Palynological Study of the Quaternary in Kyushu, Southwest Japan

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https://doi.org/10.5109/1525658

出版情報：九州大学大学院理学研究院紀要 : Series D, Earth and planetary sciences. 27 (1), pp.15-74, 1991-01-28. Faculty of Science, Kyushu University
バージョン：

Mem. Fac. Sci., Kyushu Univ., Ser. D, Earth Planet. Sci., Vol. XXVII, No. 1,
pp. 15–74, text-figs. 1–34, tables 1–6, plates 3–5, January 28, 1991

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Hideaki NOI

Abstract

The purpose of this study is to clarify the successive change of pollen assemblages, paleovegetation and paleoclimate through the Pleistocene age of Kyushu.

On the basis of synthesis of the pollen records from the Pleistocene strata in the Chikugo, Ôita, and Miyazaki areas, 33 pollen assemblage zones are recognized. These zones hereafter are designated the KP-1 to 33 zones in ascending order. The paleovegetation and the paleoclimate corresponding to each pollen zone are respectively discussed, and the comparison of each pollen zone with the isotopic stages establishsed on the deep oceanic sediments is also attempted.

The "long term transition" of pollen assemblages through the Quaternary in Kyushu is partly different from those observed in the Kantô and Kansai areas; that is to say, in Kyushu Taxodiaceae was the dominant taxon in the pollen assemblage in the time span from the latest Pliocene to about 0.8 Ma, Pinaceae became dominant after 0.8 Ma, then Pinaceae was replaced by *Fagus* at about 0.45 Ma, and after that *Fagus* kept the status at least until the beginning of the Late Pleistocene.

Liquidambar is considered to have extirpated in the Riss/Würm interglacial period. The exclusive dominance of *Alnus* or fern spores are presumed to be caused by the destruction of the vegetation by the volcanic activity.

1. Introduction

Fossil pollen is as important as mega plant fossils for investigating paleovegetation. Although the palynological method has a fault that fossil pollen is identifiable only at the genus level in contrast to specifically identifiable mega plant fossils. Nevertheless, fossil pollen is a powerful tool for restoring the paleovegitation because it is found much more frequently in the fine sediments than mega plant fossils which are generally rather sporadic in occurrence. Accordingly, we can get rather continuous data of vegetational succession more easily by examining fossil pollen from a vertical section of a stratum than by mega plant fossils. It is generally accepted that vegetation is strongly controlled by climate, so we can restore the detail of a paleoclimatic change based on pollen fossils. Paleotemperature of oceanic surface water can be determined by $\delta\ ^{18}O$ of planktonic foraminifers from ocean sediments. In contrast with this foraminiferal method, palynological one restores paleoclimate indirectly through the medium of vegetation, and is less precise. However, the palynological method may clarify not only paleotemperature but also paleohumidity, and it does not need a large-scaled equipment to get and analyse samples. Therefore it is obviously of great use for fossil pollen to discuss and restore paleoclimate.

Manuscript received Aug. 6, 1990

The palynological study of the Pleistocene in Kyushu has only got under the way, as mentioned in the succeeding chapter. Although, several papers have reported the Pleistocene palynological record in Kyushu, none of these have dealt with palynological data through the Pleistocene time. In this paper, the auther will clarify the pollen sequence of the Pleistocene in the Kyushu district by synthesizing pollen record from some areas. And, based on them, he will also refer to paleovegetational change, and paleoclimatic sequence of the Pleistocene.

The author wishes to express his gratefull thanks to Emeritus professor Tsugio Shuto, Professor Juichi Yanagida and Professor Ken'ichi Hatanaka for helpful advice. And, he is grateful to Professor Atuso Aihara and Professor Hakuyû Okada for critical reading of the manuscript.

2. Previous Study

Palynological study in Japan has begun with JIMBO (1932). After his study, scores of papers dealt with fossil pollen have been published. Nevertheless most of papers before 1950 were confined themselves only to described the paleovegetation, and did not refer to the paleovegetational and paleoclimatic changes. In 1950's, the subject shifted and extended to chronological correlations between pollen records, chronological change of paleovegetation and paleoclimate. Among these papers, NAKAMURA (1952) was the most epoch-making to recognize a few pollen zones after the post glacial age. This study was developed and elaborated by NAKAMURA (1967, 1975a, 1975b) and TSUKADA (1963, 1967, 1974). However, palynological studies of the Pleistocene, particularly the lower and middle Pleistocene, were very rare and were not stratigraphically continuous but sporadic. Successive palynological records covering hundreds thousand years had to be awaited until 1960's. In this decade, Quaternary researches became very active throughout the country as a result of explorations of coastal plains by means of deep boring. Samples from boring cores were often submitted to the palynological investigation. Under these circumstances, TAI (1966) successed to clarify the continuous pollen curves ranging from the Late Pliocene to the Late Pleistocene by analysing many samples recovered in a boring core (OD-1) which penetrated hundreds meters of strata in Osaka city. Her study concluded that the fossil pollen sequence from the Upper Pliocene to Pleistocene is divided into 2 major pollen zones, as the *Metasequoia* and *Fagus* zones in ascending order. Her results presented the first division of the Quaternary fossil pollen sequence before the Last Glacial in Japan. NASU (1970) further subdivided her *Fagus* zone and designated it's lower part the *Fagus* zone, and it's upper part the Pinaceae zone. And he established the *Fagus-Tsuga* subzone as the transitional zone between the *Fagus* and Pinaceae zones. After the above mentioned series of researches, long term palynological studies dealt with the Late and Middle Pleistocene have become gradually popular. ÔNISHI (1978) colligated fossil pollen records from Ôita, Hokuriku, San'in, Kinki, Kantô and Niigata areas to establish 6 pollen zones on the Upper Pliocene and the Quaternary. Investigation of fossil pollen records of the Quaternary distributed in the Yokohama area led NISHIMURA (1980) to establish 10 pollen zones in the Middle and Late Pleistocene. YOSHINO, SAKAI and NISHIMURA (1980) analyzed the Middle Pleistocene to Holocene sediments recovered from core samples from Saya and Tsushima in the Nôbi coastal plain and described the pollen assemblages to correlate the strata and pollen zones.

ARIAKE BAY RESEARCH GROUP (1965) was the first who obtained a large success in palynological study of the Quaternary in Kyushu. They described the pollen records from the cores drilled in Ariake Bay and the surrounding area. TAKAHASHI, KAWASAKI and FURUKAWA (1968, 1969) developed this study and distinguished 4 pollen assemblages, A to D type pollen assemblages in descending order, in the upper Quarternary. In the Ôita area, ÔNISHI (1965) described pollen assemblages from the Sekinan and Ôita Groups. However, the study was insufficient owing to too sporadic samples with poor palynological taxa. The detailed pollen analysis of the Quaternary in Kyushu district began with HASE and HATANAKA (1984). They summarized their pollen data of the Pliocene and the Pleistocene from scattered localities in Southern Kyushu, and described the outline of the succession of pollen assemblages during the age from the Late Pliocene to Late Pleistocene. On that occasion, they recognized the following 5 pollen assemblage zones; the *Metasequoia*, *Fagus*, *Criptomeria-Sciadopitys-Alnus*, *Cryptomeria* and Pinaceae zones in ascending order. On the basis of the more detailed study on the pollen records from the Ôita and Kujû Groups in Ôita area, NOI (1985) described the pollen sequence from the Late Pliocene to the Late Pleistocene and divided it into 3 major pollen zones; Taxodiaceae, Pinaceae, and *Fagus* zones in ascending order. HATANAKA (1985) gave a full account of the pollen assemblage and paleovegetation of the age after the Last Glacial in Kyushu and Yamaguchi area by examining a huge number of pollen records from over 50 sites. In contrast to his detailed palynological study, the Pliocene and Pleistocene palynological studies by Hase and HATANAKA (1984) and NOI (1985) only presented the outlines of pollen assemblages. Recently, HASE and IWAUCHI (1985), IWAUCHI and HASE (1986, 1987) and NOI (1988) reported local but detailed data of the Pleistocene pollen records from a few sites in Kyushu. Through these studies, therefore, a foundation for the palynological researches of the Pleistocene in Kyushu gradually has got under way.

3. Methods

3-1. Material

Systematically collected samples from vertically continuous strata which chronologically span throughout the Pleistocene are indispensable for revealing the complete pollen sequence of the Pleistocene. The Uncorrelated Formation (ARIAKE BAY RESEARCH GROUP, 1965) under the bottom of Ariake Bay and the Ôita Group (SHUTO, 1953) in the Ôita city area seem to meet the condition. However, these formations contain fair amount of pollen at quite sporadic horizons. Therefore, it is very hard to clarify the pollen sequence throughout the Pleistocene by the pollen records from a single formation. In consequence, the author had to complete the Quaternary pollen sequence by combining fragmentary pollen profiles from several formations, the Uncorrected Formation (ARIAKE BAY RESEARCH GROUP, 1965) from the core samples in the Chikugo plain, the Ôita and Kujû Groups (SHUTO, 1953) in the Nyû and Tsurusaki Hills in Ôita city and some core samples, the Tôriyamahama Formation (OSTUKA, 1932) in the Miyazaki plain, and the Shika and Nojiri Formations (NOI,

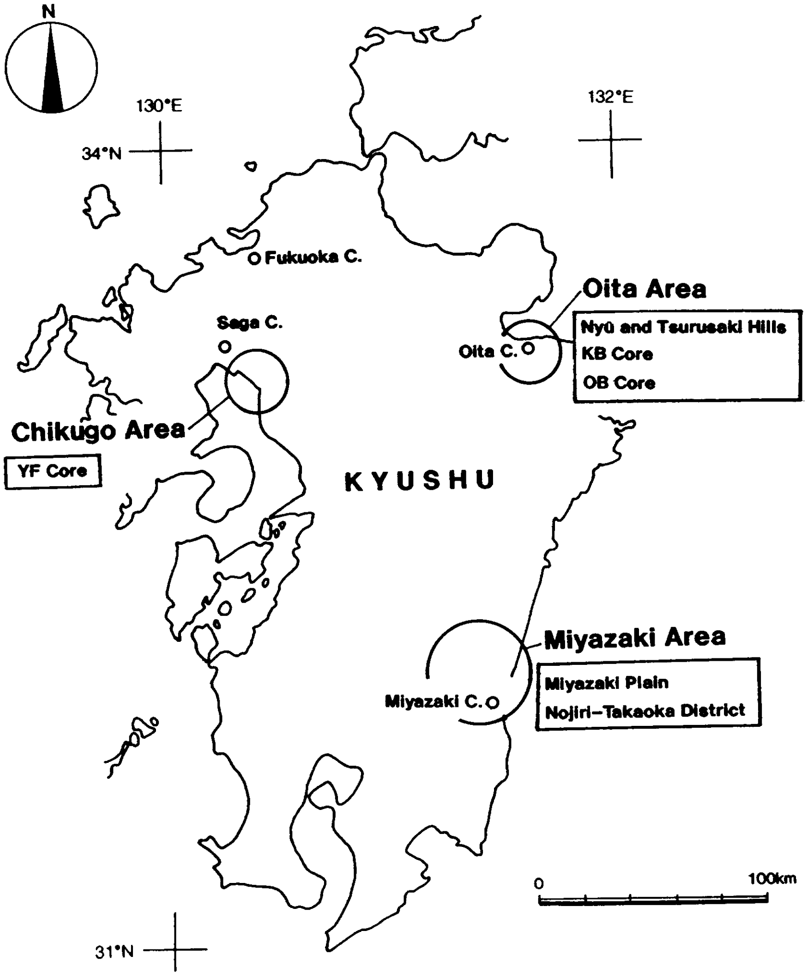


Fig. 1. Index map of the study area.

in the Nojiri-Takaoka area (Fig. 1).

3-2. Palynological Method

Pollen and spores were concentrated by the acetolysis methods (NAKAMURA, 1967) with 25% HF wash and heavy liquid (zinc halide) floatation technique showing as follows.

(1) Approximately 5 g of sediments were placed in 50-ml plastic test tube, covered with 10% KOH and boiled for 10 min. with occasional stirring.

(2) After water wash, the sediment was treated by 25% HF for several min. and washed by 10% hot HCl.

(3) The sediment was transfered into 15-ml test tube to separte minerals and pollen fractions by heavy liquid floatation technique.

