Palaeovegetation and Palaeoclimate in the Northwestern Europe and Japanese Islands during the Weichselian Stage[1)]

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Summary

The climatic curve has been obtained by a palynological investigation of a 200-meter core drilled at a bottom of 65 m below the present water level of Lake Biwa in Japan. According to the calculated age on the basis of the determination of ^{14}C, fission-track and palaeomagnetic stratigraphy, the age of the lowermost horizon of the core takes about 600,000 years B.P. The climatic curve from Lake Biwa display a clear similarity to the generalized temperature curve from Caribbean Sea, the palaeotemperature curve from Greenland and to the curve of the eustatic movements during the Weichselian stage in Japan. The similarity exists between the major trends in the inferred climatic fluctuations of Northwestern Europe, North America, Greenland and the Japanese Islands.

Introduction

Studies of vegetational history have usually, as their principal objective, interpretation of climatic history of a district. This is because of all the criteria that can be used to typify the climate of continental areas, the gross natural vegetation is the most important. In fact the inferred relation between climate and vegetation is so close that world climatic provinces have been classified and delineated principally according to the vegetation. Because a pollen diagram provides a gross rather than a detailed picture of the vegetation, it is a powerful tool in the study of regional vegetational changes. Plant macrofossil analysis can be used to provide some details of local vegetational history. Because many specific identifications are possible, macrofossils provide basic information pertinent to problems of floristic history. But beyond

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the problems of climatic history are broader questions of vegetational history, such as that of the long range stability of vegetational associations with or without the influence of climatic change, and questions concerning differential rates of migration of major species in response to controls by soil type, shade tolerance, seed-dispersal mechanisms, and competition.

The possibility of correlation of a well-known regional sequence with sequences on other continents and in the deep-sea by means of "long sequence", "continuous" pollen diagrams, depends on the contemporaneity of climatic change over all or wide parts of the earth. The only way to verify this is by means of direct or indirect absolute dating. For instance, ^{14}C dating of the change in climate during the transition from the Last Glacial age to the Holocene epoch from several places in the world have shown that this change took place between about 10,000 and 13,000 years before the present. Some minor climatic fluctuations during this interval, such as the Bölling and Alleröd interstadials, are shown to be contemporaneous in many places as far apart as North America, Africa, Asia, and Europe. Assumptions involved are that the section is continuous, not continual, and that we may decuce from demonstrated correlations of many horizons between two sections that other major climatic changes are also contemporaneous. If materials for direct dating are not available and samples which are inferred to be older than about 30,000 years are obtained, we must use other methods. Measurements of palaeomagnetic inclination or intensity can be used. Measurements of palaeomagnetic inclination can be used with fine-grained deposits such as clay, silt, and gyttja. This technique provides us with an essential tool for studying long-distance correlations between different localities.

As mentioned, climatic changes have proved to be a reliable basis of chronostratigraphy. Comparisons between many sequences must be sufficiently encouraging to support the probability of long-distance correlations on the basis of climatic change as reflected by a change of vegetation. Such correlations, of course, should be undertaken only for "continuous" "long" sequences with some fix-points determined by absolute dating and／or palaeomagnetic studies.

It is not felt at present that the change of climate during the Weichselian glacial age has been studied sufficiently throughout the Japanese Islands. Although there are some absolute dates on the later part of the Weichselian age, later than about 30,ooo years B.P., samples which are estimated to be older than about 30,000 years ago have not been measured yet. Therefore, it is not yet possible to provide correlations for some horizons in which climatic changes have been documented.

In the core obtained from Lake Biwa, the sedimentation rate is about 0.5 — 0.8 mm／yr. in the top 30 meters. The material is clayey gyttja or silt throughout the core and is essentially undisturbed. The core is continuous since about 0.6 m. y. B.P. palaeomagnetic inclination and intensity have been measured at intervals of about 2 cm throughout this core, and absolute dating has been done by the fission-track method (Nishimura *et al.*, 1975).

The results from Lake Biwa are valuable as they can be compared with results from many places in Europe and North America.

In this paper, some preliminary ideas on the Weichselian vegetational history and climatic change based on palynological studies are summarized. Emphasis is placed on the results of the study of the Lake Biwa core, but some additional data from elsewhere in the Japanese Islands is also included. A tentative comparison among the climatic changes in the Japanese Islands, Europe, and North America during the Weichselian stage is given. Although the section in Northwestern Europe has been studied well throughout the world, many different opinions have been proposed.

1. Early Weichselian Glacial Stage

Judging from the pollen sequence of Lake Biwa, Subpolar or Subalpine plants such as *Picea* and *Abies*, and deciduous plants such as *Ulmus* and *Fagus* (perhaps *Fagus crenata*) were very abundant around the lake, whereas today the vegetation is composed of some deciduous and evergreen plants such as evergreen *Quercus (Cyclobalanopsis).* This pollen zone, which is situated at about 25 meters below the present bottom, is assigned to the Nicolet stadial at the beginning of the early Weichselian glacial stage on the basis of radiogenic age determinations using the fission-track technique, and on the basis of the consolidation method. During approximately 5,000 years just after this stadial the palaeoclimate around Lake Biwa became a little cooler, and was marked by a vagetation grossly similar to that of the middle or southern part of the Cool Temperate zone of today. This time is correlated with the St. Pierre interstadial of the early Weichselian stage. A cold climate, indicated by vegetation similar to that of the northern part of the Cool Temperate zone or to the southern part of Subpolar zone, followed after the cooler climate. The pollen diagram shows that the climatic change may have resulted in a change from the north−Temperate deciduous forest community to a community of *Picea, Abies, Tsuga, Betula,* and *Fagus.* The vegetation of that stadial is believed to be similar to the vegetation of the present−day around Obihiro in the Hokkaido district the northern part of Japan. That cold age, indicated by co-2 in Figure 1 continued for about 10,000 years and is perhaps correlated with the Guildwood stadial in the North America.

