Trans. Proc. Palaeont. Soc. Japan, N.S., No. 144, pp. 490—515, December 30, 1986

822. PALYNOLOGICAL STUDY OF 200-METER CORE SAMPLES FROM LAKE BIWA, CENTRAL JAPAN II: THE PALAEOVEGETATIONAL AND PALAEOCLIMATIC CHANGES DURING THE CA. 250,000 — 100,000 YEARS B. P.*

NORIO FUJI

Department of Earth Science, Faculty of Education,
Kanazawa University, Kanazawa 920, Japan

Abstract. The writer had stated an outline of the palaeovegetational and palaeoclimatic changes during the last 600,000 years from the point of view of palynological investigation of samples taken at intervals of 5 m throughout a 200-meter core drilled at the lake bottom 65 m of water depth in Lake Biwa, Japan. The writer further treated about 200 samples taken at intervals of 25 cm over about 50 m between 55 m- to 110 m-horizons of the 200-meter long core for analyses of the detailed vegetational and climatic changes in and around the lake during about 150,000 years between about 250,000 years B.P. and 100,000 years B.P.

On the basis of the pollen diagrams, the lacustrine deposits during the time 250,000 to 100,000 years B.P. are divided palynologically into four pollen zones.

In the global correlation between the palaeoclimate from Lake Biwa, other terrestrial records from Central Europe, the sea level changes from Southern Kanto in Japan and Western Mediterranean, and the oxygen isotope records from the Caribbean Sea and Equatorial Pacific *etc.*, the writer found a remarkably noticeable similarity between major trends from them.

Introduction

The present writer had reported on outline of the palaeovegetational and palaeoclimatic changes during the last about 600,000 years based on the palynological analyses of samples taken at intervals of about 5 meters throughout a 200-meter core obtained from Lake Biwa, Central Japan (Fuji, 1973, 1983, Fuji & Horie, 1972, 1977). The climatic curve and ages ascertainable from Lake Biwa were found to display a similarity to the palaeotemperature curve (oxygen isotope ratio determination) from the Caribbean Sea (Emiliani & Shackleton, 1974) and the Equatorial Pacific (Shackleton & Opdyke, 1976, 1977), and to the environmental changes (loess, palaeosol and gastropod faunal records) from Central Europe (Kukla, 1970,

*: Received October 7 1985; revised manuscript received October 11, 1986; Read June 18, 1977 at Shizuoka University and June 24, 1984 at Akita University.

Contribution from the Department of Earth Science, Faculty of Education, Kanazawa University; New Series No. 119.

1975).

The writer further treated about 200 samples taken at intervals of 25 cm throughout about 50 meters from 55 meters to 110 meters—horizons in depth of the 200-meter core for analyses of the detailed vegetational and climatic changes around Lake Biwa in the period, about 150,000 years, between about 250,000 years B.P. and about 100,000 years B.P.

In this article, the vegetational and climatic changes ascertainable from Lake Biwa in the period between about 250,000 years ago and about 100,000 years ago will be discussed from the view point of palynological analyses.

Additionally the topography, geology, vegetation, and climate around Lake Biwa, and detailed description on the method for reconstruction of palaeoclimate were already given in the writer's paper (Fuji, 1983).

Acknowledgments

I am greatly indebted to Emeritus Prof. Herbert E. Wright Jr. of the Limnological Research Centre, University of Minnesota, Minneapolis, U.S.A., and to Prof. Shoji Horie of the Institute of Palaeolimnology and Palaeoenvironment on Lake Biwa, Kyoto University for their kind advice and for the helpful critical reading of the manuscript. I am indeed grateful for the support and encouragement of Emeritus Prof. Teiichi Kobayashi of University of Tokyo during this investigation. I also acknowledge the help of the member of the Lake Biwa Palaeolimnological Research Group, especially the late Prof. Naoto Kawai of Osaka University, Prof. Takuo Yokoyama of Doshisha University, Prof. Sei'ichi Kanari of Hokkaido University, and Prof. Nobuyuki Nakai of Nagoya University. My investigation was possible through a Scientific Grant from the Ministry of Education, Japanese Government for fifteen years (1971 to 1985) and a help of University of Minnesota, U.S.A.

Palynological investigation

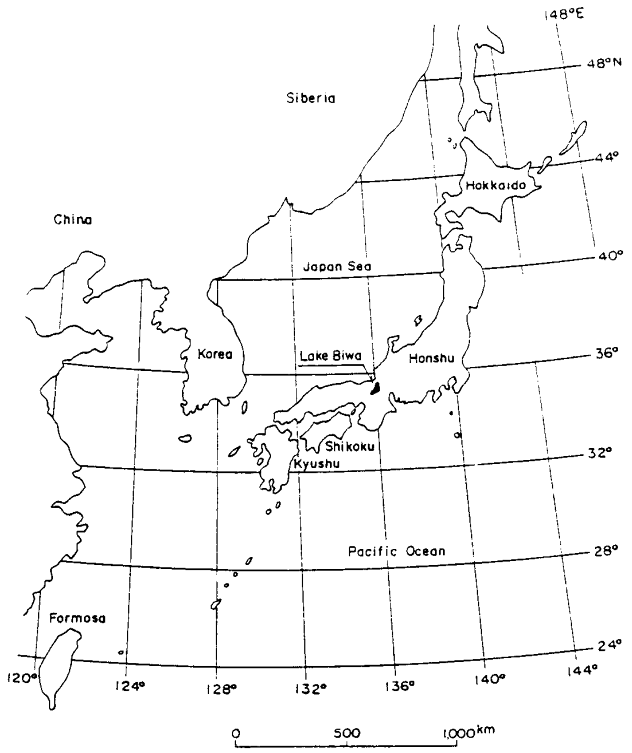
(A) Locality of the boring and samples

A 200-meter core used for the present palynological analyses was drilled in 1971 from the bottom of Lake Biwa 65 meters below the present lake water level. The core samples are composed mainly of dark greenish blue soft homogeneous muddy clay with about 30 thin volcanic ash layers. About 200 samples taken at intervals of about 25 cm from 55 meters to 110 meters below the present lake bottom were analyzed. The samples taken from the same horizons were analyzed for geochemical and organic chemical components, fossil diatom and microanimals, and also from the view points of palaeomagnetism and granulometric analyses.

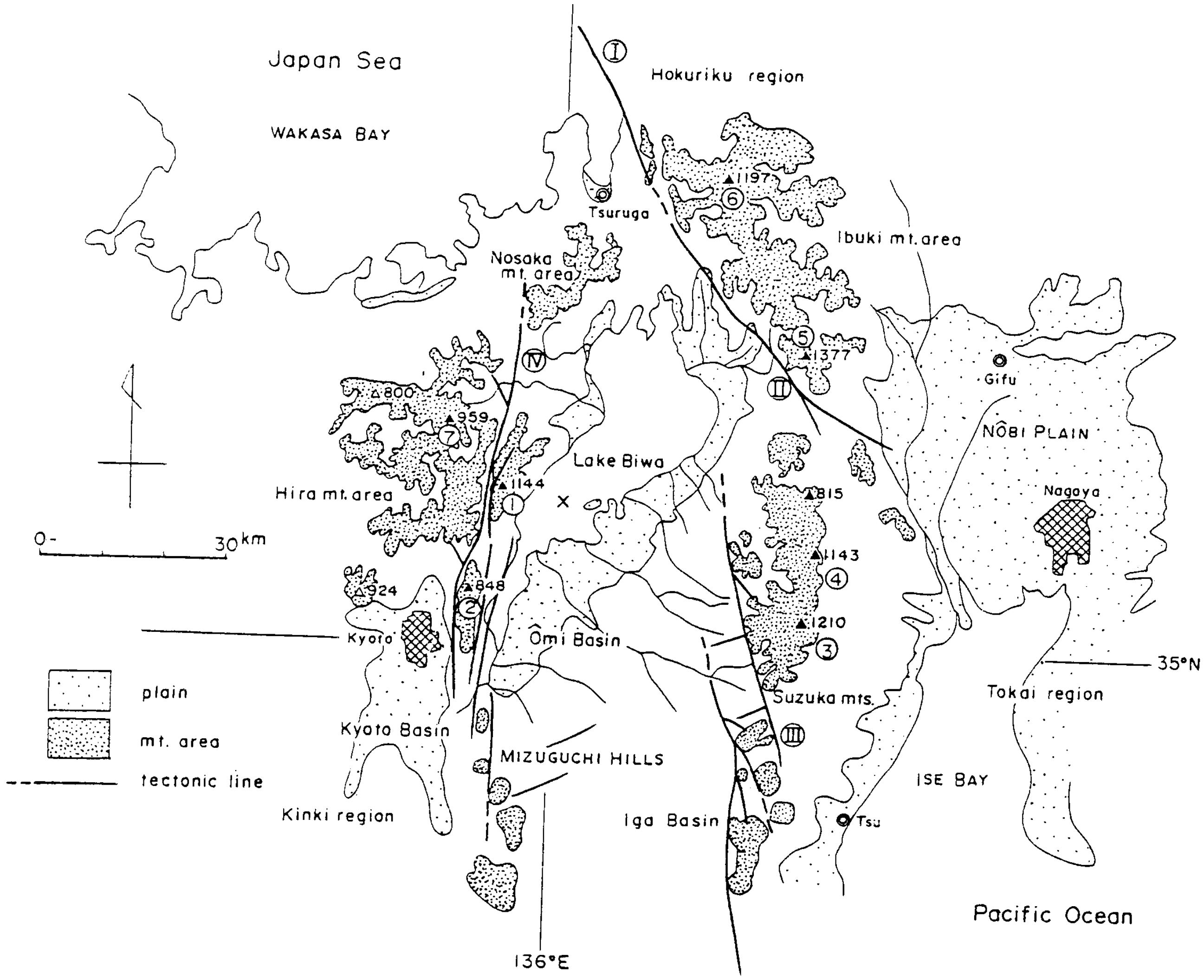
(B) Preparation and examination for pollen analyses

The samples were treated by the HF-KOH-acetolysis method, and then treated by a saturated solution of $ZnCl_2$.

The pollen grains and spores mounted on slides for a microscopic observation were identi-



Text-fig. 1. Locality map showing the studied area.



①: Mr. Hira, ②: Mt. Hiei, ③: Mt. Gozaisho, ④: Mt. Fujihara-dake, ⑤: Mt. Ibuki, ⑥: Mt. Mikuni-ga-dake, ⑦: Mt. Mikuni-dake, Ⓘ: Kaburaki tectonic line, Ⓘⓘ: Yanagase tectonic line, Ⓘⓘⓘ: Suzuka tectonic line, x : boring locality.

Text-fig. 2. Topographic map of the Lake Biwa area, Central Japan (after Fuji, 1983).

fied and counted by use of a mechanical stage of a microscope (Olympus Nomarsky-type tricular microscope). The counting of pollen grains was continued until more than 1,000 arboreal pollen grains. The identification of pollen grains was conducted with the aid of a reference collection of about 500 slides of important trees, shrubs, and acquatic herbs of the Japanese Islands in possession of the Department of Earth Science, Kanazawa University, and also a reference collection of about 9,000 slides kept in the Limnological Research Centre, University of Minnesota, Minneapolis, the United States of America.

(C) Construction of the diagrams

Shown from the left to the right in the pollen diagrams are sediment stratigraphy and lithofacies, depth in meter, spectrum number, fission-track dates, palaeomagnetic stratigraphy, pollen zoning, palaeoclimate, summary diagram, pollen profiles of each taxon and assemblage zones. The pollen sum was used on the pollen types concerned on the local situation and on the kind of deposits.

Percentages in the diagrams of this article are shown on two scales; the scale with 10 × exaggeration permits the accurate plotting of minor curves and minor fluctuations. The summary diagram is composed of changes in the ratio between total AP and total NAP, and of the percentage of boreal type plants (Polar — Subpolar plants), Cool Temperate plants, Cool Temperate — Temperate plants, plants of the middle area of the Cool Temperate — Warm Temperate zone, and plants of the southern area of the Temperate — Subtropical zone, calculated on the basis of the warmth index (month-degress) as described in a later section.

