# Climatic Changes based on Palynological Evidences from Lake Biwa, Central Japan since the Middle Pleistocene*

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**Abstract**

Samples of 200-meter and 1400-meter cores obtained from Lake Biwa, Central Japan for the investigations of the palaeovegetational and palaeoclimatic changes around the lake during the middle pleistocene can be divided into nineteen pollen zones for the 200-m core and twenty-two pollen zones for the 1400-m core from the view point of palynology and climate. For glacial stages or stadials, typical vegetation of the subpolar zone occurred in the mountanous area around Lake Biwa, while in the lowland area around the lake, characteristic plants of the Cool Temperate zone occurred. For interglacial stages or interstadials, the vegetation of the mountainous area was generally characterized by plants of the Temperate zone and/or Cool Temperate zone, while in the lowland area the vegetation was composed mainly of broadleaved deciduous and evergreen trees of the Temperate and Warm Temperate zones. The climatic change during the middle Pleistocene shows remarkable parallels with the temperature record of the Caribbean Sea and Pacific Ocean, sedimentary cycles of the Mediterranean Sea, loess cycles in Central Europe, the records of sea level change in Japan and New Guinea, and palaeoclimatic history in the Dead Sea and the Hula basins of Israel.

## Introduction

Palaeoclimatic records since the middle Pleistocene are well known for the oceans (Emiliani et al., 1974 ; Imbrie et al., 1984, and others) but are unfortunately quite rare for continental sedimentary deposits. The mean reason is probably the concentration of Quaternary studies in previously glaciated districts in which evidence had been destroyed by the successively advancing ice sheets, while the mid- and low-latitudes have been neglacted for a long time. Indeed, the only localities from which continuous continental records since the middle Pleistocene are known from Colombia (Hooghiemstra, 1984), Indonesia (Caratini et al., 1985), Greece (Wijmstra and Groenhart, 1983), and Japan (Fuji, 1976b, 1983) and Israel (Horowitz and Horowitz, 1985 ; Horowitz, 1987). In most of these localities, the continuous pollen diagrams had been obtained from analysis of lake sediments laid down in tectonically active

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lacustrine troughs, surrounded by volcanoes. The continuous subsidence and the inclusion of volcanic rocks within the lake sediments ensure uninterrupted records in most cases, and the possibilities of radiogenic age controls.

Sequences of lake sediments spanning the last 100-150 k. y. had been palynologically studied in detail both in Japan (Fuji, 1987) and in Israel (Horowitz and Weinstein-Evron, 1986). These have been dated by radiocarbon for the upper parts and by Fission-tracks and U-series for the lower, ensuring a reasonably detailed age control (Nishimura and Yokoyama, 1975 ; Horowitz, 1979 ; Weinstein-Evron, 1983 and others). These sequences led to climatic models which tied up the variations in Israel (Horowitz, 1987) and in Japan (Fuji, 1986; 1986c) with the global oxygen isotope curves.

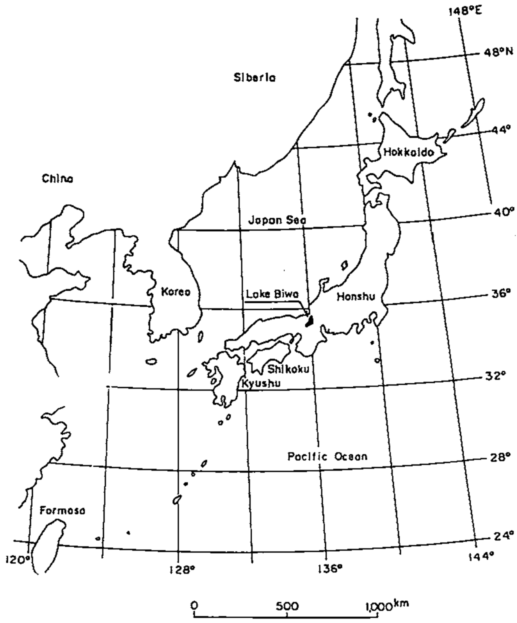


Fig. 1.  Locality map showing the studied area.