Comparison with some data from Japan is limited by the short age of old and finite radiometric dates (over 30,000 years). Thereby, detailed pollen diagrams and macroplant remains from the early Weichselian stage, and also the southern limit of boreal coniferous forest and the topography of the full-glacial age are not well known at present. Eustatic movements in the northern Japan are inferred from deposits ranging from the Pleistocene and the Holocene (Minato,1972). A trend of the curve of the movements is almost agreement with that of the writer's climatic curves.

The cold period co-2 was the coldest and longest in the Weichselian glacial stage. In North America, during this stadial a major advance of the glaciers covered the Great Lakes and the St. Lawrence region. In addition, according to the water level fluctuations in the Pacific Ocean (Kind, 1969), sea level may have been 135 meters below the presnt sea level.

Observations on directions of striae and on stratigraphy of glacial deposits indicate that the direction of the movement of the ice sheet in Finland changed during the Weichselian glacial age. In this country, two main stages of ice movement are distinguished. One is in an easterly direction and the other is a southeasterly direction in the central and southern part of the country. The same change in ice movent direction is indicated by two till layers which contain microfossils. According to Donner (1965), no indication an interstadial separating these stages has been foud. However, as mentioned earlier some thin layers of biogenic sediments were found below the till in a horizon which represents either an interstadial interrupting the last glaciation, or a cold age at the end of the Eemian interglacial stage in Sweden. According to Andersen (1961), two stages are known to exist in Denmark.

In a few areas of Sweden, two stadials, the Weichselian I and Weichselian II + III can be identified. Three stadials,Weichselian I, Weichselian II and Weichselian III are found in the southern and western parts of Scandinavian Peninsula only. Three stadials may be present in the Dösebacka and Ellesbo drumlins situated on the western slope of the Göta River Valley in Western Sweden, but there are a few different opinions in Sweden. For example, Åke Hillefors (1974) believes that the Weichselian glaciation in this area is represented by a very complicated stratigraphy, and can be subdivided into six cold and warm substages. Cold stages are represented by till beds and warm periods by glaciofluvial beds, interstadial clay and sand layers, and above all, deflation surfaces. The Weichselian I ice sheet had a southeasterly orientation controlled by a mountain range. The maximum age of this glaciation is perhaps correlated with the co-2 stadial of Lake Biwa and the Guildwood stadial of North America.

On the other hand, in Norway the ice sheet originated in the mountainous areas, and during the early phases of the Weichselian glacial stages an ice divide probably occurred close to the present-day water divide (Andersen, 1965). The maximum extent of the ice sheet during the Weichselian glacial stage is not exactly known in Norway.

In Denmark while the *Picea* and *Pinus* zones (pollen zones "h" and "i", after Andersen, 1961) were being formed during the end of the Eemian interglacial, the temperature continued to decrease, the thermophilic water plants and the foliferous forests succumbed, and *Betula nana* appeared. A subarctic heath vegetation prevailed and solifluction was common. The ice sheet covered a large part of the Scandinavian Peninsula and the eastern parts of Denmark. Accrding to Hansen (1965), the Weichselian glacial stage in Denmark is divided into four substages: the Early Weichselian, Interstadial, Main Weichselian (Last Glaciation), and Late Glacial substages. The Interstdial substage is divided into the Rodebaek interstadial, Cold stadial, and Brörup interstadial, and the Late Glacial substage is divided into three subdivisions; the Older Dryas, Alleröd, and Younger Dryas. The"Middle Bed" substage identified by Jessen and Milthers (1928) is characterized by *Betula nana*, heaths, and scattered trees, and represented a cold climate. Judging from the character of flora including mainly *Betula nana, Juniperus*, and herbs, and climatic data indicating a warmer interval with mean July temperatures of 10°−12°C, the Rodebaaek interstadial may be perhaps correlated with the Amersfoort and St. Pierre interstadials. A periglacial substage followed this interglacial one, and is correlated with the Prime Glaciation of the Scandinavian Peninsula (Ljungner, 1945 and 1949), the Guildwood stadial of North America, and the co-2 stadial of Lake Biwa on the basis of the characteristic strong climatic oscillations which occurred throughout the early Weichselian glacial stage.

The upper Pleistocene sequence of the Netherlands and Denmark is well known. For example, the type localities for the Brörup, Bölling and Alleröd interstadials are in Denmark, and the type localities for Eemian, Amersfoort, Moershoofd, Hengelo and Denekamp interstadials are in Netherlands. In Netherlands the early Weichselian glacial is divided into three stadials and three interstadials (van der Hammen *et al.*, 1971). The Eemian interstadial ends with a dominance of herbs which indicate that a vegetation lacking trees became dominant. The first stadial of tha early Weichselian glacial stage had a vegetation of this type. According to van der Hammen *et al.* (1971), the stadials are represented by maxima of the herb groub, and indicate that the vegetation was of a tundra or park tundra type. The interstadials show a minor increase of the temperate-boreal elements in the Amersfoort and Odderade interstadials and a major increase in the Brörup interstadial. Therefore, the Brörup interstadial was the warmest climate of the early Weichselian stage, being probably correlated with the St. Pierre interstadial of North America.

