*Japan Review*, 1990, 1: 113-152

# Monsoon Fluctuations and Cultural Changes During the Last Glacial Age in Japan

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(*Received 28 February 1989, revised manuscript accepted 8 April 1989*)

Southwest monsoons dramatically fluctuated during the Last Glacial Age, resulting in changes of humidity which influenced Japan's culture and environment. Wet climates during the Interglacial and Interstadials were closely linked to the active southwest monsoons, while dry climates during the cold Stadials were partly caused by the southwest monsoons being dormant. The development of accumulation terraces was also directly influenced by the fluctuations of the southwest monsoons. Several transitions in Japanese Paleolithic culture appear to have been greatly affected by the fluctuations of the southwest monsoons. For example, the Late Paleolithic culture, characterized by knife-shaped tools, adapted to the dry climate which was due to the conspicuous dormancy of the southwest monsoons during the maximum glacial period.

*Keywords*: PALEOCLIMATOLOGY, SOUTHWEST MONSOONS, LAST GLACIAL AGE, ACCUMULATION TERRACE, PALEOLITHIC CULTURE.

## INTRODUCTION

Evidence from micro-fossil and isotopic analyses of cores taken from the bottom of the Arabian Sea, Bengal Bay and Andaman Sea reveal the fluctuations of the southwest monsoons since the Last Interglacial Age (Duplessy, 1982, Fontugne and Duplessy, 1986, Van Campo, 1986, Van Campo *et al*., 1982). Rainfall during the so called *Bai-u* season (from June to July) accounts for a large part of the total summer precipitation in Japan, and is due to the flux of water vapor from the southwest monsoons (Kurashima, 1966, Yoshino, 1973, Kobayashi and Nakamura, 1976, Yasunari and Fujii, 1983, Chean, 1987). If the quantity of precipitation and water vapor transfer during the *Bai-u* are closely linked to the monsoon circulation (Suzuki, 1975, Krishnamurti, 1987), we can suppose that the fluctuations of the southwest monsoons in the Arabian Sea, Bengal Bay and Andaman Sea should directly effect the precipitation in the

*Bai-u*.

The purpose of this paper is to explain the climatic changes during the Last Glacial Age in Japan using data from the monsoon fluctuations in the Arabian Sea, Bengal Bay and Andaman Sea. The development of accumulation terraces and paleolithic cultural changes are then considered and discussed in relation to the fluctuations of the southwest monsoons.

## CLIMATIC CHANGES AT THE LAST GLACIAL AGE IN JAPAN

We first review in outline the climatic changes of the Last Glacial Age based on published data of pollen analyses. Lists of data and locations referred to are shown in Table 1 and Figs. 1 and 2. Climatic changes during the Last Glacial Age in Japan may be summarized as follows:

**120 ka-70 ka years B.P. (Early-glacial)**

This is the Early-glacial period, and only an unclear picture exists of the climatic changes during this period. Pollen and macrofossil analyses of the Kissawa formation in Kanagawa Prefecture (Fig. 2, Loc. 17, 18) (Tsuji, 1980, Tsuji and Minaki, 1982) show a decrease of warm temperate trees such as *Lagerstroemia, Melia* and *Sapium* occurring with the fall of the volcanic ash Klp-2. Thereafter rapid increase is evident in *Cryptomeria japonica, Alnus japonica* and *Picea maximowiczii.*

The native forest of *Cryptomeria japonica* is adapted to the wet climate and is presently distributed in such areas where both the winter and summer three months' total precipitation exceeds 450mm (Yasuda, 1984b). Therefore, the increase of *Cryptomeria* indicates that the climate tended towards wet, while the decrease of warm temperate trees indicates that the climate tended to become colder.

Findings from the Nariyasu site in Yamagata Prefecture (Fig. 2, Loc. 33) (Takeuchi, 1982) indicate the increase of sub-alpine trees such as *Picea, Abies* and *Tsuga* and the decrease of temperate trees like *Fagus* and *Quercus,* to have occurred at the horizon of the Blake-event (about 115 ka years B.P.). We can therefore conclude that the climate became colder. Thereafter, *Cryptomeria,* adapted to the ambient wet climate, increased rapidly. Similar vegetational changes were found at the Tsukabara formation in Fukushima Prefecture (Fig. 2, Loc. 29) (Takeuchi, 1985) and the Fujimi formation in Nagano Prefecture (Fig. 2, Loc. 24) (Sakai, 1981b).

Marked increases of *Cryptomeria* during the Early-glacial period were also reported from the results of surveys at the Kansai International Airport (Fig. 2, Loc. 13) (Furutani, 1984), Rokko island (Fig. 2, Loc. 12) (Maeda, 1985) and Ukinuma sites (Fig. 2, Loc. 34) (Yamanoi, 1986).

Based on the fission track date (Machida, 1980), Yasuda (1985) suggested that the rapid increase of *Cryptomeria* occurred approximately 120 ka years B.P.

Table 1. Lists of the locations of pollen analytical data quoted in this report.

| Loc. No. | Name | Altitude (m) | Place | Latitude | Longitude | References |
|---|---|---|---|---|---|---|
| 1 | MD76135 | -1895m | West Arabian Sea | 14° 26' 6" N | 56° 31' 3" E | Van Campo et al. 1982 |
| 2 | MD76131 | -1230m | East Arabian Sea | 15° 31' N | 72° 34' E | Van Campo 1986 |
| 3 | MD76194 | -1222m | East Arabian Sea | 10° 28' N | 75° 14' E | Van Campo 1986 |
| 4 | MD77169 | -2360m | Andaman Sea | 10° 12' 5" N | 95° 3' E | Fontugne et al. 1986 |
| 5 | Lake Rara | 3000m | West Nepal | 29° 34' N | 82° 05' E | Yasuda et al. 1988 |
| 6 | Kathmandu valley | 1350m | East Nepal | 27° 40' N | 85° 20' E | Igarashi et al. 1988 |
| 7 | Danau di Atas | 1535m | Central Sumatra | 0° 30' S | 100° 30' E | Stuijts et al. 1988 |
| 8 | Situ Bayonghong | 1065m | West Java | 7° 10' S | 106° 20' E | Stuijts et al. 1988 |
| 9 | Shinkai formation | 60m | Waki-cho, Kagoshima Prefecture | 31° 46' N | 130° 24' E | Hase et al. 1984<br>Hatanaka 1984 |
| 10 | Tokusa formation | 300m | Ato-cho Yamaguchi Prefecture | 34° 24' N | 131° 43' E | Hatanaka 1967 |
| 11 | Onomichi site | 0m | Onomichi City Hiroshima Prefecture | 34° 23' 30" N | 133° 11' 45" E | Yasuda et al. 1983 |
| 12 | Rokko Island | 0m | Kobe City Hyogo Prefecture | 34° 41' 30" N | 135° 16' E | Maeda 1985 |
| 13 | Kansai International Air Port | 0m | Osaka Prefecture | 35° 26' N | 135° 14' E | Furutani 1984 |
| 14 | Lake Biwa | 85m | Shiga Prefecture | 35° 14' N | 136° 6' E | Fuji 1984 |
| 15 | Lake Mikata | 0m | Fukui Prefecture | 35° 33' 32" N | 135° 53' 40" E | Yasuda 1982a |
| 16 | Torihatama Shell mound site | 0m | Mikata-cho Fukui Prefecture | 35° 33' 12" N | 135° 54' 20" E | Yasuda 1979 |
| 17 | Kissawa formation | 70 100m | Nakai-cho Kanagawa Prefecture | 35° 20' 20" N | 139° 13' 30" E | Tsuji 1980 |
| 18 | Kissawa formation | 50-100m | Hiratsuka City Kanagawa Prefecture | 35° 20' 30" N | 139° 15' 30" E | Tsuji et al. 1982 |
| 19 | Sagami SK-7 | 50m | Yokohama City Kanagawa Prefecture | 35° 32' 30" N | 139° 34' E | Tsuji et al. 1984 |
| 20 | Shimo-oshima formation | 8m | Tsukuba-cho Ibaragi Prefecture | 30° 8' 15" N | 140° 8' 20" E | Endo et al. 1983 |
| 21 | Ozaki site | 35m | Nerimaku Tokyo | 35° 44' 50" N | 139° 38' 40" E | Yasuda 1983a |
| 22 | Tamonjimae site | 45m | Kurume City Tokyo | 35° 45' 15" N | 139° 32' 10" E | Yasuda 1983a |
| 23 | Nakamura Peat formation | 950m | Chino City Nagano Prefecture | 36° 1' N | 138° 13' E | Iida 1973 |
| 24 | Fujimi formation | 960m | Fujimi-cho Nagano Prefecture | 35° 5' 31" N | 138° 15' E | Sakai 1981b |
| 25 | Miure formation | 1300m | Otaki-mura Nagano Prefecture | 35° 49' N | 137° 21' 50" E | Sakai 1981b |
| 26 | Ozegahara moor | 1400m | Katashina-mura Gunma Prefecture | 36° 40' N | 139° 10' E | Sakaguchi 1978 |
| 27 | Akaiyachi moor | 530m | Aizuwakamatsu Fukushima Prefecture | 37° 30' 14" N | 140° 0' 26" E | Sohma 1984 |
| 28 | Hoshojiri moor | 550m | Bandai-cho Fukushima Prefecture | 37° 37' 36" | 140° 21' 36" E | Sohma 1984 |
| 29 | Tsukahara formation | 20m | Kodaka-cho Fukushima Prefecture | 37° 30' 50" N | 141° 02' E | Takeuchi 1985 |
| 30 | Yanohara moor | 600m | Showa-mura Fukushima Prefecture | 37° 49' N | 139° 26' E | Kanauchi 1988 |
| 31 | Uemachi Terreace | 25-65m | Sendai City Miyagi Prefecture | 38° 10' 40" N | 140° 50' E | Takeuchi 1986 |
| 32 | Kawadoi basin | 280m | Nanyo City Yamagata Prefecture | 38° 5' N | 140° 18' E | Nakayama et al. 1984 |
| 33 | Nariyasu site | 94m | Yamagata City Yamagata Prefecture | 38° 19' 11" N | 140° 18' 50" E | Takeuchi 1982 |
| 34 | Ukinuma site | 86m | Murayama City Yamagata Prefecture | 38° 29' 34" N | 140° 22' 31" E | Yamanoi 1986 |
| 35 | Minami-gakuden moor | 40m | Kuriyama-cho Hokkaido | 43° 5' N | 141° 50' E | Hoshino et al. 1986 |
| 36 | Tarukawa moor | 0m | Ishikari-cho Hokkaido | 43° 15' N | 141° 20' E | Igarashi 1975 |

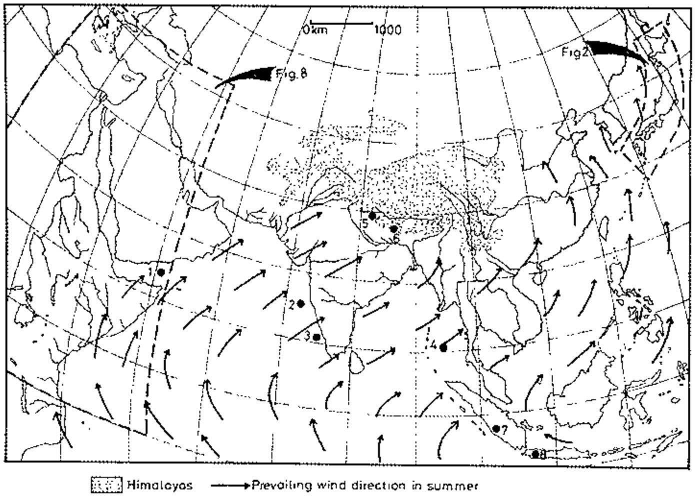


Fig.1. Map showing the sites discussed in this report.
1 MD76135 (Van Campo et al. 1982), 2 MD 76131 (Van Campo 1986),
3 MD76194 (Van Campo 1986), 4 MD 77169 (Fontugne et al. 1986),
5 Lake Rara (Yasuda and Tabata 1988), 6 Kathmandu valley (Yoshida and Igarashi 1984), 7 Danau di Atas Swamp (Stuijts et al. 1988),
8 Situ Bayongbong (Stuijts et al. 1988).