The problem of exact datings for the palaeoclimatic evidences becomes more complicated as one goes back in time. Thus the conclusions presented in this paper are based on recognition and correlation of series of climatic events, with the available datings used as quidelines, based on the climatic models previously obtained for the better dated upper parts of the sequences in both regions of Japan and Israel. A similar principle of correlating with climatic sequences is widely used among students of deep ocean sediments, and it seems that at our present state of knowledge this method constitutes the "best quess". The palaeoclimatic curves are correlated with the smoothed stacked curve proposed by Imbrie et al. (1984) for the oxygen isotope records from the oceans. The ages, stage numbers and boundaries used here conform with the above mentioned authors but differ somewhat from previously published time scales and stage boundaries.

A minor inconvenience posed by using the smoothed stacked curve is the apparent obliteration of stage 1, which clearly appears in both the Japanese Islands and Israel.

The aim of the present paper is to compare a palaeoclimatic history around Lake Biwa based on palynological investigations of 200-m and 1400-m core-samples with the palaeoclimatic records from the oceans, and palaeoenvironmental changes as sedimentary cycles and sea-level changes from the Kwanto region of Japan and New Guinea since the middle Pleistocene.

## 1. Significance of Research on the Thick Sediments from Lake Biwa

Palaeomagnetic stratigraphy has provided a means of correlating continents and oceans over the world. With the abvent of deep-sea research by DV Glomar Challenger and other oceanographic vessels, oceanographers and geologists have verified the probable existence of continental drift through work conducted on an international scale and thus established a new field of plate tectonics and neotectonics.

Recent studies of sediments in deep-sea cores (Hays et al., 1969) and of loess deposits from central Europe (Kukla, 1970) indicate successive changes of palaeoclimate during the Quaternary period.

Our understanding of climatic change during the Quaternary period are based primarily on research on terrestrial and submarine deposits However, the Quaternary system exposed on land is frequently represented by coarse-grained materials such as sand and gravel. This is true of Pleistocene deposits from the Japanese Islands but also in deposits from Europe. The pollen record, unfortunately, is not continuous in northern Europe, because, especially in the late and middle Pleistocene, deposits suitable for pollen preservation, like peat and clay, were principally formed during the interglacials and interstadials. Deposits from glacial ages are not preserved even in located between the ice sheets. Coarse-grained materials such as sand and gravel are not suitable for pollen analysis. Furthermore if the change of sea-level is explained by glacial-eustatic theory, sea-level should have been lower during the cold glacial and stadial times. Therefore, it is difficult to collect continuous samples in the Quaternary period, which is characterized by an alternation of warm and cold climatic times.

On the other hand, although sediments of both the cold and warm times are complete in the deep-sea cores, we cannot changes in climate over short times because of the extremely slow sedimentation rate.

On the basis of the above-mentioned considerations, the following conditions have to be satisfied, if climatic changes can be investigated by means of palynological, geochemical and palaeomagnetic analyses:

a : the rate of sedimentation must be large,

b : the sediments must be entirely fine-grained materials, such as silt, clay or gyttja, and

c : the sediments must be continuous since the early Pleistocene.

According to a few glacial geologic field works (Minato, 1972 ; Kobayashi, 1958 ; and Horie, 1961 etc.), several expansions of glaciers probably occurred in the Japanese Islands during the Wisconsinan glacial age, those fluctuations being closely similar to the oscillation of the ice sheets in both Europe and North America. Climatic changes in the late Pleistocene were probably synchronous throughout the Northern Hemisphere : In unglaciated areas, the bottom sediments of ancient lakes may cover the whole Pleistocene. Lake Biwa of Central Japan is such a lake (Horie, 1961 and 1962). The exact thickness of bottom deposits in the center of this lake is about 1,000m, which indicates that the lake was formed in the latest Pliocene or earliest

Pleistocene and that may have been in existence continuously. Furthermore, Lake Biwa is the third oldest lake in the world, after Lake Baikal and the Caspian.

In addition, Lake Biwa is important for the following reasons:

A: A strikingly negative gravity anomaly exists in the northern part of Lake Biwa, amounting exists in the northern part of Lake Biwa, amounting to -55 milligal. Isoanomaly lines almost coincide with the outline of coastal line of this lake (Tsuboi et al., 1954; Abe et al., 1974). Such gravity anomaly suggests us the existence of extremely thick, about 1,000 m. lacustrine sedimentary deposits.

b: A great number of endemic species of animals and plants is known in the lake. They differ markably from the biota of other plants of the Japanese Islands.

c: Judging from the previous geologic studies (Ikebe, 1933; Hayashi, 1974), the Pliocene-Pleistocene and Pleistocene-Holocene boundaries exist in lake sediments that are preserved as the lacustrine terraces. This fact affords us the evidence of an ancient Lake Biwa which appeared in sometime during the Neogene.

