(Original Paper)

The Full-glacial Refugium of *Cryptomeria japonica* in the Oki Islands, Western Japan

Hikaru TAKAHARA[1), Kyoko TANIDA[1) and Norio MIYOSHI[2)

[1) *University Forest, Faculty of Agriculture, Kyoto Prefectural University, 1 - 5 Hangi-cho, Shimogamo, Sakyo-ku, Kyoto, 606-8522 Japan*

[2) *Department of Biosphere-Geosphere System Science, Faculty of Informations, Okayama University of Science, 1 - 1 Ridai-cho, Okayama, 700-0005 Japan*

(Receivede Feb. 17, 2001, Accepted Apr. 16, 2001)

A sediment core from Dogo Island, one of the Oki Islands off the Sea of Japan coast of western Japan, provides a new pollen record that reconstructs vegetation and climate conditions during the late-glacial and full-glacial intervals (25,000 to 10,000 ^{14}C yr BP) on the Palaeo-Oki Peninsula. Between 20,000 and 15,000 ^{14}C yrs BP, hemlock-birch forests were accompanied by *Cryptomeria japonica* and spruce. The high percentages of *C. japonica* pollen indicate that *C. japonica* was common on the Palaeo-Oki Peninsula during the last glacial maximum (LGM), confirming the full-glacial refugia concept for *C. japonica* on the Palaeo-Oki Peninsula suggested by Tsukada (1980, 1982, 1986). Coniferous forests were replaced by deciduous broad-leaved trees such as hornbeam, beech, oak, elm and ash at 12,500 ^{14}C yrs BP, because of the higher temperatures and increased precipitation in the late-glacial interval. An European Younger Dryas-like oscillation ca. 11,000 ^{14}C yrs BP is indicated by a decrease in the concentration of pollen from deciduous broad-leaved trees such as hornbeam, beech, oak, elm and ash, with increases in upland herb pollen such as grass and mugwort.

Key Words : *Cryptomeria japonica*, refugium, Last Glacial Maximum, Oki Islands, Palaeo-Oki Peninsula

Introduction

Cryptomeria japonica D. Don (Taxodiaceae) is one of the most important species in Japanese silviculture. Its current natural distribution lies between Ajigasawa (Aomori Prefecture) in the north and Yaku Island (Kagoshima Prefecture) in the south (Hayashi, 1960). *C. japonica* is found from the lowland, warm-temperate zone to the subalpine zone, showing a wide altitude tolerance. On the Sea of Japan side of Japan, it is found predominantly in beech forests, while on the Pacific side, it usually grows with temperate conifers such as *Abies firma*, *Tsuga sieboldii* and *Chamaecyparis obtusa*. In regions where *C. japonica* populations are currently high, annual precipitation is above 2000 mm (Hayashi, 1960).

C. japonica has been present continuously in western Japan throughout the last interglacial, the last glacial and Holocene, except in the two known stadial periods (Oxygen Isotope Stages 2 and 4) (Takahara and Kitagawa, 2000). Tsukada (1980, 1982, 1986) presented a glacial refugium model for *C. japonica* that combined the climate conditions of the current range of *C. japonica* with palynological records for *Cryptomeria* pollen. Tsukada (1986) concluded that definite full-glacial areas of *C. japonica* distribution lay within the coastal zone, between latitudes ca. 35° and 36°N. This means that the full-glacial refugia of *C. japonica* were mainly in the Izu Peninsula and Sagami Bay areas on the Pacific side, and the Wakasa Bay area and the

Palaeo-Oki Peninsula on the Sea of Japan side [Tsukada (1984, 1985) used the term Palaeo-Oki Peninsula for the Oki Islands at the time of glaciation]. Direct evidence of refugia is available from the Izu-Sagami (Tsuji *et al.*, 1984 ; Kanauchi *et al.*, 1989) and Wakasa Bay areas (Yasuda, 1982 ; Takahara and Takeoka, 1992 ; Takahara *et al.*, 1999), but there has hitherto been no direct evidence of the proposed refugium on the Palaeo-Oki Peninsula.

This paper presents a new pollen record from the Oki Islands that corresponds to the late-glacial and full-glacial intervals. This pollen record provides evidence of the full-glacial refugium of *C. japonica*, and elucidates vegetation changes on the Palaeo-Oki Peninsula during this period.

Study area

The Oki Islands are located in the Sea of Japan, 40-80 km north off the coast of western Honshu (Fig. 1). The largest island is Dogo Island (20 km in diameter). Almost all of this island consists of mountains with peaks 500 - 600 m above sea level. The coring site is in Tsuma, Oki-gun, Shimane Prefecture, at 36°13′56″N, 133°14′15″E, at an altitude of 345 m (Fig. 2).

At the Goka Climatological Station (5 m altitude), 6 km north of the study site, the annual mean temperature is 14.0 ℃ and annual precipitation is about 2000 mm (Japan Meteorological Agency, 1972). The annual mean temperature of the study site is estimated to be 12℃ from the data at the Goka using the lapse rate of 0.006℃/m.

Most of Dogo Island is covered with secondary forests and plantations of *Cryptomeria japonica*. There are *Pinus thunbergii* forests and evergreen broad-leaved forests of *Quercus* and *Castanopsis* near the coast, with deciduous broad-leaved forests of *Quercus crispula* and *Castanea crenata* on mountain slopes above 300 m asl (Miyata and Sugimura, 1983).

The study site is a small basin, 140 m long and 55 m wide. The north side is a steep (40°) slope, covered with a mixed forest of *Abies firma*, *Castanopsis cuspidata* var. *sieboldii*, *Juglans mandshurica* and others. Plantations of