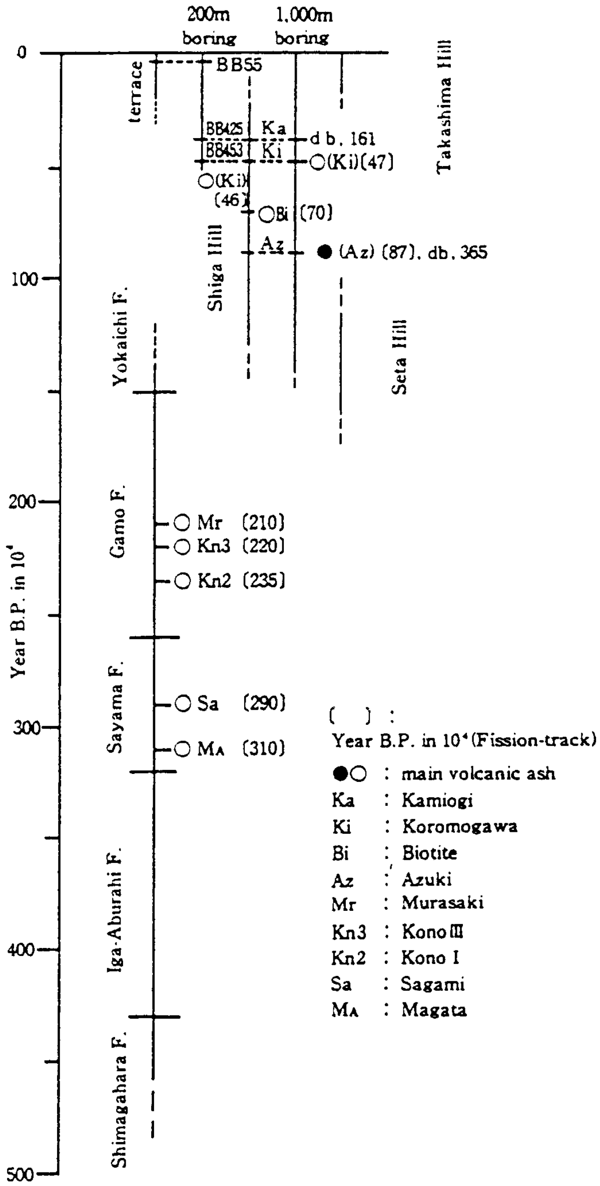
(D) Method for interpretation of palaeovegetation and climatic history

The writer depends upon the pollen analyses for the reconstruction of vegetation on the basis of the pollen spectra obtained from the 200-meter core samples. He has employed two methods, namely, (1) pollen spectra of the modern samples collected from Lake Biwa and its vicinity, and also from various localities of some climatic zones throughout the Japanese Islands, and (2) the warmth index (month-degrees). With regard to this index, the detailed descriptions were already given (Fuji, 1983).

(E) Dating and sedimentation rates

The dating of the core samples in the representative depth of the core gives important and useful information. The determination of the age for the upper 11.5 meters of the core obtained from Lake Biwa has been carried (Horie *et al.*, 1971). In the recent study of the 200-meter core samples, Nishimura and Yokohama (1975) present the invaluable data concerning the age-determination of the deeper horizon of the core by the fission-track method. These results enable the present writer to determine the date of the boundary between the glacial and interglacial ages, or between the stadial and interstadial, or of characteristic events in a climatic fluctuation of the ancient Lake Biwa.

The age was determined by applying a suitable curve-fitting method to the basic data obtained from the ^{14}C and fission-track methods as shown in Table 1. According to Kanari's calculation (Kanari & Takanoya, 1975), the absolute age at



Text-fig. 3. Chronological correlation among the Quaternary deposits in and around Lake Biwa (after Fuji, 1983).

the horizon of 200 meters below the bottom surface is 565,000 years B.P., which is not inconsistent with the stratigraphic data and the results inferred from the palaeomagnetism and palaeoclimate on the basis of the correlation between the writer's previous curve from Lake Biwa (samples from 5 meters interval) (Fuji, 1983) and Emiliani's generalized temperature curve (Emiliani & Shackleton, 1974) for the Caribbean Sea for the last about 700,000 years.

In 1973, a new method of age determination was developed for the core under the condition of a constant sedimentation rate (Yamamoto *et al.*, 1973). The age of the respective layer of the 200-meter core is estimated for the constant sedimentation rate of 0.354 mm/yr., which corresponds well to the observed sedimentation rate at the present (Toyoda *et al.*, 1968).

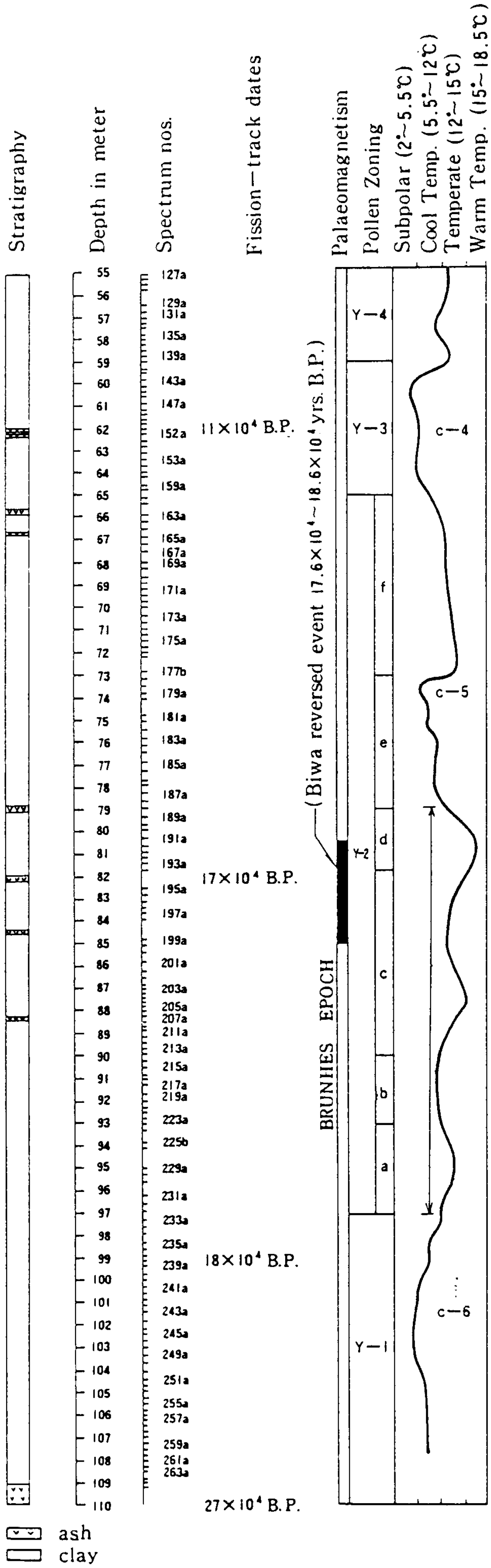
(F) Zoning of pollen assemblage

In order to facilitate description of pollen assemblages and their discussion, the pollen diagrams are divided into zones and subzones. These zones and subzones are based upon conspicuous changes in pollen percentages. Changes in the ratio, Total AP/Total NAP, can be described, while alternation of the 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 present 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. Minor differences of the pollen assemblage in the zones lead to determining subzones.

According to the present writer's analyses, the deposits are divided into four pollen zones, Y-1, Y-2, Y-3, and Y-4 in an ascending order, and the Y-2 pollen zone is classified into six pollen subzones by minor differences of pollen assemblage and their characters.

(1) **Pollen Zone Y-1**, depth: 108 — 97 m; 240,000 — 200,000 yr.B.P.

This zone is characterized by a large value of boreal conifers such as *Abies*, *Picea*, *Tsuga*, *Larix* and *Pinus haploxylon*-type. These conifers reach to 76 — 99% (about 90% on average). The characteristic plants growing only in the Subpolar or Subalpine zone (warmth index in month degrees: 15 — 55°) show the value of about 5% on average, though the plants range from 0.2 to 0.7% in the



Text-fig. 4. Stratigraphy, spectrum nos., fission-track data, palaeomagnetism, pollen zoning, and palaeoclimatic change of the 55 to 110 meters samples from a 200-meter core of Lake Biwa. Arrow part: climatic cord no. t-5 other pollen zones. In contrast to them, *Pinus diploxylon*-type, which includes the temperate *Pinus thunbergii* and *P. densiflora*, shows a low percentage. In this zone, trees such as *Ulmus*, *Betula* and *Fagus* large type which grow in the Cool Temperate zone, have the lowest value (average 1.5%) throughout all these pollen zones. The same phenomena are recognized in the frequency of plants (pollen grains) which grow in the Cool Temperate and Temperate zones, in the middle area of the Cool Temperate and Temperate zones, and in the southern area of the Temperate and Subtropical zones. The main component of the Y-1 pollen zone is *Abies* (55 – 86%), *Tsuga* (10–27%), *Picea* (5–15%), and *Pinus haploxylon*-type (4 – 8%).

(2) **Pollen Zone Y-2,** depth: 97 – 65 m; 200,000 – 126,000 yr.B.P.

The Y-2 pollen zone is characterized by the abundance of plants which grew in the Cool Temperate zone, and in the Cool Temperate and Temperate zones. However, on the frequency throughout all this zone, plants adapted to the climate of the southern part of the Temperate and Subtropical zones are not always abundant. Boreal conifers such as *Abies*, *Picea*, *Tsuga*, and *Larix* are few throughout this zone.

On the basis of fluctuations in the pollen values of boreal conifers and minor changes of other types, this zone is divided into six pollen subzones, Y-2-a, Y-2-b, Y-2-c, Y-2-d, Y-2-e, and Y-2-f.

Y-2-a Pollen Subzone, depth: 97–93 m; 200,000 – 193, 000 yr.B.P.

This pollen subzone is characterized by a drastic change of pollen assemblage; accordingly, boreal conifers including Subpolar plants such as *Pinus haploxylon*-type show an abrupt decrease (lowering to 52% from 90%) in comparison with the Y-1 pollen zone. In contrast to them, the pollen frequency of plants which thrive in the Cool Temperate and Temperate zones shows a higher value than that of the Y-1 pollen zone, although the relative frequency of plants which grow in the southern part of the Temperate and Subtropical zones do not increase as much as that of the Cool Temperate plant. This pollen assemblage is shown as follows: Subpolar or Subalpine plants (only conifers) 0.9%, boreal conifers 52%, Cool Temperate plants 5.5%, Cool Temperate – Temperate plants 0.9%; the main component is *Abies* (23–51%)-*Cryptomeria* (6–28%)-*Pinus diploxylon*-type (12–14%)-*Tsuga* (9–13%)-*Alnus* (9%)-*Fagus* small type (7%)-*Lepidobalanus* (3–7%).

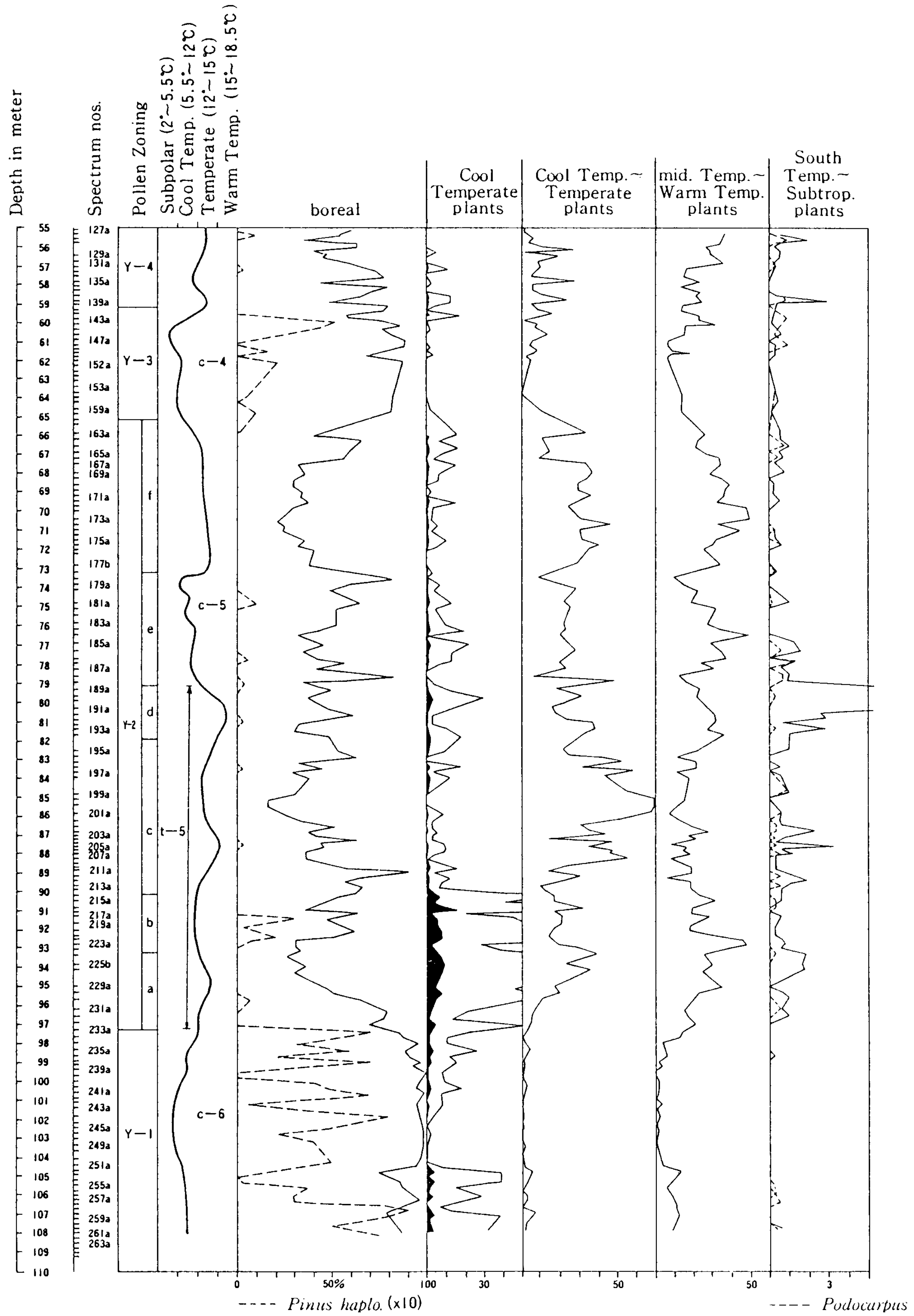
Y-2-b Pollen Subzone, depth: 93–90 m; 193,000 – 185,000 yr.B.P.