A deep boring in such a lake having an extremely long limnetic history must yield valuable samples for palynological research. These samples contain a continuous record of the change in climate since the latest Pliocene or earliest Pleistocene. These results may be correlated with changes in climate during the Quaternary period already worked out in North America (Dreimanis et al., 1972) and. Europe. From those viewpoints it may be said that the long core is significant for the promotion of our knowledge in the Quaternary geology not only in the Japanese Islands but also in the other countaries of the globe.

## 2. Stratigraphy of the Core Samples and those Lithofacies

a: Location of the Boring

A 200-m core sample for a palynological investigation was collected from Lake Biwa in the water depth of 65 m at a location between the Okinoshima Island and Omi-maiko in Shige Prefecture during the autumn of 1971. Between the spring of 1982 and spring of 1983 the Research Group of Paleolimnology and Paleoenvironment on Lake Biwa drilled a new 1400-m core at almost the same position as the 200-m core drlled in 1971.

b: 200-m Core Samples

About one and half months after recovery, the long core was cut at 1 m in length, and samples were taken at intervals of about 5 m for primary analyses. The core was then frozen and cut longitudinally. Samples vsed for geochemical analyses, palaeomagnetic, palaeontological, mineralogical, granulometric, and rediometric dating analyses were taken always from a half of the core keep under frozen state. The other half of the core was divided for observation of lithofacies and volcanic ashes under the normal state melting.

The core sediments mainly consist of soft homogeneous clay including at least 30 thin volcanic ash layers. The clay is generally blue in color when it is fresh, though it is grey or black at several horizons. The black clay contains some plants fragments. Almost all grains of sediments are smaller than 44 microns in diameter, except either large plant fragments or volcanic materials.

No sedimentary structure can be observed by the naked eye.

The volcanic materials in the core samples are divided into two types, andesitic and trachytic ashes. The former contains two pyroxenes, hornblende, and abundant volcanic glass. The latter is chiefly composed of orthorhombic pyroxene, hornblende, biotite, quartz, volcanic glass flakes, and small pumice grains and were derived from Quaternary volcanoes such as Daisen, Sande-yama etc., which occur 100-350 km west of Lake Biwa (Yokoyama, 1974).

About 2500 samples taken at intervals of about 10 cm throughout the core were analyzed for palynological investigation.

The samples taken from the same horizons have been analyzed fochemical components, palaeomagnetism, particle size, clay mineralogy, and microfossils.

c : 1400-m Core Samples

The upper 900 m of the 1400-m core is subdivided into five beds (Fuji, 1988, 1989) : P (oldest bed), Q, R, S, and T (younger) beds. The basement consists of Paleozoic and Mesozoic sedimentary rocks below abouot 900 m. Bed F is about 100 m thick and is composed of gravel. It lies unconformably on the basement of pebbles, but sand dominates the upper part. It lies unconformably on Bed P. Bed R (about 150 m thick) overlies Bed Q conformably and is composed of clay and sand layers intercalated with a few thin volcanic ashes. Bed S (about 330 m thick) consists of alternations of silt and sand layers with gravel layers. Bed T (about 250 m thick) coinsists of mostly homogeneous clay facies with about 30 thin volcanic ashes. The clays are blue in color and lack any sedimentary structures such as graded-bedding or lamination. Bed S lies unconformably on Bed R, but is overlain conformably by Bed T (Horie, 1987).

## 3. Two Methods based on the Pollen Spectra for Palaeovegetation and Climatic History

(a) Analogy with pollen spectra of modern samples from in and around Lake Biwa, and from various localities of some climatic zones throughtut the Japanese Islands.

(b) Warmth index (month-degrees) method.