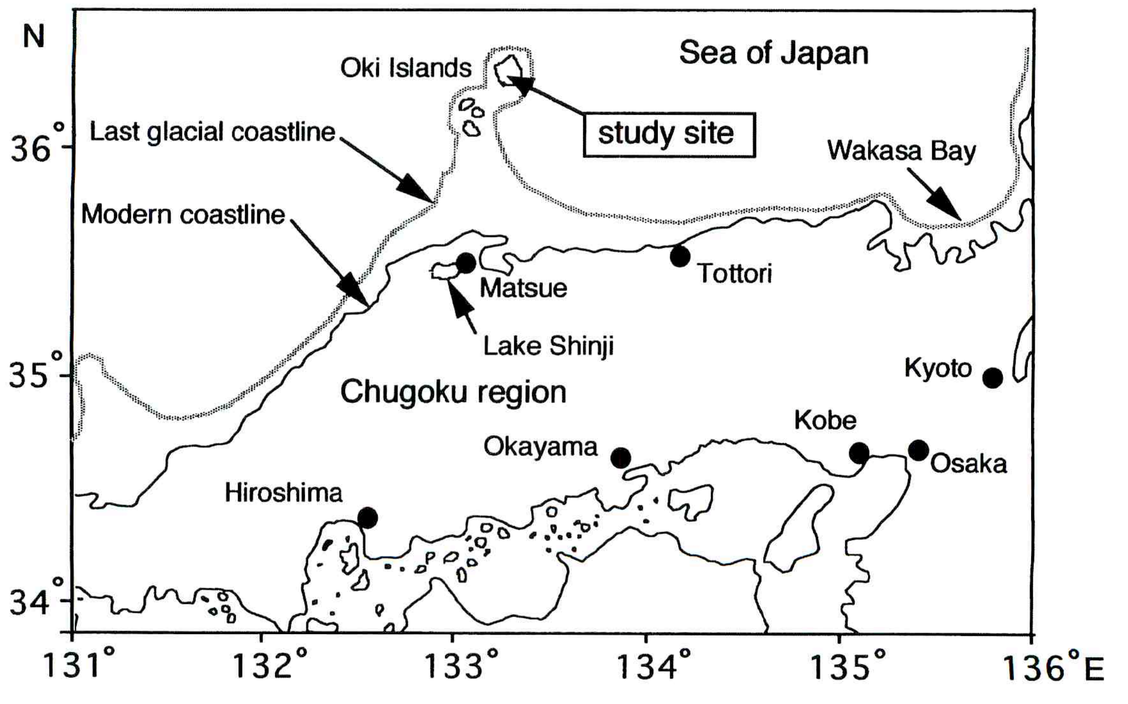


Fig. 1. Map of the Chugoku region, western Japan, showing the location of the Oki Islands and the last glacial coastline (Japan Association for Quaternary Research, 1987)

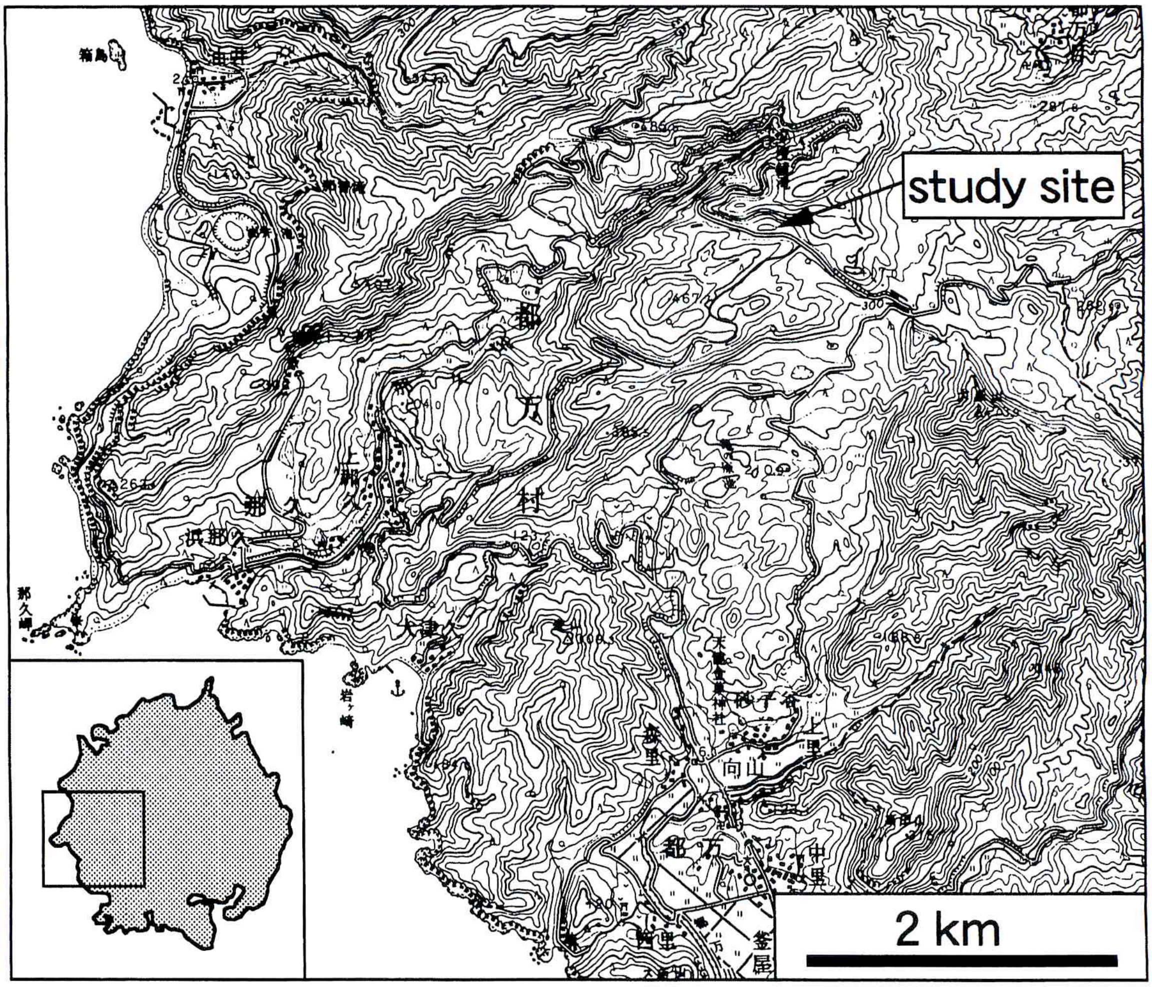


Fig. 2. Topographic map showing location of the study site. From the 1 : 50,000 topographic map of Saigo issued by the Geographical Survey Institute of Japan.

Cryptomeria japonica occupy the remainder.

Methods

A 9.25-m core was taken from the surface sediment of the small basin. The upper part (0 to 440 cm depth) was obtained using a thin-walled piston sampler, 7.5 cm in diameter, and the lower part (440 to 925 cm depth) was obtained using a Thomas-type hand borer.