The main component of this pollen subzone is *Pinus diploxylon*-type (13–37%)-*Abies* (15–36%)-*Cryptomeria* (9–29%)-*Tsuga* (26%)-*Lepidobalanus* (10–15%)-*Fagus* large type (4–16%). This pollen assemblage is as follows: Subpolar or Subalpine plants 0.3–3% (average 1.2%), boreal conifers 31–64% (average 49%), Cool Temperate plants 2–16% (average 6.2%), Cool Temperate–Temperate plants 12–32% (average 18%), middle area of the Cool Temperate–Temperate plants 17–47% (average 27%), and south area of the Temperate–Subtropical plants 0.2–0.8% (average 0.5%). As mentioned above this subzone is characterized by a little increase of plants of the Cool Temperate zone and a decrease of boreal conifers, especially the frequency of plants of the Cool Temperate zone has the highest value throughout the samples.

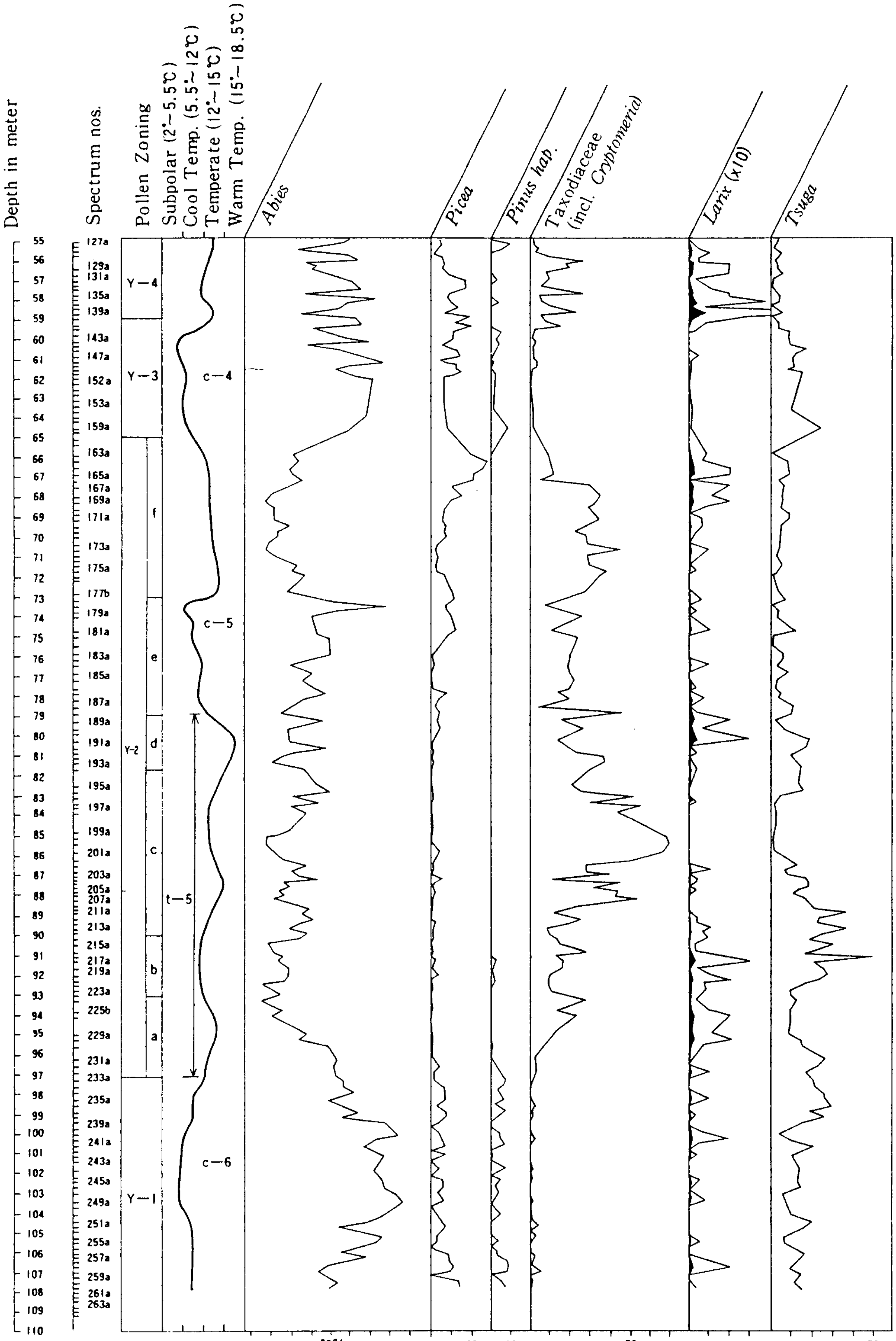
Y-2-c Pollen Subzone, depth: 90–82 m; 185,000 – 166,000 yr.B.P.

This pollen subzone is characterized by the smallest value of Subpolar or Subalpine plants throughout all the samples treated at the present and, in contrast to the above-mentioned phenomenon, by the largest value of plants thriving in the Cool Temperate–Temperate zones over all the samples. The pollen assemblage of this pollen subzone is shown as follows: Subpolar plants 0 – 1% (average 0.2%), boreal conifers 16–70% (average 44%), Cool Temperate plants 0–1.9% (average 0.6%), plants in the Cool Temperate – Temperate 14–69% (average 39%), plants growing in the middle area of the Cool Temperate and Temperate zones 7–36% (average 16%), plants thriving in the southern area of the Temperate and Subtropical zones 0–3.3% (average 0.8%).

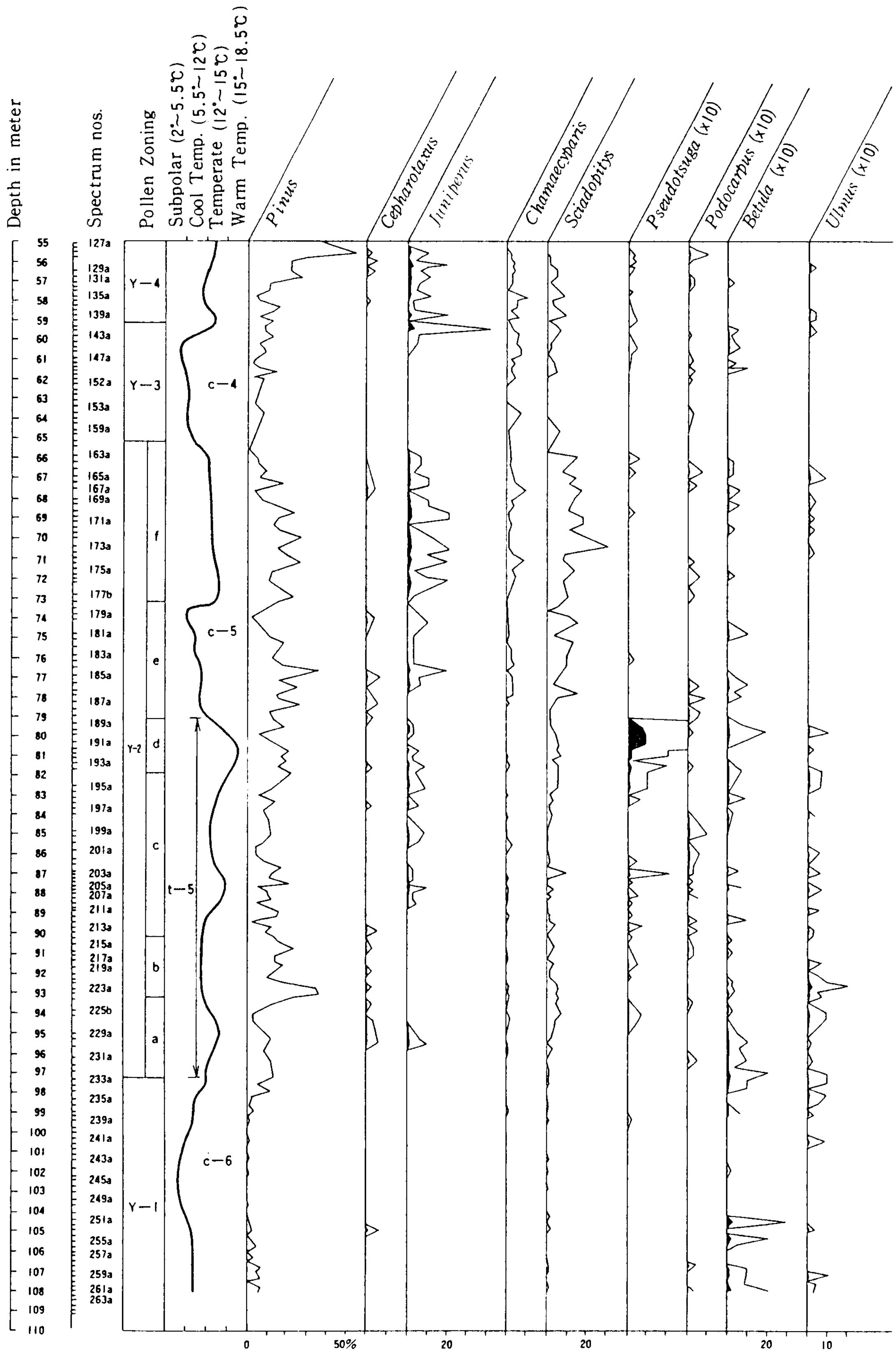
The main element of this pollen subzone is