(4) The pollen was acetolyzed for about 3 min.

(5) The polleniferous residue was mounted on microscopic slides for counting

using glycerine jelly.

Pollen and spores from each samples were counted to a sum of at least 600 grains. The result was shown by pollen diagrams which indicate relative frequency of arboreal taxa (AP).

3-3. Palynological Zonation

Local pollen assemblage zones were established by visual inspection of the pollen diagrams. Zone boundaries were placed at the points where the pollen profiles abruptly and prominently shift. Therefore, the profile of one pollen zone is unique and is practically distinguishable from zones above and below.

There exist many questions concerning the reconstruction of a paleovegetation on the basis of pollen assemblages. Pollen produced in plants are scattered and transported by wind and water before deposition. The process of this transportation is subtly different among genera according to mode of scattering and the form of the pollen. For instance, pollen from anemophirous flowers is believed to be scattered in relatively long distance, and that from entomophilous flowers to drop around the plants. Fern spores and pollen which have air sacks just like *Pinus* pollen are generally considered to be more easily transported than that of herbs. NAKAMURA, KURODA and MITSUSHIO (1974) clarified some difference of pollen spectra of samples from various depositional environments. That is to say, nonarboreal pollen is very few in the sediments of open sea and fern spores are more abundantly estimated than in the bay and river sediments. Whereas, pollen spectra from downstream and bay sediments show almost the same tendency to each other, while nonarboreal pollen are scarce in the middle and upstream sediments. And, the difference in the pollen frequency of each taxa observed the in river and bay sediments based on arboreal pollen is only a few percent. Therefore, the pollen assemblages from strata deposited in bay and river are considered to fairly represent the vegetation of the surrounding area. The strata studied in this work are those deposited in bay, lake and fluvial environments. Consequently, pollen zones recognized in those strata are regarded to represent stages of natural vegetational change.

3-4. Correlation of Pollen Zones

Local pollen zones established at every local column of limited duration are correlated to restore a continuous pollen sequence throughout the Pleistocene. Before going into correlation, many factors should be put into consideration such as productivity, scattering, and taphonomy of pollen to know to what degree a pollen assemblage reflects the actual vegetation (NASU, 1970; SOMA, 1976). However, the pollen assemblage of the bay and river sediments mainly reflects the vegetation of the catchment area and other exotic pollen is few as noted above. Consequently, it is possible to correlate the pollen zones by the pollen profiles when local elements are removed.

In the Late and Middle Pleistocene dealt in this paper, particularly in the Middle Pleistocene, many climatic cycles were recognized (SHAKLETON and OPDYKE, 1976). In other words, the resembling climate should repeatedly prevailed and it is easely considered that the similar paleovegetation might have occurred in West Japan. Accordingly, the author attempted not only to simply correlate pollen zones on the basis of resembling pollen profiles but also to compare the pollen records of the zones above and below the zone concerned. Stratigraphy, and isotopic ages are also taken into consideration.

By correlating the local pollen zones, the relatively continuous pollen sequence from the latest Early to the early Late Pleistocene was synthesized. And then, pollen zones were established and paleovegetation and the paleoclimate based on them were also discussed.

4. Results

4-1. YF Core Samples from the Chikugo Plain

The subsurface Quaternary strata in the Chikugo and Shiroishi plains and the bottom of Ariake Bay (Fig. 2) are very thick. These Quaternary sequence confirmed by core boring exceeds 330 m in thickness in the Shiroishi plain which the ARIAKE BAY RESEARCH GROUP (1965) selected as the type area of the Quaternary stratigraphy of West Japan. From their study, the alluvial deposits in the area are divided into the lower unit, the Shimabara-kaiwan Formation, and the upper one, the Ariake Clay Formation. Below the Shimabara-kaiwan Formation lies the Aso-4. And, the sediments below the Aso-4 were still undivided. Recently, SUGITANI (1983) recognized the PS bed between the Shimabara-kaiwan Formation and the Aso-4, and the DSb, DSa, DC and DG beds below the Aso-4 based on many boring data from the Chikugo and Shiroishi plains. However, the strata below the DG bed are still undivided (Table 1).

4-1-1. Geological Setting and Samples

In the Chikugo plain, the samples analyzed in this paper were collected from a core (YF core) drilled at Nishi-jûrokuchô in Yanagawa city (Fig. 2). The bottom of this bore hole reached 300 m. The sediments above and below GL 269 m are respectively unconsolidated and consolidated. These lithic character may suggest that this horizon is the boundary between the Quaternary and the Tertiary. Therefore this

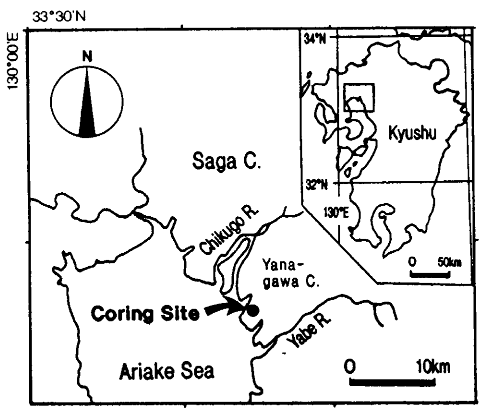


Fig. 2. Index map of the Chikugo area. The arrow shows the coring site of the YF core.

Table 1. Correlation of the subsurface Quaternary deposits in the Chikugo area.

Ariake Bay Res. Group (1965)	Fukuta (1966)	Sugitani (1983)
Ariake Clay Fm.	A1, A2 Ariake clay Fm.	F, UC, US, MC Ariake clay Fm.
Shimabara Kaiwan Fm.	B Shimabara Kaiwan Fm.	SUG, SM, SLG Shimabara kaiwan Fm.
	C1	PS river terrace deps.
Yame Clay	C2 Yame clay	Aso-4
		DSb river bed deps.
not correlated		DSa river terrace deps.
	D1	DC Last-interglacial transgression deps.
	D2	DG base gravel
	E1-E8	not correlated
	F1-F2	

Quaternary is one of the thickest and continuous Quaternary sediments in Kyushu, and is very important for investigating the pollen sequence and paleovegetational and paleoclimatic change in Quaternary age. The Quaternary strata recorded in YF core are divided into the Ariake Clay Formation (0~7.0 m), Shimabara-kaiwan Formation (7.0~9.7 m), PS Bed (9.7~12.0 m), Aso-4 (12.0~15.9 m), DC Bed (15.9~17.6 m), DG Bed (17.6~46.5 m) and Uncorrelated Formation (46.5~269 m) in descending order. The Ariake Clay Formation, which represents the Middle and Upper Alluvium (ISEKI, 1983) is mainly composed of unconsolidated, dark-gray silty clay accompanied by many shells. The Shimabara-kaiwan Formation represents the lower unit and the basal gravel of the Alluvium (ISEKI, 1983), and mainly consists of light brown, coarse grained sands with silts, and sands with gravel. The PS Bed consists of dark brown coarse grained sands. Aso-4 consists of light brown pyroclastic flow deposits containing many pumice and contains a large quantity of clastics at the top. The DC Bed deposited in the last interglacial and consists of consolidated clay which often yields many shells. The DG Bed is the basal gravel of the DC Bed and mainly consists of brown coarse grained sand with gravel. The Uncorrelated Formation consists of alternative beds of sandy clay and sand.

About 60 samples are collected from the YF core and palynologically analyzed.

4-1-2. Pollen Analysis

Pollen sequence recorded in the YF core is divided into 14 pollen assemblage zones (Fig. 3) Lower 11 zones are discriminated in the Uncorrelated Formation and

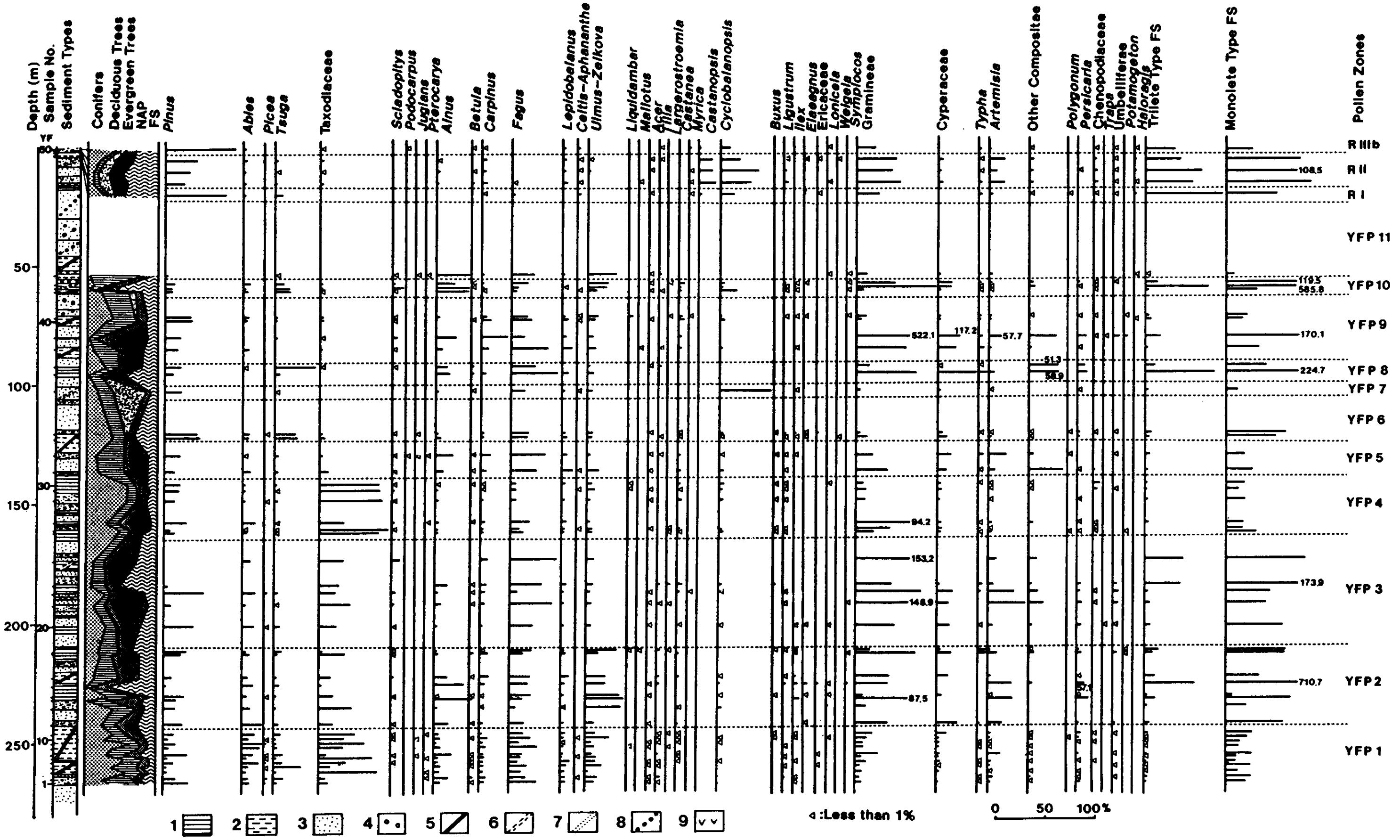


Fig. 3. Pollen diagram of the samples from the YF core. 1: Mud, 2: Silt, 3: Sand, 4: Gravel, 5: With mud, 6: With silt, 7: With sand, 8: With gravel, 9: Ash.

designated YFP-1~11 zones in ascending order. Upper 3 zones are recognized in the Ariake Clay Formation. These are respectively correlated with the pollen zones after the post glacial in Japan, such as RI, RII, and RIIIb zones in ascending order. The character of these pollen zones is described below, excepting the upper 3 zones after the post glacial.

YFP-1 Zone (Sample No. YF 1~11): YFP-1 zone is characterized by dominance of conifer and deciduous taxa. Taxodiaceae appears in relatively higher percentage throughout, but is fluctuating between 10 and 60%. Other important conifers, *Pinus* and *Abies* appear with frequency of about 10%, and *Picea* is consistently present but in low frequency. *Fagus* also shows high frequency, and *Ulmus-Zelkova* and *Alnus* occur at some 10%. Nonarboreal pollen mainly consists of Gramineae with 10 to 30% in frequency. Fern spores are mainly composed of the Monolete type spore at the percentage between 15 and 20%, and the Trilete type spore at low percentages.