Samples of one cm^3 were taken every 10 cm from peat and peaty clay layers between 114 and 720 cm depth for pollen analysis. Sixty-four samples were prepared by standard KOH (10 minutes heat (90-100℃)), acetolysis mixture (3 minutes heat (90-100 ℃)), and HF (10 minutes heat (70℃)) procedures (Faegri *et al.*, 1989 with our modification). To determine pollen accumulation rates, a known concentration of 25-μm plastic microspheres in suspension (17.4 x 10^4 grains/ml) was added to each sample before undertaking the chemical procedures (Ogden, 1986). All fossil pollen grains and spores extracted from the samples were preserved in sample tubes with silicon oil. At least 350 tree-pollen grains were counted for each level sampled. Percentages of each pollen taxon were calculated based on the tree-pollen total count. Charcoal fragment analysis was performed on a Macintosh computer using the public domain NIH Image program, version 1.5 (developed at the U.S. National Institutes of Health and available on the Internet at http://rsb.info.nih.gov/nih-image/).

Total areas (mm^2/ml) of charcoal fragments >100 μm^2 in the pollen preparations were measured.

Results and interpretation

Lithology and chronology

Sediment types are shown in Fig. 3. The lowest layer between 925 to 725 cm depth of the cored sediment is volcanic ash and with clay from 836 to 820 cm depth. This tephra layer is followed by clay lacking plant fragments (725 to 500 cm depth). The layer from 500 to 126 cm depth consists of peaty clay with small plant fragments, and includes a few very thin clay laminae. A decomposed peat horizon is present between 126 and 112 cm depth. The uppermost layer (112 to 0 cm depth) is soil that has been disturbed by human activity.

Identification of the lowest layer as tephra was based on the refractive index of volcanic glass shards (Table 1). The tephra layer was identified as Aira Tn ash (AT) that accumulated ca.25,000 years BP (Matsumoto *et al.*, 1987). Four accelerator mass spectrometry (AMS) ^{14}C dates were obtained from bulk samples of the peat and the peaty clay (Table 2). Linear interpolation of the ^{14}C AMS dates was then used to construct an age-depth relationship for the core (Fig. 3). This relationship indicates that the clay layer at 725 to 500 cm depth probably accumulated over a short interval. This layer's dearth of pollen supports such an interpretation. The average sedimentation rate for the material between 495 and 123 cm depth was 0.0265 cm/ yr.

Pollen analysis

Pollen percentage and pollen concentration diagrams are shown in Figs. 4 and 6. Pollen was rare below 500 cm depth. The pollen stratigraphy was divided by a stratigraphically constrained incremental sum of squares cluster analysis (CONISS in Tilia 2.05b ; Grimm, 1987) into four local pollen assemblage zones and two subzones based on tree pollen frequencies (Fig. 4).

The most obvious characteristic of the pollen record in zones OT-1 to OT-3 is the predominance of

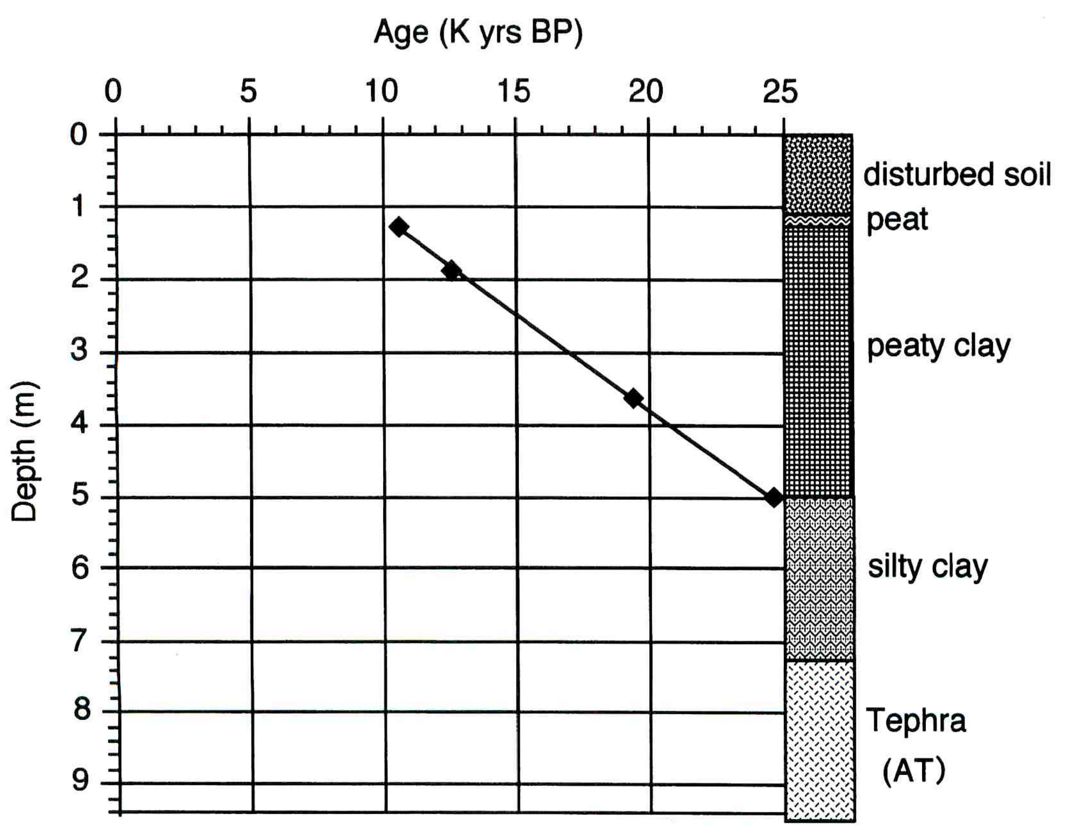


Fig. 3. Age-depth relationship for core sediment from the Tsuma site. Radiocarbon dates are shown in Table 2. Sediment types are shown on the right-hand side.

Table 1. Refractive index of volcanic glass shards in sediment from the Tsuma site

Depth (cm)	Minimum	Maximum	Mean	St. dev.	Count*
745	1.4977	1.5004	1.4993	0.0008	30
795	1.4975	1.5008	1.4992	0.0009	30
845	1.4970	1.5006	1.4994	0.0010	30
870	1.4967	1.5007	1.4993	0.0010	30
895	1.4973	1.5006	1.4994	0.0009	31
920	1.4971	1.5007	1.4993	0.0010	30

*Count of glass shards

Table 2. AMS radiocarbon dates for samples from the Tsuma site

Depth (cm)	Material	Age (^{14}C yrs BP)*	Lab. number
123.0-123.5	peat	10620 ± 60	Beta-125952
179.5-180.0	peaty clay	12680 ± 60	Beta-125950
356.0-356.5	peaty clay	19460 ± 90	Beta-125951
495.0-496.0	peaty clay	24670 ± 200	Beta-134886