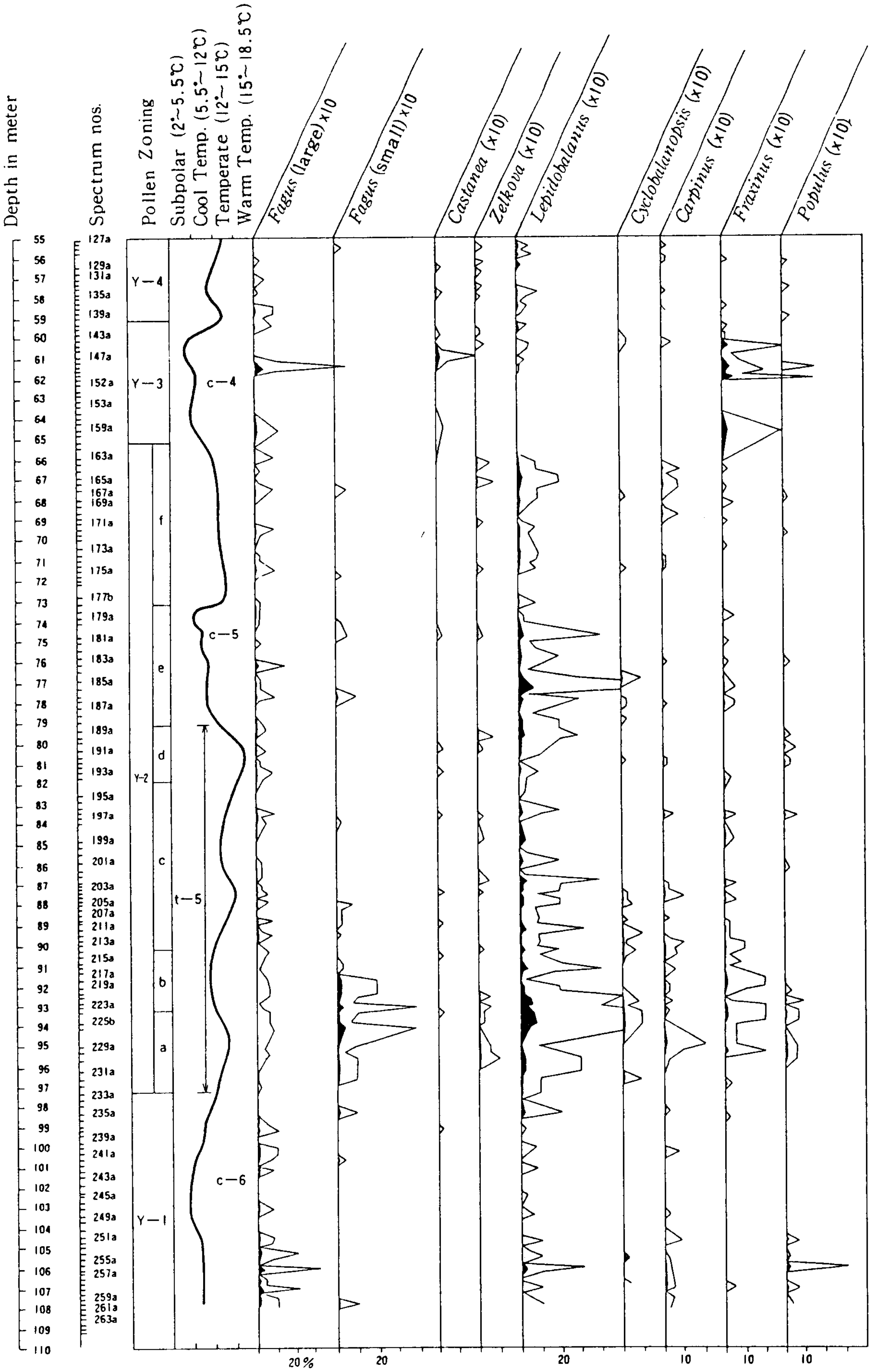
Text-fig. 5. Summary diagram of the 55 to 110 meters samples from the 200-meter core.



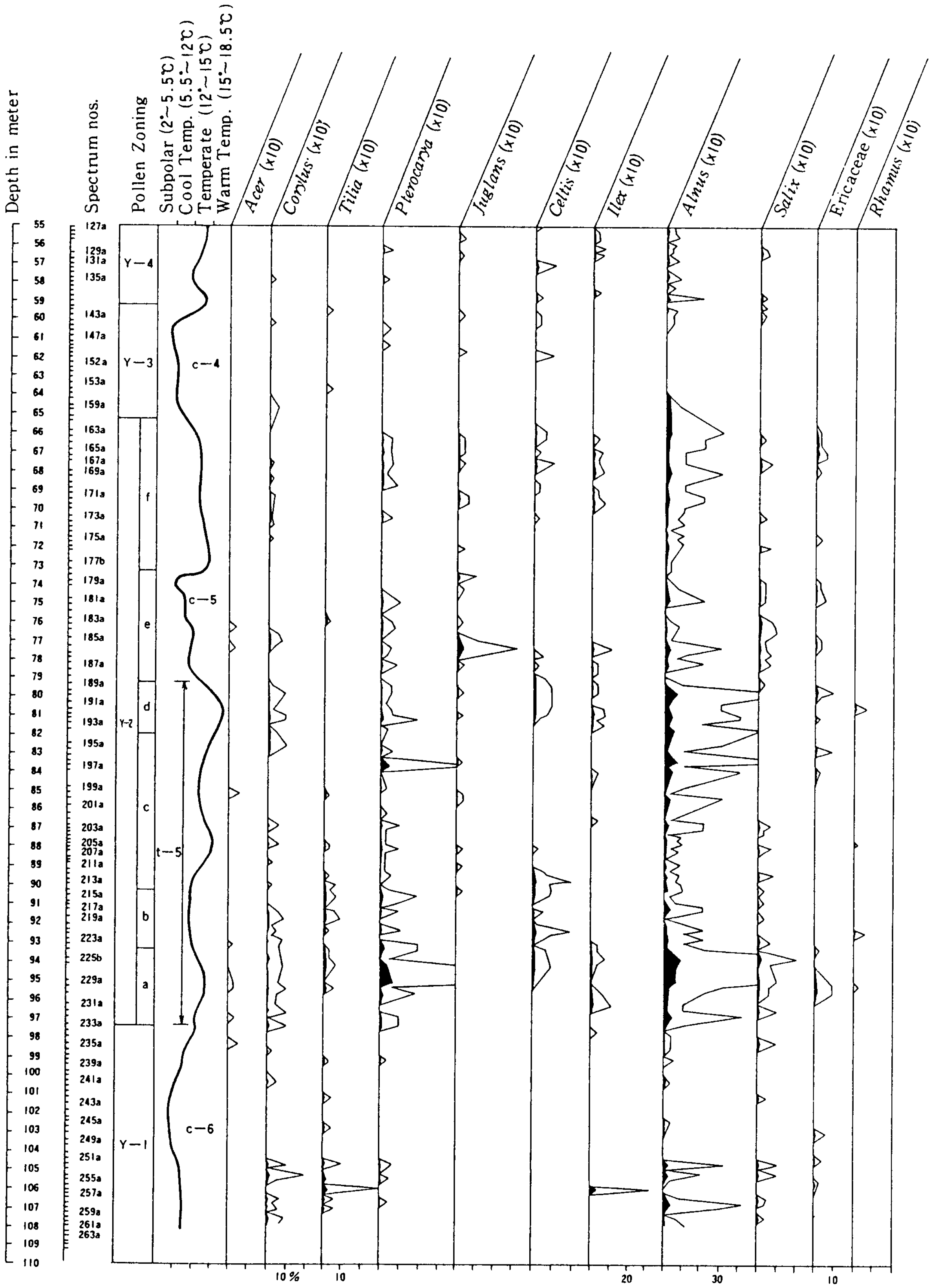
Text-fig. 6. Conifers pollen diagram of the 55 to 110 meters samples from the 200-meter core.



Text-fig. 7. Conifers and deciduous broad leaved plant pollen diagram from the 200-meter core.



Text-fig. 8. Broad leaved plant pollen diagram from the 200-meter core (1).



Text-fig. 9. Broad leaved plant pollen diagram from the 200-meter core (2).

Cryptomeria (21—69%) — *Abies* (19—46%) — *Pinus diploxylon*-type (5—22%)-*Tsuga* (2—16 %) — *Lepidobalanus* (4%) — *Sciadopitys* (2—5%).

Y-2-d Pollen Subzone, depth: 82—79 m; 166,000 — 158,000 yr.B.P.

This pollen subzone is characterized by the largest amount of plants thriving in the southern part of the Temperate — Subtropical zones. The percentage of *Podocarpus* ranges from 0.3 to 1.2% (average 0.3%). The main component of this pollen subzone is *Cryptomeria* (17—46%)-*Abies* (22—43%) — *Pinus diploxylon*-type (18—20%) — *Tsuga* (10—19%); and also, Subpolar or Subalpine zone 0—3% (average 0.9%), boreal conifers 30—63% (average 42%), Cool Temperate plants 0.3—3% (average 1.0%), Cool Temperate — Temperate plants 16—48% (average 29%), plants in the middle part of the Cool Temperate — Temperate zones 15—31% (average 26%), and plants in the southern part of the Temperate — Subtropical zones 0.6—9.6% (average 4.5%).

Y-2-e Pollen Subzone, depth: 79—73 m; 185,000 — 144,000 yr.B.P.

In this pollen subzone, a decrease of plants in the southern part of the Temperate — Subtropical zones is matched by a similar increase in the value of boreal conifers. The pollen assemblage is shown by boreal conifers 32—83% (average 54%), Subpolar plants 0—1% (average 0.3%), Cool Temperate plants 0—2.4% (average 0.7%), plants in the Cool Temperate — Temperate zones 5—48% (average 21%), plants in the middle part of the Cool Temperate — Temperate zones 9—49% (average 27%), and plants growing in the southern part of the Temperate — Subtropical zones 0—2% (average 0.5%). The main component of this pollen subzone is *Abies* (24—70%), *Pinus diploxylon*-type (10—35%), *Cryptomeria* (14—27%), and *Sciadopitys* (about 10%). Besides these conifers, *Sciadopitys* is one of evergreen conifers and grows only in the recent montane areas of the Kii Peninsula, Shikoku and Kyushu regions, and also this pollen subzone is characterized by a higher value of this plant.

Y-2-f Pollen Subzone, depth: 73—65 m; 144,000 — 126,000 yr.B.P.

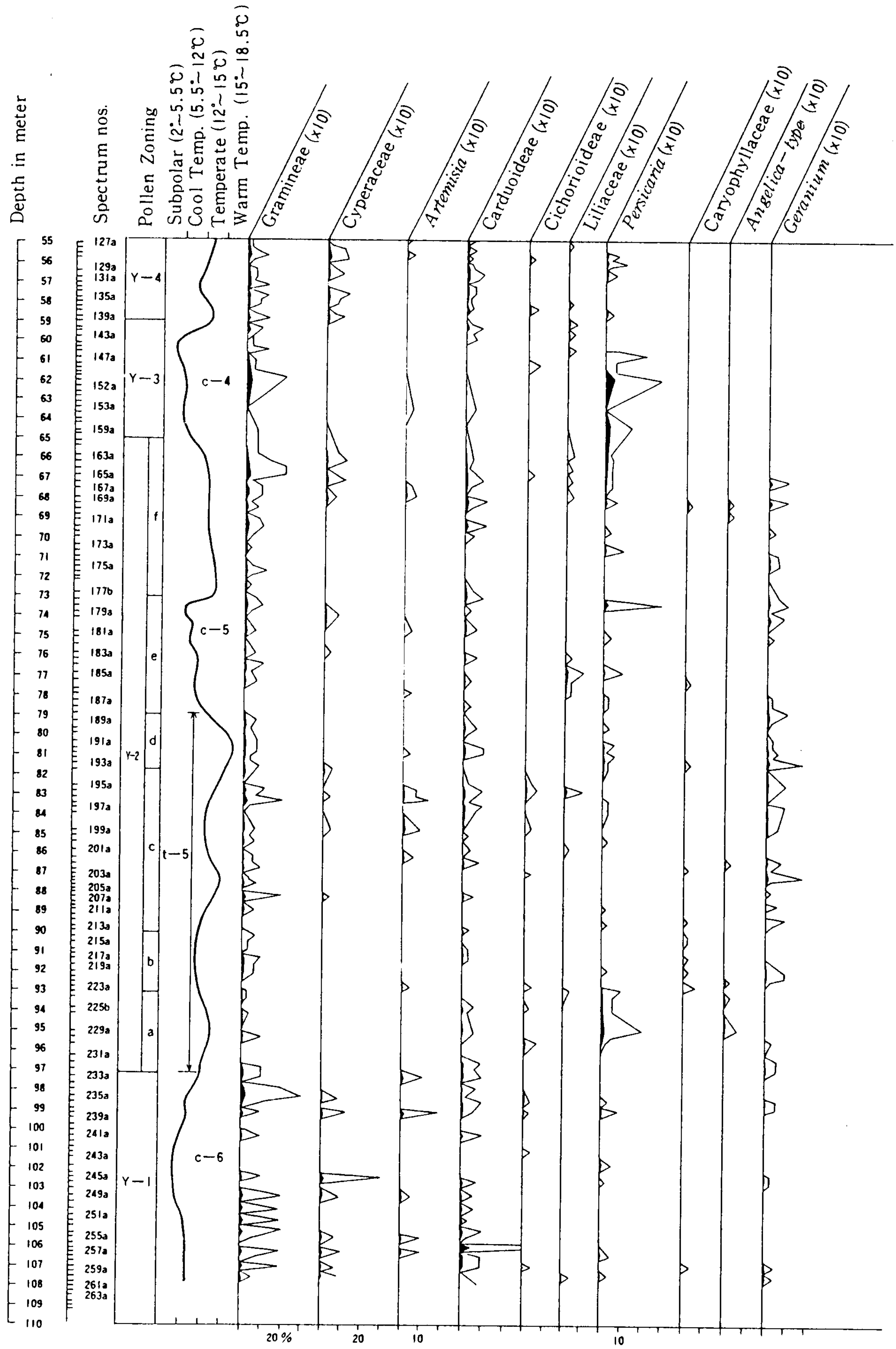
This pollen subzone is characterized by a decrease of boreal conifers. This decrease is matched by an increase of plants of the Cool Temperate — Temperate zones. The pollen assemblage of this pollen subzone is shown by *Cryptomeria* (12—46%)—*Abies* (14—45%) — *Sciadopitys* (11—29%).

