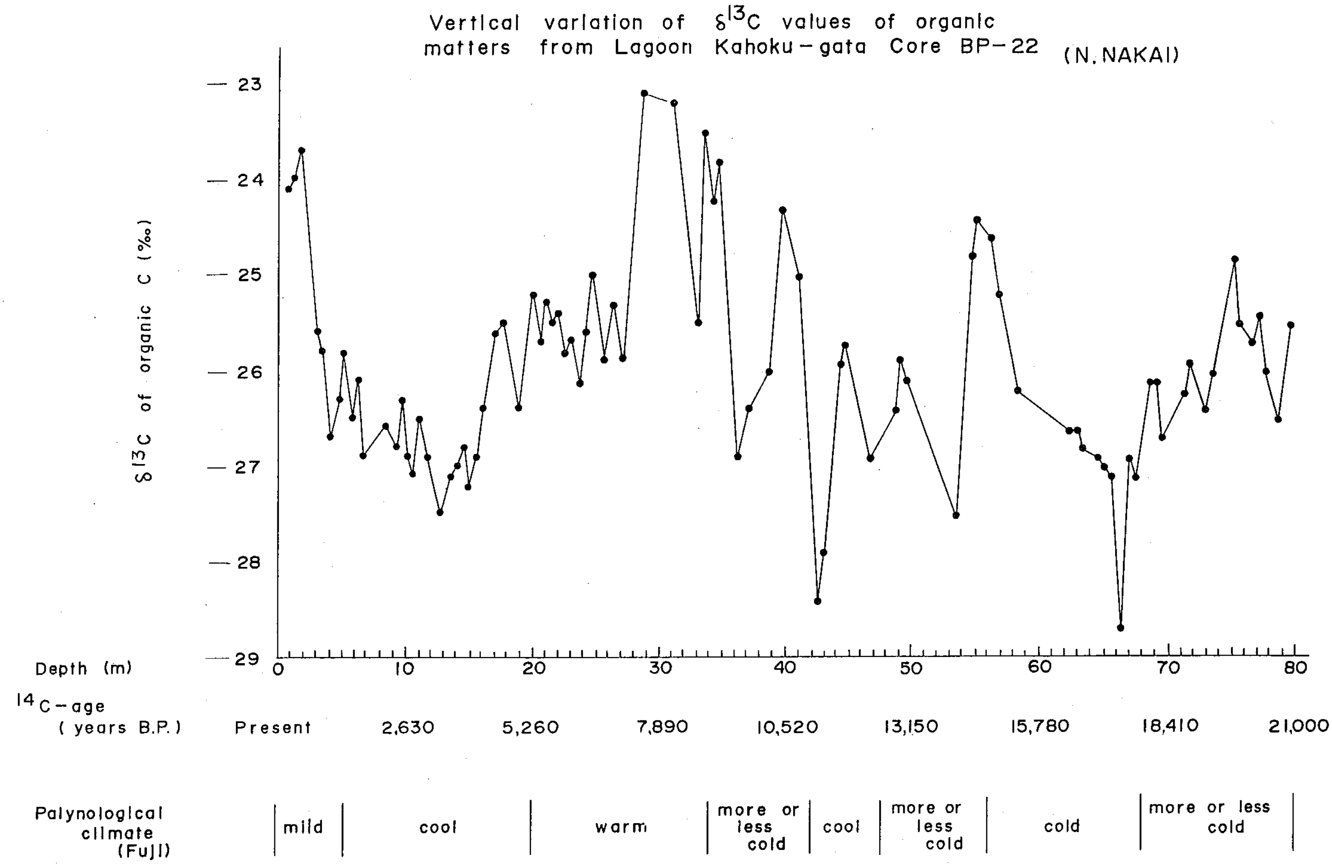
3. The Comparison between the Climatic Changes by the Isotopic and Palynological Studies



Text-fig. 8. Summary diagram of the palynological analysis of the 85-m core samples.