## 4. Pollen Assemblage Zones and Interpretation of Palaeovegetation and Climatic History

Most pollen diagrams already published include a zone system to facilitate reading and interpretation of the diagrams. It also allows comparison with diagrams from other regions. The zone system can either be regional or local. A regional zone system has the advantage in that it allows inter-regional comparison. The zone boundaries, however, are in most cases defined on climatological criteria which influence the vegetation. On the other hand, a local zone system permits a detailed discussion of the vegetational development. However, many local zone system may seem confusing if used alone. This disadvantage can be avoided by using both regional and local systems, the local tending to be a subdivision of the regional one. The pollen diagrams have been subdivided into 37 zones on the basis of conspicuous changes in pollen percentages.

## 5. Dating

The ages used here for the oxyges-isotope curve are those suggested by Imbrie et al. (1984), and are discussed in detail by these authors. However, it should be noted that these ages are only "best estimates", and to a certain extent differ from previously published datings for the Brunhes and its subdivisions. Indeed the problem of dating sequences which are older than the radiocarbon range, in spite of all other methods applied, is still open.

The cores from Lake Biwa have been dated by three methods: radiocarbon for the uppermost sectors, which seems to be the least doubtful; fission-tracks for volcanic ash layers which occur along the entire sequence, giving ages with rather wide ranges; and palaeomagnetism which gave results for the 1400-m core (Kanari and Takenoya, 1975; Nishimura and Yokoyama, 1975; Yamamoto, 1976; Horie, 1987). The author thus regard the radiocarbon ages as quite significant for dating the climatic trends in the uppermost sectors; the fission-track ages are only regarded broadly as guidelines; while it seems that at present the magnetostratigraphy should be viewed with reservation, since it contradicts both the palynostratigraphy and the numerous fission-track ages. The radiocarbon ages for the last ice age in Japan, together with correlations of the climatic trends with other sequences from various countries, are detailed by Fuji (1981), and only one of these dates is shown in Fig. 3 as a guide. However, many more radiocarbon datings are available for the Japanese sequences. Fission-track datings are shown in Fig. 3 for both the 200-m and 1400-m cores, and seem to conform with the ages indicated by the correlation of the climatic and oxygen isotope curves, based, as discussed above, on climatic treands and models developed for the last 100 k.y.

Same samples from the 200-m core analysed for the palynology, geochemistry and other micropalaeontology were studied from the viewpoint of palaeomagnetism (Kawai *et al.*, 1972). All samples are belonged to the Brunhes normal polarity epoch, the past 690,000 years, and the new three short reversed polarity events, called "B", "Biwa I", and "Biwa II" from the lake bottom, have been recognized in the core. Judging from a correlation between the palaeomagnetic results from Lake Biwa (Kawai *et al.*, 1972) and these from some deep-sea cores (Opdyke, 1972; Ninkovich *et al.*, 1966), the "B" reversed polarity event at a depth of 50 to 55 m in the 200-m core of Lake Biwa is correlated with the Blake event (Ninkovich *et al.*, 1966; Denham *et al.*, 1975) which is estimated to have lasted from 117,000 to 104,000 years ago. Then the "Biwa I" event at a depth of 80.5 to 85 m and the "Biwa II" event at a depth of 130 to 132.5 m are estimated respectively to be from 176,000 to 186,000 years ago and from 292, 000 to 289,000 years ago (Yaskawa, 1974). Accordingly, sedimentation at the 200-m-level must