* the result after applying ^{13}C/^{12}C corrections to the measured age

Tsuga and *Betula* pollen. The genus *Tsuga* in Japan consists of *T. sieboldii* (montane species) and *T. diversifolia* (subalpine species). Statistical analysis of the morphology of the marginal fringe of *Tsuga* pollen can be used to distinguish these two species of fossil *Tsuga* pollen (Takahara, 1992). The A/B ratio (A = diameter including marginal fringe ; B = diameter of the pollen body) of modern *T. sieboldii* pollen after storage in glycerol gelatin for one year tends to be less than 1.25, whereas that for *T. diversifolia* is above 1.20. The A/B ratio of fossil pollen grains in 7 levels of the core was measured after storage by the same method as used for modern pollen. The frequency distributions for the A/B ratio of fossil *Tsuga* pollen grains in layers where Pinaceae pollen is abundant are shown in Fig. 5. Both *T. sieboldii*- and *T. diversifolia*-type pollen are recognized in all zones. *T. sieboldii*-type pollen, however, tends to be more abundant. *Picea* has relatively high abundance in subzone OT-1b, and zones OT-2 and OT-3 compared with other zones. The percentages of *Cryptomeria japonica* pollen in subzone OT-1a and zone OT-2 are mostly 5-16%. In the upper part of zone OT-3, the amount of pollen from broad-leaved trees including *Ostrya/Carpinus*, *Fagus crenata* and *Quercus* subgenus *Lepidobalanus*, gradually increases, to become dominant in zone OT-4. The tree pollen concentration increases gradually from the bottom to near the top of the core, and then increases rapidly in the uppermost levels (124-114 cm depth ; Fig. 6). The pollen concentration of upland herbs increases in the lower part of zone OT-4 and abrubtly declines in the uppermost.

Vegetation reconstruction

Zone OT-1 (490-375 cm depth, ca. 25,000 to 20,000 ^{14}C yrs BP). This zone is characterized by high values of *Tsuga* and *Betula* pollen. We recognized two subzones. Subzone OT-1a (490-430 cm depth, ca. 25,000 to 22,000 ^{14}C yrs BP) contains low but consistent values for broad-leaved trees, including *Ostrya/Carpinus*, *Alnus*, *Quercus* subgenus *Lepidobalanus* and *Ulmus/Zelkova* pollen. The pollen data suggest that hemlock (both *Tsuga sieboldii* and *T. diversifolia*) and birch were the dominant trees in the vicinity of the site, together with broad-leaved trees such as hornbeams and deciduous oaks. Several percentages of *Cryptomeria japonica* pollen (3-9%, but less than 1% at 470 cm depth) confirm that *C. japonica* was present on the Palaeo-Oki Peninsula. *Fagus crenata* pollen reaches 4% in the center of the subzone, indicating that beech also existed on the peninsula.

In subzone OT-1b (430-375 cm depth, ca. 22,000 to 20,000 ^{14}C yrs BP), the broad-leaved trees and *C. japonica* exhibit reduced percentages. The abundance of *Tsuga* declines abruptly at the

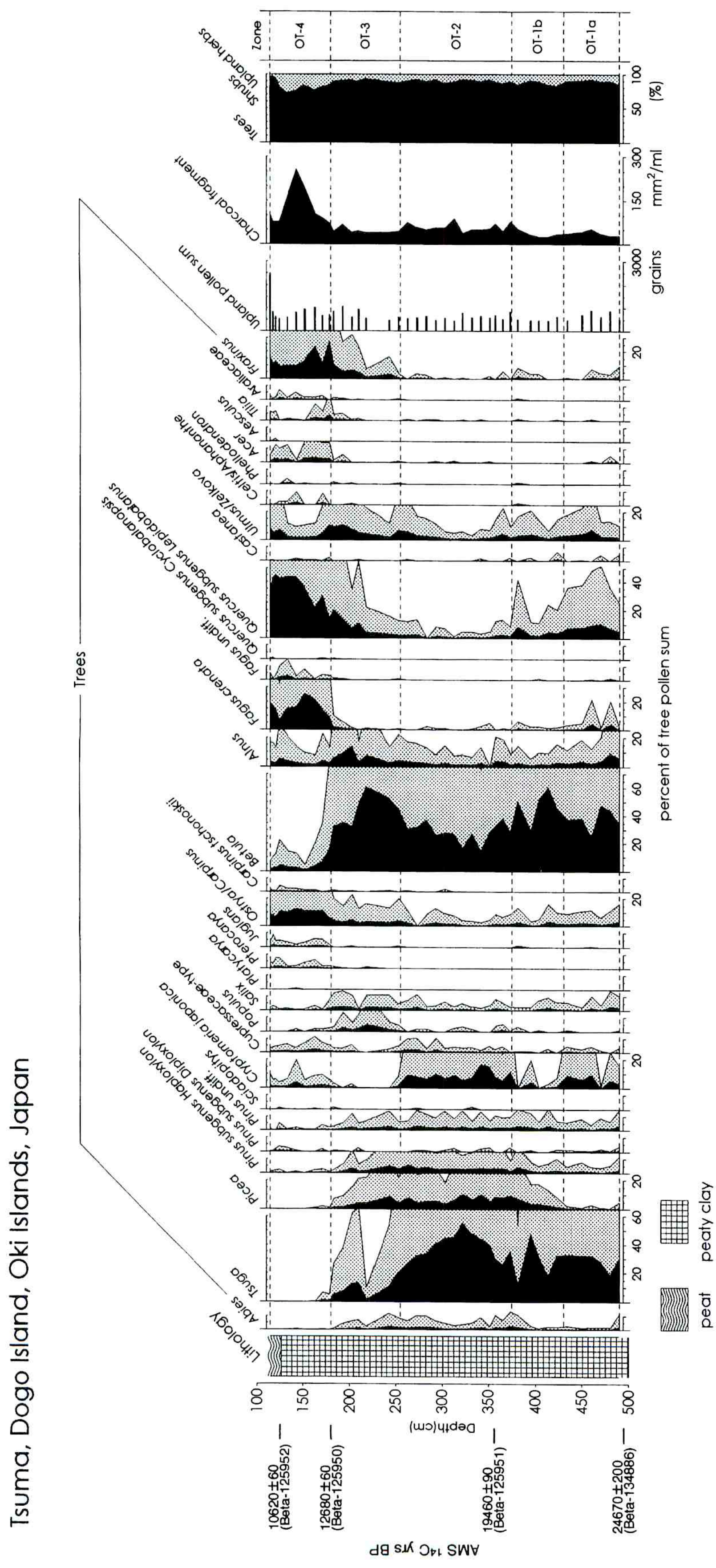


Fig. 4. Pollen percentage and charcoal fragment diagram from the Tsuma site, Dogo Island. Cupressaceae-type pollen includes Cephalotaxaceae, Taxaceae and Cupressaceae pollen. Shaded pattern shows 5 × exaggeration.