(3) **Pollen Zone Y-3**, depth: 65 — 59 m; 126,000 — 113,000 yr.B.P.

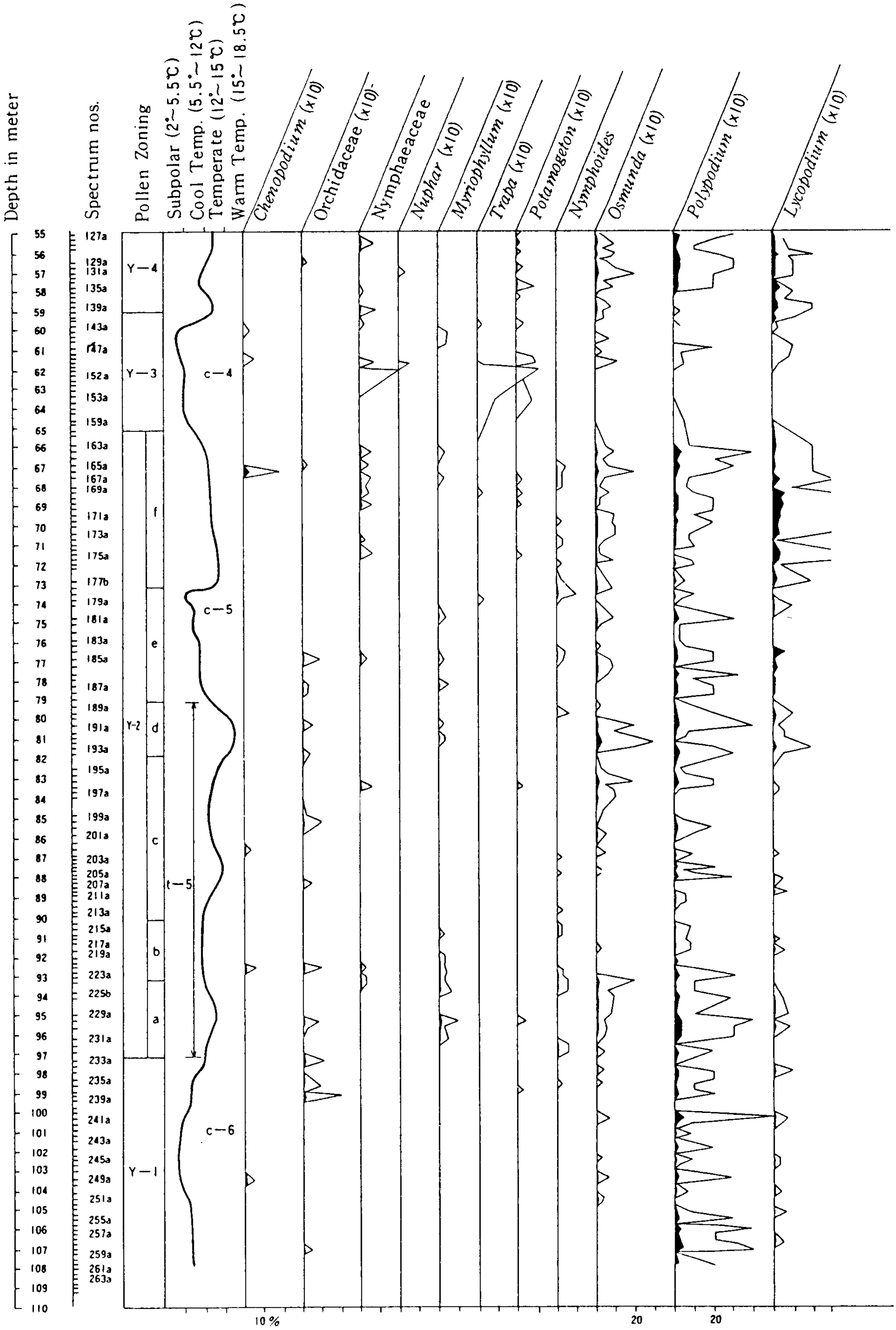
This pollen zone is characterized by a drastic increase of boreal conifers (up to about 80%) and Subpolar plants (up to 2%), and by a decrease of plants of the Cool Temperate — Temperate zones and of the middle area of the Cool Temperate — Temperate zones. The pollen assemblage is shown by Subpolar or Subalpine plants 0.8 — 5% (average 2%), boreal conifers 57—88% (average 80%), Cool Temperate plants 0—2% (average 0.6%), plants of the Cool Temperate — Temperate zones 0.4—7.5% (average 0.2%), plants in the middle area of the Cool Temperate — Warm Temperate zones 6—19% (average 11%), and plants in the southern Temperate — Subtropical zone 0—0.4% (average 0.1%). The main component is *Abies* (average about 55%)—*Picea*—*Tsuga*—*Cryptomeria*.

(4) **Pollen Zone Y-4**, depth: 59—55 m; 113,000—104,000 yr.B.P.

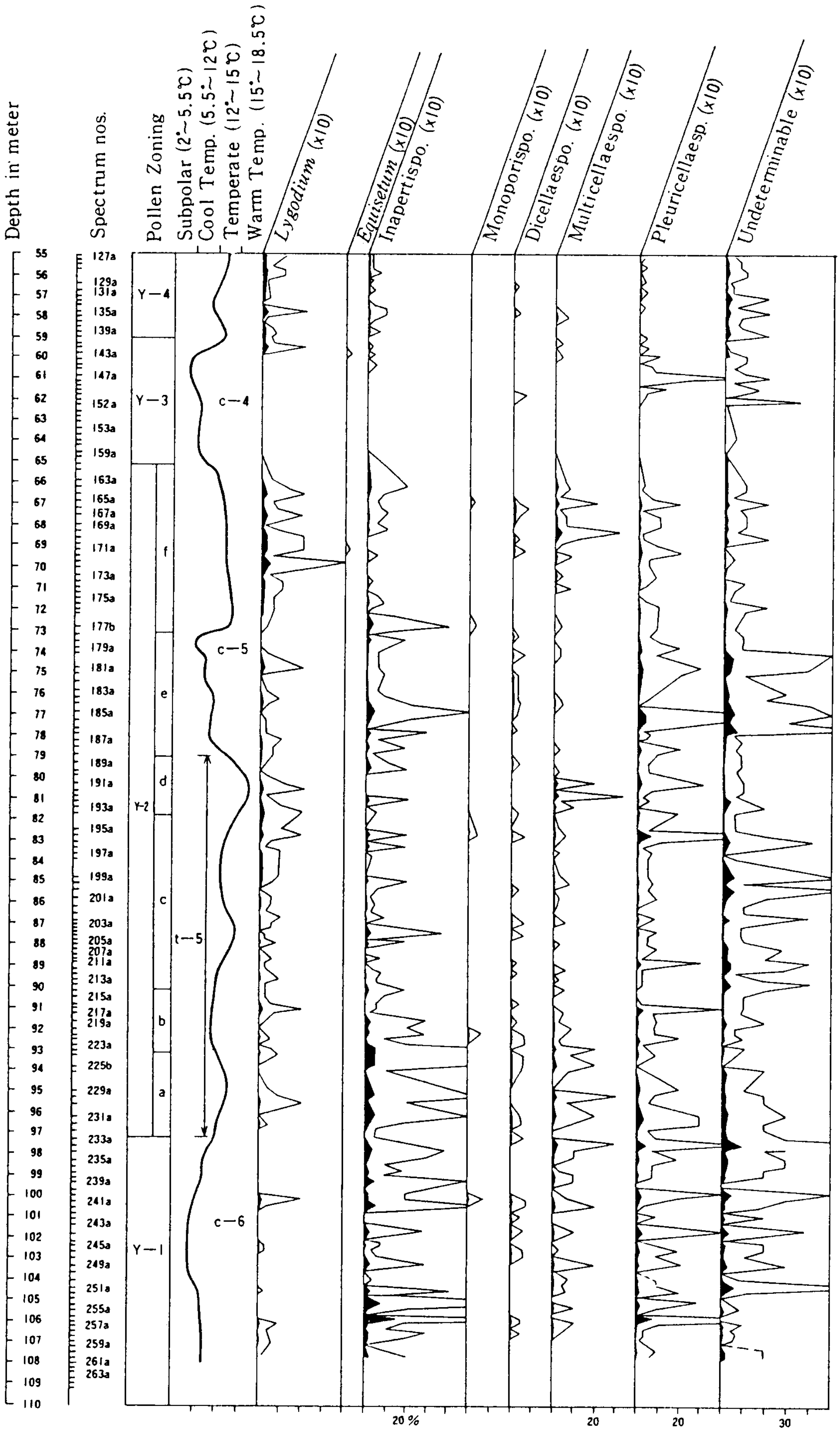
In this pollen zone, a drastic increase of plants growing in the Cool Temperate — Temperate zones and in the middle area of the Cool Temperate—Warm Temperate zones is matched by an abrupt decrease of boreal conifers and Subpolar plants. The pollen assemblage is shown as follows: Subalpine or Subpolar plants 0—4% (average 1.5%), boreal conifers 34—81% (average 57%), plants of the Cool Temperate zone 0 — 1.3% (average 0.3%), plants in the Cool Temperate—Temperate zones 2—29% (average 12%), plants in the middle area of the Cool Temperate —Warm Temperate zones 13—59% (average 29%), and plants in the southern Temperate—Subtropical zones 0—2% (average 0.8%).



Text-fig. 10. Non-arboreal pollen digaram from the 200-meter core (1).



Text-fig. 11. Non arboreal pollen diagram from the 200-meter core (2).



Text-fig. 12. Non-arboreal pollen diagram from the 200-meter core (3).

Discussion on the interpretation of vegetation and climatic history

Pollen Zone Y-1 is characterized by a high percentage of boreal conifers. The maximum value for *Pinus haploxylon*-type, one of the representative plants of the Subpolar or Subalpine zone in the Japanese Island, reaches to about 5% on average in this zone, which is the highest value over all the samples. In contrast, trees growing in the other climatic zones are not abundant. In addition, boreal conifers reach to the highest value of 76—99% (average 90%). Judging from such pollen assemblages and frequencies of the other pollen zones, the climate at that time of this zone may have been as cold as that in the northern part of the Cool Temperate zone. This cold climatic age is correlated with the "c-6" in the present writer's previous paper (Fuji, 1983).

Pollen Subzone Y-2-a is characterized generally by a drastic decrease (low to 50% from 90%) of boreal conifers, and by a high percentage of plants in the Cool Temperate — Temperate zones in comparison with the Y-1 Pollen Zone. *Abies*, *Cryptomeria*, *Pinus diploxylon*-type and *Tsuga* are the main component in this pollen subzone. The climate at the time of Pollen Subzone Y-2-a was perhaps similar to that of the Cool Temperate—Temperate zones. Therefore, the climate at that time may have been corresponded to that of the Cool Temperate — Temperate zones.

Pollen Subzone Y-2-b is featured by the abundance of plants growing in the Cool Temperate zone and in the middle area of the Cool Temperate from the view point of palaeovegetation. The frequency of *Podocarpus* pollen is more than those of Pollen Subzone Y-2-a and Pollen Zone Y-1. Accordingly, the climate at that time may have been as warm as that of Pollen Subzone Y-2-a.

Pollen Subzone Y-2-c is characterized by the smallest value of Subpolar-type plants and the largest value of plants thriving in the Cool Temperate — Temperate zones. In addition, plants in the Cool Temperate zone show a drastic decrease. Judging from these data, the climate at that time may have perhaps been similar to that of the southern part of the Cool Temperate — Warm Temperate zones.

In the Y-2-d Pollen Subzone, plants in the southern area of the Temperate — Warm Temperate zones have the highest value (average 4.5%), and, in contrast, plants thriving in the Subpolar and the Cool Temperate zones show a smaller value. Therefore, the climate at the time of Pollen Subzone Y-2-d was perhaps that of the southern area of the Temperate — Warm Temperate zones.

Pollen Subzone Y-2-e is characterized by a decrease of plants in the southern area of the Temperate — Warm Temperate zones and by a similar increase in the value of boreal conifers.

Therefore, the climate at the time of Subzone Y-2-e may have been that of the middle area of the Cool Temperate zone.