The upper Pleistocene sequence in the Mediterranean district is reported recently from the Tenaghi Philippon in the eastern Macedonia, a continuous series of lake sediments. As it is well dated by ^{14}C methods, and may be correlated easily with the other districts. According to van der Hammen *et al.* (1971), the general course of the pollen diagram from the Tenaghi Philippon during the early Weichselian stage is quite similar to that of the northwestern Europe. The early Weichselian stage starts with a rapid increase of open vegetation, including especially steppe elements. There seems to be little doubt that the Doxaton, Drama and Elevtheroupolis forest periods from the Tennaghi Philippon (interstadials) correspond to the Amersfoort, Brörup and Odderade interstadials respectively. The stadials occurring between the interstadials above-mentioned are represented by an open steppe vegetation. Judging from the pollen diagram, the Drama interstadial is clearly the warmest climate among three interstadials. It is correlated with the Brörup interstadial. All these sections reveal an open steppe vegetation during the glacial phases and forest vegetations during interglacial time.

2. Middle Weichselian Glacial Stage

The middle Weichselian stage is presumed to date from 23,000 to 55,000 years ago. The climate changed very little throughout the entire middle Weichselian stage, a cool climate prevailed over most of Japan. After the cold period correlated with the Guildwood stadial, a cool climate, resembling the middle part of Cool Temperate zone of today, continued for about 30,000 years until the beginning of the co-1 stadial. This stadial is correlated with the Nissouri stadial of North America in which there were a few short cold episodes. One limitation of the palynological studies from Lake Biwa is that cold climate which was as cold as those of the co-1 and co-2 stadials was restricted to areas farther north of the Japanese Islands. The beginning of the early middle Weichselian stage should probably be correlated with the Port Talbot interstadial, and diagram at this time is marked by high percent pollen grains of *Pinus, Abies,*

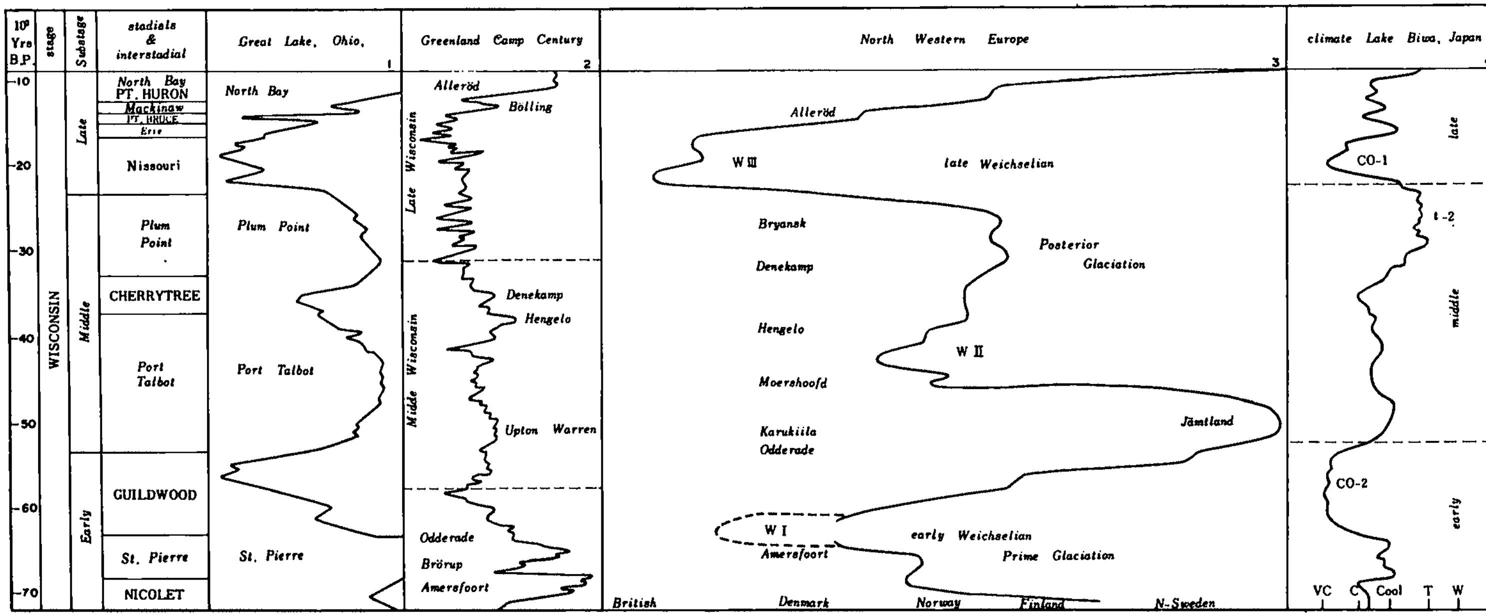

Fig.1　Correlation diagram of the ice sheet development development (diagrams 1&3), climate (4), and temperature (2) from some selected regions. In these curves cold climate, as represented by glacial advance and ice sheet develoment, and lowering of temperature are indicated by a shift toward the left. Diagrams I and 3 : change of glacial or ice sheet margins ; 1 : Dreimanis *et al.*, 1972 : 2: Dansgaard *et al.*, 1971 ; 3 : Lundqvist, J. 1974 ; 4 : the present paper (Fuji,N).