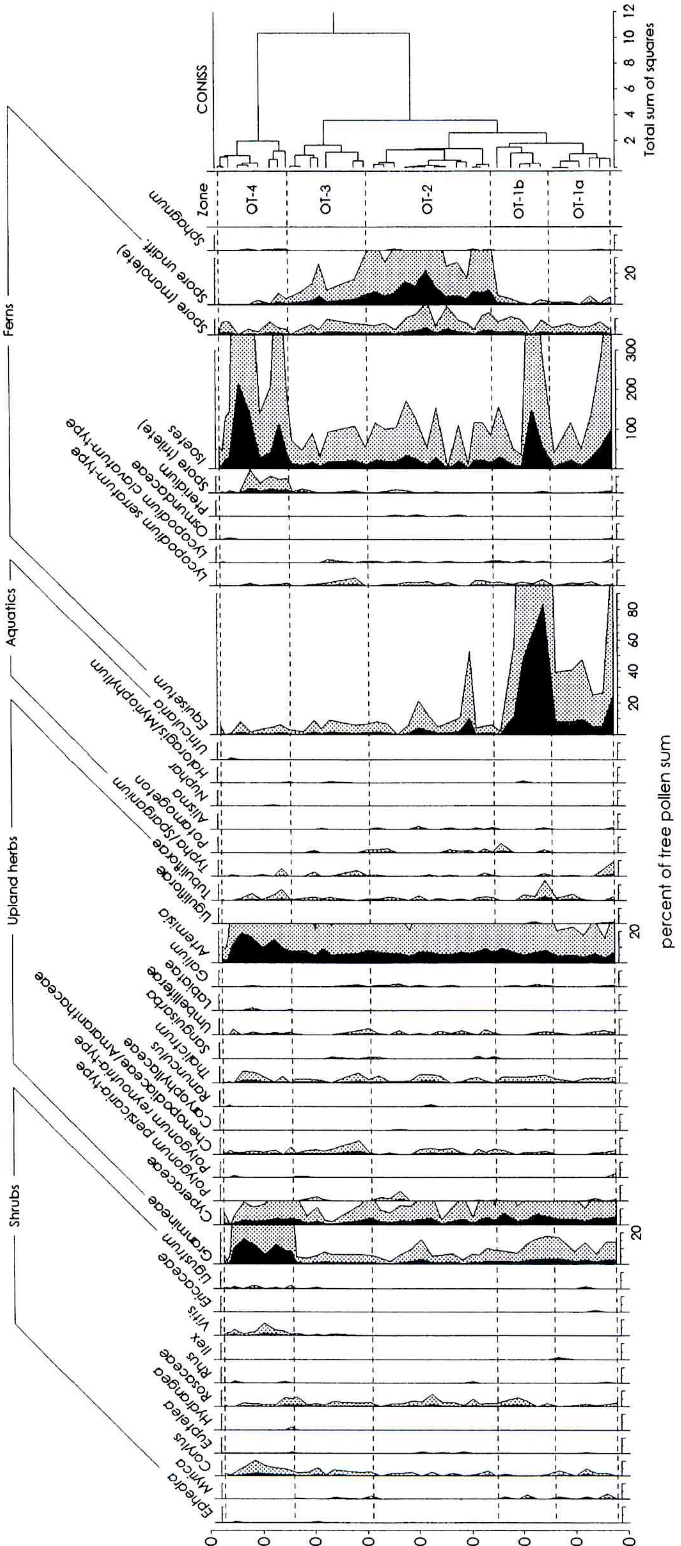


Fig. 4. (continued).