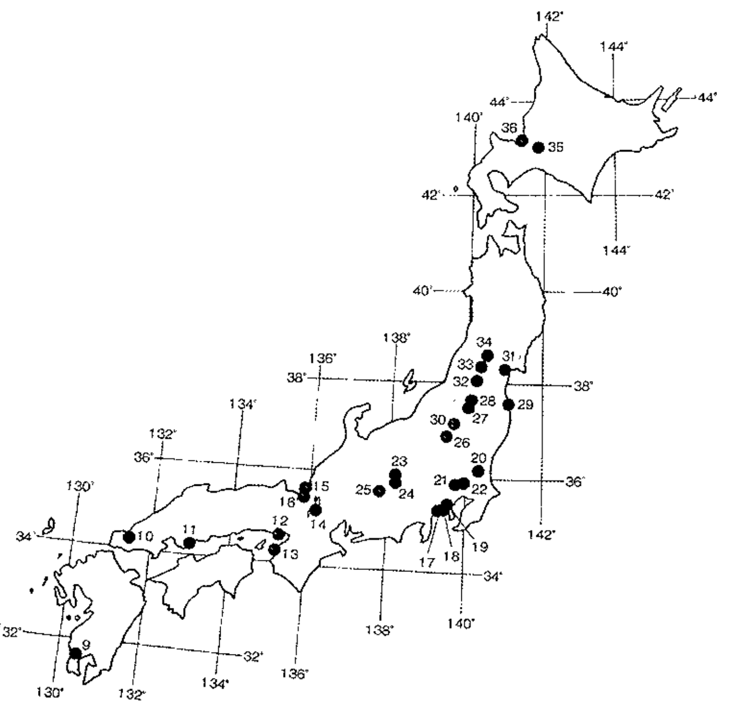

Fig.2. Map showing the sites of pollen analyses discussed in this report. Numbers of locality correspond with the Loc. number of Table 1.

This date corresponds with the oxygen isotopic stage 5e/5d boundary. Based on the increase in *Cryptomeria*, Yasuda (1985) estimated the beginning of the Early-glacial period to be at approximately 120 ka~110 ka years B.P., supporting the findings and estimations of Dansgarrd *et al*. (1982), Kukla and Briskin (1983), de Beaulieu and Reille (1984), Follieri *et al*. (1986), Richmond and Fullerton (1986) and Labeyrie *et al.* (1987). The rapid increase of *Cryptomeria* with *Picea* and *Abies* signals the ending of the Last Interglacial Age and the opening of the Last Glacial Age in Japan. However, the vast majority of Japanese Quaternary palynologists and geologists support a doctrine which sets the opening of the Last Glacial Age at 70 ka~60 ka years B. P. (e.g. Japan Association for Quaternary Research, 1987).

Results from the Grand pile peat bog in France (Woillard, 1978) include the Brϕrup and Odderade Interstadials (van del Hammen *et al*., 1971) within the Last Interglacial Age. However, the Brϕrup and Odderade Interstadials were probably as warm as the Holocene. Two characteristic transgressions were explained in terms corresponding to the Brϕrup and Odderade Interstadials of the Netherlands. Two transgressions in Japan are Hikihashi transgression at 100 ka years B.P. and the Obaradai transgression at 80 ka years B.P. (Fig. 11) (Machida, 1980).

Aharon and Chappell (1986) and Shackleton (1987) have pointed out the existence of a serious discrepancy between the sea level oscillations and oxygen isotopic records. Due to this discrepancy, we are unable to confirm the opening date of the Last Glacial Age from oxygen isotopic records alone. However, recent results of pollen analyses from the Oerel moor in northern Germany (Behre and Lade, 1986), Les Échets moor in France (de Beaulieu and Reille, 1984) and Valledi Castiglione in Italy (Follieri, 1986) help explain two cold epochs which existed before and between the two Interstadials (Fig. 3). Pollen flora indicate that these cold epochs were as cold as the Stadial in the Last Glacial Age and continued for over 1 ka years (Fig. 3). Sasajima *et al*. (1980) suggest that the short regressions also existed before and between two Interstadials in Kagoshima Prefecture, Japan. Accordingly, if a cold climate similar to that of the Stadial did continue for over 1 ka years, culture and daily life would have been severely affected.

It is supposed that the first cold epoch between 120 ka and 110 ka years B.P. probably had a marked effect upon Japanese culture and environment. If we consider the possibility of a future Glacial Age, and if our object of paleoclimatic study is to forecast future climatic changes, we should focus much attention on this first cold epoch just before the Brϕrup Interstadial. The opening of the Last Glacial Age should be placed at the time of this first cold epoch at between 120 ka and 110 ka years B.P.; a rapid increase of *Cryptomeria* with subalpine and cool temperate coniferous trees like *Picea maximowiczii* and *Tsuga diversifolia* characterizes this first cold epoch.

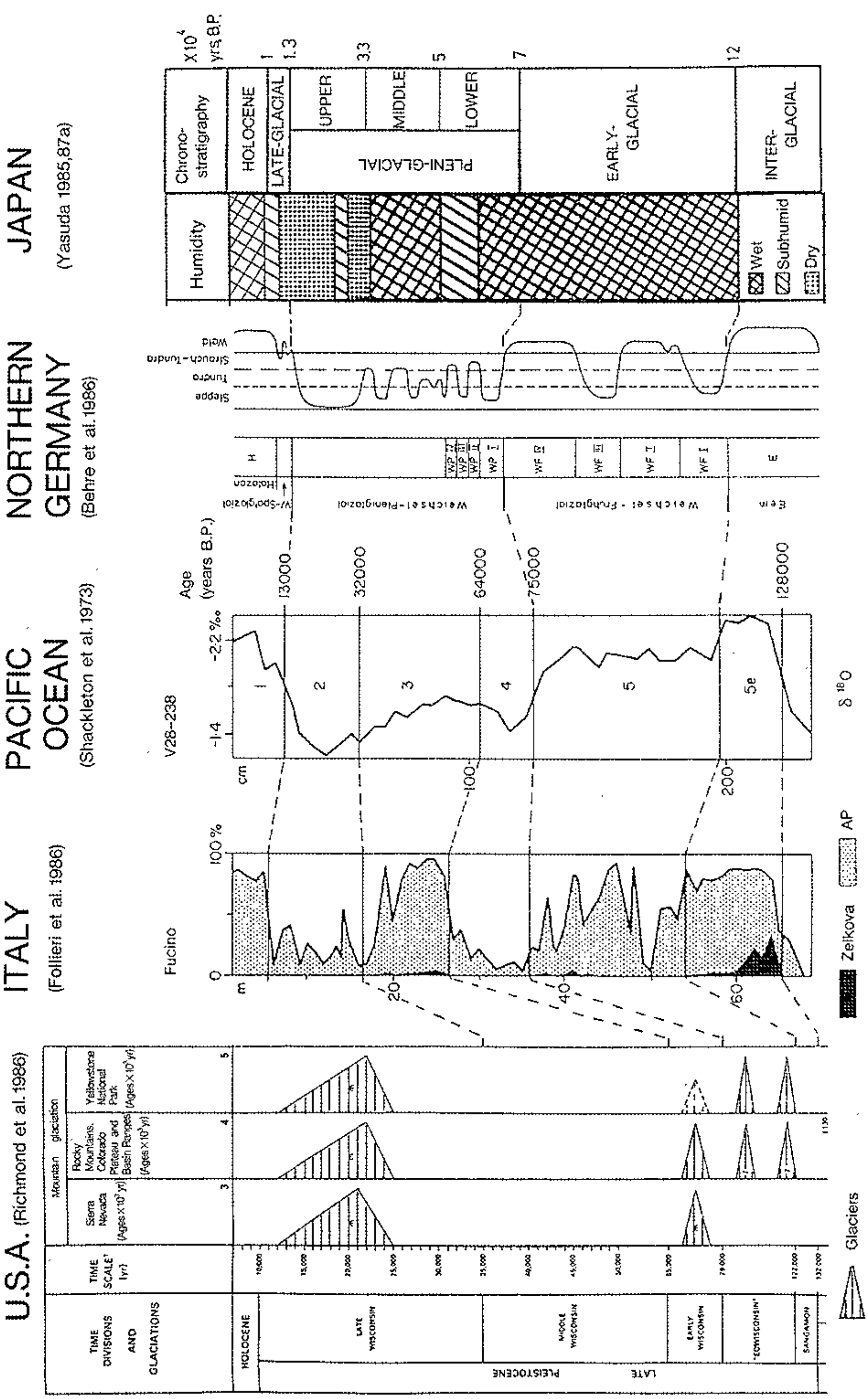


Fig.3. Comparison of various data of climatic changes since the Last Interglacial Age (Yasuda, 1988).

**70 ka-50 ka years B.P. (Pleni-glacial I)**

One of the characteristic features of this period is the sudden decline of *Cryptomeria*. At the Nariyasu site (Fig. 2, Loc. 33) (Takeuchi, 1982), *Cryptomeria* decreases with other temperate trees about 70 ka years B.P., and thereafter, *Abies, Picea* and *Betula* increase rapidly, indicating a cold and dry climate.

This cold and dry climate continued until about 50 ka years B.P. Results which indicate a cold and dry climate between 70 ka and 50 ka years B.P. are also reported in other sites. A sudden decline of *Cryptomeria* at about 60 ka years B.P. is found at Yanohara moor in Fukushima Prefecture (Fig. 2, Loc. 30) (Kanauchi, 1988), while results from Lake Biwa (Fig. 2, Loc. 14) (Fuji, 1984) suggest a climatic deterioration at around 70 ka years B. P. Evidence from the Hoshojiri and Akaiyachi moors in Fukushima Prefecture (Fig. 2, Loc. 27, 28) (Sohma, 1984) show the existence of a cold epoch between 60 ka to 50 ka years B.P., and finding from the Ukinuma site (Fig. 2, Loc. 34) indicate a cold and dry climate at around 52 ka years B.P. (Yamanoi, 1986), while from the Sagami region (Fig. 2, Loc. 19) (Tsuji *et al*., 1984) a cold climatic epoch at around 55 ka years B.P. is reported.

The beginning of this cold and dry epoch corresponds to the opening of the Pleni-glacial in Europe (Wijimstra 1969, de Beaulieu and Reille, 1984) and to the oxygen isotopic stage 5/4 boundary (Kukra and Briskin, 1983).

**50 ka-33 ka years B.P. (Pleni-glacial II)**

This period is an Interstadial, as shown clearly in the results from Lake Mikata (Fig. 2, Loc. 15) (Yasuda, 1982a). Fig. 4 shows a pollen diagram from Lake Mikata. Percentage values are expressed as total tree pollen sum, except for *Alnus*.The MG pollen zone (Fig. 4), covering from 50 ka to 33 ka years B.P., indicates high values of *Cryptomeria* with *Fagus* and *Quercus* subg. *Lepidobalanus,* showing a reincrease of *Cryptomeria* during this Interstadial. High values of *Cryptomeria* together with temperate trees like *Fagus* and *Quercus* are also reported from the Shinkai formation (Fig. 2, Loc. 9) (Hase and Hatanaka, 1984), Tokusa formation (Fig. 2, Loc. 10) (Hatanaka, 1967), Rokko island (Fig. 2, Loc. 12) (Maeda, 1985), Ozegahara moor (Fig. 2, Loc. 26) (Sakaguchi, 1978), Hoshojiri moor (Fig. 2, Loc. 28) (Sohma, 1984), the Miure formation (Fig. 2, Loc. 25) (Sakai, 1981b), the Nariyasu site (Fig. 2, Loc. 33) (Takeuchi, 1982), the Kawadoi basin (Fig. 2, Loc. 32) (Nakayama and Miyagi, 1984) and Minamigakuden moor (Fig. 2, Loc. 35) (Hoshino *et al.,* 1986). This increase of *Cryptomeria* with *Fagus* and *Quercus* indicates that the climate became warmer and wetter than that of the previous Stadial.