The comparison between the profiles for environmental changes by the isotopic and geochemical studies and the fossil pollen and diatom analyses gave a close agreement to each other (Nakai *et al.*, 1982). According to the studies, it is concluded that the isotopic and chemical records of embayment sediments can be used as useful indicators for the past environment.

To study the environmental changes such as the climatic and sea-level fluctuation in the past geologic time, the 15-m and 85-m core samples were analyzed by N. Nakai for the stable carbon isotopic composition ratio ($^{13}C/^{12}C$) of sedimentary organic materials. Total organic materials in the cores have a $\delta^{13}C$-range from −29 to −23 ‰ relative to PDB-standard. Large ranges of $\delta^{13}C$ values are due to the past depositional history affected primarily by the relative contribution of terrestrial- and marine-derived organic materials to the bottom sediments. Besides a difference in the source of organic materials, $\delta^{13}C$ value is affected by the sedimentary environment and temperature conditions. From the fluctuation pattern of $\delta^{13}C$, the present writer can find the following feature indicating the sea-level and the climatic (temperature) changes during the end of the last glacial age, Würmian or Wisconsinian glacial age, and the Holocene. A cold climate can apparently be seen at the lower horizon of the core in the ^{14}C-age of 9,000 to 14,000 years B.P. According to the investigation based on diatom analysis (Fuji *et al.*, 1981), a sea-level at that time was about −50 to −5 m in the studied area. After that period, the sea-level rose gradually, and the high sea-level and climatic optimum appeared in the ^{14}C-age of 8,000 to 4,000 years B.P. corresponding to "the Jomonian Transgression". This warm and high sea-level period is followed



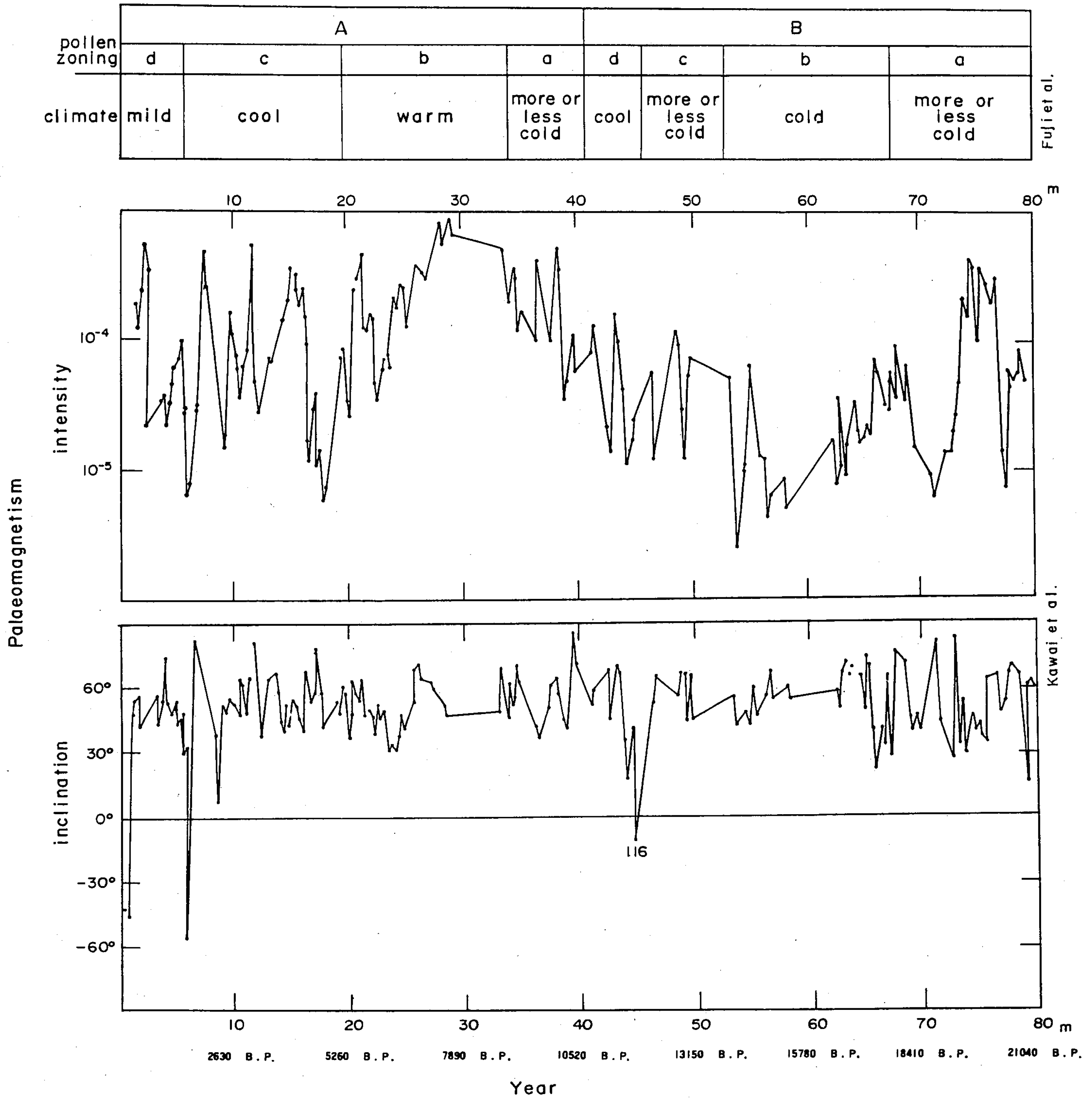
Text-fig. 9. Vertical variation of $\delta^{13}C$ values of organic matters found from the 85-m core samples (after Nakai, Mori and Ohta, 1982).