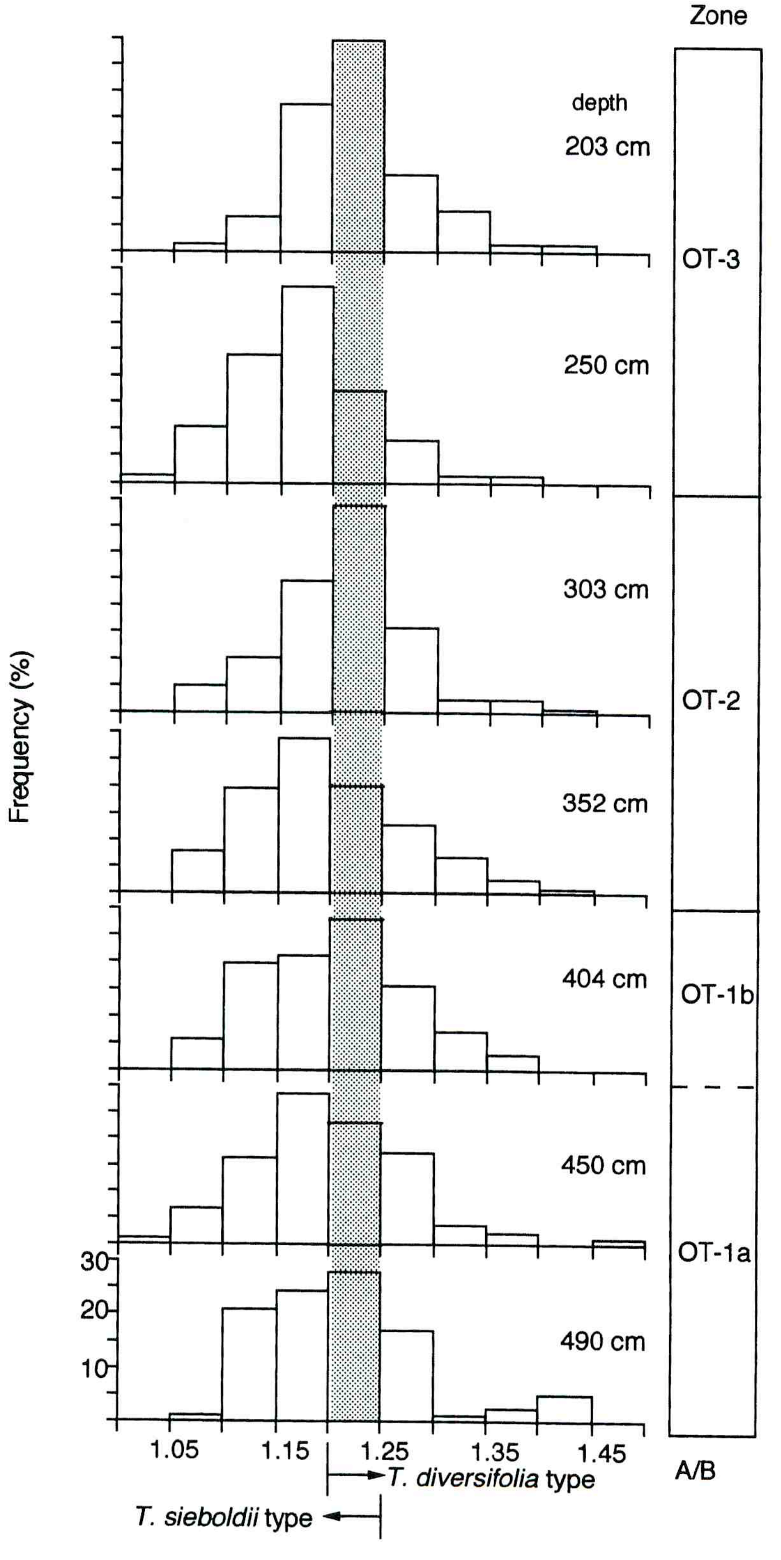


Fig. 5. Frequency distribution of the A/B ratio of fossil *Tsuga* pollen (A = diameter including marginal fringe ; B = diameter of the pollen body) at selected levels in layers in which Pinaceae pollen is abundant.

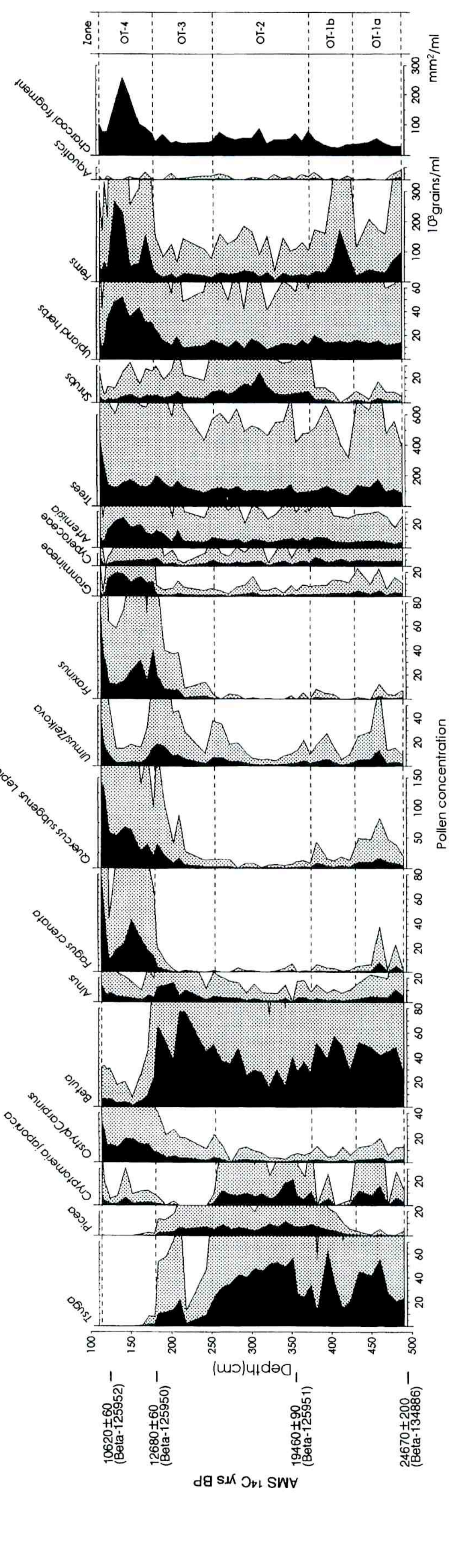


Fig. 6. Pollen concentration diagram for selected taxa from the Tsuma site. Note that the horizontal axis changes in scale for each pollen taxon.

beginning of the subzone, but then increases in the middle and falls again in the uppermost. From the pollen assemblage of this subzone, hemlock and birch were the predominant forest trees, although their abundance fluctuated. Percentages of *Picea* pollen increases slightly towards the top of the subzone (2-7%) indicating that spruce may have been part of the hemlock-birch forest near the site.

Zone OT-2 (375-250 cm depth, ca. 20,000 to 15,000 ^{14}C yrs BP). In this zone, *Tsuga* values are generally higher, and *Betula* values lower, than in the underlying subzone OT-1b. *Picea* and *C. japonica* exhibit comparatively high percentages (4-10% and 2-16%, respectively), implying that the hemlock-birch forests were accompanied by spruce and *C. japonica*.

Zone OT-3 (250-175 cm depth, ca. 15,000 to 12,500 ^{14}C yrs BP). The abundance of *Tsuga* pollen begins to decline in the middle of Zone OT-2, and is lowest in the middle of zone OT-3. After a temporary increase in the upper part of Zone OT-3, it then declines again. *Betula* percentages remain high, but tend to decrease towards the top of the zone. The broad-leaved tree pollen (*Ostrya/Carpinus*, *Quercus* subgenus *Lepidobalanus*, *Ulmus/Zelkova* and *Fraxinus*) begins to increase in the middle of the zone. *Fagus crenata* increases at the top of the zone. These changes in the pollen assemblage indicate that the period between ca. 15,000 and 12,500 yrs BP marked a transition from hemlock-birch forests to cool-temperate deciduous broad-leaved forests.

Zone OT-4 (175-114 cm depth, ca. 12,500 to 10,000 ^{14}C yrs BP). This zone is dominated by *Ostrya/Carpinus*, *Fagus* crenata, *Quercus* subgenus *Lepidobalanus* and *Fraxinus* pollen. High percentages of upland herb pollen (Gramineae and *Artemisia*) are present, except in the uppermost layers. The pollen concentration of these broad-leaved trees increases rapidly in the uppermost layers (124-114 cm depth). From 12,500 to 10,000 ^{14}C yrs BP, cool-temperate deciduous broad-leaved forests of beech, deciduous oak, hornbeam and ash had developed in the peninsula. A temporary decline of this type of the forests, however, is evident just below the top of the zone.