**33 ka-28 ka years B.P. (Pleni-glacial III)**

In the pollen diagram from Lake Mikata, *Cryptomeria* becomes unstable after 41 ka years B.P. and *Tsuga* thereafter becomes increasingly abundant (Fig. 4). Two species of *Tsuga* occur in Japan: *T. diversifolia* grows in the subalpine and cool-temperate zones, while *T. sieboldii* grows in warm and cool temperate

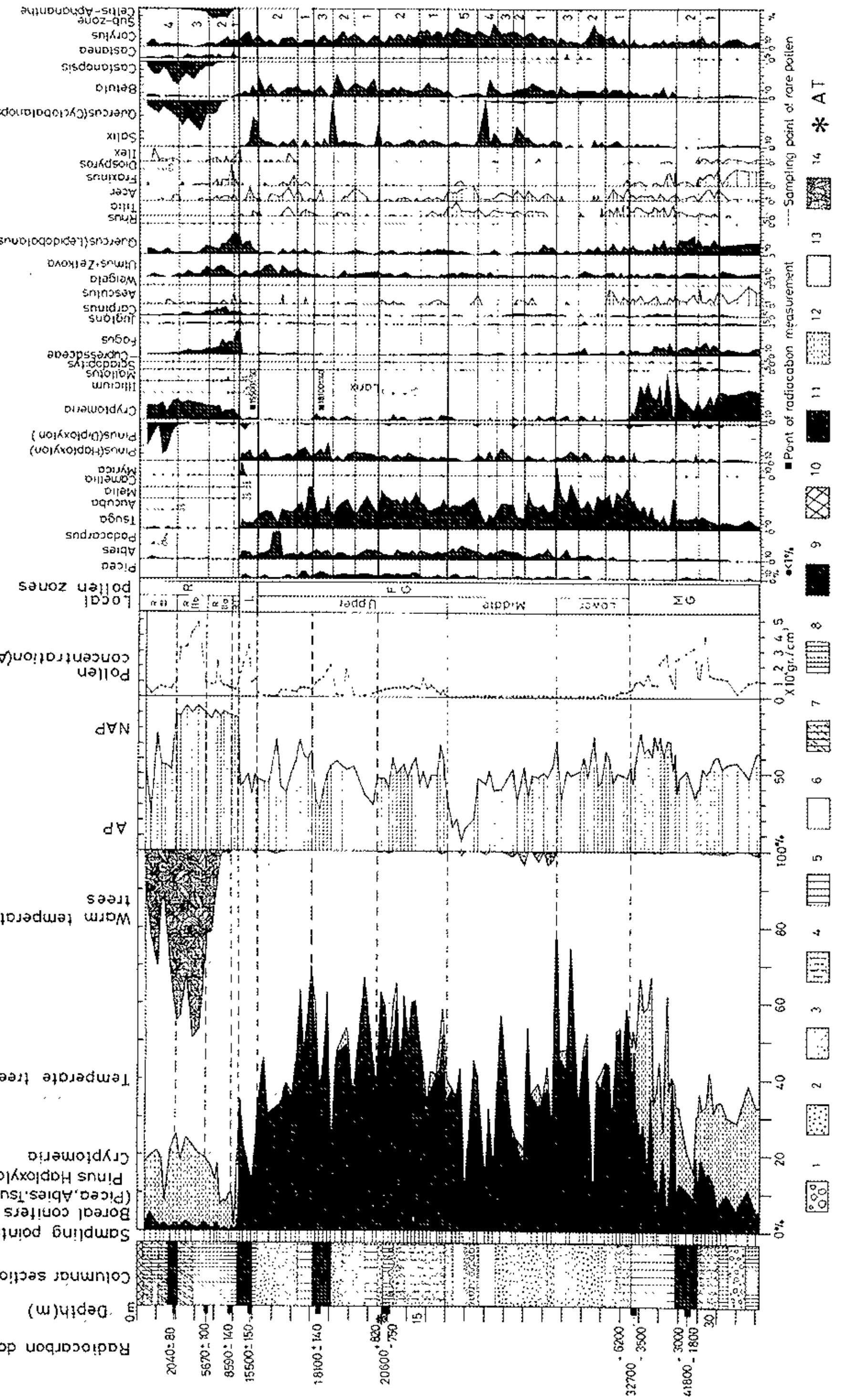


Fig.4. Pollen diagram from the Lake Mikata, Fukui Prefecture (Yasuda 1987a).
1 Gravel, 2 Coarse sand, 3 Fine sand, 4 Sandy silt, 5 Green-grey silt, 6 Blue-grey silt, 7 Silty clay, 8 Humic clay, 9 Peat, 10 Floating mud, 11 Conifers(*Pinus* subg. *Haploxylon*, *Picea*, *Abies*, *Tsuga*), 12 *Cryptomeria*, 13 Temperate trees. 14 Warm temperate trees.

zones. Both species are adapted to a dry climate and unstable soil and are distributed on the Pacific side of Japan (Hayashi, 1969), being unable to extend into the area of heavy snowfall. Observations of fossil pollen grains by SEM indicate *T. diversifolia* to have been dominant. Therefore, the evidence obtained from the decrease of *Cryptomeria* and the increase of *Tsuga* indicates that a cold and dry climate became dominant. Between 41 ka to 33 ka years B.P. *Cryptomeria* and *Tsuga* were in competition (Fig. 4), but thereafter *Tsuga* predominated, accounting for over 60% of the total tree pollen sum, whereas *Cryptomeria* decreased markedly and remained at very low frequencies until 10 ka years B.P. *Tsuga* maintains its high values together with *Picea, Abies, Pinus* subg. *Haploxylon* and *Betula* until 13 ka years B.P. A cold and dry climate was established at 33 ka years B.P. This climatic turnabout around 33 ka years B. P. was also reported from Ozegahara moor (Fig. 2, Loc. 26) (Sakaguchi, 1978), Hoshojiri moor (Loc. 28) (Sohma, 1984) (Fig. 5) and the Nariyasu site (Loc. 33) (Takeuchi, 1982) (Fig. 6).

**28 ka-25 ka years B.P. (Pleni-glacial IV)**

This is a small Interstadial when the climate showed a temporary amelioration. Although the pollen frequency values are low, *Salix, Corylus, Tilia* and *Acer* increase in the middle of the FG zone of Lake Mikata (Fig. 4), and warm temperate trees like *Quercus* subg. *Cyclobalanopsis* and *Symplocos* appear, indicating the climate to have become milder. At the Nariyasu site (Fig. 6) (Takeuchi, 1982), *Cryptomeria* shows an increase with *Fagus* and *Quercus* at local pollen zone ND. Radiocarbon data from the Lake Mikata and Nariyasu sites show that this small Interstadial is located between 28 ka and 25 ka years B.P. Although this temporary amelioration was also reported from Nagano Prefecture, Central Japan (Sakai, 1981a, 81b), no evidence for its occurrence has been found at other sites.

**25 ka-13 ka years B.P. (Pleni-glacial V)**

This is the coldest Stadial throughout the Last Glacial Age. Results from Tarukawa moor in Hokkaido (Loc. 36) (Igarashi, 1975) indicate that the cold climate began around 25 ka years B.P. Similar climatic tendencies were also reported from high mountainous areas in Central Japan (Sakai, 1981a). However, results from the Shimo-oshima formation (Loc. 20) (Endo *et al.*, 1983) and Tamonjimae site (Loc. 22) (Yasuda, 1983a) in the lowlands of the Kanto plain and the Onomichi site in the Setouchi district (Loc. 11) (Yasuda and Tsubota, 1983) show that the cold climate appeared after 21 ka years B.P. In these lowland areas, *Quercus* subg. *Lepidobalanus* and other temperate trees decreased while *Pinus* subg. *Haploxylon* rapidly increased with *Picea, Abies* and *Tsuga,* suggesting that the climate tended to become cold and dry. Climatic deterioration first becomes evident in the results from northern Japan and mountainous districts where climatic changes resulted in an immediate vegetational response via the descent of the forest zones. Conversely, lowland

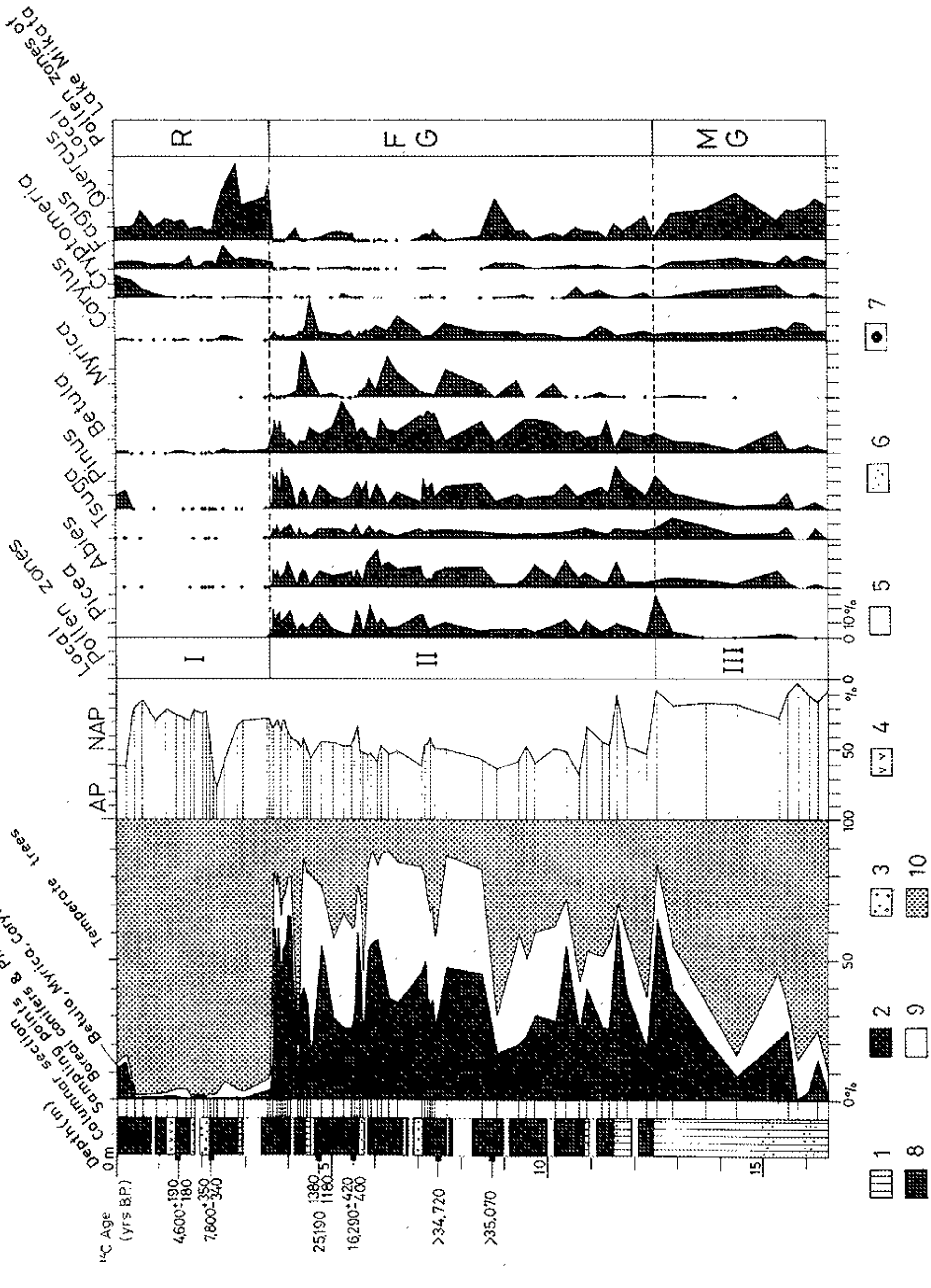


Fig.5. Pollen diagram from the Hoshojiri moor, Fukushima Prefecture (Yasuda 1987c). 1 Clay, 2 Peat, 3 Sand, 4 Pumice, 5 Volcanic ash, 6 Charocal, 7 Less than 1% of total tree pollen sum, 8 Boreal conifers (*Picea, Abies, Tsuga* and *Larix*) and *Pinus*, 9 *Betula, Myrica* and *Corylus*, 10 Temperate trees.

forest zones did not descend until the beginning of the maximum glacial epoch at 21 ka years B.P. From 21 ka to 18 ka years B.P., a very cold and dry maximum glacial epoch continued during which time the mean annual temperature was 7–9℃ lower and precipitation was less than 1/3 of that of the present (Yasuda, 1983b). After 18 ka years B.P., the climate tended to ameliorate; especially after 15 ka years B.P. In the pollen diagram from Lake Mikata (Fig. 4), *Tsuga* showed a decrease and *Quercus* an increase at the horizon dated at 15500±150 years B.P. Pollen diagrams from the Nariyasu site indicated a marked decrease of *Picea* at the horizon dated at 14720±420 years B.P. and an increase of *Quercus* (Fig. 6). The decreases of sub-alpine and cool temperate conifer trees and the increase of *Quercus* after 15 ka years B.P. suggest that the climate became markedly warmer.