YFP-2 Zone (Sample No. YF 12~19): The dominance of conifer and deciduous tree pollen characterizes this zone, and the characteristics are the same as those of the YFP-1 zone. However, Taxodiaceae is less dominant than in the YFP-1 zone, and shows 30% even at the highest value. *Picea* is poorly presented. *Ulmus-Zelkova* increases up to some 30%, and becomes a main component of deciduous trees. Gramineae is the most important taxon among nonarboreal pollen, and fluctuates in frequency between 10 and 88%. Besides Gramineae, Cyperaceae and *Artemisia* are presented at relatively higher percentages. The amount of monolete type fern spores is high and reaches 710% at YF 16. Trilete type fern spores occur with frequency of some 10% and often reaches 50%.

YFP-3 Zone (Sample No. YF 20~24): Conifers dominated by *Pinus*, *Abies*, Taxodiaceae and deciduous taxa represented by *Fagus* characterize this zone. Taxodiaceae, *Pinus*, and *Abies* have almost the same tendency as is seen in the overlying zone. *Ulmus-Zelkova* declines drastically to a few percent, while *Fagus* increases up to the maximum value of 46%. Nonarboreal pollen is dominated by Gramineae, which often shifts up to 150%. Other important nonarboreal taxa are Cyperaceae, *Artemisia*, and Other Compositae. Fern spores mainly consist of Monolete type, which appear at the frequency of some 30% in the upper part of this zone.

YFP-4 Zone (Sample No. YF 25~30): Taxodiaceae characterizes this zone with its high frequency of about 60%. Except for *Pinus* (nearly 10%) and *Abies* (a few percents), conifers are poorly discriminated. *Cyclobalanopsis* is persistent throughout the zone at a frequency of few percent. Although Gramineae shows high frequency, other herbs occur at low percentage or sometimes they are completely absent. While fern spores are characterized by monolete type spores in frequency of about 20%, those of trilete type are scarce.

YFP-5 Zone (Sample No. YF 31~32): In this zone, Taxodiaceae drastically decreases to about 10%. Dedicuous taxa, on the other hand, such as *Fagus*, *Carpinus*, and *Alnus* become prominent and characterize this zone. Particularly, *Fagus* is as high as 40%. Conifers are low in percentages except for *Pinus* and Taxodiaceae, both of which appear at about 10%. Herbs are dominated by Gramineae, Cyperaceae, *Artemisia*, and other Compositae and their frequency reach 40% altogether. Fern spores are mainly composed of Monolete type spores with frequency of 20 to 40%.

YFP-6 Zone (Sample No. YF 33~34): Conifer and deciduous taxa are mixed again in this zone. Conifers are dominated by *Pinus* with up to 40%, and *Tsuga* at frequency of about 20%, and accompanied by *Abies* and Taxodiaceae. Main components of deciduous taxa are *Fagus*, *Ulmus-Zelkova* and *Lepidobalanus*. Other than Gramineae and Cyperaceae, which reveal at about 10%, herbs are poorly represented. Fern spores are mainly composed of Monolete type with frequency of some 50%.
YFP-7 Zone (Sample No. YF 35): This zone is represented only by a horizon of YF 35, and is characterized by dominance of *Cyclobalanopsis* with frequency of 50%. Other important arboreal taxa are *Pinus* and *Fagus*, respectively at about 10%, and *Ulmus-Zelkova* at a few percent. The amount of herbs is very small, while Gramineae, Cyperaceae and Chenopodiaceae have very scarce value. Fern spores are also low in amount.
YFP-8 Zone (Sample No. YF 36~37): Ever green taxa become absent and conifer and deciduous taxa appear again in mixture. Among conifers, *Pinus* and *Tsuga* are dominant. The former shows some 10% in frequency, while the latter increases in the upper part of this zone reaching 40% at most. *Fagus* is the main component of deciduous trees with frequency between 20 and 50%. Such deciduous genera as *Alnus*, *Ulmus-Zelkova*, and *Carpinus* are also important. Herbs are composed mainly of Gramineae, Cyperaceae, Other Compositae, and *Persicaria*. Among them, Other Compositae is especially prominent and reaches over 50%. Both Monolete and Trilete type fern spores are fairly well represented. Particularly, monolete type spores reach 224% at the horizon of YF 37.
YFP-9 Zone (Sample No. YF 38~41): In this zone *Tsuga* decreases to a few percent, and is concomitant with a slight increase of *Abies* to some 10%. *Pinus* is consistently present with frequency between 10 and 30%. Deciduous trees are dominated by *Fagus* with frequency between 10 and 40%. Other important deciduous taxa are such as *Carpinus Lepidobalanus*, and *Ulmus-Zelkova*. *Liquidambar* is seldom detected by a few percents. Herbs are composed of Gramineae and Cyperaceae with high frequency in the lower part of this zone, while, becoming lower in the upper part. Fern spores are mainly composed of Monolete type.
YFP-10 Zone (Sample No. YF 42~44): Conifer, deciduous, and evergreen taxa are mixed. *Tsuga* increases again to some 10%, and *Pinus* and *Abies* consistently appear at a few percent. *Sciadopitys* is variable but relatively high in frequency. Deciduous trees mainly consist of *Alnus*, *Fagus* and *Ulmus-Zelkova*. Among evergreen trees, *Cyclobalanopsis* increases to reach 20% at the horizon YF 42. Herbs are characterized by Gramineae and Cyperaceae. Monolete type spores show high percent, such as over 100% in the upper part of this zone.
YFP-11 Zone (Sample No. YF 45): This zone is characterized by dominance of deciduous taxa. Conifers drastically decrease to be scarce, and evergreen taxa become absent. Deciduous taxa are mainly composed of *Alnus*, *Fagus* and *Ulmus-Zelkova* with frequency between 20 and 40%, respectively. Other deciduous taxa are very few. Other than Gramineae of about 10%, herbs are also scarce. Amount of fern spores is smaller than that of other pollen zones of this site. Monolete type spores are recognizable in a few percent and these of Trilete type are less than 1%.

4-2. Ôita Area

The Tertiary and Quaternary strata are widely distributed around Ôita City, which has been regarded as one of the standard areas of the Late Cenozoic stratigraphy in West Japan. The standard stratigraphy of the Tertiary and Quaternary of this area was established by SHUTO (1953a, b, 1962, 1970) and SHUTO *et al.* (1966, 1971) and he designated them the Sekinan, Ôita, and Kujû Groups. OKAGUCHI (1976) partly emended the stratigraphy in her reexamination. On that occasion she dated some intercalated pyroclastic flow deposts by fission track dating method. Fortunately, the Quaternary sediments of the Nyû and Tsurusaki hills (Fig. 4) shows a nearly complete succession ranging from the Early to Late Pleiocene (Table 2, Fig. 6). Therefore, it is easily considered that the Quaternary sediments provide a very suitable basis for revealing the successive change of pollen assemblages through Quaternary age. The author analyzed the systematically collected samples from the Quaternary of the Nyû and Tsurusaki hills (Fig. 5), the KB core drilled at Furugô (Fig. 5), and the OB core at the mouth of the Ôno River in Ôita

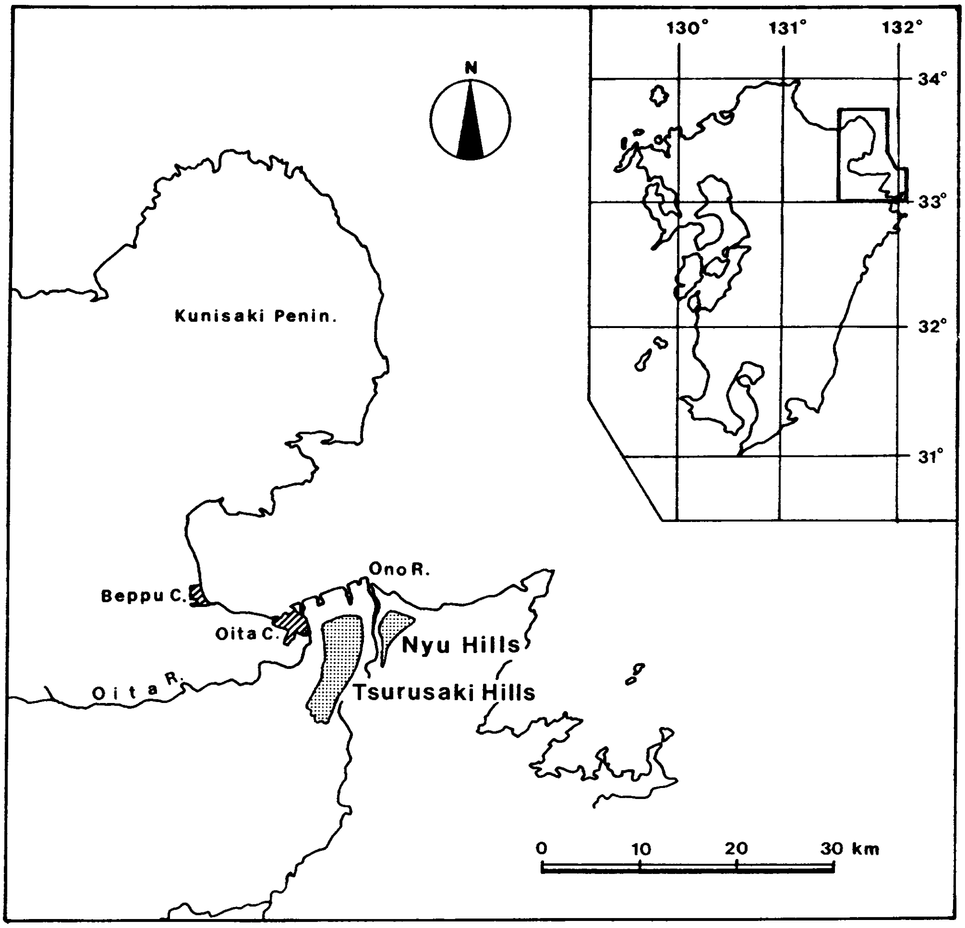


Fig. 4. Index map of the Nyû and Tsurusaki Hills.

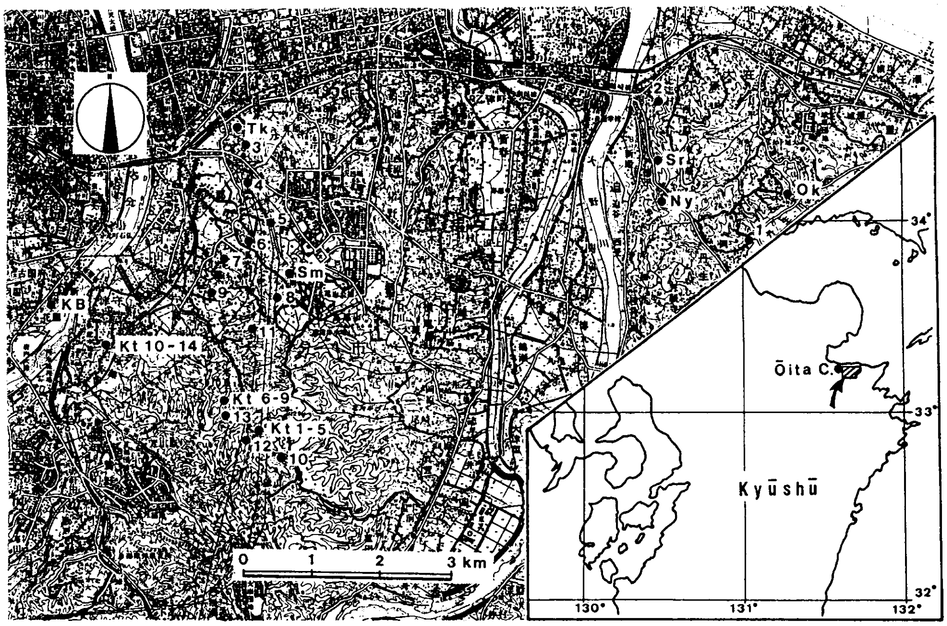


Fig. 5. Index map of the columnar sections of the Nyû and Tsurusaki Hills shown in the Fig. 6. KB indicates the coring site of the KB core.

city (Fig. 7).