Tsuga, with deciduous *Quercus, Fagus* and evergreen *Quercus* around Lake Biwa. In the Tokusa basin of the southwestern part of the Japanese Islands, the vegetation may have been that of a deciduous forest including *Fagus* and *Alnus* with evergreen *Quercus,*and Taxodiaceae. This assemblage has a radiocarbon date of 31,900 $\pm^{3,200}_{2,300}$ years B.P. (Hatanaka *et al.,* 1971). In the Itami basin near Lake Biwa, a new pollen diagram shows that a forest with abundant *Pinus, Abies* with *Fagus,* deciduous and evergreen *Quercus, Sciadopitys* and other broadleaf trees existed. Radiocarbon dates on the forest are 32,700 $\pm^{3,300}_{2,500}$ years B.P. and 29,00 ±1,200 B.P. A pollen diagram from Lake Shinji of the southwestern part of the Japanese Islands is marked by a high percent pollen of *Pinus, Abies, Tsuga, Fagus,* deciduous *Quercus* and evergreen *Quercus.* In the Niigata district of the Central Japan, the forest of that time, 30,000 years ^{14}c years B.P., was dominated by *Alnus, Cryptomeria,* deciduous *Quercus* and *Fagus* with less *Picea, Abies* and *Betula.* The report suggests that a vegetation similar to the Cool Temperate zone may have existed there. At Kumanoyu near Hakodate of the southern Hokkaido distict, the pollen assemblage for the second peat layer is dominated by *Abies* and *Picea,* lacking *Betula ermani* (Nakamura, 1973). This assemblage suggests that tha vegetation may have been the lower Subalpine. Thus unlike the forest of today, which is the north Cool Temperate zone or south Subpolar zone in the lowland of Hokkaido district, the forest of that time was different. The Subalpine forest occurred higher than about 500 to 600 meters above the presnt sea level in this district. The nature of the full-glacial vegetation of that time is almost completely unknown over the Japanese Islands. If the above-mentioned result is correct, it is inferred that the temperate during that time may have been 2° to 3° C lower than that of the present time. In the southwestern part of the Japanese Islands, evergreen *Quercus* grew together with *Fagus* as shown by the pollen biagrams from Lake Biwa and Itami. From this fact it may be inferred that the climate of that time was probably milder in winter and cooler in summer than that of the present time.

During the middle part of the middle Weichselian stage, pollen diagrams from Lake Biwa show high *Abies, Pinus* and deciduous *Quercus* with less *Betula* and *Fagus.* The vegetation suggests that the Warm Temperate forest was eventually replaced by the Cool Temperate forest around Lake Biwa and the southern limit of Subpolar forest during that time was probably somewhere in the south Cool Temperate zone of today, perhaps extending as far south as 38° N latitude. Detailed pollen diagrams and radiocarbon dates for this cold time are so few that little can be said about the vegetation of this time. From the change of assemblage within the continuous pollen sequence, it is inferred that this cold period is correlative with the short Cherry Tree stadial (perhaps Würm II or Weichselian glacial II stage), which lasted only about 4,000 years. pollen assemblages from the lowermost gravel and muddy sand layer (radiocarbon date of 28,770 ±2,600 years B.P.) of the Ekota plant bed in Tokyo indicate a north Temperate forest characterized by abundant *Fagus* and sparse conifers. The lowermost mud layer (radiocarbon date of 28,000 ±1,700 years B.P.) of the Dochu bed in the Shikoku district was dominated by *Picea, Pinus* and *Abies* (Nakamura, 1966), and a south Subpolar forest or north Cool Temperate forest may have occurred there. According to Minato's investigation

(1972), mountain-glaciers formed some cirques around Mt. Tottabetsu "0" and "I" subglacial epochs in the Hidaka mountain chain and also in the Japan Alps (Hida "I" epoch) of the Central Japan during the cold age (Würm II stadial).

In the Hokaido district of the Northern Japan, a mammoth molar was found in the Kogoshi terrace deposits, which are about 10 m above present sea level (Minato,1972). This mammoth-bearing gravel bed is covered by a rhyolitic pumice fall that has an age of about 32,000 ^{14}C years B.P. This terrace deposits and Tottabetsu "O" subglacial epoch should probably be correlated with the Cherry Tree and Roxana LII or Roxana LIII. This cold period may be corresponded to the lower sea level epoch (about 80 meters below the present sea level) in the Minato's eustatic movements curve (1972). pollen diagrams (abbreviation : t−2 ; about 15 meters below the present bottom of Lake Biwa) show that the climate, after a short cold period, may have been similar to the present climate, or perhaps a little cooler, until the beginning of the late Weichselian glacial stag, and that this time is perhaps correlated with the Plum Point interstadial of North America. The climate of that time was so much cooler in summer that boreal conifers and *Fagus,* which was *Fagus crenata,* representing the Cool Temperate forest, grew around Lake Biwa, and so much milder in winter that evergreen broadleaf tree, as evergreen *Quercus,* grew around the lake. In Chichibubetsu of the Ishikari Lowlands (Nakamura,1968) the vegetation was dominated by *Picea* and *Abies,* with less *Betula* and nonarboreal pollen. *Selaginella selaginoides* was eliminated from this area.

The Jämtland and Göta Älv interstadials have been dated at more than 40,000 and 25,000 to 35,000 years B.P. respectively in Sweden. In the Jämtland interstadial almost the whole Scandinavian Peninsula was deglaciated. However, in the Göta Älv interstadial probably only the west cost and southern part of the penninsula were deglaciated, some Swedish geologists do not agree with this opinion. In the Jämtland interstadial the climate was perhaps cooler than today, and sea level lower (J.Lundqvist, 1967). The interstadial is perhaps correlated with the Karuküla of Europe and the Port Talbot interstadial of North America.

In Denmark, in the Brörup interstadial pollen diagrams suggest that *Betula, Pinus* and *Picea* forest occurred widely. Andersen's study (1961) on the deposits covering in the Brörup boy basins indicates that the forest implies a mean July temperature of 13°−15°C.