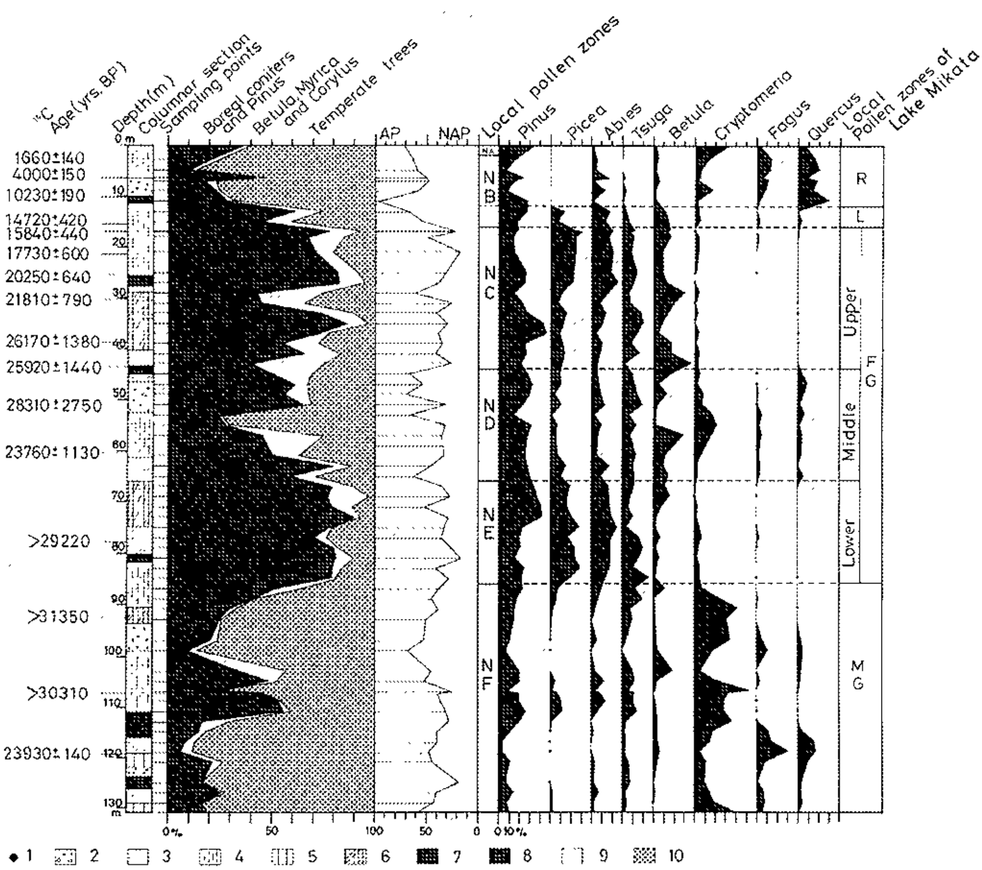


Fig.6. Pollen diagram from the Nariyasu site, Yamagata Prefecture (Yasuda 1987c).
1 Less than 1% of total pollen sum, 2 Coarse sand, 3 Fine sand,
4 Sandy silt, 5 Silt, 6 Silt including peat, 7 Peat, 8 Boreal
conifers (*Picea, Abies, Tsuga, Larix*) and *Pinus*, 9 *Betula, Myrica* and *Corylus*, 10 Temperate trees.

**13 ka-10 ka years B.P. (Late-glacial)**

This period is Late-glacial. Although the climate became markedly warmer after 15 ka years B.P., a dry climate persisted until 13 ka years B.P. A marked increase of precipitation appears 2000-3000 years later than that of the rise of temperature. Precipitation, especially winter snow fall, increased after 13 ka years B.P. (Yasuda, 1978, 82b), ensuring an adequate water supply in the growing season, helped to create a suitable soil condition for the growth of deciduous broad leaved trees like *Fagus* and *Quercus*. Results from Ozegahara moor (Loc. 26) (Sakaguchi, 1978) show that the *Fagus crenata* forest started to expand after 13 ka years B.P. *Fagus crenata* pollen in the Torihama shell mound site (Loc. 16) (Yasuda, 1979) already at 11.8 ka years B.P. attained more than 20% of the total tree pollen sum except *Alnus*.

The *Fagus crenata* forest expanded rapidly after 13 ka~12 ka years B.P., especially on the Japan Sea side (Yasuda, 1978, 82b, 84b), while on the Pacific side, the *Alnus* forest was undergoing a similar expansion. The expansion of *Fagus crenata* especially on the Japan Sea side and *Alnus* on the Pacific side indicates that the climate became wet after 13 ka~12 ka years B.P. Yasuda (1978, 87a) estimated the beginning of the Late-glacial period as the point when there was an increase of humidity, 13 ka years B.P.

**After 10 ka years B.P. (Holocene)**

At the Torihama shell mound site (Loc. 16), *Cryptomeria* showed a rapid increase following the deposition of land-slide gravel at 10 ka years B.P. (Yasuda, 1979). *Cryptomeria* was able to expand its range by taking advantage of the unstable soil conditions caused by the increase in precipitation. The climate became warm and wet.

According to the results of pollen analyses, climatic changes at the Last Glacial Age in Japan can be summarized as follows;

From ca. 120 ka to 70 ka years B.P.; although the detailed climatic features are not yet clear, it is believed that a cool and wet climate dominated during the Early-glacial, except during two warm Interstadials at 100 ka and 80 ka years B.P.

From ca. 70 ka to 50 ka years B.P.; Stadial. Climate was cold and dry.

From ca. 50 ka to 33 ka years B.P.; Interstadial. Climate was cool and wet.

From 33 ka to 28 ka years B.P.; Stadial. Climate was cold and dry.

From 28 ka to 25 ka years B.P.; Short Interstadial. Climate was cool and relatively wet.

From 25 ka to 13 ka years B.P.; Stadial. Climate was cold and dry. A cold maximum epoch continued between 21 ka and 18 ka years B.P.

From 13 ka to 10 years B.P.; Late-glacial. Climate was cool and wet.

After 10 ka years B.P.; Holocene. Climate became warm and wet.

## INFLUENCES OF MONSOON FLUCTUATIONS UPON THE CLIMATIC CHANGES IN JAPAN

### Monsoon Fluctuations

*Arabian Sea and Indian Ocean*

Pollens from the tropical rain forests in east Africa are transported by southwest monsoons into the Arabian Sea, whereas dry land pollens from the Arabian desert and Iranian Plateau are carried there by northeast monsoons. Results of oxygen isotopic and pollen analyses of a core (MD76135) (Fig. 1, Loc. 1) taken from the bottom of the Arabian Sea (14° 26′ 6″ N., 56° 31′ 3″ E.) show high frequencies of tropical rain forest pollen at the Last Interglacial Age (oxygen isotopic stage 5e) (Van Campo *et al.*, 1982). Pollen from tropical rain forests makes up more than 60% of the total pollen sum (Fig.7). High pollen frequencies from tropical rain forests indicate that southwest monsoons were active at the Last Interglacial. Tropical rain forest pollen, which constitutes over 20% of the total pollen sum, maintains a relatively high value during the Early-glacial period, but this value suddenly decreases to less than 10% at the beginning of the Pleni-glacial at around 70 ka years B.P.(Fig.7). Low frequencies of tropical rain forest pollen continue until about 50 ka years B.P. These findings indicate that the southwest monsoons became dormant at the Stadial between 70 ka and 50 ka years B.P. Later, at the Interstadial between 50 ka and 33 ka years B.P., tropical rain forest pollen increases (Fig.7) and shows relatively high values, suggesting reactivation of the southwest monsoons.

Tropical rain forest pollen decreases markedly after 30 ka years B.P. and reaches its lowest value at around 18 ka years B.P. (Fig.7), indicating that the southwest monsoons became almost dormant after 30 ka years B.P. and were at the weakest at around 18 ka years B.P.

Further evidence for this marked dormancy of the southwest monsoons at 18 ka years B.P. is proposed by the low lake levels in East Africa at that time (Butzer *et al.*, 1972, Street and Grove, 1976, 79) (Fig.8) and other geomorphological indicators (Kadomura, 1986). East Africa witnessed a severe drought during the maximum glacial epoch.

A reconstruction of the sea-surface salinity in the northern Indian Ocean (Duplessy, 1982) indicated that the low-salinity area along the southwestern coast of India disappeared at 18 ka years B.P., because of the decrease of river discharge into the Indian Ocean. The decrease in river discharge is directly attributable to the dormancy of southwest monsoons.

The low frequency values of tropical rain forest pollen in the MD76135 core continue throughout the maximum glacial epoch, but tend to increase again after 12.5 ka years B.P. (Fig.7). Although a temporary decline is evident at around 11 ka years B.P., tropical rain forest pollen rises rapidly after 10 ka years B.P. and attains more than 60% of the total pollen sum between 9,000 and 8,000 years B.P., suggesting a reactivation of the southwest monsoons at the scale of the Last Interglacial (Fig. 7). Further evidence for this reactivation of southwest

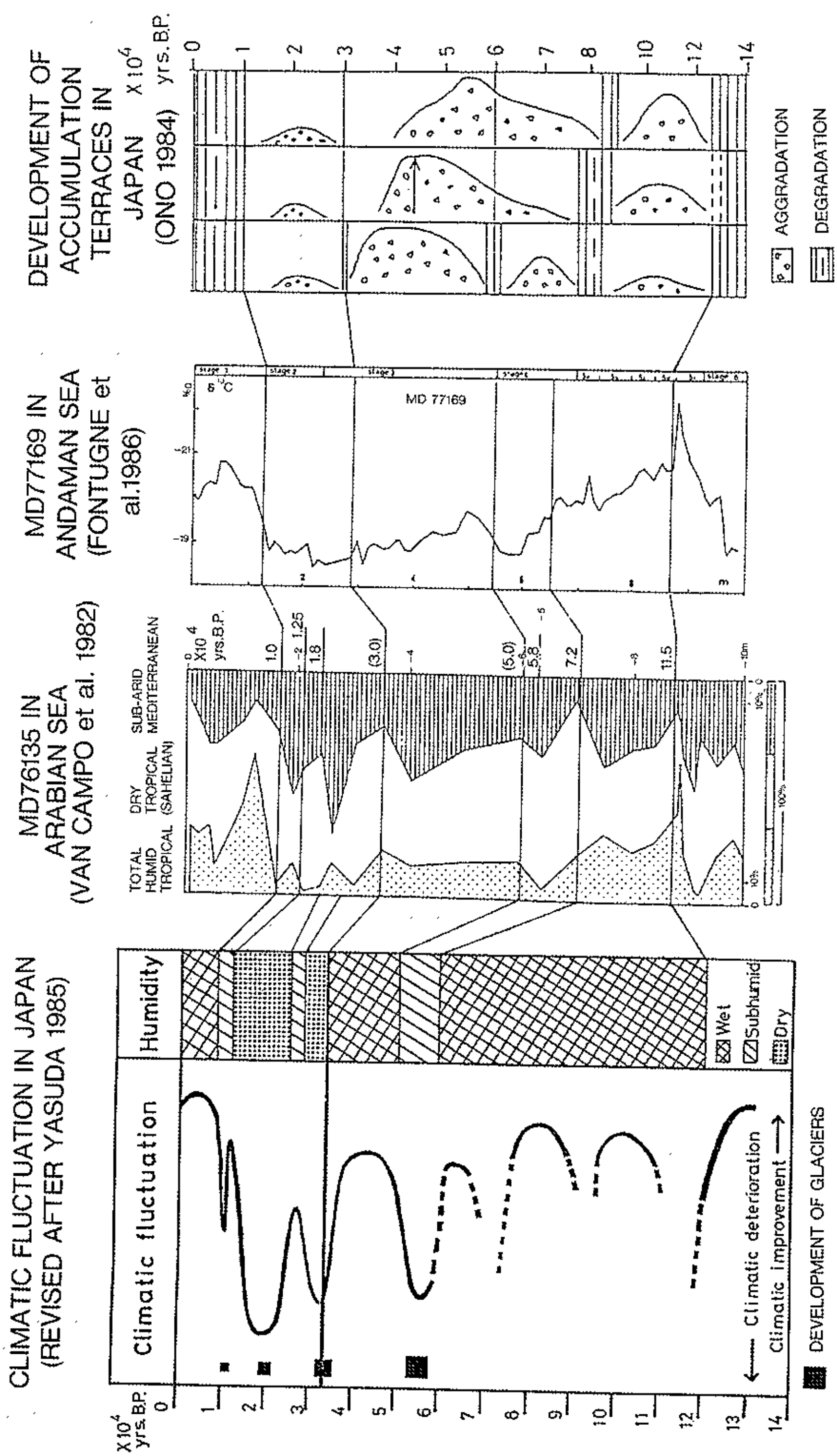


Fig.7. Comparison of data of climatic changes with the development of accumulation terraces.

monsoons after 12.5 ka years B.P. is provided by the results of pollen analyses (Hamilton, 1982) and by the rise of East African lake levels, including Lakes Victoria (Kendall, 1969), Rudolf (Owen *et al.*, 1982), Nakuru (Butzer *et al.*, 1972), Mahoma (Livingstone, 1967), Ziway and Shala (Gillespie *et al.*, 1983) (Fig. 8). This rise of lake levels in East Africa was caused by very heavy rainfall beginning at 12.5 ka years B.P. (Butzer, 1980).