by a low sea-level and a cool climate corresponding to a small scale regression called "the Yayoian Regression" in Japan and correlated internationally with "a little ice age". After the small scale regression, about 1,500 years B.P., the sea-level rose again gradually toward the present sea-level.

The climatic change by the isotopic analysis above-mentioned gives a close agreement to the climatic change based on the palynological study as shown in Text-fig. 9.

4. The Comparison between Changes of the Palaeoclimate and Palaeomagnetism

The palaeomagnetic study of the 85-m core



Text-fig. 10. Diagram showing the changes of the palaeomagnetism and the palaeoclimate based on the palynological anlysis of the 85-m core samples (after Kawai & Nakajima, unpubl. data).

samples has been made by the late Dr. Naoto Kawai, former Professor of Osaka University and Assistant Professor Tadashi Nakajima of Fukui University. The result of the palaeomagnetism on the 85-m core is shown in Text-fig. 10. Judging from the results of the palaeomagnetic and palynological studies, it seems to be concluded that when the intensity of the magnetism was weak, the climate was a cold condition, and in contrast, when the intensity was strong, the climate was a warm or mild condition. The relationship between the palaeomagnetism and plaeoclimate as above-mentioned has been found in the long core samples obtained from the bottom of Lake Biwa, Central Japan (Kawai *et al.*, 1975).

5. Correlation

In Northwestern Europe, the Late Glacial Period is divided into five stages on the basis of changes of palaeoclimate, namely, the Oldest Dryas (12,400 to 15,000 years ago), Bölling (12,100 to 12,400 years ago), Older Dryas (11,800 to 12,100 years ago), Alleröd (11,000 to 11,800 years ago), and Younger Dryas (10,350 to 11,000 years ago).

As a detailed dating on the deposits from Lagoon Kahoku-gata has not been measured, the writers cannot correctly state the age of the boundary between some pollen subzones and pollen zones. However, judging from the changes of palaeoclimate based on the palynology and ^{14}C dating and palaeomagnetic stratigraphy of a few horizons, the ages of some pollen subzones are estimated roughly as mentioned already in the description of individual pollen zones.