Discussion

Vegetation history in coastal areas of the Sea of Japan, western Japan

In the interval between 25,000 and 22,000 ^{14}C yrs BP, the Palaeo-Oki Peninsula was covered by hemlock-birch forests, with subordinate populations of *Cryptomeria japonica* and deciduous broad-leaved trees, including hornbeam, oak and beech. Around the Wakasa Bay area, east of the study site, hemlock and birch were abundant in forests similar to those of the Palaeo-Oki Peninsula, but with comparatively higher abundance of fir and haploxylon pine (Yasuda, 1982 ; Takahara, 1993 ; Takahara and Takeoka, 1992 ; Takahara *et al.*, 1999). Hemlock species included both *Tsuga sieboldii* and *T. diversifolia*, as deduced from statistical analysis of pollen morphology. The presence of subalpine conifers such as *T. diversifolia* implies cold conditions, and the *C. japonica* and beech indicate relatively wet conditions during this period.

A decline in deciduous broad-leaved trees and *C. japonica* ca. 22,000 ^{14}C yrs BP suggests decreasing precipitation. The predominance of hemlock and birch, with only small amounts of spruce, also indicates climate deterioration towards colder and dryer conditions.

Between 20,000 and 15,000 ^{14}C yrs BP, the hemlock-birch forests were accompanied by *C. japonica* and spruce. The *C. japonica* pollen percentages at the study site represent the highest values known in western Japan for the LGM. Mixed forests, consisting predominantly of pinaceous conifers such as hemlock, spruce, fir and haploxylon pine, together with birch, reached their maximum extent. Significant numbers of *C. japonica* evidently grew on the Palaeo-Oki Peninsula.

Changes in the composition of late-glacial forests between 15,000 and 12,500 ^{14}C yrs BP are signalled by fluctuating percentages of hemlock, an abundance of birch, and an incipient increase in the proportion of deciduous broad-leaved trees such as hornbeam, beech, oak, elm and ash. The decline in hemlock and spruce was the result of rising temperatures in the late-glacial. A contemporaneous decline in pinaceous trees, also indicative of warming, has been recognized elsewhere in western Japan (Takahara, 1994).

The abrupt development of deciduous broad-leaved forests composed mainly of deciduous oak, beech, hornbeam and ash suggests that temperatures and precipitation had increased appreciably at ca. 12,500-12,000 ^{14}C yrs BP. The decline of deciduous broad-leaved trees and the increase of upland herbs such as grass and mugwort, which grow on open sites, at ca. 11,000 ^{14}C yrs BP, imply a climate reversal, possibly that of the Younger Dryas.

Full-glacial refugia of *Cryptomeria japonica*

Based on this study and previous palynological data (Takahara and Takeoka, 1992 ; Takahara *et al.*, 1999), it is clear that *Cryptomeria japonica* had full-glacial refugia along the coastal corridor of the Sea of Japan, western Japan. The population of *C. japonica* in the Palaeo-Oki Peninsula was larger than at other sites in western Japan. The inference of *C. japonica* refugium in the Palaeo-Oki Peninsula (Tsukada, 1980 ; 1982 ; 1986) is confirmed by the evidence from this study.

Generally, the climate of the Japanese Archipelago was cold and dry during the LGM (Tsukada, 1983 ; 1985). The abundance of *C. japonica* on the Palaeo-Oki Peninsula in the LGM, however, implies wet conditions. The Palaeo-Oki Peninsula was in the coastal area and jutted into the Sea of Japan, which was likely the source of the interpreted atmospheric moisture.

In the Wakasa Bay area, which is also regarded as a *C. japonica* refugium, the species increased abruptly in the early Holocene, and then spread throughout the Holocene (Yasuda, 1982 ; Takahara and Takeoka, 1992 ; Takahara *et al.*, 1999). On the other hand, around Lake Shinji (Fig. 1), which is located south of the study site, on the Sea of Japan coast in the middle Chugoku region, development of *C. japonica* during the early Holocene is not evident (Onishi, 1977), probably because southward migration of *C. japonica* from the Palaeo-Oki Peninsula into the present coastal area of the middle Chugoku region was prevented by a rapid rise in sea-levels in the late-glacial.

Future investigations of Holocene palynological records from the Oki Islands will facilitate a more detailed interpretation of the history of *C. japonica* distribution.

Ackknowledgments

We gratefully acknowledge the village office of Tsuma-mura for their help in acquiring the core from the study site. We thank Akira Ogura for measuring charcoal fragments and helping with field work, and Asako Nakamura for her help in the field. This study was supported by a Grant-in-Aid for Basic Scientific Research (C)(2)(No. 09660170, to Hikaru Takahara) by the Ministry of Education, Science, Sports and Culture, Japan.

References

Faegri, K., P. E. Kaland, and K. Krzywinski : Textbook of Pollen Analysis 4th Edition. Wiley, New York, 328pp. (1989).

Grimm, E. C. : CONISS: A FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computers & Geosciences* **13**, 13-35 (1987).

Hayashi, Y. : Taxonomical and Phytogeographical Study of Japanese Conifer. Norin-Shuppan, Tokyo, 246pp. (1960). (in Japanese)

Japan Association for Quaternary Research (ed) : Quaternary Maps of Japan. University of Tokyo Press, Tokyo, (1987). (in Japanese with English caption)

Japan Meteorological Agency : The monthly normals of temperature and precipitation at climatological stations in Japan (1941-1970). *Tech. Data. Ser.* **36**, p.162, Tokyo (1972). (in Japanese)

Kanauchi, A., Y. Tahara, J. Nakamura and S. Sugihara : Stratigraphy and pollen analysis of the boring core at Lake Ippekiko (Numa-Ike) Ito City, Shizuoka Prefecture, Japan. *The Quaternary Research (Dai-yonki-Kenkyu)* **28**, 27-34 (1989). (in Japanese with English summary)

Matsumoto, E., Y. Maeda, K. Takemura and S. Nishida : New radiocarbon age of Aira-Tn (AT). *The Quaternary Research (Daiyonki Kenkyu)* **26**, 79-83 (1987). (in Japanese with English summary)

Miyata I. and Y. Sugimura : Vegetation of Shimane Prefecture. *In* A. Miyawaki (ed.), Vegetation of Japan-Chugoku region (Nihon

Shokuseishi Chugoku), Shibundo, Tokyo, pp. 404-413 (1983).

Ogden III, J. G. :An alternative to exotic spore or pollen addition in quantitative microfossil studies. *Can. J. Earth Sci.* **23**, 102-106 (1986).