Evidence of massive flooding of the River Nile during the Late-glacial and early Holocene, due to very heavy rain, was discovered in a core taken from the bottom of the Mediterranean south of Crete (Fig. 8). Rossignol-Strick (1982) found two sapropel formations dated at 11.8～10.4 ka years B.P. and 9 ka～8 ka years B.P. from the KS52 core and concluded these layers to have been formed under the influence of the River Nile.

The reactivation of the southwest monsoons after 12.5 ka years B.P. is also supported by the results of pollen analyses of the MD76131 (15° 31′ N. 72° 34′ E. 1230m in depth) and MD77194 (10° 28′ N. 75° 14′ 1222m in depth) cores in the Indian Ocean (Van Campo, 1986) (Fig. 1, Loc. 2, 3), while based on the fluctuations of mangrove pollen, Van Campo (1986) suggested river discharge to have risen after 11 ka years B.P.

Results from the Arabian Sea and the Indian Ocean indicate that the southwest monsoons fluctuated as follows;

From ca. 130 ka to 115 ka years B.P.; southwest monsoons were active.

From ca. 115 ka to 70 ka years B.P.; southwest monsoons were rather active.

From ca. 70 ka to 50 ka years B.P.; southwest monsoons were dormant.

From ca. 50 ka to 30 ka years B.P.; southwest monsoons were relatively active.

From ca. 30 ka to 12.5 ka years B.P.; southwest monsoons were very dormant.

After ca. 12.5 ka years B.P.; southwest monsoons began reactivation and especially during the early Holocene were very active.

Similar tendencies of the southwest monsoons were revealed in the results of the Bengal Bay and Andaman Sea studies.

*Bengal Bay and the Andaman Sea*

Carbon isotopic analyses of the MD77169 core (10° 12′ 5″ N., 95° 03′ E. 2360m in depth) (Fig. 1, Loc. 4) from the bottom of the Andaman Sea, resulting from a significant contribution of terrigenous organic carbon, show low $\delta^{13}C$ values at 12.7 ka years B.P. (Fig.7). Fontugne and Duplessy (1986) concluded that this increased terrestrial contribution was a product of the strengthened southwest monsoons and possibly the melting of ice caps in the Himalayas under the warm and wet climate. Low values of $\delta^{13}C$ continue throughout the Early-glacial period. However, organic sediment matter deposited during 70 ka～50 ka years B.P. exhibits higher $\delta^{13}C$ values (Fig. 7), indicating weakened southwest monsoons and a decrease in river discharge. Isotopic stage 3 (Fig. 7), which almost corresponds with the Interstadial between 50 ka to 33 ka years B.P., shows intermediate values between the Holocene and Stadial. The highest isotopic value is observed during the maximum glacial epoch between 21 ka

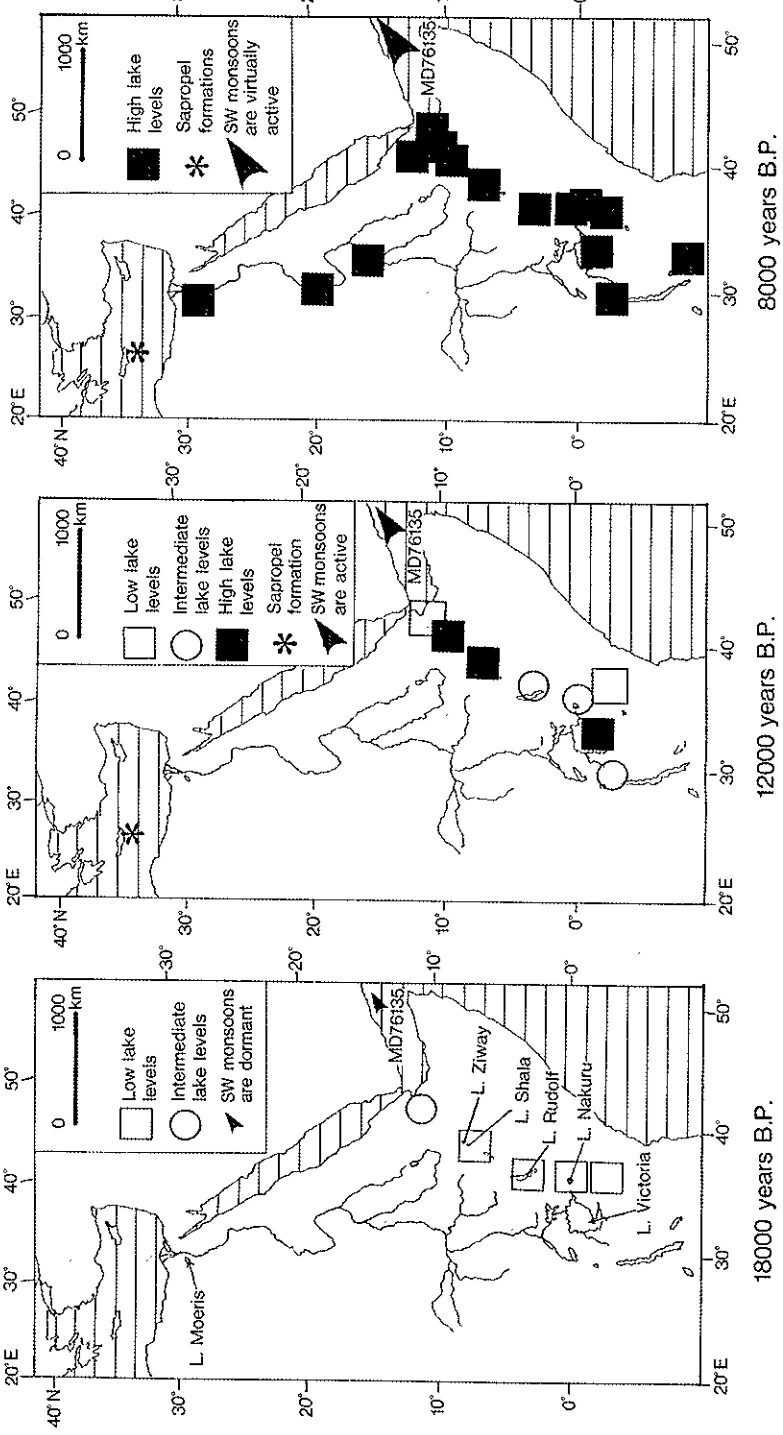


Fig.8. Fluctuations of lake levels in East Africa (Yasuda 1987b).
Based on the data of Butzer et al. (1972), Street et al. (1976) and Kadomura (1986).

~18 ka years B.P. All evidence suggests that the weakened southwest monsoons brought less precipitation, and that a cold climate developed along the glaciers of the Himalayas and Tibetan upland, resulting in a decrease of discharge of the Ganges, Brahmaputra, Irrawaddy and Salween Rivers (Fig. 1).

Results of the MD77169 core from the Andaman Sea are consistent with the pollen analytical results obtained from the Kathmandu valley in Nepal (Fig. 1, Loc. 6) (Igarashi *et al*., 1988), Lake Rara in western Nepal (Fig. 1, Loc. 5) (Yasuda and Tabata, 1988) and Danau di Atas Swamp in west Sumatra (Fig. 1, Loc. 7) and Situ Bayongbong in west Java (Fig.1, Loc. 8) (Stuijts *et al*., 1988). In the Kathmandu valley, *Picea, Abies* and *Betula* show high values at 19 ka years B.P., indicating a cold and dry climate. Although there are no palynological indications to this effect, the inversion of radiocarbon dates between 18 ka and 17 ka years B.P. at Danau di Atas suggests a lowering of lake levels and a drier climate (Stuijts *et al.*, 1988).

The terrigenous organic carbon recovers after 10 ka years B.P. (Fig.7). It is believed that the strengthened southwest monsoons resulted in an increased river discharge, while melt water from the ice caps which covered the Himalayas and Tibetan upland carried terrestrial materials into Bengal Bay and the Andaman Sea. Results of pollen analyses from Danau di Atas Swamp and Situ Bayongbong show that the climate ameliorated after 12.5 ka years B.P., with a hot and wet climate prevailing after 10 ka years B.P. (Stuijts *et al.*, 1988).

Pollen analytical results from Lake Rara (Yasuda and Tabata, 1988) clearly show that the climate tended to become warmer and wetter after 10 ka years B. P., although up until 8.5 ka years B.P. the climate was cooler and relatively drier than that of the present.

The results of analyses of the samples taken from the bottom of Bengal Bay and the Andaman Sea confirm the findings from the Arabian Sea and Indian Ocean.

**Influences of Monsoon Fluctuations upon the Climatic Changes in Japan**

Fig. 7 shows the climatic changes of the Last Glacial Age in Japan in comparison with results of isotopic and pollen analyses from the Arabian and Andaman Seas. Monsoon fluctuations which are explicable in terms of the isotopic and pollen analyses of the cores taken from the Arabian Sea and Andaman Sea are almost consistent with climatic changes in Japan.

Pollen flora during the Early-glacial period (120 ka~70 ka years B.P.) in Japan are characterized by high values of *Cryptomeria. Cryptomeria* is adapted to heavy rain and heavy snow districts. Yasuda (1985), therefore, concluded that the climate during the Early-glacial period was wet. Frequency values of *Cryptomeria* during the Early-glacial period sometimes attain more than 70% of the total tree pollen sum. If there is an adequate water supply, *Cyptomeria* is able to grow even in thin surface soil, unlike beech and oak. Therefore *Cryptomeria,* availing itself of the unstable and thin surface conditions, was able to expand its range into the habitats of the beech and oak forest.

The very high values of *Cryptomeria* indicate that as a result of the frequent occurrence of landslides and floods, the areas of thin and unstable surface soils expanded during the Early-glacial period. This may have been due to heavy rain during the summer especially during the *Bai-u*. Results of isotopic and pollen analyses from the Arabian and Andaman Seas indicate that the southwest monsoons were still active at the Early-glacial period, although they were weaker than those of the Last Interglacial. The activity of the southwest monsoons in the Arabian Sea and Bengal Bay, causing frequent landslides and floods, probably supported the expansion of *Cryptomeria* in the Early-glacial period.

In the Stadial between 70 ka and 50 ka years B.P., *Cryptomeria* decreased, the climate became cold and dry, and the southwest monsoons also became dormant. The dry climatic conditions at the Early-glacial period were partly caused by the decrease of summer precipitation, which is linked to the dormancy of the southwest monsoons. *Cryptomeria* and other temperate trees increased again in the Interstadial between 50 ka and 33 ka years B.P., when a relatively warm and wet climate appeared. Tropical rain forest pollen showed an increase in the MD76135 core and $\delta^{13}C$ showed relatively low values in the MD77169 core, suggesting the reactivation of the south-west monsoon.

However, at around 33 ka years B.P. in Japan, a dramatic climatic turnabout occurred (Yasuda, 1982a, 84b), and the climate became cold and dry. This is clearly illustrated in the abrupt decrease of *Cryptomeria* and rapid increase of *Tsuga* in the pollen diagram from Lake Mikata (Fig. 4). It is significant that the southwest monsoons became dormant after 33 ka years B.P. Although the dry climate after 33 ka years B.P. was mainly due to the decrease of snow fall in winter (Yasuda, 1982a), the decrease of the summer precipitation linked to the dormancy of southwest monsoons also played an important role in the reduction of the humidity.

Between 21 ka and 18 ka years B.P., a very cold and dry climate prevailed throughout Japan and the southwest monsoons were virtually dormant. Although temperatures increased markedly after 15 ka years B.P., humidity remained at the same level and the dry climate continued until 13 ka years B.P.

The Japanese climate became moister after 13 ka years B.P. (Yasuda, 1982a) and the southwest monsoons became active at around this time. Although the observed increase of humidity was mainly caused by the rise in snow fall (Yasuda, 1982a), the reactivation of the southwest monsoons and the resultant rise in summer precipitation was probably also an important factor influencing the increase in humidity. *Cryptomeria* rapidly increased after 10 ka years B.P. Summer precipitation, especially the frequency of heavy rain in the *Bai-u*, rose after 10 ka years B.P. Results from the Arabian Sea, Indian Ocean, Bengal Bay and Andaman Sea indicate that the southwest monsoons also became active after 10 ka years B.P. It is supposed that heavy rain linked to the reactivated southwest monsoons resulted in landslides and large floods, giving rise to areas of thin and unstable surface soils which were suitable for *Cryptomeria*.