Pollen Subzone Y-2-f is characterized by a decrease of boreal conifers and, in contrast to this phenomenon, plants of the Cool Temperate — Temperate zones and of the middle area of the Cool Temperate — Warm Temperate zones decreased. Namely, the climate at the time of this pollen subzone may have been similar to that of the northern area of the Temperate zone. As mentioned above, from the view point of the palaeoclimate, Pollen Zone Y-2 may perhaps be one of the interglacial age, and is divided into six subzones. The palaeoclimate at the time of Pollen Zone Y-2 was clearly warmer than those of Pollen Zones Y-1 and Y-3. Most of this pollen zone correspond to the "t-3" mentioned in the present writer's previous paper (Fuji, 1983).

Pollen Zone Y-3 is characterized by a drastic increase of boreal conifers and by an increase of plants of the Cool Temperate — Temperate zones and of the middle area of the Cool Temperate — Warm Temperate zones. Therefore, the climate at the time of this pollen zone may have correspond to a climate of the northern area of the Cool Temperate zone and this time was perhaps one of the glacial age. This pollen zone is correlated with the "c-4" of the present writer's previous paper (Fuji, 1983).

Pollen Zone Y-4 is characterized by a drastic increase of plants in the Cool Temperate — Temperate zones and in the middle area of the Cool Temperate — Warm Temperate zones and by an abrupt decrease of boreal conifer trees. The climate at that time may have been similar to that of the middle area of the Cool Temperate zone or that of the northern area of the Temperate zone.

Data for "time-stratigraphy"

Ages of boundaries between the pollen zones can be estimated by some means such as ^{14}C, fission-track, sedimentary rate, and palaeomagnetic stratigraphy *etc.* (Horie, 1984).

In regard with radioactive age of an upper part of the 200-meter core, the following data are obtained by Isotopes A Telddyne Co. (Horie *et al.*, 1971).

0.8±0.05 m in depth ...	1,430±95 yr.B.P.
4.5±0.15 m in depth ..	3,650±105 yr.B.P.
11.5±0.2 m in depth ..	14,980±460 yr.B.P.

Within the core samples some volcanic ash layers are intercalated. They are at least about forty layers, from which Nishimura and Yokoyama (1975) could successfully obtain the following ages by fission-track method as follows:

37 m in depth	8×10^4 yr.B.P.
62 m in depth	11×10^4 yr.B.P.
82 m in depth	17×10^4 yr.B.P.
99 m in depth	18×10^4 yr.B.P.
110 m in depth	27×10^4 yr.B.P.
181 m in depth	46×10^4 yr.B.P.

In a chronostratigraphic investigation of the core samples, it is necessary to establish the rationale of interpolating between the discrete values of absolute dates. A depositional layer, which once deposited on the surface of the lake bottom, begins to contrast its thickness through the consolidation process under the cumulative load of deposits having a unit section, a depositional layer of thickness $d\zeta$ with bulk density ρ_B, which is situated at the depth ζ beneath the bottom surface at present, is originally that which had deposited on the surface t years ago, forming a layer of thickness dS with bulk density ρ_{BO}. During these t years, the layer has experienced contractions of Δ per unit thickness through consolidation, so that $d\zeta = dS\,(1-\Delta)$. Since the contraction is due to the squeezing of water, the equation of mass conservation then is $\rho_B\,(1-\Delta) = \rho_{BO} - \rho\Delta$, where ρ is the density of water. Thus, the integration of dS over the last t years, that is, the total thickness if not yet consolidated, is

$$S = \int_0^\zeta \frac{d\zeta}{1-\Delta} = \int_0^\zeta \frac{\rho_B - \rho}{\rho_{BO} - \rho}\, d\zeta \, \ldots\ldots\ldots (1)$$

While, assuming the sedimentation rate h(t) to be constant (= h_0),

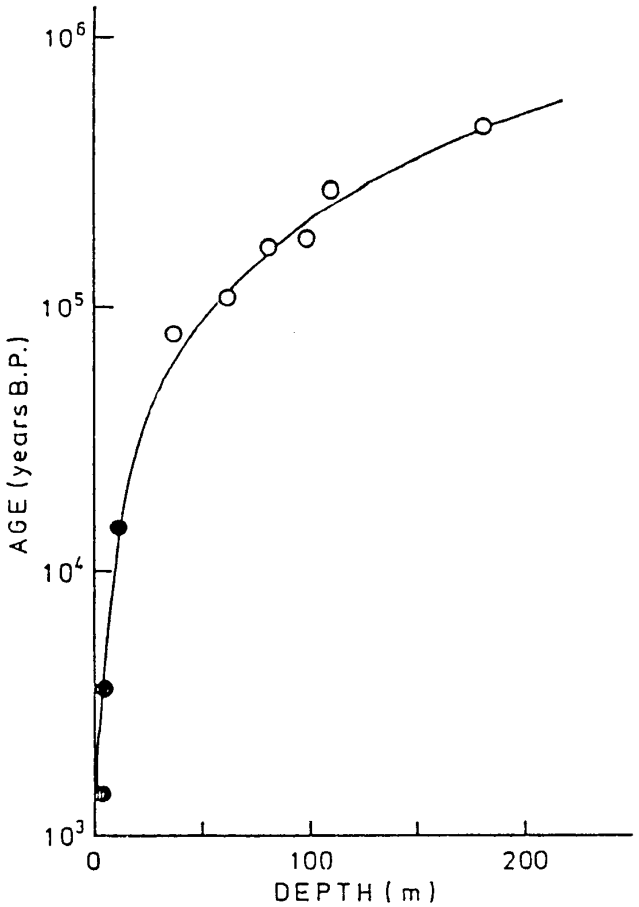
$$S = \int_0^t h\,(t)dt = h_0 t \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Hence, equating (2) to (1) yields:

$$t = \frac{1}{h_0\,(\rho_{BO} - \rho)} \int_0^\zeta (\rho_B - \rho)d\zeta \quad \ldots\ldots (3)$$

Equation (3) ensures the age-scaling along the core sample, when the vertical profile of bulk density and reference ages are given. According to Equation (3), a preliminary age-scale for the 200-meter core was composed in reference to the ^{14}C (Horie *et al.*, 1971) and fission-track dates (Nishimura *et al.*, 1975). The age-scale is empirically modified as shown in Text-fig. 13 (Yamamoto, 1976). On the basis of the age-scale figure (Text-fig. 13), ages of every meter of the 200-meter core are shown in Table 1 (Yamamoto & Higashihara, 1978).

According to the palaeomagnetic stratigraphy (Horie, 1984), the polality epoch of the 200-meter core belongs to the Brunhes normal polality epoch since ca. 0.7 million years ago. Within the core, there appear four magnetic anomalies. The age of the youngest event (50 to 55 m in depth of the 200-meter core) in the four magnetic anomaly events is 100,000 yr.B.P., and so close to the age of the Blake event, which was discovered from the deposits collected from the Atlantic and Caribbean Sea, and of which age



Text-fig. 13. An empirically modified age-scale (solid line), with nine reference ages including three ^{14}C dates (solid circle) and six fission-track dates (open circle) (After Yamamoto, 1976).

was found to be between 114,000 and 108,000 yr.B.P.

Correlation between the deep-sea and terrestrial records, and discussion

The International Subcommission on Stratigraphic Classification recognized generally three principal categories of stratigraphic subdivision for use through the geologic column. These categories are lithostratigraphy, biostratigraphy, and chronostratigraphy. However, in regard with the Quaternary stratigraphy, these are imperfect.

The Quaternary possesses rather special features that make it unique in the geologic record. Therefore, there is a growing consensus that the subdivisions of the most recent part of the stratigraphic record should follow the geologic procedures, and two further categories have been employed. These are morphostratigraphy and climatostratigraphy.

Climatostratigraphy is undoubtedly useful concept and, insofar as the Quaternary at mid- and high-latitudes tends to subdivided into glacials and interglacials.

In the deep-seas, long sequences of relatively undisturbed sedimens are preserved records which frequently extend back beyond the beginning of the Quaternary. Within these sediments, the microfauna contains a record of changing oxygen isotope ratios which do not only provide evidence for the past glacial and interglacial oscillations, but also form the basis for stratigraphic subdivision and long distance correlation. Sediments from deep-seas hold a number of advantage over terrestrial sequences from the point of view of stratigraphic subdivision and correlation throughout the world as follows:

(1) The records are more commonly continuous and relatively undisturbed.
(2) A common technique such as oxygen isotope analysis can be used.
(3) As the oxygen isotopic changes are a consequence of climatic changes, they are used for climatostratigraphy.
(4) The sedimentary records can be dated and correlated by the independent method of palaeomagnetic stratigraphy.

However, if terrestrial sequences provide the following certain characteristic features, correlation betwen the marine and terrestrial successions can be established.

(1) A lengthy stratigraphic record must be available.
(2) Within terrestrial sequences, evidence of climatic change must be clear and unequivocal.
(3) The record of sedimentation must be continuous.
(4) The terrestrial sequences can be dated by palaeomagnetic or radiometric method.

The most impressive and important example of lake sediment sequences as one of standards for the world-wide correlation of terrestrial

Table 1 An empirically modified age-scale (After Yamamoto, 1976)

Depth ζ (m)	Age t (10^3yr. B. P.)	Depth ζ (m)	Age t (10^3yr. B. P.)	Depth ζ (m)	Age t (10^3yr. B. P.)	Depth ζ (m)	Age t (10^3yr. B. P.)
1	1.39	51	95.49	101	214.26	151	365.07
2	2.24	52	97.65	102	216.98	152	368.29
3	3.24	53	99.82	103	219.73	153	371.54
4	4.31	54	101.98	104	222.44	154	374.75
5	5.47	55	104.17	105	224.58)	155	378.00
6	6.77	56	106.32	106	228.00	156	381.25
7	8.09	57	108.50	107	230.77	157	384.45
8	9.50	58	110.69	108	233.58	158	387.69
9	10.98	59	112.90	109	236.39	159	390.96
10	12.54	60	115.07	110	239.23	160	394.19
11	14.14	61	117.28	111	242.06	161	397.42
12	15.82	62	119.49	112	244.93	162	400.69
13	17.48	63	121.73	113	247.80	163	403.91
14	19.22	64	123.96	114	250.70	164	407.17
15	21.04	65	126.19	115	253.60	165	410.42
16	22.84	66	128.42	116	256.49	166	413.68
17	24.72	67	130.69	117	259.42	167	416.89
18	26.59	68	132.95	118	262.38	168	420.14
19	28.49	69	135.20	119	265.34	169	423.38
20	30.43	70	137.45	120	268.29	170	426.63
21	32.40	71	139.74	121	271.28	171	429.90
22	34.36	72	142.06	122	274.27	172	433.14
23	36.39	73	144.34	123	277.28	173	436.37
24	38.37	74	146.66	124	280.30	174	439.61
25	40.43	75	149.01	125	283.31	175	442.84
26	42.48	76	151.36	126	286.36	176	446.10
27	44.52	77	153.70	127	289.40	177	449.32
28	46.59	78	156.08	128	292.47	178	452.55
29	48.65	79	158.46	129	295.51	179	455.80
30	50.75	80	160.83	130	298.61	180	459.02
31	52.84	81	163.24	131	301.68	181	462.24
32	54.93	82	165.64	132	304.78	182	465.49
33	57.04	83	168.08	133	307.91	183	468.70
34	59.15	84	170.52	134	311.00	184	471.94
35	61.25	85	172.99	135	314.13	185	475.15
36	63.39	86	175.45	136	317.29	186	478.39
37	65.52	87	177.92	137	320.41	187	481.59
38	67.64	88	180.42	138	323.56	188	484.80
39	69.76	89	182.95	139	326.75	189	488.03
40	71.87	90	185.48	140	329.89	190	491.23
41	74.02	91	188.01	141	333.07	191	494.45
42	76.15	92	190.57	142	336.25	192	497.65
43	78.29	93	193.12	143	339.43	193	500.87
44	80.42	94	195.72	144	342.63	194	504.06
45	82.58	95	198.34	145	345.80	195	507.28
46	84.74	96	200.97	146	349.00	196	510.47
47	86.89	97	203.59	147	352.20	197	513.68
48	89.04	98	206.24	148	355.43	198	516.86
49	91.18	99	208.89	149	358.62	199	520.08
50	93.31	100	211.58	150	361.85	200	523.25