According to the writer's investigation on the deposits obtained from Lagoon Kahokugata, Pollen Subzone A-a (about 8,000 to 11,000 years ago, more or less cold) may be correlated with the Preboreal and the Late Younger Dryas stage; Pollen Subzone B-d (about 11,000 to 12,000 years ago, cool) with the early Younger Dryas — Alleröd — Older Dryas stages; Pollen Subzone B-c (about 12,000 to 14,000 years ago, more or less cold) with Bölling — the late Oldest Dryas; and Pollen Subzone B-b (about 14,000 to 16,500 years ago, cold) with the early Oldest Dryas and the previous age, respectively.

In addition, Pollen Subzone A-b (about 5,000 to 8,000 years ago, warm) may be correlated with the Atlantic stage; Pollen Subzone A-c (about 5,000 to 1,500 years ago, cooler than that of the present-day) with the Subboreal; and Pollen Subzone A-d (the present-day to about 1,500 years ago, mild and wet) with the Subatlantic stage, respectively.

6. Conclusion

(1) The palaeovegetation and palaeoclimate during the last about 20,000 years in and around Lagoon Kahoku-gata are analysed by a palynological investigation.

(2) Judging from the pollen analyses, the palaeoclimate may be inferred as follows:

Subzone B-a: 16,500 — 21,000 years ago; cold or slightly cold, dry;

Subzone B-b: 14,000 — 16,500 years ago; cold and slightly dry;

Subzone B-c: 12,000 — 14,000 years ago; more or less cold, slightly dry;

Subzone B-d: 11,000 — 12,000 year ago; cool, slightly wet;

Subzone A-a: 8,000 — 11,000 years ago; more or less cold, slightly wet;

Subzone A-b: 5,000 — 8,000 years ago; warm and wet;

Subzone A-c: 1,500 — 5,000 years ago; cool and slightly dry;

Subzone A-d: the present-day — 1,500 years ago; mild and wet.

(3) Judging from the palynological investigation of the samples obtained from the 15-m boring core of Lagoon Kahoku-gata, the deposits below this lagoon are divided into three pollen zones as Zones α, β and γ in an ascending order.

Zone α: 1,500 — 3,500 years ago; cool or slightly cool.

Zone β: 500 — 1,500 years ago; more or less warm.

Zone γ: the present-day — 500 years ago;

mild as the present-day.

(4) A change of the Carbon-13 (^{13}C) and Carbon-12 (^{12}C) ratio is shown in Text-fig. 9. The pattern of the change of $\delta^{13}C$ corresponds to pattern of the change of $\delta^{13}C$ corresponds to the pattern of the change of palaeoclimate. Especially, the boundary between Zones α and β is sharper than the boundary between Zones β and γ.

(5) The frequency of pollen grains of *Oryza* (rice plant) found in Zones β and γ is larger than the value in the Zone α. This phenomenon shows the remarkable development of rice-cultivation around Lagoon Kahoku-gata during the age of Zones β and γ, and this inference is supported by many old documents and pieces of archaeological evidence.

(6) The pollen zones of the core samples below Lagoon Kahoku-gata are correlated with the divisions in Northwestern Europe as follows: Subzone A-d may be correlated with the Subatlantic stage, Subzone A-c with Subboreal, Subzone A-b with Atlantic, Subzone A-a with Preboreal and the late Younger Dryas, Subzone B-d with the early Younger Dryas — Alleröd — Older Dryas, Subzone B-c with Bölling — the late Oldest Dryas, Subzone B-b with the early Oldest Dryas and its previous age, and Subzone B-a with times before the Oldest Dryas, respectively.

References

Faegri, K. and Iversen, T. (1964): *Textbook of Pollen Analysis.* Copenhagen, Munksgaarb., 237 pp.

Fuji, N. (1975): The coastal sand dunes of Hokuriku district, Central Japan. *Quaternary Res.*, vol. 14, p. 195—220.

—— (1982a): Chronostratigraphic subdivision of the Postglacial deposits in the Japanese Islands. *Striae*, vol. 16, p. 24—35.

—— (1982b): Paleolimnological study of Lagoon Kahoku-gata, Central Japan. *Abstract of the 11-INQUA Congress (Moscow)*, vol. 1, p. 97.