Onishi, I. : Palynological study of the subsurface Quaternary deposits in the Izumo coastal plain, San'in district, Japan. *Jour. Geol. Soc. Japan* **83**, 603-616 (1977). (in Japanese with English summary)

Takahara, H. : Pollen morphology of the genus *Tsuga* in Japan. *Bull. Kyoto Pref. Univ. For.* **36**, 45-55 (1992). (in Japanese with English summary)

Takahara, H. : Vegetation history since the last glacial period around the Yamakado Moor, Shiga Prefecture, western Japan. *Jpn. J. Palynol.* **39**, 1-10 (1993). (in Japanese with English summary)

Takahara, H. : Vegetation history since the last glacial period in the Kinki and the eastern Chugoku region, western Japan. *Bull. Kyoto Pref. Univ. For.* **38**, 89-112 (1994). (in Japanese with English summary)

Takahara, H. and H. Kitagawa :Vegetation and climate history since the last interglacial in Kurota Lowland, western Japan. *Palaeogeography, Plaeoclimatology, Palaeoecology* **155**, 123-134 (2000).

Takahara, H. and M. Takeoka : Vegetation history since the last glacial period in the Mikata lowland, the Sea of Japan area, western Japan. *Ecological Research* **7**, 371-386 (1992).

Takahara, H., Y. Uemura, T. Danhara, K. Takemura and S. Nishida : Vegetation history since the last glacial around Oofuke Moor, in the Tango Peninsula, western Japan. *Jpn. J. Palynol.* **45**, 115-129 (1999). (in Japanese with English summary)

Tsuji, S., M. Minaki and S. Osawa : Paleobotany and paleoenvironment of the late Pleistocene in the Sagami region, central Japan. *The Quaternary Research (Daiyonki-Kenkyu)* **22**, 279-296 (1984).

Tsukada, M. : The history of Japanese cedar : the last 15000 years. *Kagaku* **50**, 538-546 (1980). (in Japanese)

Tsukada, M. : *Cryptomeria japonica* : Glacial refugia and late-glacial and postglacial migration. *Ecology* **63**, 1091-1105 (1982).

Tsukada, M. : Vegetation and climate during the last glacial maximum in Japan. *Quaternary Research* **19**, 212-235 (1983).

Tsukada, M. : A vegetation map in the Japanese Archipelago approximately 20,000 years B.P. *Jpn. J. Ecol.* **34**, 203-208 (1984). (in Japanese, with English summary)

Tsukada, M. : Map of vegetation during the last glacial maximum in Japan. *Quaternary Research* **23**, 369-381 (1985).

Tsukada, M. : Altitudinal and latitudinal migration of *Cryptomeria japonica* for the past 20,000 years in Japan. *Quaternary Research* **26**, 135-152 (1986).

Yasuda, Y. : Pollen analytical study of the sediment from the Lake Mikata in Fukui Prefecture, Central Japan : Especially on the fluctuation of precipitation since the last glacial age on the side of Sea of Japan. *The Quaternary Research (Daiyonki-Kenkyu)* **21**, 255-271 (1982). (in Japanese with English summary)

最終氷期最盛期におけるスギ逃避地-隠岐島島後

高原　光[1)]・谷田　恭子[1)]・三好　教夫[2)]

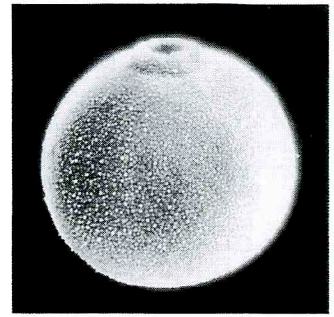
[1)] 京都府立大学農学部附属演習林　〒606-8522　京都市左京区下鴨半木町１-５
[2)] 岡山理科大学総合情報学部生物地球システム学科　〒700-0005　岡山市理大町１-１

島根県隠岐郡都万村（島後）の標高 345m に位置する小規模な盆地から採取した堆積物の花粉分析の結果から，隠岐島島後における最終氷期最盛期から晩氷期にかけての植生と気候変動を解明した。約 20,000 年から約 15,000 年前（放射性炭素年代）の最終氷期最盛期に，ツガ属とカバノキ属が優勢で，トウヒ属とスギの伴う森林が発達していた。この結果は，Tsukada（1980, 1982, 1986）が推定した隠岐島におけるスギの逃避地を裏付ける証拠である。その後，15,000 年前から 12,500 年前には，ツガ属，トウヒ属などのマツ科針葉樹が減少し，落葉広葉樹が増加しはじめた。12,500 年前には，マツ科針葉樹を中心とする森林は，ブナ，コナラ亜属などの冷温帯落葉広葉樹林に置き換えられた。約 11,000 年前には，単位体積あたりの落葉広葉樹花粉量が減少し，イネ科，ヨモギ属などの陽性草本の花粉が増加した。この変化によって示される植生の変化を引き起こした気候変化は，ヨーロッパにおいて認められている Younger Dryas 期に相当する可能性があることを示した。

地球の過去から現在を考える．
自然環境の変遷を時間を追って解明します．

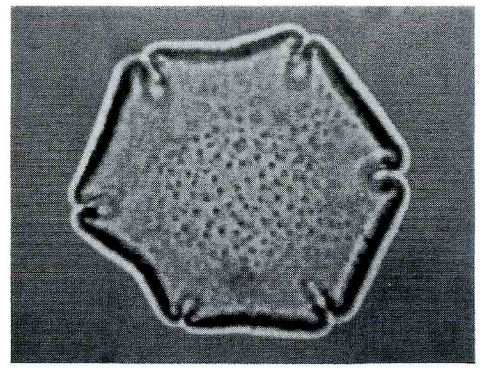
年代・地層対比の手段に

石灰質ナンノ化石分析，珪藻化石分析，有孔虫化石分析，放散虫化石分析，花粉化石分析，
火山灰分析（重鉱物組成・屈折率測定），^{14}C 年代測定．



岩石・土壌・資材の分析に

岩石・土壌・コンクリート薄片作製，顕微鏡観察，X 線回折試験，海浜・河川の重鉱物分析，資材評価．
pH・EC・有機炭素・CEC 測定，蛍光 X 線試験，示差熱分析，赤外線分光分析，粒度分析，電子顕微鏡観察．



考古学調査に

計画立案，遺跡の層序地形解析・古環境解析，遺構解析，遺物分析．

パリノ・サーヴェイ株式会社

本　社　〒103-0023　東京都中央区日本橋本町 1-10-5　日産江戸橋ビル 2F
TEL 03-3241-4566（代表）　FAX 03-3241-4597
研究所　〒375-0011　群馬県藤岡市岡之郷戸崎 559-3
TEL 0274-42-8129　FAX 0274-42-7955
大阪支店　〒564-0044　大阪府吹田市南金田　2-3-26 ﾌｧｰ・ｲｰｽﾄ21　503
TEL 06-6193-9885 FAX 06-6193-9886