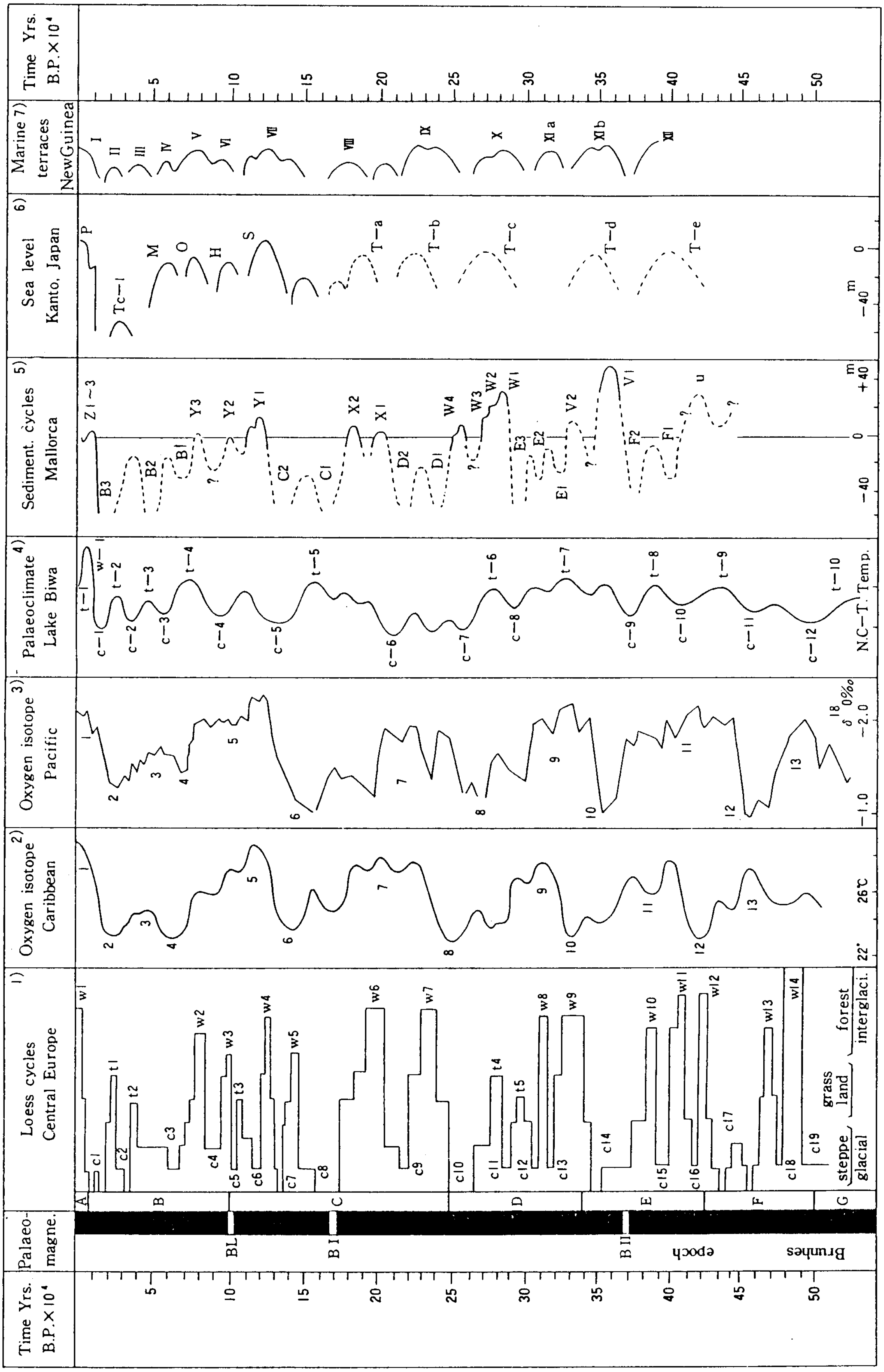
record is the record from Lake Biwa, Japan (Lowe & Walter, 1984). Namely, lacustrine sediments obtained from Lake Biwa accept four indispensable conditions as above-mentioned. In addition, although sediments of both cold and warm times are complete within sediments from the deep-seas, we cannot evaluate changes in climate over short times because of the extremely small rate of sedimentation in the deep-seas.

The tentative age-climate curve based upon a pollen analyses of the 200-meter core samples at 5 meters intervals was carried out by the present writer (Fuji, 1983, 1984; Fuji & Horie, 1977), and also more detailed curve checked by pollen analyses of both the 200-meter and 1,400-meter cores samples, and based upon a corrector empirically modified age-scale of the 200-meter core (Yamamoto & Higashihara, 1978) has been stated as shown in Text-fig. 13.

In the following part of this section, the writer will compare tentatively the climatic change from Lake Biwa with the oxygen isotope stratigraphy in the Caribbean Sea and Equatorial Pacific, environmental changes in Central Europe reconstructed by loess, palaeosol and gastropod faunal records, and Mediterranean and Japanese sedimentary cycles and relative sea level changes *etc.* However, both the palaeoclimatic changes in Lake Biwa and the global climatic changes have not been elucidated either. Namely, the global climatic changes should be based reasonably upon the various records from the deep-seas and terrestrial sequences, but the major changes have not been stated yet. And also, the present writer finished only a pollen analysis of the 200-meter core samples at 5 meters intervals, and of the 1,400-meter core samples at 6 meters intervals obtaind from Lake Biwa. He, therefore, is working the detailed pollen analysis at 25 cm intervals of both the cores. After his detailed analysis, the palaeoclimatic changes in and around the lake will be elucidated. And, if the global climatic changes will be elucidated, the writer will try the detailed correlation between the climatic record from the lake and the major climatic changes throughout the world. Therefore, the correlation stated in the following elucidation means of couse tentatively.

Concerning the oxygen isotopic records from the Caribbean Sea, Emiliani (1955) and Emiliani & Shackleton (1974) divided the isotopic curves into sixteen stages. The present writer (Fuji, 1983) compared his palaeoclimatic curve with Emiliani's isotope temperature record depicted on the the modified time scale, and found a rather significant correlation between them. Especially, during the age about 270,000 to 100,000 years B.P., the c-5 and c-6 cold climatic periods, and the t-5 temperate climatic period described in this paper may be correlated with Emiliani's stage nos. 6, 8, and 7, respectively. The fact suggests that the palaeoclimatic change around Lake Biwa was primarily controlled by the global glacial-interglacial cycles, but in a few exceptional periods of short duration the climate was brought under the influence of a strong local character and/or a problem in regard to absolute age inferred.

The stratigraphic subdivision of the oxygen isotope record was subsequently extended analysis of sediments in Core V28-238 obtained from a depth of 3,120 m at 01° 01′ N, 160° 29′ E on the Solomon Plateau in Western Pacific by Shackleton and Opdyke (1973). Within this core, twenty-three isotopic stages younger than Jaramillo Geomagnetic Event were recognized, and the record was interpreted as reflecting more or less continuous sediments since about 870,000 years B.P. And, the isotopic stages were also recognized in the upper part of Core V28-239. On comparison between the present writer's palaeotemperature curve and the record from V28-238 Core, a noticeable similarity between major trends of the two curves seems to be more than similarity between Emiliani's curve (Emiliani & Shackleton, 1974) and the palaeoclimate curve from Lake Biwa (Fuji, 1983; Fuji & Horie, 1977). That is, at that time described in this article, the Fuji's c-5 and c-6 cold periods, and t-5 mild climatic period may be corresponded to the Shackleton's stage nos. 6, 8, and 7, respectively. And also, in addition, the c-7 cold period may be correlated with the cold stage between stages nos. 8 and 9.


Time Yrs. B.P.×10⁴
Marine terraces NewGuinea 7)
Sea level Kanto, Japan 6)
Sediment. cycles Mallorca 5)
Palaeoclimate Lake Biwa 4)
Oxygen isotope Pacific 3)
Oxygen isotope Caribbean 2)
Loess cycles Central Europe 1)
Palaeo-magne.
Brunhes epoch
steppe glacial
grass land
forest interglaci.
N.C−T. Temp.

Text-fig. 14. Tentative comparison of the palaeoclimate from Lake Biwa, with oxygen isotope records from deep-seas, sedimentary cycles from Mallorca, sea level changes from Japan and New Guinea, and loess cycles from Central Europe.
1: Loess cycles and climate (Kukla, 1970, 1975). In loess cycles, w1 to w14, t1 to t5, and c1 to c19 are termed expediently for correlation by Fuji.
2: Isotope curve from the Caribbean Sea (Emiliani & Shackleton, 1974).
3: Isotope curve from Equatorial Pacific (Shackleton & Opdyke, 1973).
4: Palaeoclimatic change curve from Lake Biwa (Fuji, 1983).
5: Sedimentary cycles from Mallorca, Western Mediterranean (Butzer, 1975). Time before 30,000 years ago was estimated on the basis of Butzer's data (1975).
6: Sea level changes from Southern Kanto, Japan (Machida, 1975).
7: Marine terraces in New Guinea (Chappell, 1974). Time was estimated on the basis of Chappell's data (1974).
In palaeomagnetic data, BL: Blake event, B I: Biwa I event, B II: Biwa II event.

On the sedimentary cycles and relative sea level changes, since changes of eustatic sea levels are partly related to climatic changes, there should be some broad correlation between dated sea level changes in regions not affected by glacio-isostasy and the glacial and interglacial cycles recorded in the deep-sea cores. There should be some correspondence between ages of lowered sea level and cold condition, although climatic change and sea level change may be slightly out of phase since time is required for the melting of the ice sheets following climatic improvement. Of cource, a following few problems to be solved are in combining the sea level change with the climatic change: (a) Eustatic sea level changes from various regions throughout the world are affected by both the voluminal change of ocean water and tectonic movement; and (b) the correlation between the quantity of ice sheets and the global climate has not been well established.

A work on the Pleistocene sedimentary records of Mallorca in Western Mediterranean is a typical example for comparison between deep-sea and terrestrial records. Parts of the Mallorca littoral with arid climate are characterized by well-developed calcareous dunes, and widespread (Butzer, 1962). According to Butzer (1963), these aeolian sediments accumulated through deflation of freshly-exposed marine deposits during glacio-marine regressions, and each regression can be correlated with each glacial period in areas affected by glacier. Interglacial high sea levels are recorded by marine terraces and beach deposits. The shoreline stratigraphy in Mallorca is divided into six terrestrial and six marine hemicycles, which have been dated partly on the basis of biostratigraphy and radiometric dating of marine shells (Butzer, 1975). These sequence can be correlated with the loess sequence in Central Europe, and with the oxygen isotope records from the deep-sea floors.

As shown in Text-fig. 14, the palaeoclimatic curve from Lake Biwa (Fuji, 1983; Fuji & Horie, 1977) shows a significant correlation with the sedimentary cycles from Mallorca (Butzer, 1975) from the points of view of chronology and pattern of change of curve. Namely, the following facts can be pointed out:

(a) The postglacial relative high sea level (Z1, Z2, and Z3) coincides with the warm W-1 and mild climate t-1 periods.

(b) The relative low stands of sea level (B3, B2, and B1) during the latest Pleistocene may be corresponded to the cold C-1, C-2, and C-3 periods, respectively.

(c) And, especially concerning the present paper, the high sea levels inferred from the marine terraces Y1 and Y3 from Mediterranean are correlated with the cooler or mild climatic age between c-5 and c-4 periods from Lake Biwa, and with t-4 period, respectively.

(d) The lower sea level C1 and C2 (Mediterranean) may be correlated with the slightly cold or cold c-5 period (Lake Biwa).

(e) The high sea levels X1 and X2 (Mediterranean) coincide with the short temperate age just after the cold c-6 period, and with temperate t-5 period (Lake Biwa).

(f) The low sea levels D1 and D2 (Mediterranean) are corresponded to the cold age between c-7 and c-6 periods (Lake Biwa), and to the cold c-6 period, respectively.

The fact as mentioned above, suggests that the high sea level corresponds to the temperate period of Lake Biwa, and that the low stand of sea level to the cold one. The facts as recognized between the curves from Lake Biwa and Mallorca can be pointed out by comparing the palaeoclimate curve from Lake Biwa with the sea level curve of Southern Kanto in Japan (Machida, 1975), and with the sea level curve from New Guinea (Chappell, 1974) as follows:

(a) The high sea level P from Japan and I from New Guinea during the latest Pleistocene to Holocene is correlated with the warm w-1 and t-1 periods from Lake Biwa.

(b) The relative low stand of sea level Tc-1 (Japan) and II (New Guinea) coincides with the cold c-1 period (Lake Biwa).

(c) The high sea level suggested by the marine Misake M and Obaradai O (Japan) and V (New Guinea) may be corresponded to the t-3 period (Lake Biwa).

(d) And, especially concerning the present paper, the high sea level S (Japan) and VII (New Guinea) in the Shimosueyoshi transgression correlated with the Riss/Würm interglacial coincides with the temperate age between the c-5 and c-3 periods (Lake Biwa).