4-2-1. Geological Setting and Samples

4-2-1-1. Nyû and Tsurusaki Hills

The Quaternary strata on the Nyû and Tsurusaki hills are divided into two units, the lower, the Plio-Pleistocene Ôita Group, and the upper, the Middle and Late Pleistocene Kujû Group. Pollen samples are collected from the Katashima sands and gravel, Shimogori alternation, and Takajo alternation of the Ôita Group, and the Shimura sand and gravel, and the Nyû and Oka muds of the Kujû Group. Their horizons are shown in Fig. 6. Lithology of strata which include the collected samples of pollen are briefly described below.

Ôita Group

Takio Formation

The Takio Formation is subdivided into the Katashima sands and gravel, Hada pyroclastic rocks, and Shimogori alternation in ascending order.

The Katashima sands and gravel: This member consists of three units, the lower basal gravel bed mainly composed of cobbles, the middle tuffaceous sands characterized by sands with hornblede, biotite and pumice, and the upper sands and gravel comprising interbedded pumiceous sands and silts. A bed of pyroclastic flow deposits, hereafter designated with abbreviation Kpfl, is extensively distributed in this area at about 20 m below the top of this member. Pollen samples are collected at Mera (Kt 1~9) and Magari (Kt 10~14).

Shimogori alternation: This member is mainly composed of interbedded black coarse

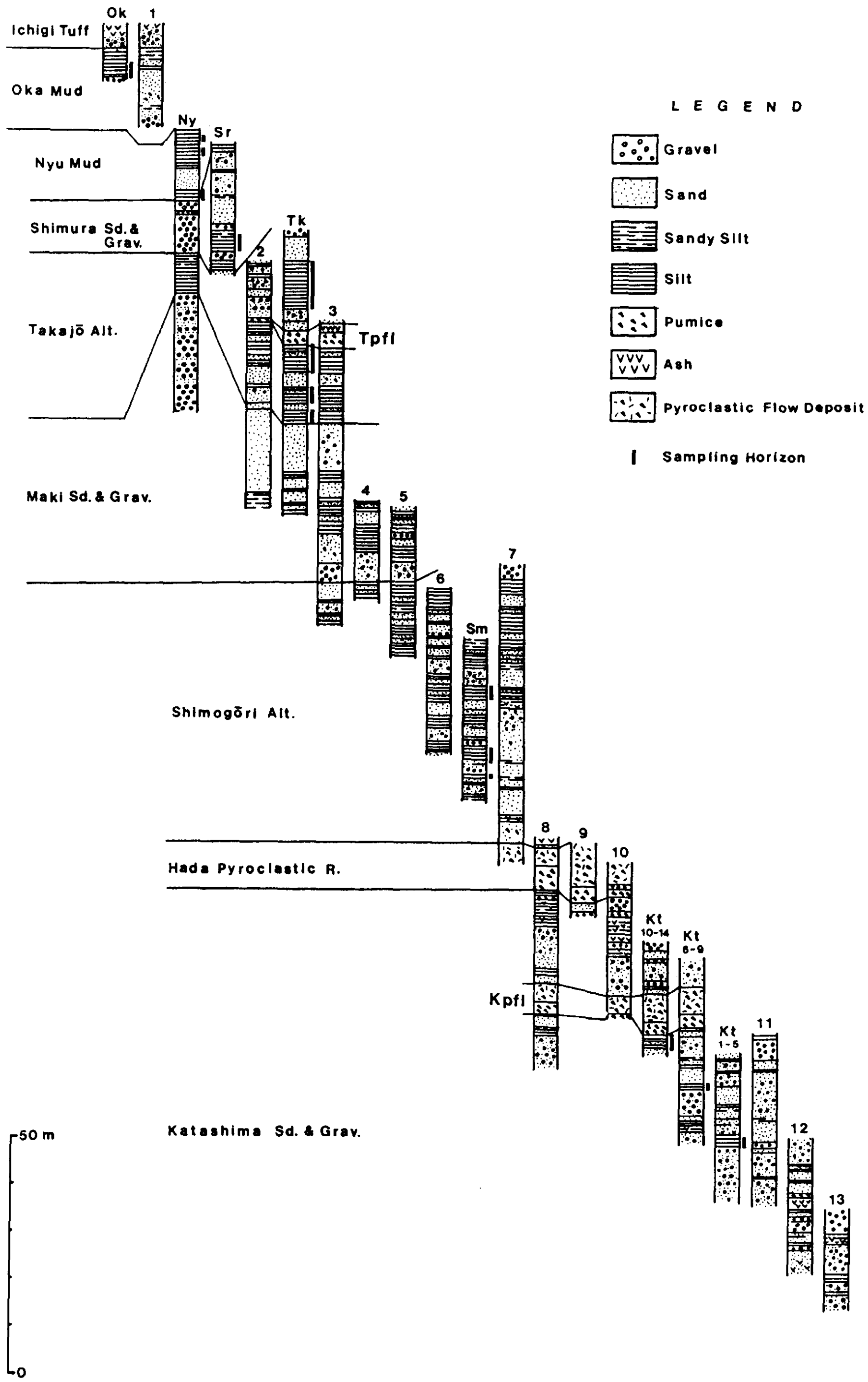


Fig. 6. Columnar sections of the Quaternary deposits in they Nyû and Tsurusaki Hills.

Table 2. Quaternary stratigraphy of the Nyû and Tsurusaki Hills; after SHUTO *et al.* (1966) and OKAGUCHI(1976).

AGE		STRATIGRAPHY Shuto et al. (1966) and Okaguchi (1976)		
PLEISTOCENE	Late	Kuju Group	Jobaru F.	Ichigi Tuff
PLEISTOCENE	Late	Kuju Group	Jobaru F.	Oka Mud*
PLEISTOCENE	Middle	Kuju Group		Kobarudai Sd. & Grav.
PLEISTOCENE	Middle	Kuju Group	Ozai F.	Nyu Mud*
PLEISTOCENE	Middle	Kuju Group	Ozai F.	Shimura * Sd. & Grav.
PLEISTOCENE	Middle	Oita Group	Tsurusaki F.	Takajo Alt.*
PLEISTOCENE	Middle	Oita Group	Tsurusaki F.	Maki Sd. & Grav.
PLEISTOCENE	Early	Oita Group	Takio F.	Shimogori Alt.*
PLEISTOCENE	Early	Oita Group	Takio F.	Hada Pyroclastic R.
PLEISTOCENE	Early	Oita Group	Takio F.	Katashima * Sd. & Grav.
PLIO-CENE		Sekinan Group		

grained sands and gravel, and has cross laminations of large scale. Bluish gray silt beds which are considered to be marine in origin are intercalated. Pollen samples are collected at Hase (Sm).

Tsurusaki Formation

This formation conformably overlies the Takio Formation for the most part, but partially they are unconformable with each other. The Tsurusaki Formation is divided into two members, the lower, the Maki sands and gravel, and the upper, the Takajô alternation. Pollen records are obtained only from the Takajô alternation.

Takajô alternation: This member mainly consists of alternating beds of pumiceous sands and silts with frequent intercalation of sands and gravel, and involves marine silts beds in the upper part. Pollen samples are collected at Kano (Tk).

Kujû Group

Ôzai Formation

The Ôzai Formation is divided into two members, the lower, the Shimura sands and gravel, and the upper, the Nyû mud. Pollen records are obtained from both of them.

The Shimura sands and gravel: This member first begins with sands and gravel intercalated with sandy silts, gradually becomes to irregularly alternating beds of sands and gravel in the middle, and is characterized by alternating beds of granules to pebbles and silty sands in the upper. Pollen samples are collected at Higashiuebaru (Sr).

Nyû mud: This member comprises tuffaceous silty sands, bluish gray silts with shells, and pebbly sands. Pollen samples are collected at Higashiuebaru (Ny).

Jôbaru Formation

This formation constructs the middle terrace and is divided into the Oka mud and the Ichigi tuff which is correlated with Aso-4. Pollen records are available only from the Oka mud.

Oka mud: This member begins with gravel beds of pebbles and cobbles, and mainly consists of pebbly tuffaceous silts and pumiceous sands. This member fills some buried valleys with bluish gray silts of marine origin. Pollen samples are collected at Ichigi (Ok).

4-2-1-2. KB Core

Some samples of the subsurface Quaternary were obtained by a core boring drilled more than 600 m at Furugô (Kb) (Fig. 5). The performance of the boring is not satisfactory but samples were collected from the fragmental core between GL 0 and 280 m, below which they represented only by slime.

A bed of pyroclastic flow deposit between the depth of 30 and 45 m must serve as a key for establishing stratigraphy of this core samples. Kpfl observed in the Katashima sands and gravel in the Tsurusaki hills is traceable westwards as far as Magari, where it becomes weekly welded with thickness of about 10 m (Fig. 6). Kpfl decreases its topographical altitude westwards and sinks under the alluvial plain. Under these situation, the pyroclastic flow deposit observed between 30 and 45 m in the KB core is naturally correlated with Kpfl. Above this pyroclastic flow deposits, any other assigned to the Hada pyroclastic rocks is not present in the KB core. Moreover, the sample KB 17 in the KB core is clearly indicates the Pleistocene in age from its lithology. Therefore, core sediments below the depth of KB 17 are correlated with the strata below the Hada pyroclastic rock. The lower part of the Katashima sands and gravel is characterized by gravel to gravelly sands around the coring site. This leads to an expectation that the Katashima sands and gravel, within the KB core, are correlative with core sediments over the depth of the gravel beds at 190 m, and

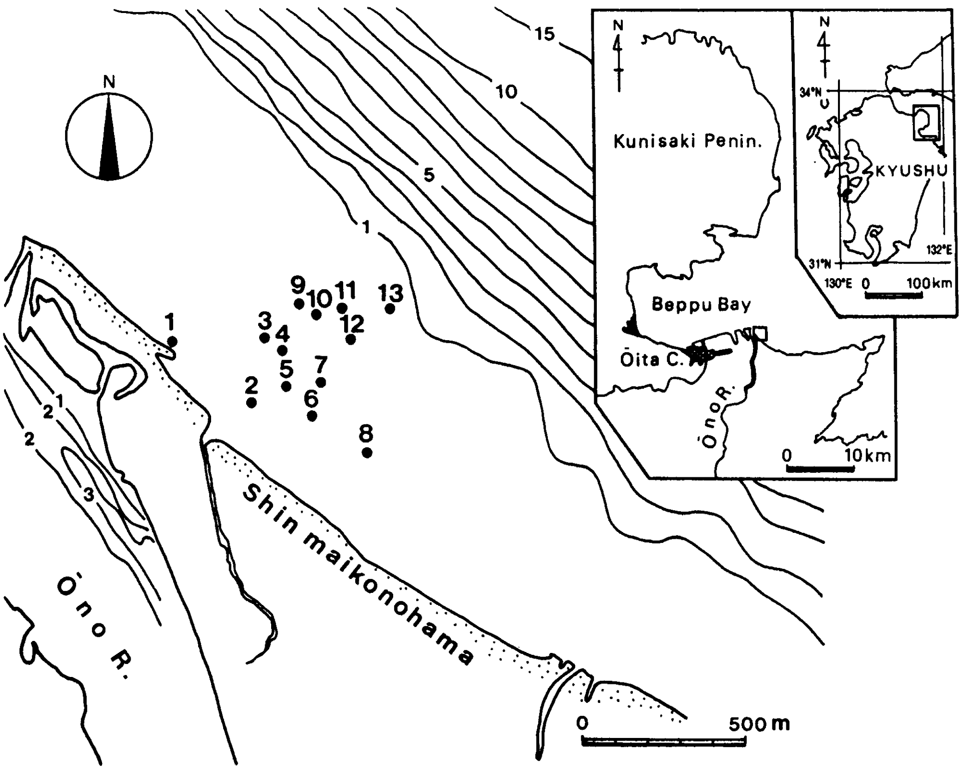


Fig. 7. Index map of the coring site in the area near the mouth of the Ôno river. Core No. 1 is designated OB core for convenience.

strata below the depth are carrelated with the Sekinan Group. Seventeen samples from the core are palynologically analyzed.

4-2-1-3. OB Core

A dozen of all-core borings were carried out in the reclaimed land at the mouth of the Ôno River (Fig. 7). The longest core attains to over 220 m. The sub-surface geology of this area was investigated based on these core samples, and some samples were selected for palynological analysis.