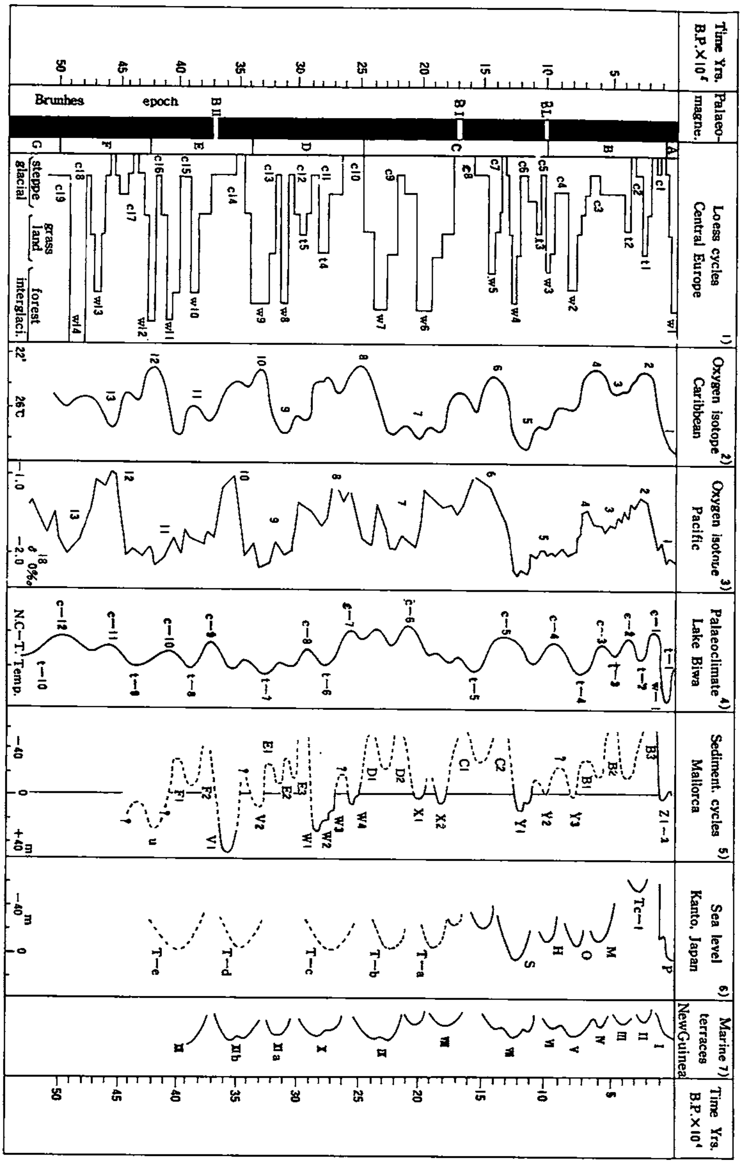


Fig. 2. Tentative comparison of the palaeoclimate from Lake Biwa, oxygen isotope records from deep-seas, sedimentary cycles from Mallorca, sea level changes from Japan and New Guinea, and loess cycles from Central Europe. 1 : Environmental change by loess cycles in the Central Europe (Kukla, 1970 and 1975 ; cord and nos. in the figure were marked conveniently by Fuji). 2 : Isotope curve from the Caribbean Sea (Emiliani *et al.*, 1974). 3 : Isotope curve from Solomon Plateau in Equatorial Pacific (Shackleton *et al.*, 1973). 4 : Palaeoclimatic change curve from Lake Biwa (Fuji, 1983). 5: Sedimentary cycles from Mallorca in Western Mediterranean (Butzer, 1975 ; Time before 30,000 years ago was estimated on the basis of Butzer's data by Fuji). 6 : Sea level changes from Southern Kanto in Japan (Machida, 1975). 7 : Marine terraces in New Guinea (Chappell, 1974 ; Time was estimated on the basis of Chappell's data). In palaeomagnetic data : BL, Blake event ; BI, Biwa I event ; BII, Biwa II event, respectively.

have begun from the early stage of Brunhes normal polarity epoch. Therefore, pollen analysis of this long core stated in this paper has produced a record for most of the Brunhes epoch.

The phases of vegetation development during the time not covered by the radiocarbon and fission-track age determinations need to be dated by the other methods. Geological studies from the surroundings of Lake Biwa unfortunately do not provide much evidence for such dating. So the changes in vegetation and associated climatic changes inferred from the palynological results offer the possibility for further dating.

## 6. Provisional Correlation between the Palaeoclimatic Record of Lake Biwa and Other Records from Marine and Terrestrial Deposits

One of the most impressive and important examples of a lake sediment sequence as a standard for world-wide correlation is that of Lake Biwa, Japan, where the four conditions are fulfilled as follows: (1) clear and unequivocal evidence of climatic change, (2) long stratigraphic record, (3) a continuous record, (4) dating and correlation by the independent means, such as palaeomagnetic stratigraphy and/or radioisotopic methods. Moreover, unlike sediments from the deep-sea, sedimentation rates were rapid enough to evaluate changes in climate over short time-scales (Fuji, 1983, 1984, 1988).

A comparison is made between the record of climatic change of the last 500 ka from Lake Biwa with the oxygen isotope stratigraphy of the Caribbean Sea and the Equatorial Pacific Ocean, environmental change in Central Europe reconstructed from loess, palaeosol and gastropod faunal records, and with sedimentary cycles and relative sea level changes from the Mediterranean, Central Japan and New Guinea. Correlation is based on the pattern and amplitude of the fluctuations shown.