In the Netherlands, after the Odderade interstadial, the early Pleniglacial began with an extremely cold climate indicated by being very scarce or absent, resulting in a polar desert. This cold stadial lasted until the start of the Moershoofd interstadial which seems to have begun shortly after 50,000 years B.P. Two warm ages such as the Hengelo and Denekamp interstadials started after the short polar desert phase, and are dated at about 38,000 and 30,000 years B.P. respectively. The climate during the middle Pleniglacial may have been generally less cold and more humid than the early and late Pleiniglacial substages. This short stadial found in the middle Pleniglacial had polar desert vegetation with tundra plants such as *Salix polaris* and *Saxifraga oppositifolia* etc. In the Moershoofd interstadial the increase of birch pollen grains is very slight, and the vegetation of the other two interstadials may be a shrub tundra. The short stadial between the Hengelo and Denekamp interstadials is probably correlated with a cooler period represented by about 18 meters of the core from Lake Biwa, judgind from the climatic condition during this time.

According to Lundqvist's figure, (1974) the climate in the Northwestern Europe during the interval between the Moershoofd and Hengelo interstadials was colder than that of the time between the Hengelo and Denekamp interstdials. However, his conclusion is contrary to the opinion of van der Hammen *et al.* (1971). According to the present writer's data from Lake Biwa, Lundqvist's interpretation is correct. This correlatin must be further investigated in the near future by the using of detailed data.

In the Mediterranean district of about 60,000 years B.P., a long period of steppe climate continued until about 14,000 years B.P. This period is interrupted only by some minor increases of *Quercus* and *Pinus* during Heraklitsa, Kalabaki and Krinides interstadials, which are correlated with the Moershoofd, Hengelo and Denekamp interstadials respectively.

3. Late Weichselian Glacial Stage

The deposits during the late Weichselian glacial stage occupy the interval between about 8 and about 12 meters below the present bottom of Lake Biwa, and are inferred tn date from 12,000 to 23,000 years ago.

The pollen sequence of this stage starts with an abrupt change towards a cold climate just after the period of milder climate indicating the end of the middle Weichselian stage. For example, the pollen assemblage of the co-1 age of Lake Biwa shows that the climatic change may have resulted in a change from a Temperate forest with deciduous broadleaf trees into a community of *Abies, Tsuga, Betula, Fagus* and *Pinus.* The *Pinus* was not determined positively as *Pinus koraiensis.* A little pollen of evergreen *Quercus* that did not grow around Lake Biwa at that time, although it now grows there, must certainly have been transported in from afar, perhaps from the more southern part of the Japanese Islands. Most of the evergreen broadleaf trees and some of the deciduous broadleaf trees may have been excluded from the surroundings of Lake Biwa at that time. As the vegetation of that time seems to be similar to that of the forest of the north Cool Temperate zone found in the southern part of the Hokkaido district at present, the men annual temperature at that time is believed to have been about 7° to 8° C lower than that of the present. Juding from the palynological analyses of Lake Biwa, the coldest time is inferred to have been about 18,000 years ago. According to Minato (1972) and Kind (1969), sea level at that time in the Pacific Ocean was about 135 meters or 120 meters, respctively, lower than at the present aroud the Japanese Islands.

The vegetation inferred by pollen diagrams from Lake Biwa indicates a similar assemblage for the co-2 stadial of the early Weichselian stage. If this is correct, the cold co-1 stage may be correlated with the Nissouri stadial of the late Weichselian in North Amerca. Some data on the climate of the Nissouri stadial wihich is correlated with the co-1 stadial are as follows. In the Hokkaido district, pollen counts from the Chichibubetsu bed (radiocarbon date of 24,000±150 years B.P.; Nakamura, 1973) and Kumanoyu bed (radiocarbon date of 14,600±950 years B.P.; Nakamura,1973) are dominated by nonarboreal pollen grains and *Betula.* A pollen diagram of the Otsuki member (radiocarbon date of 23,800±1,100years B.P and 25,400±900 years B.P.; Suzuki *et al*.,1967) is characterized by *Abies*,*Picea*, *Pinus* and *Cryptomeria* with deciduous broadleaf trees except *Fagus*. Farther south in the Japanese Islands, the *Menyanthes* bed of the Nara basin near Lake Biwa includes *Tsuga*, *Picea*, *Abies*, *Betula*, decidus *Quercus* and *Alnus*. The vegetation of that time around the Nara basin may be perhaps similar to some forests in the northern part of Cool Temperate zone at the present. The southern limit of the vegetation of the Subpolar zone during that cold time was probably somewhere in the northern part of the Central Japan, perhaps extending into the southern part of Northwestern Japan or the Kwanto plain. The forest line during this cold period was about 1,500 meters lower, and Subalpine vegetation was vastly expanded in the northern part of the Japanese Islands. The various forest belts were lower as well, although probably by unegual amounts. This lower of the forest line is similar to the amount of lower of the snow line, which is inferred from study of the altitude of cirques and the distribution of moraines. The detailed vegetation of the coldest time throughout the late Weichselian glacial stage is still almost completely unknown.

As stated above, at about 18,000 radiocarbon years ago the vegetation now typical of the Subpolar or Subalpine zone in the Japanese Islands may have occupied the lowland of the northern part of the Japanese Islands. After the cold time, alternating cold and mild climates occurred repeatedly in the Japanese Islands. In the 11.6 m core sample dated at 14,980 ± 460 years B.P. from the bottom of the 1967 Lake Biwa core a pollen diagram 10.5 meters below the lake bottom is dominated by *Picea*, *Abies*, *Tsuga*, *Alnus* and *Pinus* (*P.haploxylon*-type), but a sample from 11.2 meters below the bottom has relatively little *Pinus haploxylon*-type and *Tsuga*. It is dominated by *Picea* and some trees belonging to the Temperate zone. The latter horizon may be correlated with Alleröd interstadial. The vegetation and climatic change during the Late Glacial age in the Japanese Islands will be analysed in detail by using of the longer core samples from Lake Biwa in the near future.