The Quaternary under the mouth of the Ôno River is divided into 5 formations which are designated hereafter with abbreviation ON-I to ON-V Formations, respectively, in ascending order (Fig. 8). The characteristics of them are briefly described below.

ON-I Formation: This formation, over 105 m's thick, is composed of regularly alternating beds of sands with volvanic material and silts to sandy silts. This formation occasionally intercalates gravel beds, and comprises sea shells. The sediment is relatively consolidated with N values of over 50 in average. The carbon-14 age of wood from the depth of 128.5 m shows over 40,000 y.B.P.

ON-II Formation: This formation, about 40 m in thickness, mainly consists of sands and gravel with lenses of silts and sands of 3~7 m's thick. Gravel is mainly composed of andesites and schists. N values are all shown by more than over 50.

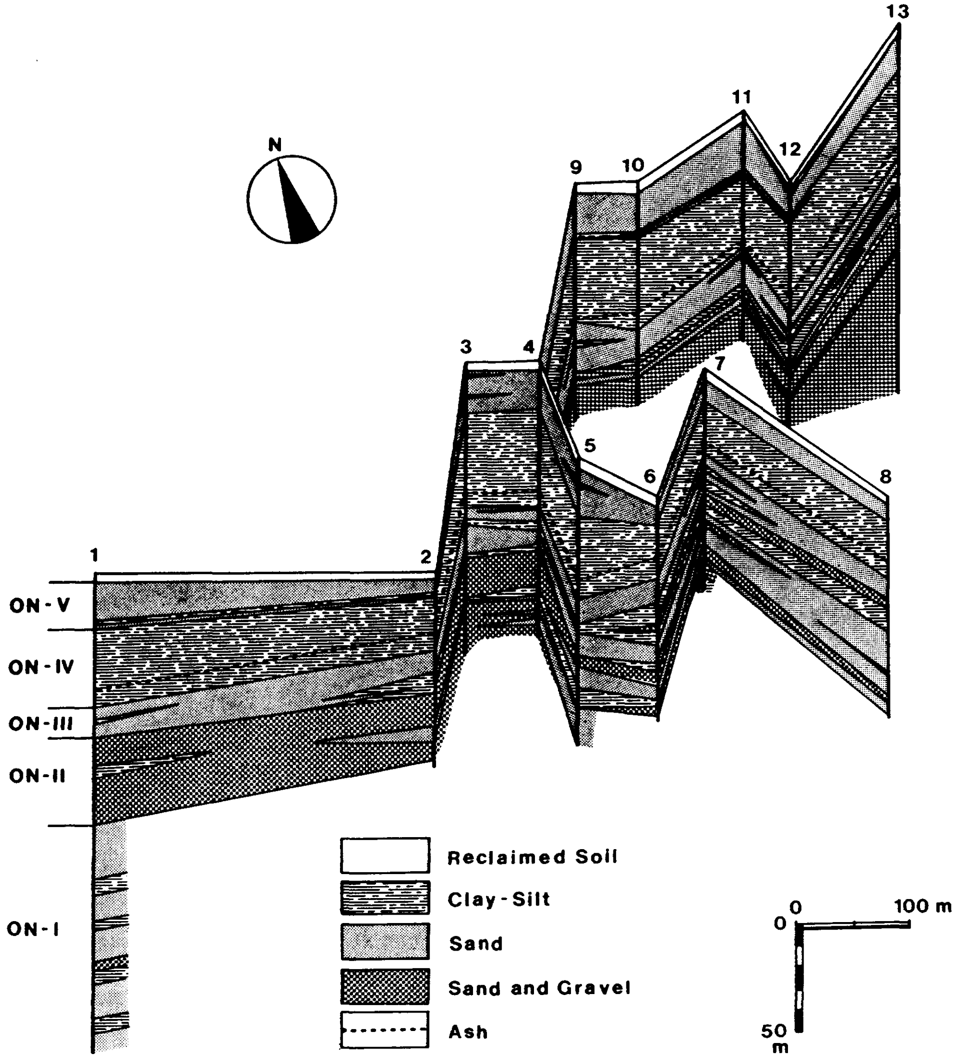


Fig. 8. Panel diagram of the subsurface Quaternary deposits near the mouth of the Ôno river. The coring sites are shown in the Fig. 7.

ON-III Formation: This formation is mainly composed of medium to fine grained sands with occasional lenses of sandy silts, and has a thickness of about 15 m. N values range between 20 and 40.

ON-IV Formation: This formation comprises bluish gray sandy silts and clays with sea shells, and is as thick as 30 m. This formation contains a glassy ash layer of about 10 m's in thick in the lower part, which is correlated with Akahoya (Ah). N value is about 10. The carbon-14 age of wood from the depth of −39.0 m indicates 4,920±140 y.B.P. (evaluated by TELEDYNE ISOTOPES).

ON-V Formation: This formation is estimated to be 25 m in thickness, and mainly consists of medium to fine grained sands with occasional intercalation of silt beds with sea shells in the lower part. This formation sometimes grades into the ON-IV

Formation. N value ranges between 10 and 30, but occasionally declines below 10. A wood fragment from the depth of −23.0 m has been dated as 4,070±120 y.B.P. by carbon-14 method (evaluated by TELEDYNE ISOTOPES).

Pollen samples are obtained at about 5 m intervals from the core No. 1 (OB Core).

4-2-2. Pollen Analysis

4-2-2-1. Nyû and Tsurusaki Hills

Based on pollen records from the Quaternary in the Nyû and Tsurusaki hills, 13 pollen zones are discriminated. Among them, 4 zones (Kt-I~IV) are recognized within the Katashima sands and gravel (Fig. 9), 2 (Sm-I~II) within the Shimogôri alternation (Fig. 10), 4 (Tk-I~IV) within the Takajô alternation (Fig. 11, 12), and 1 zone respectively each within the Shimura sands and gravel (Sr) (Fig. 13), the Nyû mud (Ny) (Fig. 14) and the Oka mud (Ok) (Fig. 15).

Kt I Zone (Sample No. Kt 1~5): Dominance of *Pinus*, *Abies* and *Picea* characterizes this zone. Deciduous taxa are generally very low in frequency except for *Alnus*. Evergreen taxa are absent. Gramineae and Cyperaceae reveal in high frequency. On the other hand, *Artemisia* and Other Compositae are consistently present but in low frequency.

Kt II Zone (Sample No. Kt 6~8): In this zone *Pinus*, *Abies* and *Picea* decrease in frequency. Deciduous taxa such as *Alnus*, *Ulmus-Zelkova*, *Fagus* and *Carpinus* increase and mix with conifers. Among herbs, Gramineae and Cyperaceae are still prominent and *Artermisia* and Other Compositae are also still consistently present.

Kt III Zone (Sample No. Kt 9~12): *Abies* and *Picea* continuously decrease in this zone to appear sporadically. On the contrary, though strongly fluctuate, are generally present in high percentage. Gramineae is still abundant, while Cyperaceae decreases and *Artemisia* and Other Compositae slightly increase.

Kt IV Zone (Sample No. Kt 13~14): Conifers decrease below 1% except for *Pinus*, which maintains in a few percent. Deciduous taxa such as *Alnus*, *Ulmus-Zelkova*, *Carpinus*, and *Fagus* become dominant, and characterize this zone. Herbs are mainly composed of Gramineae, and subsequently of Cyperaceae and *Artemisia*.

Sm I Zone (Sample No. Sm 1~2): *Pinus* becomes very prominent with over 90%

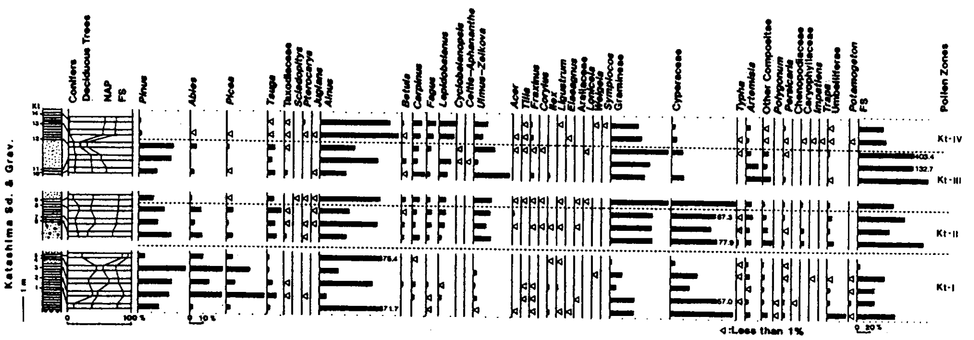


Fig. 9. Pollen diagram of the Katashima sand and gravel Member in Nyû and Tsurusaki Hills. The samples are collected from the site Kt 1~5, Kt 6~9 (Mera), and Kt 10~14 (Takio) shown in the Fig. 5.

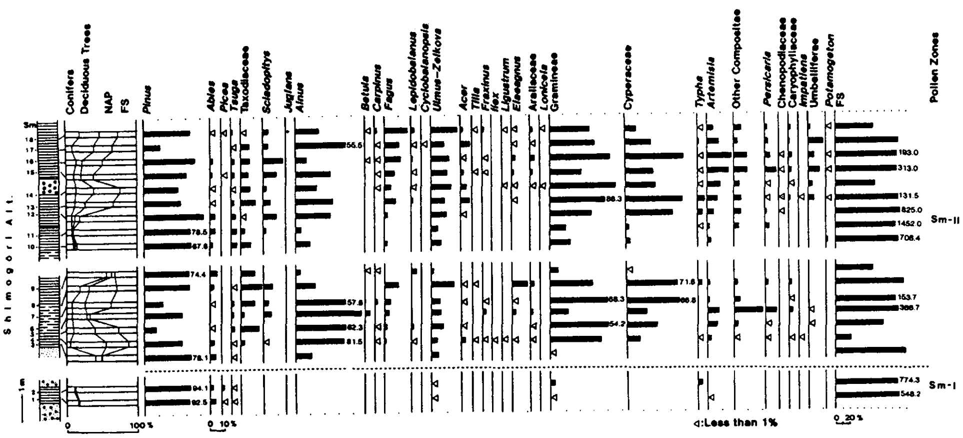


Fig. 10. Pollen diagram of the Shimogôri alternation Member. The samples are collected from the site Sm (Akeno) shown in the Fig. 5.

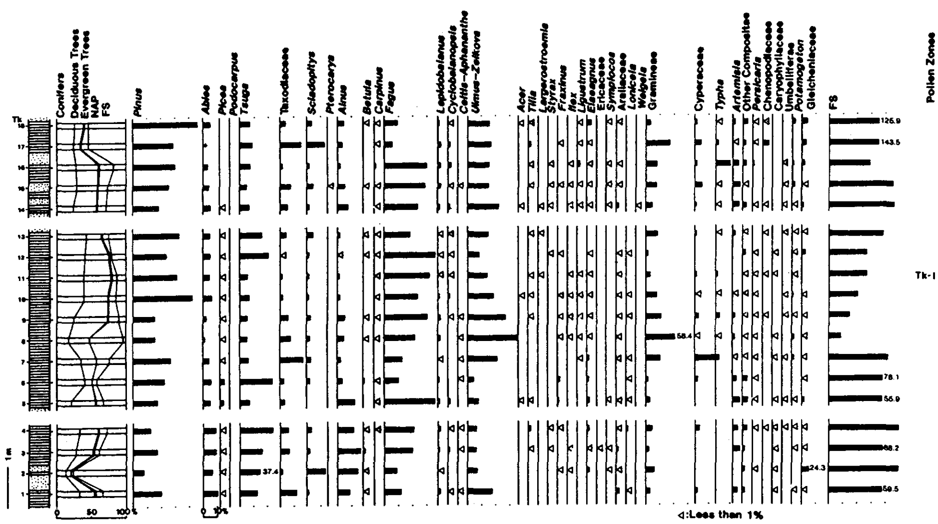


Fig. 11. Pollen diagram of the lower part of the Takajô alternation Member. The samples are collected from the site Tk (Takajô) shown in the Fig. 5.

among the AP. *Abies*, *Picea*, Gramineae and *Typha* present but are very small in amount.