These comparisons indicate that the climatic changes in Japan, especially the fluctuations in humidity at the last glacial age, were strongly influenced by the fluctuations of the southwest monsoons in the Arabian Sea, Indian Ocean, Bengal Bay and Andaman Sea.

## DEVELOPMENT OF ACCUMULATION TERRACES

We now examine the effects of the fluctuations of the southwest monsoons upon the development of landforms during the Last Glacial Age in Japan.

*Shitsujun-hendo-tai* was the name given by Yoshikawa (1985) to the tectonically active and intensely denuded regions in monsoon Asia. Stepped landforms like river terraces are one of the characteristic features of the *Shitsujun-hendo-tai*. Kaizuka *et al.* (1983) pointed out that the development of river terraces might be caused by the fluctuations of the denudation and transportation by rivers in the glacial-interglacial cycles. The fluctuations of intensity and frequency of the heavy rain in the *Bai-u* and typhoon seasons may affect the denudation and transportation properties of a river.

This chapter discusses the development of such accumulation river terraces in relation to monsoon fluctuations.

Based on geomorphological studies in the Tokachi plain in Hokkaido (Ono and Hirakawa, 1975), the River Tenryu in the Tokai district, and the River Sagami in the Kanto district, Ono (1984) established the developmental epoch of the accumulation terraces at 80 ka~40 ka years B.P. (Fig. 7). In central Japan, accumulation terraces were estimated as having been formed between 70 ka and 40 ka years B.P. in the Chigaya valley (Ito and Masaki, 1984), 90 ka~40 ka years B.P. in the the Matsumoto basin (Oguchi, 1988) and 55 ka~50 ka years B.P. in the River Joganji, Hokuriku district (Machida and Arai, 1979). Furthermore, the existence of accumulation terraces before 30 ka years B.P. has been reported from the Ou mountain range in the Tohoku district (Toyoshima, 1984, 86), the River Ara, Kanto district (Yoshinaga and Miyadera, 1986) and the Miyazaki plain, Kyushu district (Nagaoka, 1986).

Geomorphological evidence indicates the accumulation terraces to have been formed in the Last Glacial Age, mainly before 30 ka years B.P. Accumulation terraces are composed of a thick gravel bed and require an adequate deposition of gravel for their development. Subsequently, a sufficient tractive force is necessary for the transportation of gravel.

In the upper stream areas of Central Japan and Hokkaido, resulting from the descent of forest zones, a periglacial environment extended during the cold Stadials at 70 ka~50 ka years B.P., 33 ka~28 ka years B.P. and 25 ka~13 ka years B.P., and large amounts of debris were produced by the active cryoturbation. In other areas which escaped the periglaciation, the debris production rate also increased due to the cold climate and the sparseness of forests.

Since heavy rains and large floods are necessary conditions for the development of accumulation terraces (Nakagawa, 1981), we can assume the frequent occurrence of heavy rains and large floods before 40 ka years B.P.

This supposition is endorsed by the fluctuation patterns of the southwest monsoons, which were active during the Early-glacial period (ca. 120 ka～70 ka years B.P.) and the Interstadial between 50 ka～33 ka years B.P., although the activations were relatively weaker than those of the Last Interglacial and Holocene. Investigations into the grain-size and roundness of gravel (Ono, 1984, Yoshinaga and Miyadera, 1986) suggested that the scale of the floods at the Early-glacial and Interstadial were smaller than those at the Holocene and Last Interglacial.

Although the effects have not yet been clarified, it is believed that large floods during the typhoon season may also have played an important role in the transportation of debris.

The development of the accumulation terraces ceased around 30 ka years B.P., whereafter geomorphological evidence indicates a downward erosion of the river bed, resulting in the formation of terrace scarps.

We can infer a large amount of debris to have been produced in the periglacial slope during the maximum glacial epoch between 21 ka～18 ka years B.P. If there had been enough tractive force, this debris may have developed into accumulation terraces. However, there was only a slight development of the accumulation terrace and conversely, the river bed was actually denudated. The southwest monsoons were very weak during this maximum glacial epoch and accordingly the frequency and intensity of the large floods and heavy rains may well have decreased.

Thus the transition from aggradation to denudation of the river bed at around 30 ka years B.P. was probably partly due to a decrease in the frequency and intensity of heavy rain which was linked to the dormancy of the southwest monsoons.

Geomorphological studies on the Japan Sea side (Yasuda, 1987a) and Tohoku district (Nakayama and Miyagi, 1984, Toyoshima, 1987, Saijo, 1987) indicate unstable slopes and frequent land slides as having occurred after 13 ka～12 ka years B.P. Similarly, the effects of running water on mountain slopes and river discharge increased after 13 ka years B.P. in the Matsumoto basin (Oguchi, 1988).

In the Torihama shell mound site (Loc.16) (Fig.9), due to its ability to expand its range into unstable soil conditions, *Cryptomeria* increased rapidly on the surface of land-slide gravel which was deposited at 10 ka years B.P. The frequency and intensity of heavy rain in the *Bai-u* season, resulting in unstable and thin surface soil conditions, increased after 10 ka years B.P. Isotopic results from the Arabian and Andaman Seas (Fig.7) show that the southwest monsoons became markedly active after 10 ka years B.P. and resulted in an increase in the frequency and intensity of heavy rain during the *Bai-u* season and consequential unstable and thin surface soils. The increases observed in the

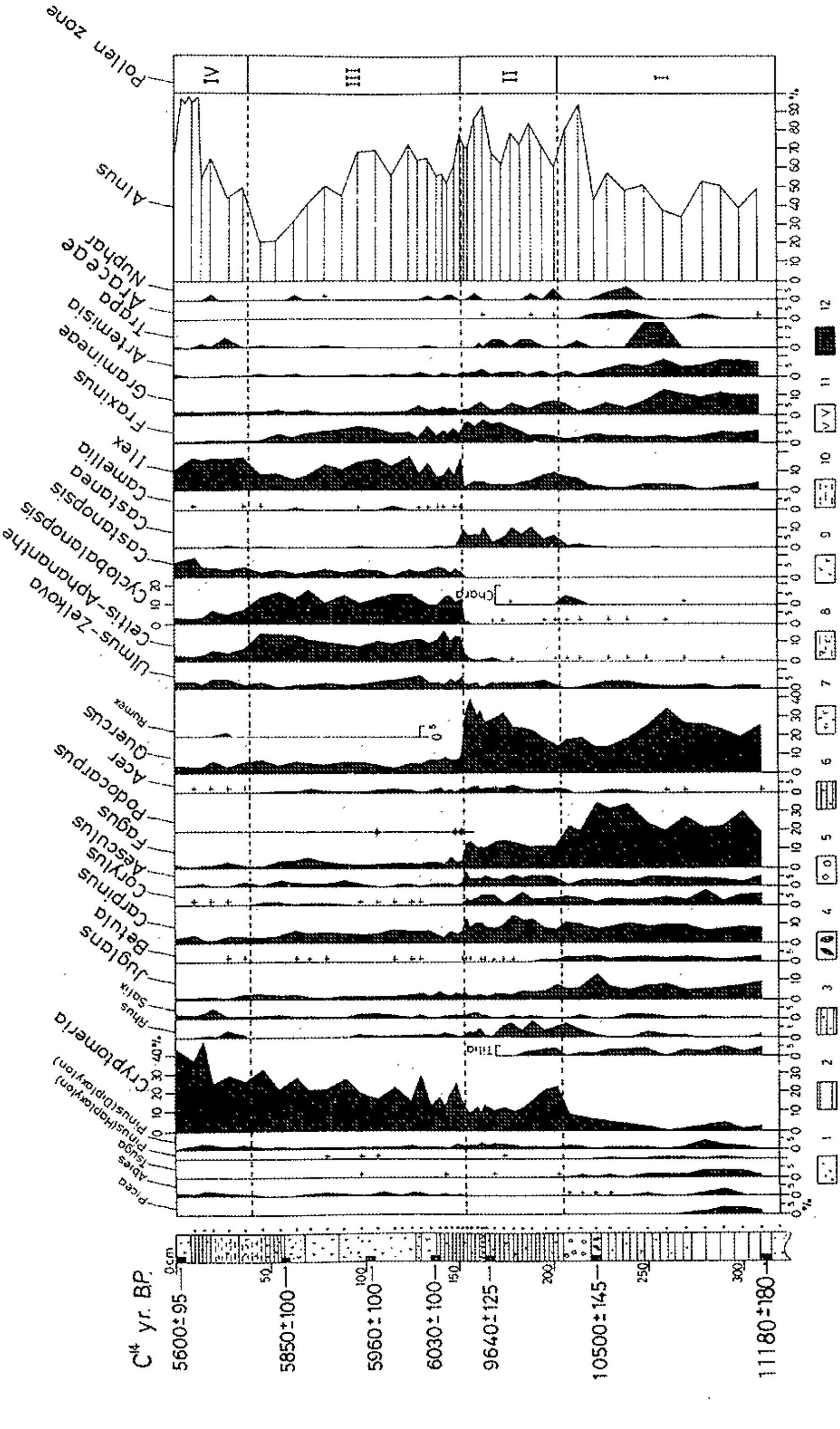


Fig.9. Pollen diagram from the Torihama shell mound site, Fukui Prefecture (Yasuda 1979).
1 Blue-grey clay, 2 Dark-grey clay, 3 Brown-grey clay, 4 Brown woody peat, 5 Blue grey gravel, 6 Brown peaty clay, 7 Highly humified peat including sand, 8 Peaty clay including sand, 9 Highly humified peat, 10 Humic silt, 11 Volcanic ash, 12 Sampling points for radiocarbon dating.

denudation and discharge of the rivers at this time are probably also partly due to this reactivation of the southwest monsoons.

## MONSOON FLUCTUATIONS AND CULTURAL CHANGES

The earliest evidence of human habitation on the Japanese archipelago has been found at the Sozudai site in Oita Prefecture (Fig.10-2) (Serizawa, 1965) and at the Minogahama site in Yamaguchi Prefecture (Fig.10-5) (Ono, 1986) dating back to earlier than 30 ka years B.P. Serizawa (1967, 82) found evidence of the Earier Paleolithic period after excavation at the Hoshino site in Tochigi Prefecture (Fig.10-9) and the Iwajuku D site in Gunma Prefecture (Fig. 10-10), while Ono found evidence of Early and Middle Paleolithic periods after excavation at the Sorayama and Torigasaki sites in Shimane Prefecture (Fig. 10-6, 8) (Ono, 1974, 86).

These pioneer works, however, did not gain wide acceptance in archeological circles. A new discovery by a young archeologist's group (Sekki-Bunka-Danwakai, 1983) was made at the Zazaragi site in Miyagi Prefecture (Fig. 10-12). The site is located on a hill in the middle drainage of the River Eai and yielded clearly recognizable stone implements from several cultural horizons composed of volcanic ash. Sixteen Strata and 10 cultural layers were investigated. Results of the radiocarbon, fission track and thermo-luminescence datings indicated the absolute ages. Artifacts, indicating the evidence of habitation dating back to older than 30 ka years B.P., were recovered from Strata 12, 13, 14 and 15.