A few cores containing recods of the vegetation during the Late Glacial age have been collected recently over the Japanese Islands. For example, in the southwestern district of Japan, the pollen count for Ohita (Hatanaka, 1973) of the Kyushu district is dominated by *Pinus* together with some deciduous broadleaf trees such as *Ulmus* or *Zelkova* and deciduous *Quercus*, together with *Picea* and *Abies*. From Dateno of kochi city in the shikoku district, pollen grains of *Abies*, *Picea*, *Pinus*, *Tsuga* and deciduous *Quercus* etc. were found. In the central Japan, Nakamura (1972) found *Fagus* and deciduous *Quercus* from deposits, radiocarbon dated at 11,400±300 years B.P. and 10,500 years B.P. respectively, near the mouth of River Nagara, and also an assemblage with abundant *Tsuga* and *Abies* from Yokkaichi near Nagoya. In the Kwanto district, from the peat layer lying under the Upper Loam bed on the Maebashi terrace the Kwanto Loam Research Group reported dominant *Pinus*, *Abies*, and *Picea* and minor *Fagus* and deciduous *Quercus*. This pollen assemblage indicates that the vegetation of that time may have been similar to that of the lower part of the Subalpine forest or the southern part of the Subpolar zone at the present. In the same case, in the V_3-layer, of the famous Ekota plant bed in Tokyo radiocarbon dated between 11,330 ± 260 years B.P. and 11,843 ± 300 years B.P., the same vegetation has been found. In the Ozegahara swamp of Nikko National Park, the diagram is marked by dominant pollen grains of *Pinus, Abies* and *Tsuga* with small amounts of *Betula, Alnus* deciduous *Quercus* from the Old Peat layer. Further north in the Japanese Islands, in the Hokkaido district, pollen diagrams from Furen (radiocarbon date of 9,750 ± 225 years ago) and Chichibubetsu are dominated by *Picea, Abies, Pinus* and *Ulmus*. There contain especially high percentages of nonarboreal pollen. The vegetation characterized by the two pollen assemblages mentioned above may be similar to the forest-like park-land distrcted in the northern part of the Subpolar zone or around the upper part of the Subalpine zone at the present.

. As stated above, the vegetation during the Late Glacial age following the Nissouri stadial is summarized as follows: alternating cold and mild climates occurred repeatedly in the Japanese Islands. The vegetation in some districts durinng the cold periods is inferred to be as follows: in the Hokkaido district there was a forest similar to the upper part of the Subalpine zone or a park-land; in the northern Kwanto district, the vegetation was similar to that of lower part of the Subalpine zone or the Southern part of the Subpolar zone; in the southern part of the Japanese Islands, *Abies, Tsuga* and deciduous broadleaf trees such as deciduous *Quercus* and *Betula* probably dominated.

On the other hand, during the mild periods, for example, from the middle layer of the Ohmi-hachiman plant bed (dated at 12,650 ± 250 radiocarbon years B.P.), the vegetation shown by the pollen diagram was mixed, with some trees of the Subalpine or Temperate zones together with *Quercus glauca, Q. stenophylla* which grow in the Warm Temperate zone at the present. The climate represented by this vegetation is believed to be correlated with the Alleröd age of Europe.

Although it is believed that the sequence of climatic changes in the Late Glacial age were clearly worldwide, this has not yet been clearly demonstrated in the Japanese Islands. The problem may not be solved until many more detailed pollen diagrams and numerous radiocarbon dates are obtained throughout the islands. Furthermore the vegetation may have been more localized in its manifestations. It will be still more years before the European and North American sequences of Quaternary chronology and biostratigraphy can be compared with that of Japan.

Although in southern Sweden, Denmark and European continent the latest Glaciation (Ljungner,1945 and 1949) is subdivided into early and late stages by the Göta Älv and Denekamp interstadials respectively, the climate during the interstadials was not as warm as that of the Jämtland interstadial. For example, in the Göta Älv interstadial it appears that only the west coast and southernmost part of Scandinavian Peninsula were deglaciated, although some different opinions have been proposed. Therefore, almost the whole of Finland may have been covered by ice during the late Weichselian glacial stage. In the main part of Scandinavia the ice sheet of the Weichselian Glaciation III (the late Weichselian glacial stage) appears to have been a direct continuation of the Weichselian Glaciation II (the middle Weich- selian glacial stage), although again different opinions have been proposed. Although the maximum extent of the ice sheet throughout the Weichselian glacial stage is not known, the southernmost coast of Norway was definitely covered by ice, and the maximum extent of the ice sheet in Sweden was dated at about 20,000 years B.P. or somewhat later (Andersen, 1965). According to Pratje (1951) and Valentin (19577), large parts of the North Sea were covered by the Weichselian ice sheet, although the time of this cover has not been Alpine plants with unusual distribution patterns such as *Artemisia norvegica* and *Saxifraga hieracifolia* grow in the mountain districts of Norway. Many plants growing in these districts are the same as, or closely related to species growing in Greenland and Canada. According to Nordhagen (1937) and Dahl (1955), the distribution pattern and some other botanical data indicate that the plants survived in ice-free refuges during the Weichselian stage, not far from their present-day habitats.

The younger Dösebacka-Ellesbo interstadial in Sweden may be ccorrelated with the Hengelo-Denekamp interstadials in Holland. Organic matter from sand layers at Ellesbo and clay lamina at Dösebacka have been ^{14}C dated at 30,350 and 24,020 years B.P. respectively. In the Japanese Islands, about 25,000 years B.P., the Hichinoe terrace deposits (^{14}c dating 25,8500±1,300 years B.P.; Takeuchi, 1970), the horizon 155 meters below the B-24 Well in Niigata (^{14}C dating 24,600 ± 1,500 years B.P.; Niigata Quaternary Research Group, 1972), and the middle horizon of Tomita Gravel bed (^{14}C dating 26,000 ± 800 yyears B.P.) had vegetation which was the same as or similar to the vegetation which grows in the present Temperate or montane zone in the Japanese Islands. This indicates, therefore, that a minor warm period occurred during this short time: This warm period may be correlated with the younger Dösebacka interstadial. As the Göta Älv interstadial has been dated 25,000 − 35,000 years B.P. in Sweden, this interstadial may be correlated with the short warm period of the Japanese Islands just mentioned.