—— and Kobayashi, R. (1978): Palynological investigation of the Holocene deposits from Lagoon Kahoku-gata, Central Japan. *Bull. Japan Sea Res. Inst. Kanazawa Univ.*, vol. 10, p. 29—51.

—— and Miyamatsu, M. (1981): Fossil diatom assemblage of the latest Quaternary deposits from Lagoon Kahoku-gata, Kanazawa, Central Japan. *Bull. Fac. Educ., Kanazawa Univ., Natural Sci.*, vol. 30, p. 83—96.

Kawai, N., Yaskawa, K., Nakajima, T., Torii, M. and Hatsuhara, N. (1975): Voice of geomagnetism from Lake Biwa. In *Paleolimnology of Lake Biwa and the Japanese Pleistocene*, vol. 3, p. 143—160.

McAndrews, K. (1973): Pollen analysis of the sediments of the Great Lakes of North America. In *the 3rd. Internat. Palynological Conferences, "Palynology Holocene and Marine Palynology* (ed. N. A. Khotinsky)", Moscow, Nauka, p. 76—80.

Nakai, N., Ohta, T., Fujisawa, H. and Yoshida, M. (1982): Paleoclimatic and sea-level changes deduced from organic carbon isotope ratios, C/N ratios and Pyrite contents of cored sediments from Nagoya Harbor, Japan. *Quaternary Res.*, vol. 21, p. 169—177.

Nakai, N., Mori, S. and Ohta, T. (1982): Climatic and sea-level changes deduced from $\delta^{13}C$ and C/N of sedimentary organic matters and Pyrite contents of sediment columns from brackish basins for the past 20000 years. *Fifth Internat. Conf. Geochronol. Cosmochronol., Isotope Geol.* (*Abst.*), 261—262.

Kohoku-gata 河北潟, Kanazawa 金沢, Jomonian Age 縄文時代, Yayoian Age 弥生時代, Kokahoku-irie 古河北入江, Konan-ohashi 湖南大橋, Tsubata 津幡, Asano River 浅野川, Lake Biwa 琵琶湖, Yurakucho Transgression 有楽町海進

能登半島基部の河北潟底下には，過去２万余年間の，いわゆる有楽町海進によって形成された沖積層が連続して堆積している。ボーリングによって得られたこの地層を花粉分析し，各時代の古植生を復元した結果，次に述べるような結論をえた。

(1) 過去約２万年間の古気候の変化と北欧地域の花粉分帯との対比

最近 1,500 年間（花粉亜帯 A-d）‥‥温和で湿潤，Subatlantic 期に対比

1,500～5.000 年前（花粉亜帯 A-c）‥‥冷涼でやや乾燥，Subboreal 期に対比

5,000～8,000 年前（花粉亜帯 A-b）‥‥温暖湿潤，Atlantic 期に対比

8,000～11,000 年前（花粉亜帯 A-a）‥‥やや寒冷でやや湿潤，Preboreal ～ Younger Dryas 後期に対比

11,000～12,000 年前（花粉亜帯 B-d）‥‥冷涼やや湿潤；Younger Dryas 前期～Older Dryas 期に対比

12,000～14,000 年前（花粉亜帯 B-c）‥‥やや寒冷やや乾燥；Bölling～Oldest Dryas 後期に対比

14,000～16,500 年前（花粉亜帯 B-b）‥‥寒冷でやや乾燥；Oldest Dryas 前期～それ以前に対比

16,500～21,000 年前（花粉亜帯 B-a）‥‥寒冷～やや寒冷で乾燥；Oldest Dryas 期以前

(2) 上述の花粉分析に基づく古気候の変化は，同一ボーリング・コア・サンプルの $\delta^{13}C$ 分析（名大・中井信之）より解析して得られた古気候の変化ともよく一致する。

(3) 河北潟周辺での稲作農耕は，放射性炭素測定による年代によると約 2,400 年前（北陸での縄文晩期頃）に開始され，顕著な稲作農耕は約 1,000 年前からで，この推定は，当地域の古記録ともよく符合する。