Sm II Zone (Sample No. Sm 3~16): Both conifer and deciduous taxa are dominant in this zone. Conifers are mainly composed of *Pinus*, *Cryptomeria* and *Sciadopitys*, and deciduous taxa consist of *Alnus*, *Ulmus-Zelkova* and *Fagus*. Herbs comprise Gramineae and Cyperaceae as the main elements, but the taxonomic diversity is also remarkable in several minor taxa.

Tk I Zone (Sample No. Tk 1~18): This zone is also characterized by mixing of conifers and deciduous taxa. Conifers chiefly comprise *Pinus*, *Cryptomeria*, *Tsuga* and *Abies*. Deciduous taxa are characterized by *Fagus* and *Ulmus-Zelkova*.

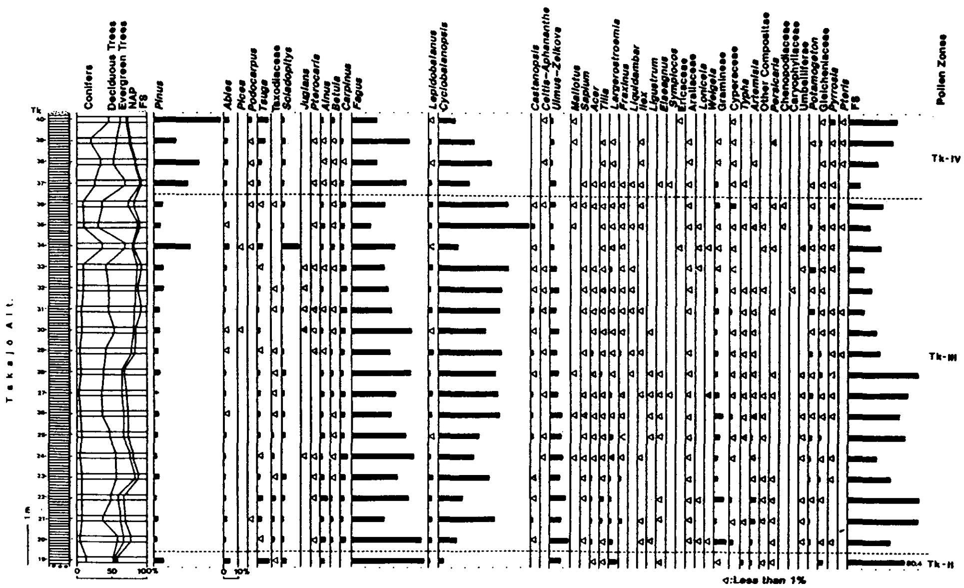


Fig. 12. Pollen diagram of the upper part of the Takajô alternation Member. The samples are collected from the site Tk (Takajô) shown in the Fig. 5.

Cryptomeria shows two cycles of fluctuation between 20% and less than 1%. Evergreen taxa including *Cyclobalanopsis* are very scarce. Among herbs, Gramineae and Cyperaceae range between a few percent and 20%, and *Typha*, *Atremisia* and Other Compositae appear in the lesser amounts.

Tk II Zone (Sample No. Tk 19): This zone is only recognized in one horizon. High frequency of *Fagus*, about 50%, characterizes this zone. Small amount of conifers and evergreen taxa are associated with *Fagus*. Herbs are small in amount except for a few percent of *Typha*.

Tk III Zone (Sample No. Tk 20~36): *Cyclobalanopsis* sharply increases in frequency and mixes with *Fagus*. This is the characteristic feature of this zone. Another important deciduous taxon is *Ulmus-Zelkova* of about 10%. Conifers are generally scarce, while *Pinus* abruptly increases at the horizon of Tk-34. Herbs are also negligible, although Gramineae is present at a few percentage. Fern spores consistently contain the warmer elements such as *Pyrosia* and *Greichenia*.

Tk IV Zone (Sample No. Tk 37~40): *Cyclobalanopsis* which is dominant in the underlying zone slightly decreases, and conifers such as *Pinus* and *Tsuga* increase in frequency to characterize this zone. Conifers have an increasing trend of frequency from the bottom to the top of this zone. Herbs are very small in amount.

Sr Zone (Sample No. Sr 1~8): Deciduous taxa such as *Fagus*, *Lepidobalanus* and *Ulmus-Zelkova* reach over 50% and they characterize this zone. Each taxon of conifers shows less than a few percent. An evergreen taxon, *Cyclobalanopsis* consistently presents but is low in frequency. Herbs are also low, while Gramineae abruptly increases at the horizon of Sr. 9.

Ny Zone (Sample No. Ny 1~18): Deciduous taxa composed of *Fagus*, *Ulmus-Zelkova* and *Carpinus* characterize this zone. Other than a few percent of *Pinus*, Conisfers

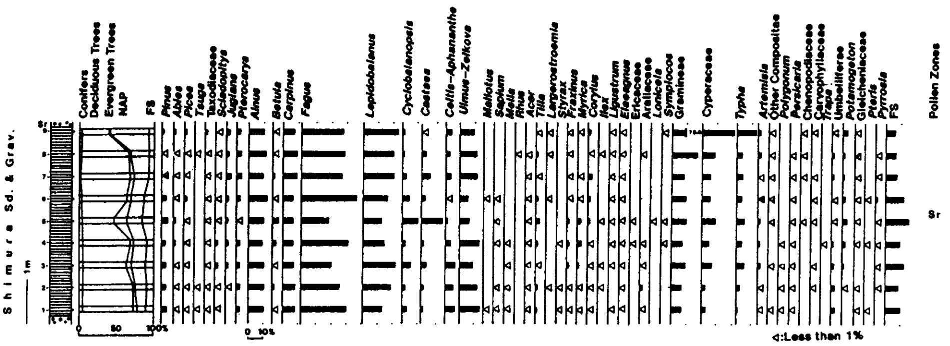


Fig. 13. Pollen diagram of the Shimura sand and gravel Member. The samples are collected from the site Sr (Tokuhira) the Fig. 5.

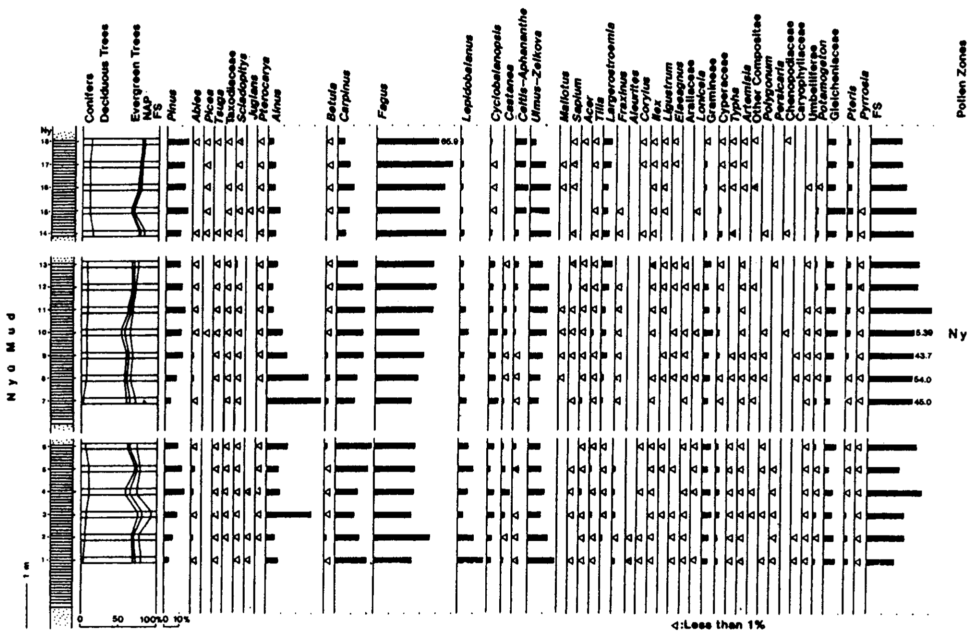


Fig. 14. Pollen diagram of the Nyû mud Member. The samples are collected from the site Ny (Tokuhira) shown in the Fig. 5.

present sporadically. Among evergreen taxa, *Cyclobalanopsis* consistently occurs with the frequency of a few percent. *Lepidobalanus* shows a decreasing trend, whereas *Fagus* increases towards the top and reaches over 60%. *Largerstroemia* also graually increases towards the top, reaching over 5% above a horizon at Ny 8. Herbs are consistently small in amount. Fern spores are characterized by consistent existance of *Gleichenia* in a few percent. *Pteris* also presents continuously but is low in occurrence.

Ok Zone (Sample No. Ok 1~5): Deciduous taxa such as *Fagus* and *Ulmus-Zelkova* reach 50% and become prominent in this zone. *Lagerstroemia* and *Liquidambar* are

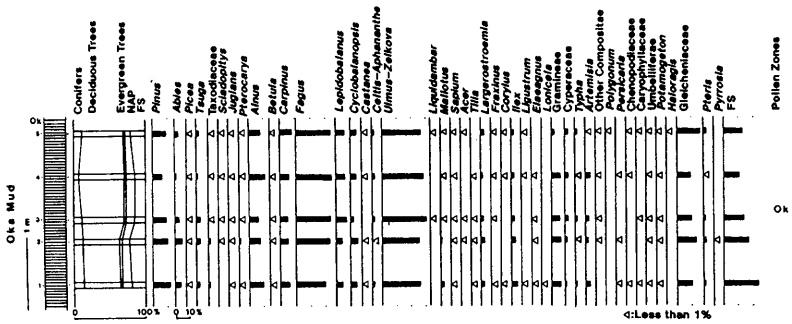


Fig. 15. Pollen diagram of the Oka mud Member. The samples are collected from the site Ok (Ichigi) shown in the Fig. 5.

characteristically detected. *Cyclobalanopsis* consistently occurs with frequency of a few percent. Conifers are generally low in frequency, excepting *Pinus* of 10%. Herbs are also small in amount, whereas Gramineae, Cyperaceae and *Artemisia* appear at a few percent. Fern spores are featured by *Gleichenia* which consistently appears with 10% in frequency.

4-2-2-2. KB Core

The pollen sequence from the KB core samples is composed of 5 pollen zones KB I~V zones in ascending order as follows (Fig. 16).

KB Zone (Sample No. KB 1~5): A mixed occurrence of deciduous and coniferous taxa characterize this zone. Deciduous taxa are mainly composed of *Ulmus-Zelkova*, *Fagus* and *Lepidobalanus*, and conifeous ones comprise Taxodiaceae, *Tsuga* and *Pinus*. Each taxon is represented with about 10% in frequency. None of evergreen taxa is discriminated. Among herbs, Gramineae and Cyperaceae are generally high in frequency, and *Typha*, *Artemisia* and Other Compositae are subsequent with frequency between 3 and 20%. Fern spores become occasionally prominent, reaching some hundreds percent. *Pteris* characteristically reaches 20% or more at the horizon of KB 3.

KB II Zone (Sample No. KB 6~9): Deciduous and coniferous taxa occur in mixture as well as the overlying zone, whereas Taxodiaceae increases up to 30% and characterizes this zone. Conifers slightly decrease under the same pace with the increase of Taxodiaceae. Gramineae, Cyperaceae and *Typha*, which have irregular fluctuations present in the frequency between 30 and 80%. Among herbs *Artemisia*, Other Compositae, *Persicaria* and Umbelliferae are present as the subordinate elements.

KB III Zone Sample No. KB 10~13): While Taxodiaceae decreases in frequency to less than 1%, *Pinus* increases to 20%. Other conifers such as *Abies*, *Picea* and *Tsuga* also increase by a few percent. Deciduous taxa are mainly composed of *Alnus*, *Fagus* and *Lepidobalanus*, which respectively increase up to about 10%. *Cyclobalanopsis* reappears but is in low frequency. Herbs are abundant in the lower part, however, becoming small in amount upward with exception of Gramineae which shows frequency of 25%.