In Denmark, the Main Weichselian glacial stage is divided into six substages, namely, the Main (Main Stationary Line), Eastern Jylland, Belt, Langland, "G", and Öresund substages (Hansen *et all.*, 1960). Although the Main Weichselian ice sheet did not cover the whole of Denmark, it reached a western boundary called the Main Stationary Line between the northwestern and central parts of Jylland. This boundary extends from Denmark to Hamburg and thence to the Brandenburg terminal moraines of Germany.

The changes in climate, glaciation, and vegetation during the stadial and interstadial in the above-mentioned districts of Europe were summarized clearly by palynologists. Recently van der Hammen and others (1971) presented a schematic representation of the glacial-interglacial cycle in the Northwestern Europe. According to them an interglacial begin with the replacement of the open (tundra) vegetation by pine-birch forest. Further amelioration of the cilimate results in the replacement of the pine forest by temperate deciduous trees. First there is a maximum of hazel *(Corylus)*, but gradually an oak forest, with local elms *(Ulmus)* and limes *(Tilia)*, becomes dominant. Then there is a further increase of shade, and a slightly acid forest soil is formed. Hornbeam appears, and is reflected as a clear zone in the pollen diagram. At the same time fir *(Abies)* and spruce *(Picea)* begin to appear, often resulting in well-marked

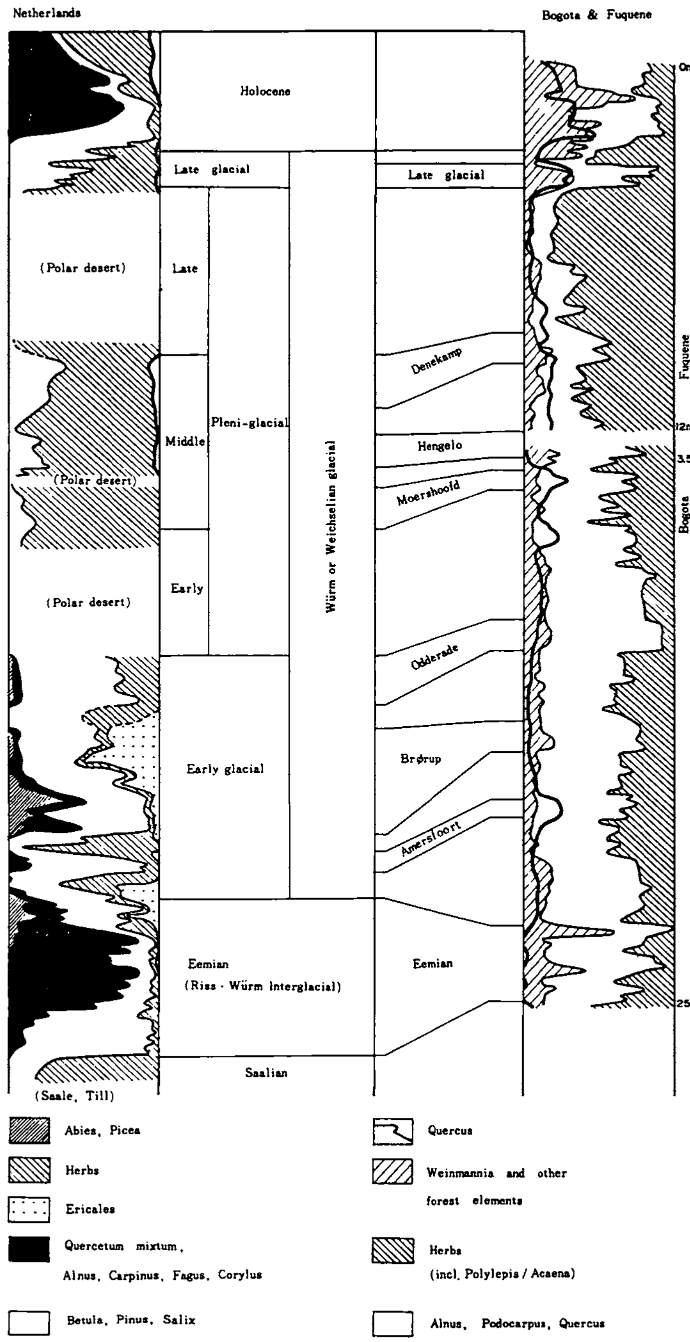

Fig.2 pollen diagrams for the Last interstadial (Eemian), Last glacial (Weichselian), Holocene from the Netherlands, Bogota, and Fuquene (redrawn by Fuji after van der Hammen T. *et al.*, 1971).