Thereafter, more than 65 Paleolithic sites, including the Nakamine (Fig. 10-11) and Babadan A sites (Fig.10-13) have been found in Miyagi Prefecture. Although some controversy still exists (Oda and Keally, 1986) over the Paleolithic research in Miyagi Prefecture, we conclude that their works are not based on flawed research. Stratum 19 of the Babadan A site (Sekki-Bunka-Danwakai, 1986) was dated by thermo-luminescence dating at 122.4 ka years B.P. Ichihazama pumice, underlying Stratum 19, was dated at 146 ka years B. P. by fission track dating. Based on the results of chronometric dating and tephrochronological correlation, Stratum 20 of the Babadan A site was concluded older than 130 ka years B.P. The oldest evidence was recovered from the Nakamine site, about 25km south of the Zazaragi site (Miyagiken Kyoiku Iinkai, 1985): dated at 370 ka years B.P. by thermal-luminescence dating. Schematic typological changes of artifacts, recovered from the site-horde mentioned above, are summarized in Fig.11. In comparison with climatic changes, several characteristic epochs are recognized as follows:

### Older than 130 ka years B.P.

Artifacts from Strata 20, 30, 31 of the Babadan A site and Stratum 7 of the Nakamine site are mainly made of chalcedony and jasper (Fig.11-1,2). The

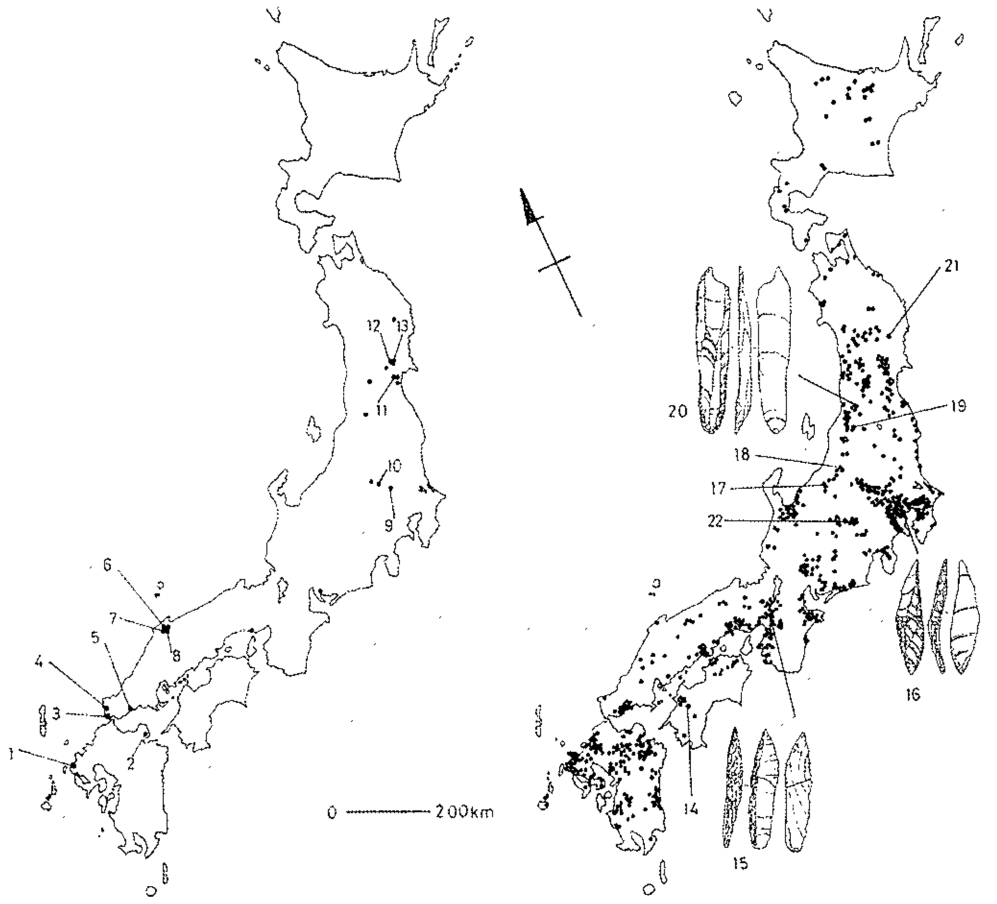


Fig.10. Distributional maps showing the Early and Middle Paleolithic sites(left) and Late Paleolithic, Metholithic sites(right). Based on Ono(1974), Serizawa(1974) and Inada (1988).
1 Fukui-dokutsu site, 2 Sozudai site, 3 Ayaragi site, 4 Isogami site,
5 Minogahama site, 6 Torigasaki site, 7 Tamatsukuri site, 8 Sorayama site,
9 Hoshino site, 10 Iwajuku D site, 11 Nakamine site, 12 Zazaragi site, 13 Babadan A site, 14 Kamikuroiwa site, 15 Ko site and *Ko-type* knife, 16 Moro site and *Moro- type* knife, 17 Nojiriko site, 18 Tazawa site, 19 Kosegasawa site,
20 Higashiyamagata site, 21 Hanaizumi site, 22 Yadegawa site.

shape of flakes are small ranging between 1-4 cm. Assemblages of artifacts older than 130 ka years B.P. are mainly composed of convergent scrapers (Fig.11-1) and burians (Fig.11-2). Artifacts recovered from Stratum 7 of the Nakamine site and dated at 370 ka years B.P., show a close typological relationship with that of *Homo erectus* of the 7th Layer in Zhoukoudian, China (Liu, 1985).

Although it is difficult to determine the correlation between climatic changes

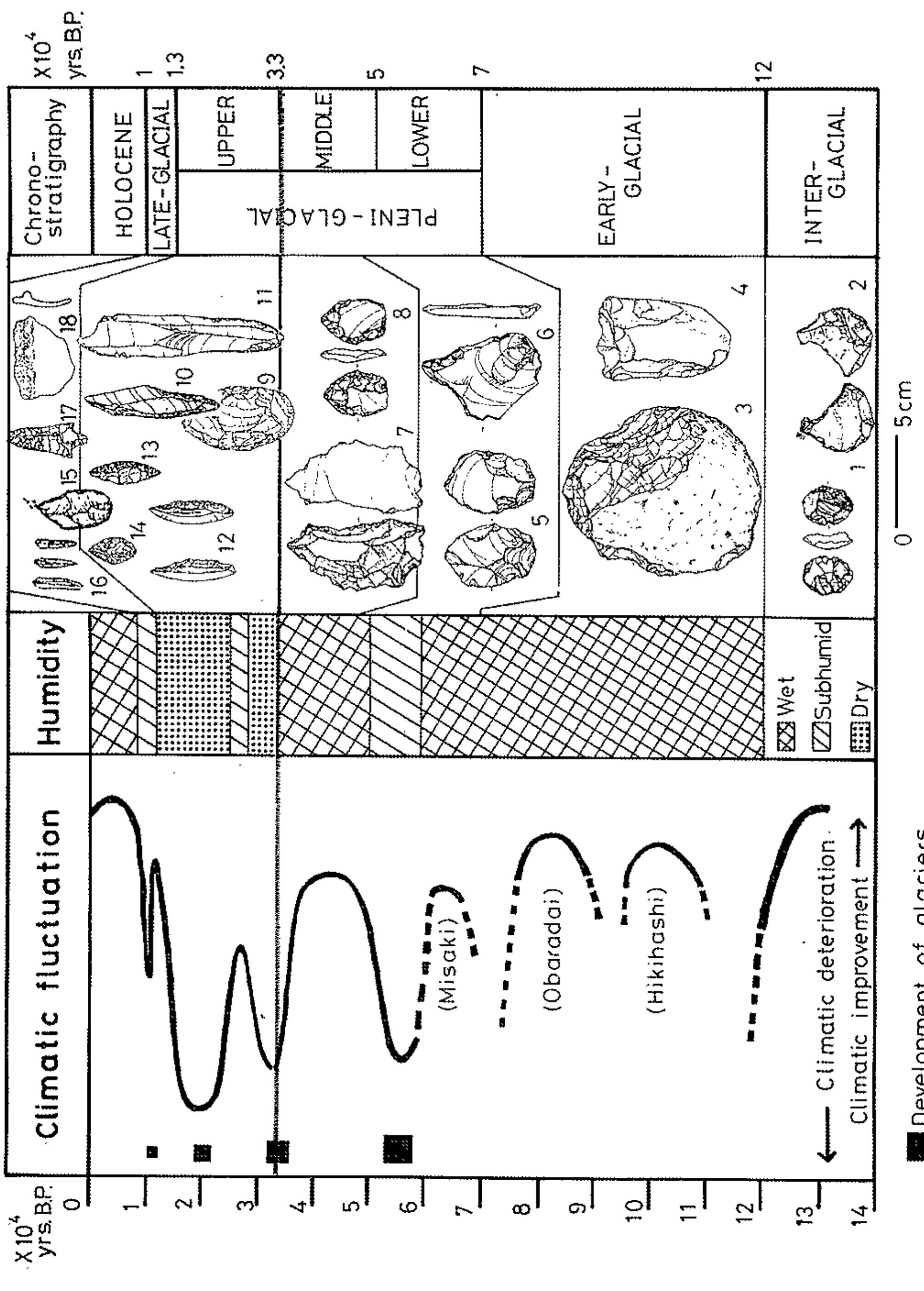


Fig.11. Comparison of the climatic fluctuations with the typological changes of stone tools. Stone tools are quoted from Serizawa (1982), Sekki-Bunka-Danwakai (1983,86) and Inada (1988).

and typology of stone tools before 130 ka years B.P., the climatic background of Stratum 7 of the Nakamine site and 7th Layer of the Zhoukoudian site show a high correlation. The paleoclimate of the 7th Layer was warmer, even warmer than that of Beijing today, and correlates with the Interglacial at oxygen isotopic stage 11 and to the reverse event at 380 ka years B.P. of Biwa III in Japan (Liu, 1985). Results of pollen analyses of the core taken from the bottom of Lake Biwa (Fuji, 1984) indicate the existence of a warm epoch at 380 ka years B.P. Stratum 7 of the Nakamine site is composed of red weathering soil, suggesting a warm and wet climate (Miyagiken Kyoiku Iinkai, 1985). The paleoclimatic and chronological backgrounds of the 7th Layer of the Zhoukoudian site thus seem to parallel Stratum 7 of the Nakamine site.

**From 130 ka to 70 ka years B.P.**

Artifacts recovered from Stratum 19 of the Babadan A site were placed at between 90 ka~70 ka years B.P. (Okamura, 1987). The typological assemblage is characterized by a crude biface (large handaxe)(Fig.11-3,4) which is made of coarse quartz andesite. The flakes are amorphous in shape. Although detailed paleoclimatic features at this period have yet to be clarified, generally the Early-glacial period was cool and moist as signified by the dominance of *Cryptomeria*. Heavy rain linked to the active southwest monsoons, resulting in unstable and thin surface soil conditions, benefited *Cryptomeria.*

**From 70 ka to 43 ka years B.P.**

The dominance of the crude biface terminates about 70 ka years B.P. (Fig.11) and thereafter, at Stratum 10, *Cauteaux ados*, (Fig.11-5), the convergent scraper (Fig.11-6) and denticulate (Fig.11-7) become increasingly dominant. Flakes of conformed shape (triangular or trapezeum) become evident and the size tends to become larger, ranging between 2~6 cm. These changes indicate the emergence of a new technology in the production of stone implements, influenced by Mousterian culture (Okamura, 1987). The paleoclimatic background at this period was cold and dry and due to the dormancy of southwest monsoons, the frequency and intensity of heavy rains decreased. Successors of the Mousterian culture probably expanded from Siberia, passing through land bridges which emerged due to the regression during the cold stadial between 70 ka and 50 ka years B.P.

**From 43 ka to 33 ka years B.P.**

The crude biface completely disappears at Stratum 7 of the Babadan A site and Stratum 15 of the Zazaragi site; about 43 ka years B.P. (Fig.11). Typological variations of scrapers, including convergent (Fig.11-8) and denticulate scrapers (Fig.11-7), increase, and flakes of a conformed shape become entirely dominant. The overwhelming use of hard shale began in this epoch and seems to have been succeeded by the subsequent epochs in north-east Japan.

Stratum 7 of the Babadan A site and Strata 12, 13, 14 and 15 of the Zazaragi site are situated in the Interstadial between 50 and 33 ka years B.P. The increase of typological variation of stone tools and the overwhelming use of hard shale are probably the fruits of the development of *Homo sapiens*'s culture under a relatively warm and moist climate.

**From 33 ka to 13 ka years B.P.**

A significant cultural break, i.e. the emergence of blade technology, appears about 33 ka years B.P. (Fig.11) with obsidian being used for raw material. The appearance of blade technology suggests the acquisition of mass production of artifacts by *Homo sapiens sapiens* in the Late Paleolithic age. Kato (1988) called this invention the "Late Paleolithic Revolution." Blade technology flourished from 33 ka to 13 ka years B.P. with knife-shaped tools (hereafter called knives)(Fig.11-10,11,12) being representative of this period. Based on the typological assemblage, the Late Paleolithic period may be subdivided into three sub-epochs (Serizawa, 1967).

*Sub-epoch 1 (from 33 ka/30 ka to 23 ka/21 ka years B.P.)*

An assemblage was composed of scraper, knife, semi-conical core, trapizoidal tool and levalloiscore. From the beginning, a partly polished hand axe (Fig. 11-9) characterized this epoch (Anbiru, 1986, Inada, 1988). Although the knife was present, its ratio in the assemblage was low and this epoch actually constituted a formative period of the knife culture.

There was a dramatic climatic turnabout around 33 ka years B.P., becoming cold and dry, and this climatic deterioration might have brought about a cultural break. The intensity and frequency of heavy rain decreased in the *Bai-u* season, and overall precipitation decreased both in summer and winter. Oxygen isotopic, foraminiferal and diatom analyses of cores taken from the bottom of the Japan Sea indicate a deoxidized sea bottom environment appearing after 30 ka years B.P. because of the interruption of the warm water Tsushima current by land bridges (Oba, 1983). This would have played an important role in the decrease in precipitation in winter. It is believed that precipitation decreased to less than one-third of the present level (Yasuda, 1983b).