KB IV Zone (Sample No. KB 14~15): *Cyclobalanopsis* remarkably increases to

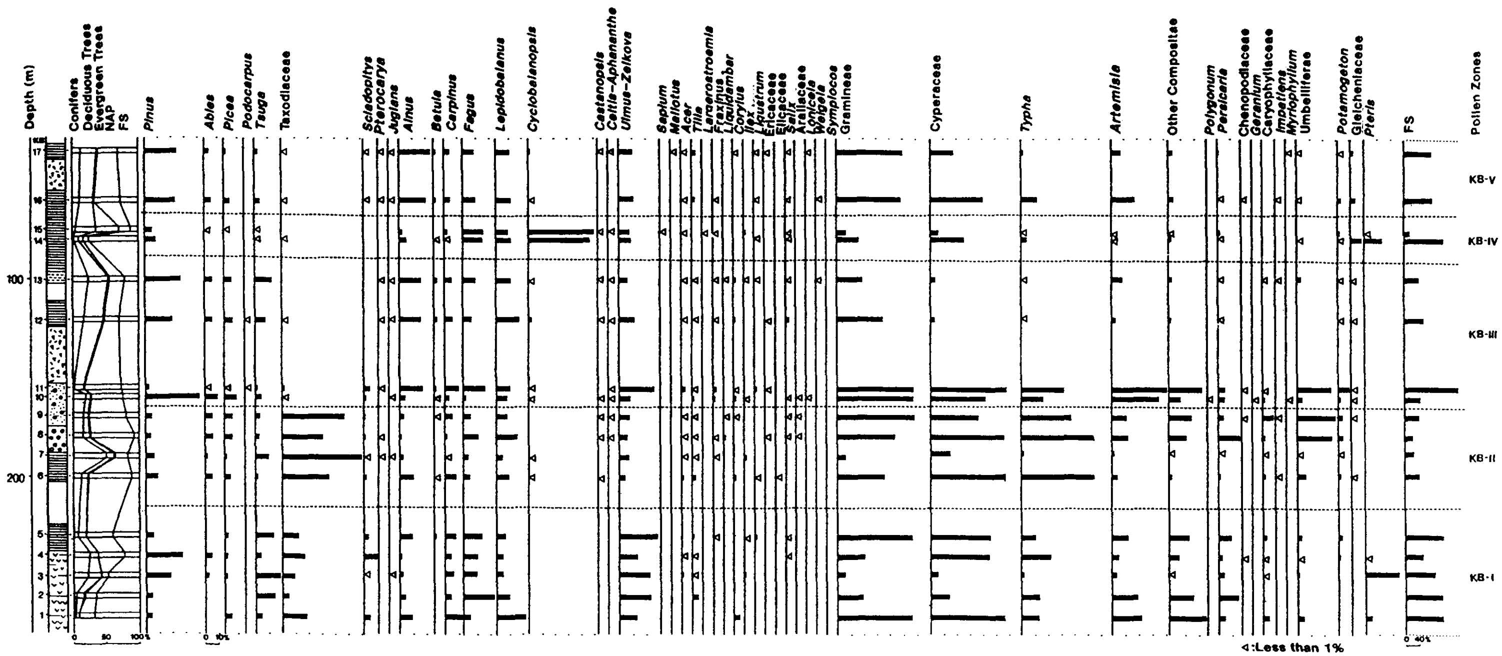


Fig. 16. Pollen diagram of the Quaternary deposits from the KB core samples cored at Furugô.

40~50% and characterizes this zone. *Fagus*, *Lepidobalanus* and *Ulmus-Zelkova*, respectively about 10%, are accompanied with *Cyclobalanopsis*. Other than a few percent of *Pinus*, conifers are scarcely discriminated. Herbs mainly comprise Gramineae and Cyperaceae, respectively in frequency between 10 and 30%. Although, fern spores are very prominent, about 400% of the NAP at the horizon of KB 14, they abruptly decrease to 20% at the upper most part of this zone.

KB V Zone (Sample No. KB 16~17): *Cyclobalanopsis* sharply decreases to a few percent and *Pinus* increases to 20% in frequency. *Abies*, *Picea* and *Tsuga* slightly increase to a few percent. *Alnus* also increases in frequency to more than 20%, while *Fagus*, *Lepidobalanus* and *Carpinus* keep the changeless condition. Therefore, the mixing of the coniferous and deciduous taxa are the most remarkable feature of this zone. Herbs are mainly composed of Gramineae and Cyperaceae and subordinately comprise *Typa*, *Artemisia* and Other Compositae. Among fern spores, *Gleichenia* is an important component.

4-2-2-3. OB Core Samples

Baded on pollen records from the ON-I to ON-V Formations, 9 pollen zones (Fig. 17) are discriminated. Of them, 4 zones are recognized within the ON-I Formation and hereafter these are treated under the designation of the OBI to OBIV zones.

OBI Zone (Sample No. OB 1~4): The coexistance of deciduous taxa such as *Lepidobalanus*, *Alnus*, *Carpinus*, *Fagus* and *Ulmus-Zelkova* characterize this zone. Conifers such as *Pinus*, *Abies* and *Cryptomeria* consistently appear but are low frequency. Among evergreen taxa, *Cyclobalanopsis* and *Myrica* present, but in low frequency.

OBII Zone (Sample No. OB 5~13): *Lepidobalanus*, *Alnus* and *Carpinus* of deciduous taxa become low in frequency, and conifers, especially *Pinus*, *Abies*, *Picea*, *Tsuga* and Taxodiaceae increase in amount to characterize this zone. *Cyclobalanopsis* successively appears but in low frequency. *Largerstroemia* increases to a few percents.

OBIII Zone (Sample No. OB 14~20): Conifers decrease their influence except for *Pinus*, while deciduous taxa increase their power. Among conifers, Taxodiaceae and *Picea* remarkably lose their influence to about 1%, however, *Pinus* occasionally becomes higher in frequency than in the underlying zone. *Lepidobalanus* characteristically increases among deciduous taxa up to about 15% in frequency, whereas *Lagerstroemia* is not detected. *Cyclobalanopsis* is present only sporadically, while *Buxus* occurs successively.

OB-IV Zone (Sample No. OB 21~25): Gradual decrease of deciduous taxa except for *Fagus* and *Ulmus-Zelkova* characterizes this zone. That is to say, *Lepidobalanus*, *Alnus* and *Carpinus* abruptly decrease to a few percent. On the contrary, Taxodiaceae increase keeping pace with the decrease of the deciduous taxa. However, increase of *Abies*, *Picea* and *Tsuga* is insignificant, *Pinus* has a upward decreasing trend. *Cyclobalanopsis* reappears and successively occurs.

Five zones are recognized above the ON-I Formation. The pollen sequence after the last Glacial in Japan is classified into 7 pollen zones, EG, FG (NAKAMURA, 1968), L, RI, RII, RIIIa and RIIIb zones (NAKAMURA, 1952; TSUKADA, 1959, 1963, 1967, 1974). This classification is well known and commonly used. Five zones above

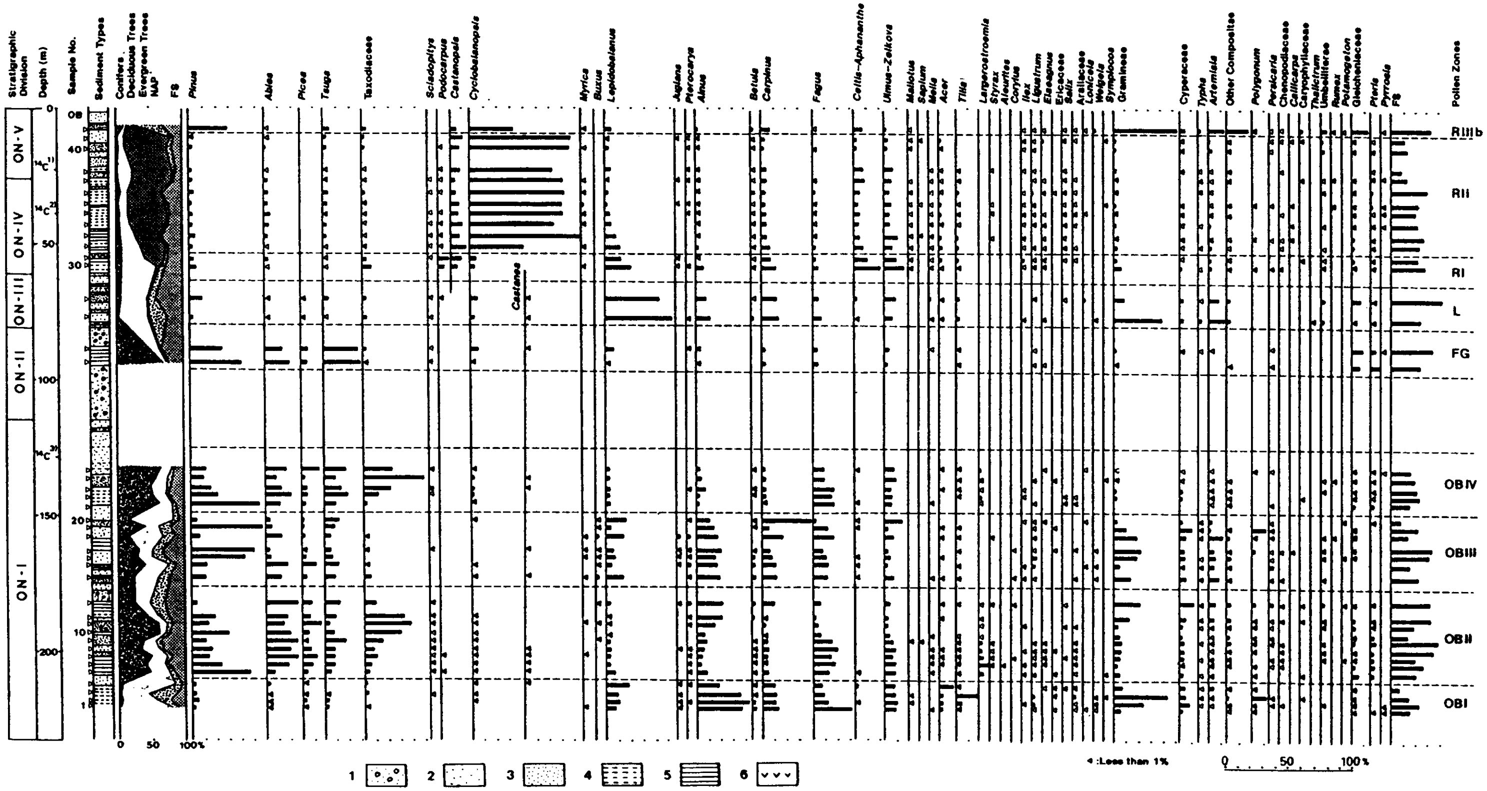


Fig. 17. Pollen diagram of the Quaternary from the OB core. 1: Sand and gravel, 2: Coarse or medium grained sand, 3: Fine grained sand, 4: Silt, 5: Mud, 6: Ash.

mentioned are assigned to FG, L, RI, RII and RIIIb zones respectively. However, the descriptions of them are omitted here.

4-3. Nojiri-Takaoka Area

The Nojiri-Takaoka area is located at 20 km west of Miyazaki City. This area is underlain by the Middle and Upper Pleistocene formations (ENDO, 1968; KINO and OTA, 1976), of which the fine grained beds are considered to be lacustrine in origin (NASU, 1966). These Pleistocene formations yield many fossil pollen, and their chronology is confirmed by fission track dating method applied to the intercalated pyroclastic flow deposits. Therefore these formations are considered to serve for a concrete basis for investigating paleovegetation and paleoclimate in the Middle Pleistocene of Kyushu.