Emiliani's stages 1, 2, 3, 4, 6, 7 and 8 are correlated with Lake Biwa code numbers t-1 to w-1 (warm stages), 3-1 (cold stage), t-2 to t-3 (warm or mild stage), c-3, c-5, t-5, and c-6 to c -7 (Emiliani *et al.*, 1974; Fuji, 1976), Emiliani's stages 9, 10, 11, 12 and 13 may correspond respectively to t-6 to t-7, c-9, t-8 to t-9 and c-11 to c-12, and t-10.

In conclusion, judging from this detailed comparison there are a few differences between Emiliani's generalized temperature curve from the Caribbean Sea and the present writer's climatic curve from Lake Biwa, still there seems a general similarity between the curves.

Twenty-three isotopic stages were recognised in cores V28-238 and V28-239 from the Western Pacific (Shackleton and Opdyke, 1973, 1976). A comparison between the Lake Biwa record and that of core V28-238 is shown in Fig. 2. Major trands are more similar than those between Caribbean and Biwa record. Shackleton's isotope stages 9, 10, 11, 12, and 13 may be correlated with Lake Biwa events t-7, c-9, t-8 to t-9.

Secondly, the Quaternary sedimentary record from Mallorca in the Western Mediterranean (Butzer, 1975) is compared with the Lake Biwa records. As shown in Fig. 2, the curve from Lake Biwa shows good correlation with the sedimentary cycles from Mallorca, high sea levels as well as with the sea level records from Southern Kanto in Central Japan (Machida, 1975) and New Guinea (Chappell, 1974).