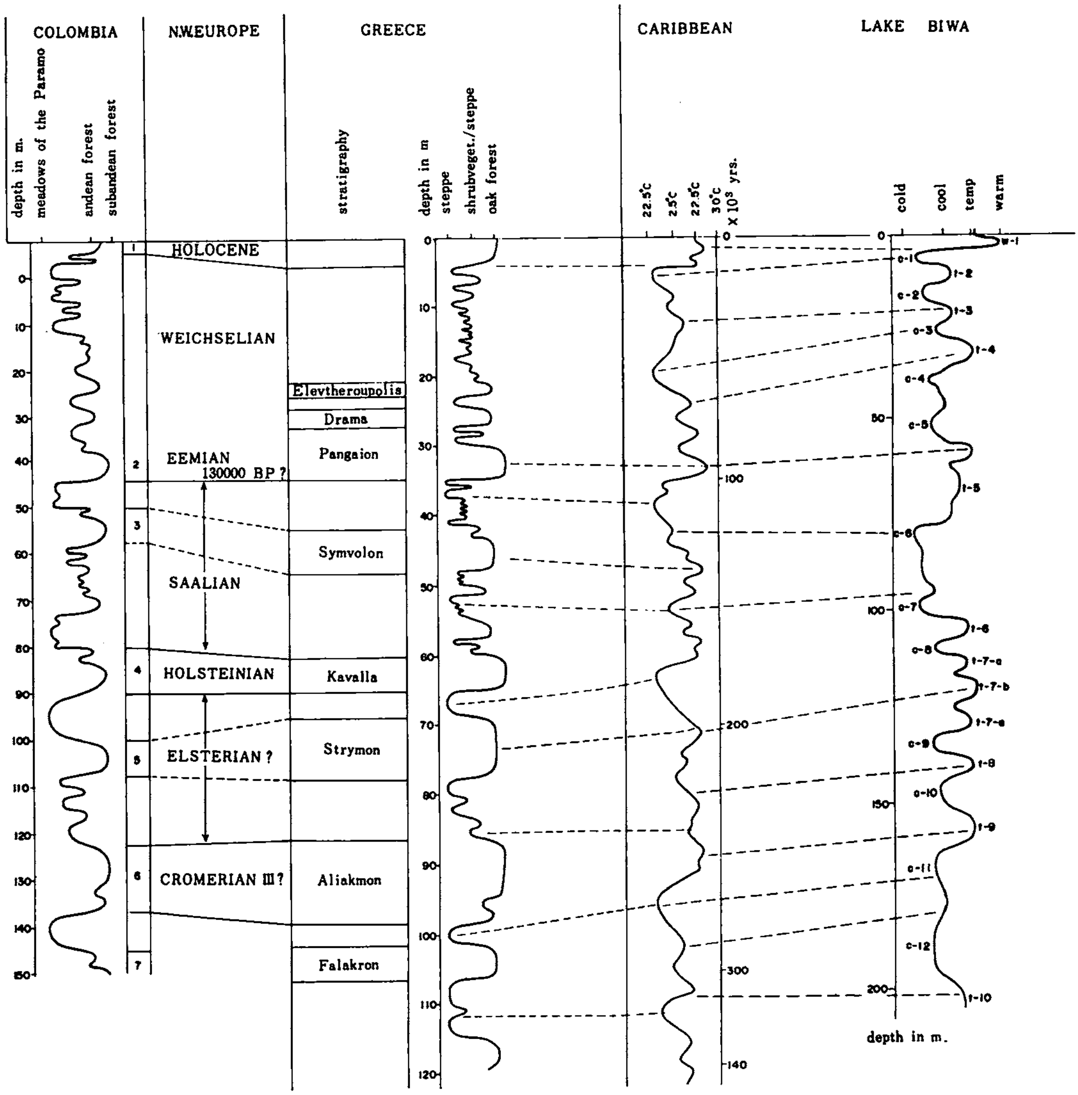

Fig. 3 Correlation diagram between the climatic changes in Clombia and Greece (van der Hammen *et al.*, 1971), the temperature curve from Caribbean Sea (Emiliani, 1966), and the climatic change from Lake Biwa (Fuji). The c-1 and c-2 in Fig. 3 mean co-1 and co-2 in Fig. 1 respectively.

zones in the pollen diagrams. Spruce, especially, appears above the hornbeam zone. Finally the temperature begins to decrease, resulting in pine-birch forest. Upon further decrease of temperature this forest is replaced by an open herd (tundra) vegetation. Extreme full-glacial conditions cause the complete or almost complete disappearance of vegetation and the establishment of a polar desert in a zone immediately south and southwest of the ice sheet. So-called steppe elements are more frequent in the late glaciations, but there seems to be doubt that the climate was always relatively dry during the later part of the glacials and the early part of the interglacials. The climate was relatively humid during the later interglacials and the earlier glacials.

The change of vegetation in the Japanese Islands during the Weichselian glacial stage is summarized roughly as follows: during the stadials the vegetation which now occurs in the Subpolar or Subalpine zones in the Japanese Islands migrated southward into lower areas. On the other hand, during the interstadials the vegetation was composed mainly of the plants growing in the temperate or montane zone of the present Japanese Islands, and sometimes contained some Subtropical plants. Such changes of vegetation in the Japanese Islands were different from those of Europe and were caused by the topography of East Asia. From a worldwide view point the change of vegetation during the Pleistocene period in East Asia, including the Japanese Islands, has been explained by Gray: glaciated mountain chains such as Pyrenees, Alps, Carpathians, and Caucasian Mountains were responsible for the extinction of plants in Europe and western Asia. However, the northwest trending mountain chains and valleys of East Asia and eastern Noth America permited some temperate or Warm Temperate plants to migrate southward to warmer distincts during the glacial or stadial and to return northward during the interglacial or interstadial intervalss. However, the wither dose not think that the changes in vegetation during the Weichselian stage, especially during some interstadials, can be represented by so simple a model. For instance, in the southwestern part of the Japanese Islands during the middle Weichselian glacial stage evergreen *Quercus* (=*Cyclobalanopsis*) grew together with *Fagus*. From this fact it may be presumed that the climate during this interstadial was cooler in summer, so that *Fagus* could survive, and milder in winter, thus allowing evergreen *Quercus* to exist. Such a climate might be a result of the influence of the Japan Current on the Japanese Islands in that age.

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