(e) The high sea levels inferred from the marine T-a (Japan) and VIII (New Guinea), T-b and IX, T-c and X, T-d and XIb, and T-e and XII may be corresponded to the temperate t-5 (Lake Biwa), slightly cool age between the c-7 and c-6, the temperate t-6, temperate t-7 periods, and to the temperate t-8 period, respectively.

With regard to aeolian deposits, within lengthy aeolian depositional sequences from central Europe, one of standards for correlation in the Quaternary was provided. Many soil layers are intercalated in the loess sequences, and the complete succession appears to contain a record of glacial and interglaccial conditions (Kukla, 1970, 1975). In the succession, the loess layers are interpreted as representing glacial condition, and on the other hand, the interbedded palaeosoils are considered to be indicative of interglacial condition. These records indicate that within the last 1.6 million years, seventeen major glacial and interglacial conditions have affected central Europe (Text-fig. 14).

As shown in Text-fig. 14, in comparison with the palaeoclimatic curve from Lake Biwa and the central European loess record (Kukla, 1970, 1975) for the past 500,000 years, the following facts can be pointed out:

(a) The warm w1 age in the glacial cycle A from Europe coincides with the w-1 and t-1 periods from Lake Biwa.

(b) The c1, t1, c2, t2, and c3 ages in the middle and late glacial cycle B (Europe) are correlated with the c-1, t-2, c-2, t-3 and c-3 periods from the lake, respectively.

(c) The warm w2 and w3 ages (Europe) may be corresponded to the t-4 period (Lake

Biwa) from the view point of a pattern of climatic change.

(d) The cold c5 and c6 ages (Europe) may be corresponded to the c-4 period (Lake Biwa) stated in this article.

(e) The cold c7 and c8 ages in the early part of glacial cycle C (Europe) may coincide with the c-5 period (Lake Biwa), and the warm w5 age with the temperate age between the c-5 and c-4 periods, respectively.

(f) The warm w6 and w7 ages in the early part of glacial cycle C (Europe) may be corresponded to the temperate t-5 period (Lake Biwa).

As described above, the writer can find a remarkably noticeable similarity between major trends of the records from Lake Biwa, other terrestrial sediments and the deep-seas. However, a more reliable conclusion will be arrived at when more absolute dates and palynological results will be obtained for the 200-meter and 1,400-meter cores from Lake Biwa.

Conclusions

(1) Pollen diagrams were obtained from 200 samples during the 55 meters to about 110 meters-horizons of the 200-meter core which was drilled at the bottom 65 m below the present water surface of the lake in 1971.
According to the calculated age on the basis of the determination of ^{14}C, fission-track and palaeomagnetic stratigraphy, the age during the 55 meters- and 110 meters-horizons is from about 100,000 yr.B.P. to about 250,000 yr.B.P.

(2) Judging from the pollen diagrams, the samples during the 55 meters- to 110 meters-horizons are divided into four pollen zones: Zones Y-1, Y-2, Y-3 and Y-4, and the Y-2 zone is further divided into six pollen subzones.

(3) The palaeoclimate inferred on the basis of pollen assemblage of every sample is as follows:

periods palaeoclimate inferred

Y-1 Period: Northern part of the Cool Temperate zone; corresponding to the c-6 period of the present writer's previous paper (Fuji, 1983), the 8 stage from the Shackleton and Opdyke's oxygen isotope curve, and to the D2 of the relative change curve of sea level from Mediterranean.

Y-2-a Subperiod: Southern part of the Cool Temperate – Temperate zones.

Y-2 b Subperiod: Middle part of the Cool Temperate zone.

Y-2-c Subperiod: Southern part of the Cool Temperate — Temperate zones.

Y-2-d Subperiod: Southern part of the Temperate - Warm Temperate zones. Y-2-a to Y-2-d Subperiods correspond to the t-5 period from Lake Biwa, the 7 stage of the isotope curve, and to the X1 to X2 from Mediterranean.

Y-2-e Subperiod: Middle part of the Cool Temperate zone; corresponding to the c-5 from Lake Biwa, the 6 stage of the isotope curve, and to the C2 from Mediterranean.

Y-3 Period: Northern part of the Cool Temperate zone; corresponding to the c-4 period from Lake Biwa, and to the low sea level age between the Y2 and Y3 marine terraces in Mediterranean.

Y-4 Period: Middle part of the Cool Temperate zone — northern part of the Temperate zone.

(4) Concerning the tentative correlation between the palaeoclimate from Lake Biwa, palaeotemperature from the deep-seas such as Caribbean Sea and Equatorial Pacific, environmental changes in Central Europe, and sea level changes in Mediterranean and Japan, the present writer can find a noticeable similarity between the records from above-mentioned regions as shown in Text-fig. 14.

References

Butzer, K. W. (1962): Coastal geomorphology of Majorca. *Ann. Assoc. Amer. Geogr.*, 52: 192—212.

——(1963): Climate geomorphologic interpretation of Pleistocene sediments in the Eurafrican subtropics. *Viking Fund. Publ. Archaeology.* **36**: 1—27.

——(1975): Pleistocene littoral-sedimentary cycles of the Mediterranean Basin: a Mallorquin view. In *After the Australopithecines* (Butzer, K. W. and Isaac, G. L. eds.), Mouton Press, The Hague, 45—71.

Chappell, J. (1974): Geology of coral terraces, Huon Peninsula, New Guinea. A study of Quaternary tectonic movements and sea level changes. *Geol. Soc. Amer. Bull.*, **85**: 553—570.

Emiliani, C. (1955): Pleistocene temperatures. *Jour. Geol.*, **63**: 538—578.

—— and Shackleton, N. J. (1974): The Brunhes Epoch: Isotopic palaeotemperatures and geochronology. *Science,* **183**: 511—514.

Fuji, N. (1973): Change of climate during the Wisconsin stage based on palynological study of 200 meters core sample of Lake Biwa in Japan. *Proc. Japan Acad.*, **49**: 737—741.

——(1982): Palynological study of a 200-meter core sample from Lake Biwa, Central Japan. II: Palaeoclimate during the 100,000 — 300,000 years B.P. *Proc. Japan Acad.*, **58**, Ser. B, 275—278.

——(1983): Palynological study of 200-meter core samples from Lake Biwa, Central Japan. I: The palaeovegetational and palaeoclimatic changes during the last 600,000 years. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, 132: 230—252 .

——(1984): Pollen analysis. In *Lake Biwa, Monographiae Biologiae* vol. **54** (Horie, S. ed.), Dr. W. Junk Publishers, Dordrecht/Boston/Lancaster 497—530.

—— and Horie, S. (1972): Palynological study on 200 meters core sample of Lake Biwa in Japan. *Proc. Japan Acad.*, **48**: 500—504.

—— and —— (1977): Palynological study of a 200-meter core sample from Lake Biwa, Central Japan. I: Palaeoclimate during the last 600,000 years. *Proc. Japan Acad.*, **53**: 139—142.

Horie, S. (1984): *Lake Biwa, Monographiae Biologiae* vol. **54** (Horie, S. ed.): Dr. W. Junk Publishers, Dordrecht/Boston/Lancaster, 654 pp.

——, Mitamura, O., Kanari, S., Yamamoto, A. and Fuji, N. (1971): Paleolimnological study on lacustrine sediments of Lake Biwa-ko. *Disaster Frev. Res. Inst. Annuals, Kyoto Univ.*, 14(B): 745—762.

Kanari, S. and Takenoya, Y. (1975): An estimation of the deposition rate of Lake Biwa during the past 560,000 years. In *Paleolimnology of Lake Biwa and the Japanese Pleistocene,* **3**: 235—240.

Kukla, G. J. (1970): Correlation between loesses and deep-sea sediments. *Geol. Fören. Stockh. Förh.* **92**: 148—180.

——(1975): Loess stratigraphy of Central Europe. In *After the Australopitheciens* (Butzer, K. W. and Isaac, C. L. eds.), Mouton Press, The Hague, 99—188.

Lowe, J. J. and Walker, M. J. C. (1984): *Reconstructing Quaternary Environments.* Longman Inc., New York, 389 pp.

Machida, H. (1975): Pleistocene sea level of south Kanto, Japan, analysed by tephrochronology. *Roy. Soc. New Zealand Bull. (Quaternary Studies),* **13**: 215—222.

Nishimura S. and Yokoyama, T. (1975): Fission-track ages of volcanic ashes of core samples of Lake Biwa and the Kobiwako group (2). In, *Paleolimnology of Lake Biwa and the Japanese Pleistocene,* **3**: 138—142.

Shackleton, N. J. and Opdyke, N. D. (1973): Oxygen isotope and palaeomagnetic stratigraphy of Equatorial Pacific core V28-238: oxygen isotope temperature and volumes on a 10^5 and 10^6 year scale. *Quat. Res.*, **3**: 39—55.

——(1976): Oxygen isotope and paleomagnetic stratigraphy of Pacific core V28-239, late Pliocene to late Holocene. *Geol. Soc. Amer. Mem.*, **145**: 449—464.

——(1977): Oxygen isotope and paleomagnetic evidence for early Northern Hemisphere glaciation. *Nature,* **270**: 216—219.

Toyoda, Y., Horie, S. and Saijo, Y. (1968): Studies on the sedimentation in Lake Biwa from the viewpoint of lake metabolism. *Mitt. Internat. Verein. Limnol.*, **14**: 243—255.

Yamamoto, A. (1976): Paleoprecipitational change estimated from the grain size variations in the 200m-long core from Lake

Biwa: *Paleolimnology of Lake Biwa and the Japanese Pleistocene*, 4: 179—203.
——, Kanari, S. and Fukuo, Y. (1973): Grain size analysis of sediments and their consolidation in a core from Lake Biwa-ko. *Jap. Jour. Limnol.*, 34: 63—74.
—— and Higashihara, M. (1978): Granulometric data for the 200 meter core samples from Lake Biwa (IV). *Bull. Osaka Electro-Communication Univ.*, 14: 117—130.

Aburaki 油木, Gamō 蒲生, Gifu 岐阜, Hokuriku region 北陸地方, Honshu 本州, Iga Basin 伊賀盆地, Ise Bay 伊勢湾, Kaburaki 甲楽城, Kinki region 近畿地方, Kyoto 京都, Kyushu 九州, Lake Biwa 琵琶湖, Mizuguchi Hill 水口丘陵, Mt. Fujihara-dake 藤原岳, Mt. Gozaisho-dake 御在所岳, Mt. Hiei 比叡山, Mt. Hira 比良山, Mt. Ibuki 伊吹山, Mt. Mikuni-dake 三国岳, Mt. Mikuni-ga-dake 三国ヶ岳, Mt. Nosaka 野坂山, Nagoya 名古屋, Nobi Plain 濃尾平野, Omi Basin 近江盆地, Sayama 佐山, Shiga Hill 滋賀丘陵, Shikoku 四国, Shima-ga-hara 島ヶ原, Seta 瀬田, Suzuka 鈴鹿, Takashima 高島, Tsu 津, Tsuruga 敦賀, Tōkai region 東海地方, Wakasa Bay 若狭湾, Yanagase 柳瀬, Yōkaichi 八日市.

琵琶湖底 200 m ボーリング・サンプルの花粉学的研究 II: 約25万～10万年前における古植生と古気候の変遷: 日本における第四紀を通じての古植生の変遷とそれに基づく古気候の変化を究明し, 世界における第四紀の気候変化の標準の1つを日本で作成することを目的として, 1971年秋, 琵琶湖の水深 65 m の湖底から約 200 m に及ぶボーリングを実施した。そして, 殆んど完全に連続する過去60万年間の湖成層の採集に成功した。このコア・サンプルの 5 m 間隔での試料に基づく過去60万年間の古植生と古気候の変遷についての第一報 (藤, 1983) に続いて, 約25万～10万年前の古植生と古気候の変遷を, 200 m コアの 25 cm 間隔で採集したコア・サンプルの花粉分析によって解析した。その結果, この期間約15万年間は, 4花粉帯6花粉亜帯に細分され, それぞれの花粉帯と花粉亜帯の詳細な花粉組成とそれに基づく植生と気候を推定した。そして, さらに, この気候変遷を, 現在までに公表されているカリブ海と赤道太平洋からの酸素同位体比による古水温変化, 地中海の Mallorca と南関東, およびニューギニアから得られた海水準変化・海成段丘分布, そして, 中部ヨーロッパで得られたレスのサイクルなどの同時期の変化と比較検討した結果, これらとは全般的にみてよく類似した変化の認められることが判明した。

藤　則雄