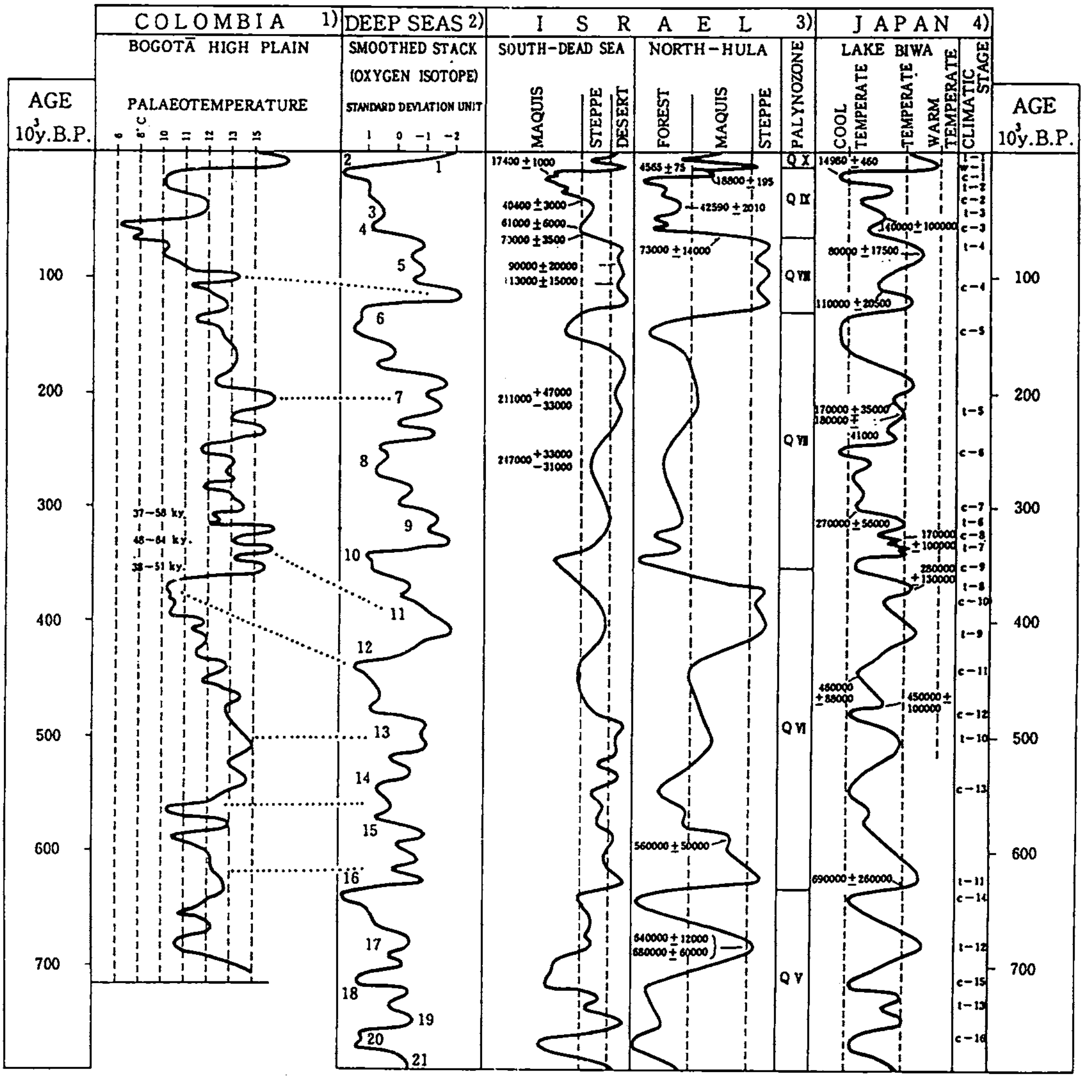


Fig. 3. Correlation of palaeoclimate curves for the Brunhes Epoch in Central Japan, northern and southern Israel with the smoothed stacked oxygen isotope record for the oceans (Fuji and Horowitz, 1989) and the palaeotemperature curve for Colombia in South America. The Israeli curves are based on continuous pollen diagrams of lake sediments, and display climatic trends in terms of vegetal compositions.

The correlations presented here for the Brunhes Epoch paleo climates of Japan with the oxygen isotope record of the oceans are based on models obtained from detailed studies of the climatic trends from some oceans for the last 100 k.y. The principles for modelling and correlation are discussed by Fuji (1973, 1975, 1976a, 1981, 1986a,b) for Japan.

The oceanic glacial and stadial phases are manifested in Japan by periods of considerable cooling, when the typical vegetation of the present-day subpolar and subalpine northern regions of Japan prevailed at higher elevations around Lake Biwa. The lowlands of Central Japan had been occupied during the cooler times by flora of the present-day Cool Temperate regions of the country. During the warmer interglacials and interstadials the floral configuration around Lake Biwa resembled pretty much the present-day, with the higher regions occupied by plants of a Cool Temperate to Temperate affinity and the lower elevation maintained broad-leaved deciduous and evergreen trees of the Warm Temperate zones.

The climate for the Brunhes Epoch in the Japanese Islands seems to have been essentially oceanic, influenced primarily by the arctic cold fronts system and cold sea currents. The response to glaciation of the northern hemisphere seems quite straight-forward, by cooling and south-ward migrations of the vegetation belts, and the correlation with the oxygen isotope curves is well founded. The differences between the Japanese palaeoenvironmental and the oxygen isotope curves are subordinate, expressed either by differences of relative amplitude of the climatic trends or by several additional or lacking minor stages. The latter, and to a certain extent also the former differences could easily be a result of insufficient sampling intervals or differences in the local rates of subsidence for certain periods, which may appear as sectors of higher or lower resolution on the pollen diagrams. The details of these differences are readily observable in Fig. 3, and will be further discussed.

The correlations between the palaeoclimatic trends of Central Japan, Israel and the oceanic oxygen isotope curve are primarily based on the recognition of sequences of events tied up by the detailed analyses and datings of the upper part of the sections which served for development of the climatic models. The correlations are controlled by direct and indirect radiometric datings which seem to conform with the palynostratigraphy.

There seem to be hardly any differences in the shapes of the curves for the last 100 k.y., except for some minor ones which are most probably a result of closer sampling, as is the case in the Hula basin of Israel. Since the oxygen isotope curve used here was smoothed by Imbrie et al (1984) one cannot expect all minor peaks to be observable. This is quite apparent with the interglacial peak known before as stage 1, which is clearly reognizable on the Japanese and Israeli curves (Fuji and Horowitz, 1989).