Typological correlation of the knife (Kato, 1988) indicates a close cultural relationship with the Late Paleolithic in China. Based on the physical characteristics of Paleolithic human skeletons, Hanihara (1984, 86) suggested that the oldest migrants (Paleomongoloids) came from the southern Asian Continent. Successors of *Homo sapiens sapiens*, who invented the blade technology, were probably able to immigrate to Japan over the Tsushima land bridge and replaced the successors of *Homo sapiens* who had probably declined due to climatic deterioration.

Climatic deterioration at this period was also suggested by the extinction of *Zelkova* at 31 ka years B.P. in Italy (Follieri *et al.*, 1986)(Fig.3). Richmond and Fullerton (1986) set the boundary between Middle Wisconsin and Late Wisconsin at 35 ka ~ 30 ka years B.P. (Fig.3).

It is notable that important anthropological events occurred in Europe at this period in that *Homo sapiens* (Neanderthal) became extinct and *Homo sapiens sapiens* (Modern) began to extend. *Homo sapiens* (Neanderthal) probably became extinct due to the climatic deterioration during 35 ka～30 ka years B.P., whereas, *Homo sapiens sapiens* (Modern) were able to extend their range, adapting to the cold and dry climate (Yasuda, 1982a).

*Sub-epoch 2 (from 23 ka/21 ka to 15ka years B.P.)*

This is the zenith of the knife culture. The ratio of the knife in the assemblage rises markedly and the number of Late Paleolithic sites increases (Fig.10). Regionalization of the knife culture appears (Fig.10). The knives found in northern Japan are nearly all made by end-blow technology and constructed from obsidian and hard shale. Knives in northern Japan, therefore, have long sharp edges, the *Sugikubo*-type and *Higashiyamagata*-type (Fig.10-20, Fig. 11-11) being typical examples and found in the Chubu and Tohoku districts and the *Moro*-type (Fig.10-16, Fig.11-10) in the Kanto and Chubu districts. Knives recovered in south-west Japan, however, are nearly all made by the *Setouchi* side-blow technique (Fig.10), and are made of andesite. Knives in south-western Japan, therefore, have short sharp edges (Fig.11-12), as typified by the *Ko*-type (Fig.10-15), recovered from the Ko site in Osaka Prefecture. The *Ko*-type knife culture was principally found in the Setouchi district and attained its zenith after 21 ka years B.P. (Inada, 1988).

It is interesting to note that the zenith of the knife culture corresponds exactly with the maximum glacial epoch when the southwest monsoons were dormant. We can say that the knife culture of Late Paleolithic age in Japan developed through adapting to the cold and dry climate.

*Sub-epoch 3 (from 15 ka to 13 ka years B.P.)*

This sub-epoch is defined by the appearance of a lanceolated point (*Yarisaki-gata-sentoki*)(Fig.11-13,14) and micro blades (Fig.11-16)(Anbiru, 1986). The ratio of knives shows a decrease, suggesting the knife culture to be at an ebb.

The climate became warmer after 15 ka years B.P., although the humidity remained low. The invention of the lanceolated point was probably a strategy of Late Paleolithic people in adaptating to faunal changes caused by the climatic amelioration. The knife culture probably began to wane with the decrease of large mammals, such as *Megaceros kinryuensis* and *Bison priscus* found at the Hanaizumi site (Fig.10-21)(Yasuda, 1978), and *Elephas naumanii* and *Sinomegaceros yabei*, found at the Nojiri-ko site (Fig.10-17)(Nojiri-ko Hakkutsu Chosa Dan, 1975).

**After 13 ka years B.P.**

The micro blade culture flourished at this time. Blades from north-eastern Japan and the Japan Sea side are accompanied by *Araya*-type gravers (Fig. 11-15) similar to those of Siberia, suggesting an influx of the descendants of the Siberian mammoth hunters into Japan. Kato (1988) indicated that the root of the *Araya*-type graver can be traced back to the Baikal region. The Tsushima land bridge which connected north-western Kyushu with the south of Korea had already disappeared at this time, while the Soya land bridge which linked northern Hokkaido to Siberia through Sakhalin still existed. In all likelihood, the people who brought the micro blade culture from the Baikal region mainly crossed over to Japan by the Soya land bridge. It is also possible that the immigration was carried out using boats similar to the umiak to cross the Tsugaru strait (Yasuda, 1987c).

On the other hand, micro blades from south-western Japan have a semi-conical core, as represented by artifacts from the Yadegawa site (Fig.10-22). The cultural contrast between northern and southern Japan, which was already evident during the knife cultural period, is still in evidence.

Following the flourishing of the micro blade culture, the tanged projectile point (*Yuzetsu-sentoki*)(Fig.11-17) culture appears in Hokkaido, Honshu and Shikoku, but not Kyushu. Serizawa (1974) estimated the beginning of the tanged projectile point culture at 13 ka years B.P. It is notable that the oldest earthenware at the Kamikuroiwa site (Fig.10-14)(the horizon was dated at 12, 165 ± 600 years B.P.) in Ehime Prefecture, and at the Tazawa and Kosegasawa sites in Niigata Prefecture (Fig.10-18,19), were found together with tanged projectile points. Although the first appearance of earthenware may possibly date back even further, we can suppose that the appearance and development of earthenware is closely linked to the tanged projectile point culture (Okamoto, 1986).

At this time, the Kyushu district shows a peculiar feature, namely that the micro blade culture continues to exist while the tanged projectile point culture has not yet appeared. The oldest pottery was recovered together with micro blades at Fukui-dokutsu site in Nagasaki Prefecture, Kyushu district (Fig.10-1). This pottery is decorated with micro linear clay projections and is called *Sairyusenmon* (Fig.11-18). Charcoal collected from the horizon which contains the *Sairyusenmon* pottery is dated at 12,400 ± 350 years B.P. (Gak-949) and 12, 700 ± 500 years B.P. (Gak-950)(Serizawa, 1974), making this the oldest pottery yet found in the world. However, it is still unclear whether the oldest pottery was actually invented in Japan or not. Kato (1988) pointed out that the new micro blade culture (*Fukui* type) which produced the technology of pottery probably expanded from southern China, passing through Korea; thus, one possible clue to the origin of pottery is to look into the tradition of this micro blade culture.

As mentioned above, the climate ameliorated at 13 ka years B.P., and humidity significantly increased. Reactivation of the southwest monsoons began at 12.5 ka years B.P., increasing summer precipitation. In Japan the climatic amelioration at 13 ka years B.P. encouraged the development of temperate deciduous broad-leaved trees like beech and oak, which produced a considerable crop of nuts. Pottery is usually used for cooking, and particularly for the boiling of vegetables.

The Kyushu district in particular, located at the southwestern extreme of Japan, had ideal growing-conditions for temperate deciduous broad-leaved forests immediately after this climatic amelioration, and since it was also the most likely entry-point for the diffusion of Asiatic continental culture, it seems reasonable that the oldest pottery should be found there.

The climatic amelioration resulted in a deterioration of the habitat of the large mammals adapted to the cold and dry climatic condition of the maximum glacial epoch. In addition, overpopulation and advancement in the techniques of hunting may have resulted in overkilling. Instead of large mammals, small animals like deer and wild boar, which were adapted to forest life, increased.

The emergence of the tanged projectile point and the invention of clay pottery might have been a survival strategy of Metholithic people adapting to the lack of food resources. It must be noted that the climatic amelioration around 13 ka years B.P. brought a revolutionary change in the development of Japanese culture, marking the beginning of the Jomon culture.

Although further detailed data are required, it can be said that the climatic disruption linked to the fluctuations of the southwest monsoons, resulting in dramatic changes of humidity, greatly influenced the cultural changes during the Last Glacial Age in Japan.

## CONCLUSIONS

Fluctuations of the southwest monsoons in the Arabian Sea, Bengal Bay and Andaman Sea greatly influenced Japanese culture and the environment during the Last Glacial Age.

1) The southwest monsoons were active at the Last Interglacial and Early-glacial periods, and relatively active at the Interstadial between 50 ka and 33 ka years B.P. On the other hand, the southwest monsoons were dormant at Stadials; between 70 ka～50 ka years B.P., between 33 ka～28 ka years B.P. and between 25 ka～13 ka years B.P. At the maximum glacial epoch during 21 ka and 18 ka years B.P., the southwest monsoons were virtually dormant, but after 12.5 ka years B.P., began to reactivate.

2) Fluctuations of the southwest monsoons, resulting in fluctuations of humidity, influenced the Japanese climate and vegetation. When the southwest monsoons were dormant, a dry climate and conifer forests mainly composed of *Pinus* subg. *Haploxylon, Tsuga, Picea* and *Abies* prevailed, whereas when the southwest monsoons were active, a wet climate and *Cryptomeria* with temperate trees like *Fagus* and *Quercus* were dominant.

3) The intensity and frequency of heavy rain in summer was closely linked to the fluctuations of the southwest monsoons. When the southwest monsoons were active, large floods, resulting in increased river discharge, occurred frequently. Conversely, when the southwest monsoons were dormant, the intensity and frequency of heavy rain decreased.

4) The developmental epochs of the accumulation terraces occurred before 30 ka years B.P., when the southwest monsoons were still active. The transition of the geomorphic agent, ie. from aggradation to the denudation of the river around 30 ka years B.P., was caused by the decrease of heavy rain linked to the dormancy of the southwest monsoons. Frequent land-slides and unstable slopes after 13 ka years B.P. were partly caused by the increase of heavy rain closely linked to the reactivation of the southwest monsoons.

5) Several transitions in Japanese paleolithic culture appear to have been influenced by these climate changes. Important cultural breaks seem to have occurred at 70 ka years B.P., at 33 ka years B.P. and 13 ka years B.P. The climatic turnabout at ca. 33 ka years B.P. witnessed an especially important anthropological event in that *Homo sapiens* became extinct and *Homo sapiens sapiens* flourished. This anthropological event might have been due to the climatic deterioration at 33 ka years B.P.

6) Paleolithic culture, characterized by the knife-shaped tool, flourished in the maximum glacial epoch, adapting to the cold and dry climate. Climatic amelioration at 13 ka years B.P. compelled Late Paleolithic people to new survival strategies. The inventions of the lanceolated point, tanged projectile point and pottery were the fruits of the survival strategies of the Paleolithic and Metholithic peoples. The opening of the Jomon Age in Japan seems to have been stimulated by such climatic disruption.

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## 日本列島における最終氷期のモンスーン変動と旧石器文化

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**要旨**：南西モンスーンは、最終氷期以降にも、劇的に変動した。その変動は、日本列島の気候の乾湿の変動に大きな影響を及ぼした。とりわけ、夏季の降水量は、アラビア海からベンガル湾における南西モンスーンの変動と密接にかかわって変動した。アラビア海やアンダマン海の海底コアの花粉分析、酸素同位対比、炭素同位対比の分析結果は、南西モンスーンは、最終間氷期や完新世には、著しく活発であり、亜間氷期にも相対的に活発であったことを、明らかにした。それらの時代の日本列島の気候は湿潤であった。一方、寒冷な亜氷期には、南西モンスーンは、不活発で、日本列島の気候は乾燥化した。こうした南西モンスーンの変動と密接に連動した気候の乾湿の変動は、日本列島の自然環境と文化に大きな影響を与えた。堆積段丘の形成には、南西モンスーンと連動した梅雨期の降水量の変動が深く関わっていた。日本列島の堆積段丘は、主として、40,000年前以前に形成され、30,000年前以降は、侵食期となる。こうした、堆積から侵食への転換は、南西モンスーンと連動した豪雨の頻度が減少したためと判断される。10,000年前以降、南西モンスーンの活発化と連動して、再び豪雨が、頻発化した。日本の旧石器文化の変遷も、南西モンスーンと連動した気候変動から大きな影響を受けたことが、明らかとなった。

南西モンスーンの変動期と連動する日本列島の気候転換期には、旧石器の形態や組成にも大きな変化がみとめられた。日本列島の旧石器文化が、前期旧石器から後期旧石器へと

大きく変化する33,000年前は、日本列島が著しい寒冷、乾燥気候にみまわれ始める時代に対応していた。日本の後期旧石器文化を代表するナイフ型石器の形態と組成の変化も、気候変動と深い関わりがあった。13,000年前にはじまる気候の温暖、湿潤化は日本列島の植生に大きな変化をもたらしたのみでなく、新たな、縄文時代を開幕させる上において重大な役割を果した。