The extent of climatic changes as inflicted by the environments and vegetation is however not in all cases similar, and differences in amplitude can be observed between the various curves. Thus the three glacial peaks of the last 70 k.y. are clearly manifested in Japan, but to a lesser extent in Israel. There is a difference in Israel between the amplitude of changes in the north and the south, for instance stage 4 is better seen in the north. It seems that these differences should be ascribed to different responses of the various types of vegetations to the changing climates. Since the environmental gradient from north to south is so pronounced in Israel and the country lies within the desert border, small changes of climate could cause considerable changes of the flora in one locality and seem subordinate in the other. Adaptations to changing conditions and survival in local ecologic niches could also contribute to the apparent amplitude of deduced climatic changes.

The responses to the changing global climate would naturally be different in Japan, where the ocean acts as buffer and the environmental gradient is much more gradual than in Israel. Hardly any environmental border regions exist in Japan, with the possible exception of the higher mountains, which were subject to glaciation and eternal snow.

According to Fuji and Horowitz's investigation, Stage 5 is quite different in the oceans, Japan and Israel . In Israel almost the entire stage is interglacial in nature, with the 2 peaks of 5b and 5d rather subdued. In Japan, on the other hand, 5a seems to be the warmest (t-4), while the cool phase c-4 is rather prominent within stage 5. The usual subdivision of stage 5 is not too clear in Japan, despite the close sampling of this interval. It seems that these differences in stage 5 between the regions depend on the different responses of the Sahara Desert and the Pacific Ocean to the changing ice volumes. While the Sahara became dominant during the interglacial, inflicting a desert climate on Israel for almost all its length, the influence on Japan became buffered and milded by the ocean. The cooler c-4 could possibly reflect cooling of the ocean from meltwater resulting from deglaciation during 5e times.

Stage 6 displays similar tendencies in the oceans, Japan and Israel. It seems however that the pluvial climate in Israel lasted for a shorter time, which may be a result of the time needed for ardoreal repopulation.

Stages 7, 8 and 9 bear almost identical trends in the oceans and Japan, but are somewhat different in Israel. The smoother curve for these stages in Israel may have been a result of insufficient sampling, which does not seem likely. Stages 10-6 are represented in Israel by a pluvial climate. expressed not only by the pollen spectra but also by an extensive development of lakes and spring activity in the Dead Sea Rift, depositing lacustrine sediments and travertines in the Dead Sea and the Hula basins. These are accompanied by an extensive fluvial activity in the central Jordan Valley, where gravel was laid down (Horowitz, 1979). It seems that throughout these stages the influence of the Sahara considerably diminished, the pluvial climate prevailed and had only been interrupted by interstadials during stages 9 and 7. It should also be noted that during this time interval, although the shape of the Japanese curve resembles pretty much the oxygen isotope record, the warm phases in Japan are not as warm as the preceeding or the succeeding ones.

Stages 10-12 are quite similar for the oxygen isotope and the Israeli records but somewhat different in Japan, where the extreme of stage 11 interglacial is followed by a considerable cooling of c-10. This may be similar to the situation at stage 5, and may again result from cold currents around the Japanese Islands (Ujiie, 1979) which cooled the ocean and caused a cold phase within stage 11.

From stage 12 down to 16 again the four curves show similar tendencies, only the amplitudes of changes both in Lake Biwa and the Hula are greater than those of the oxygen isotope curve, while the curve for southern Israel is rather flattened.

The Japanese sector from t-8 down to t-11 is dominated by climates which seem to be warmer than the average, and the cool phases are milder than average, and the cool phases are milder than above. A similar tendency is seen in the Israeli curves, and it seems that the interval from stage 11 down to the beginning of stage 15 could best be described as an interglacial interrupted by several stadials. Again the differences between the oceanic and continental seqvences may be ascribed to a different response of the northern hemisphere to the glaciation or deglaciation procennes.

From stage 16 down to the bottom of the discussed sequences the curves show essentially similar configurations, except for some less details in Lake Biwa and the Hula, probably due to larger sampling intervals. As above, the swings in the continental records seem to be more pronounced than in the oceanic, which was also noted in Colombia for this time sector (Hooghiemstra, 1984).

Some minor differences between the four curves can however be observed, such as the termination of stage 16 which is so clear in the oceans, Japan and the Hula but much less so in southern Israel. A similar case is the interglacial peak of stage 17 which is subdued in southern Israel, in contrast to the peak of stage 19, which is more pronounced in southern Israel than in the other localities. These discrepancies may dither be a result of local phenomena or due to insufficient sampling.

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