4-3-1. Geological Setting and Samples

The basement for the Pleistocene beds in this area is mainly the Shimanto Supergroup, and partly the Miyazaki Group. The basement forms a depression which opens towards the west. The Pleistocene beds are accumulated upon this basin, and

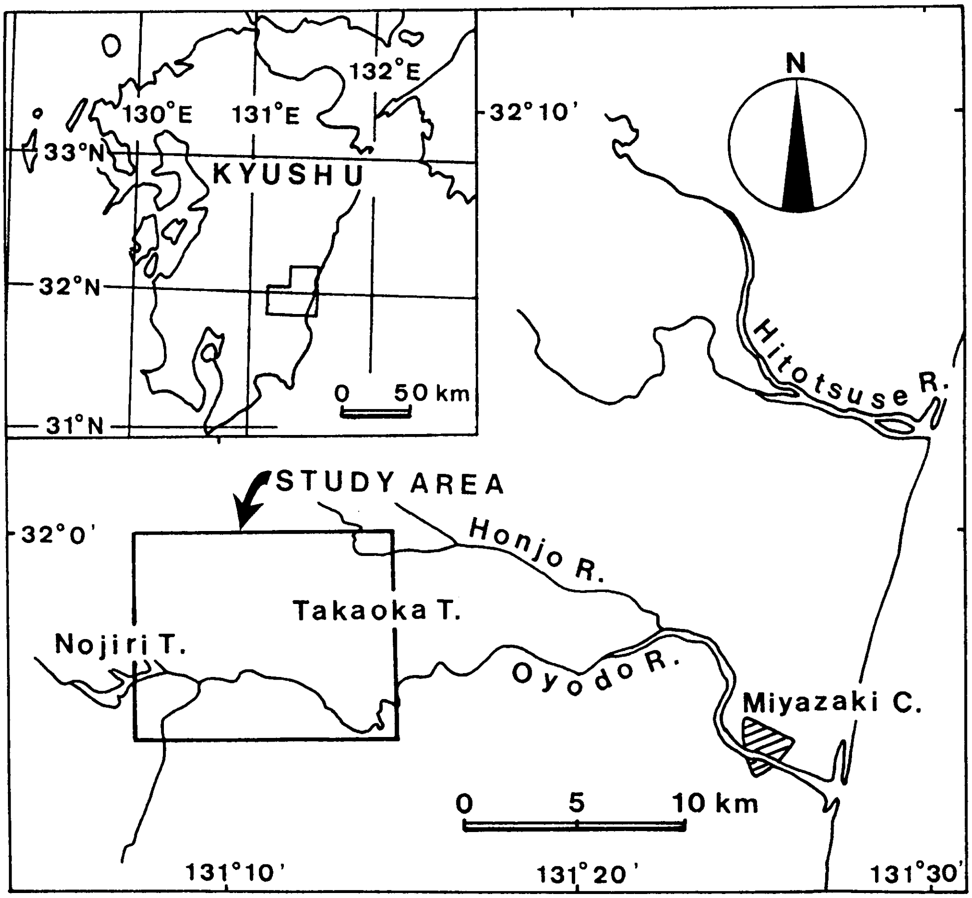


Fig. 18. Index map of the study area of the Nojiri-Takaoka area.

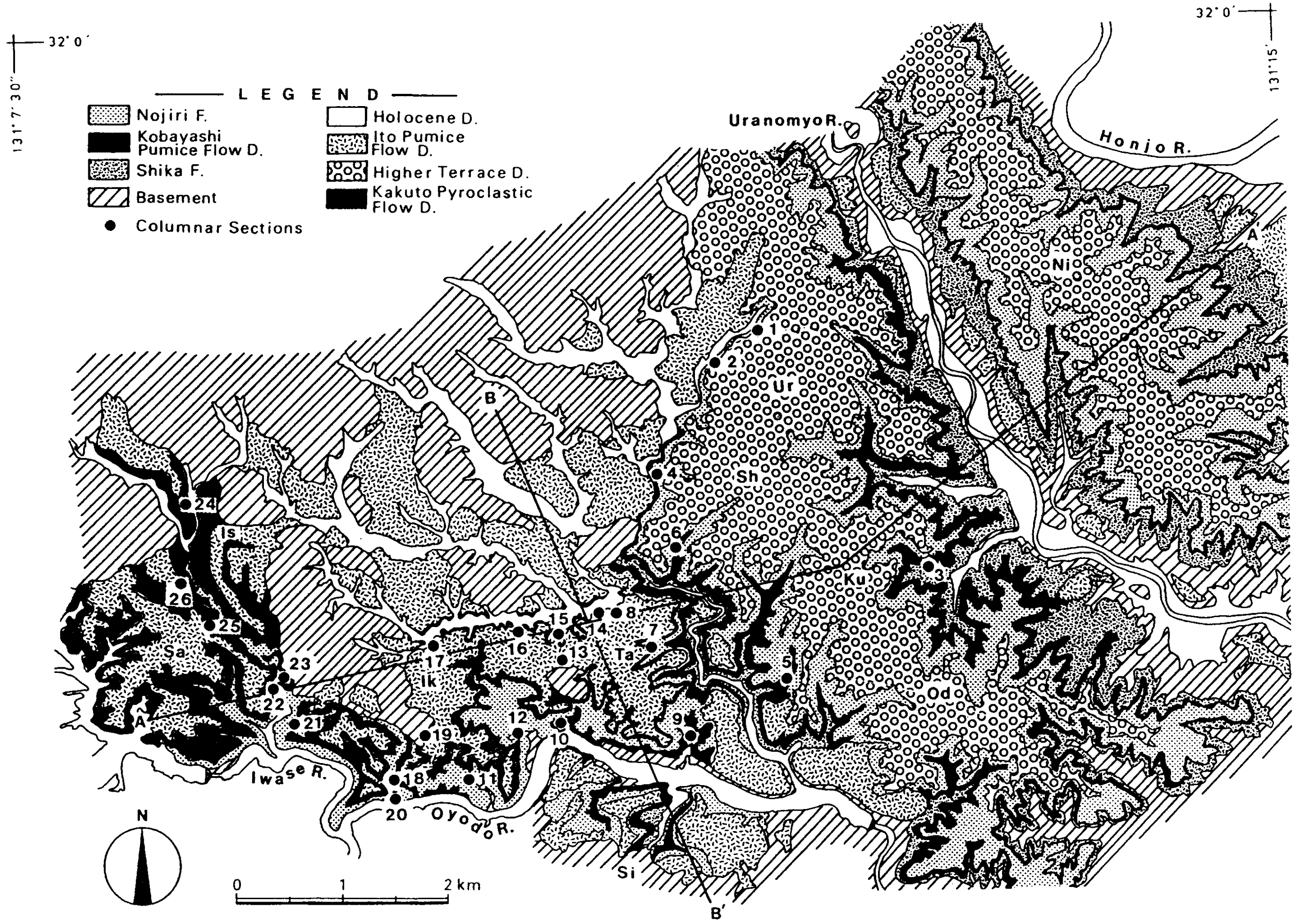


Fig. 19. Geological map of the Nojiri-Takaoka area. Ni: Nitanno, Ur: Uranomyo, Sh: Shinmura, Ku: Kugino, Od: Odamoto, Ta: Tatsugami, Ik: Ikenoo, Si: Shika.

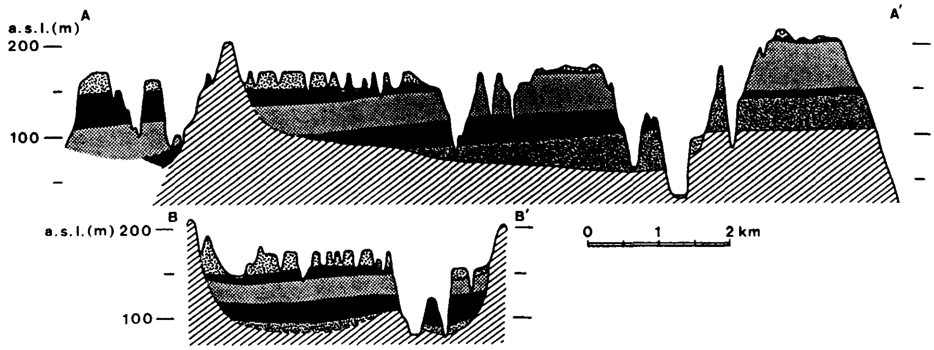


Fig. 20. Geological sections of the Nojiri-Takaoka area.

Table 3. Stratigraphic correlation of the Quaternary in the Nojiri-Takaoka district.

Age		Shuto(1962)		Endo(1968)		Kino and Ota (1976)	This Study
QUATERNARY	Late Pleistocene			Younger Hyuga Loam Member		Younger ejecta from Kirishima Volcano	Younger Ejecta from Kirishima Volcano
QUATERNARY	Late Pleistocene			Laminated sand		Pumice and pumiceous sand	
QUATERNARY	Late Pleistocene			younger pumice-flow deposit (YPF) Welded tuff		Volcanics of Aira Volcano: Ito pumice flow deposits	Ito Pumice Flow Deposits
QUATERNARY	Late Pleistocene			Pumice-fall		Volcanics of Aira Volcano: Osumi pumice fall deposits	Osumi Pumice Fall Deposits
QUATERNARY	Late Pleistocene			Older Hyuga Loam Member		Older ejecta from Kirishima Volcano	Older Ejecta from Kirishima Volcano
QUATERNARY	Middle Pleistocene	Higashimorogata F.	Kamiya sand and gravel	Morogata G.	Kugino F.		Higher Terrace Deposits
QUATERNARY	Middle Pleistocene	Higashimorogata F.	Kamiya sand and gravel	Morogata G.	Kugino F.	Kakuto welded tuff	Kakuto Pyroclastic Flow Deposits
QUATERNARY	Middle Pleistocene	Higashimorogata F.	Kamiya sand and gravel	Morogata G.	Kugino F.	Higher terrace deposits	Nojiri F.
QUATERNARY	Middle Pleistocene	Higashimorogata F.	Kamiya sand and gravel	Morogata G.	Nojiri F.	Kobayashi pumice flow deposits	Kobayashi Pumice Flow Deposits
QUATERNARY	Middle Pleistocene	Higashimorogata F.	Horiguchi mud	Morogata G.	Nojiri F.	Shika F.	Shika F.
Pre-Quaternary		Shimanto Supergroup		Shimanto Supergroup		Shimanto Supergroup	Basement

slightly dip westwards (Fig. 18, 19, 20, 21; Table 3).

Shika Formation: This formation is equivalent to the lower half of the Kamiya sand and gravel and the Horiguchi mud of the Higashimorogata Formation (SHUTO, 1962), Nojiri Formation (ENDO, 1968) excluding the pumice flow deposits in the upper part, the Tuffaceous silt and sand (NARUSE, 1966), and the Shika Formation (KINO and OTA, 1976). In the Shika-Odate area, this formation consists of the basal gravel bed, a few meters thick, and tuffaceous silts to sandy silts of the main part with occasional intercalations of thin beds of sands and ashes. In the areas to the west of Shika and northeast of Odamoto, the sediments mainly comprise gravel. The maximum thickness of this formation is 30 m.

Kobayashi pumice flow deposits: These deposits were named by KINO and OTA

(1976) and correlated with the pyroclastic flow deposits in the upper part of the Nojiri Formation (ENDO, 1968). They are mainly composed of weekly welded pumice flow deposits with a pumice fall layer at the base, and ash flow deposits in the upper part. These deposits conformably overlie the Shika Formation and are about 30 m in the maximum thickness and about 5 m in the minimum.

Noriji Formation: This formation is correlated with the Kugino Formation (ENDO, 1968) and the Higher terrace deposits (KINO and OTA, 1976) in this area. This formation begins with a gravel bed, about 10 m thick, which unconformably covers the Kobayashi pumice flow deposits or the basement. In the western part of the study area, this formation mainly comprises sands, gravel and tuffaceous silts with occasional intercalation of ash layers, while it becomes gravelly toward the east. This formation ranges from 30 to 50 m in thickness.

Kakuto pyroclastic flow deposits: These deposits are correlated with the Kakuto welded tuff (KINO and OTA, 1976), the Pumiceous Shirasu Formation (ENDO, 1958) and the Older Shirasu (ENDO, 1968). The Kakuto welded tuff which is typically developed in the area to the east of Kobayashi City is traced along the Iwase river as far as the study area, covering the Nojiri Formation. This formation is composed of pyroclastic flow deposits with many pumice and exotic rock fragments, and commonly shows eutaxitic structure. These sediments are strongly welded in the northwestern part of the study area. However, they become weekly welded in the western part, and then they are not welded in the eastern part of the study area. They become thinner eastwards, showing the maximum thickness of 40 m and the minimum one of 10 cm.

The Kakuto pyroclastic flow deposits were divided into two units, the upper and the lower, by ARAMAKI (1969) in the Kokubu area and by MIYACHI (1978) in the Hitoyoshi basin. From ARAMAKI (1969), the heavy mineral composition of the lower and upper units are Qz-Plg-Hyp-Hb-(Aug)-Op and Plg-Hyp-(Aug-Hb)-Op, respectively. The Kakuto pyroclastic flow deposits in the study area have a heavy mineral composition of Plg-Hyp-(Aug-Hb)-Op type. This datum leads to an estimation that the deposits in the study area are correlated with the upper unit of the Kakuto pyroclastic flow deposits in the Kokubu and Hitoyoshi areas.

Higher terrace deposits: ENDO (1981) mentioned that the higher terrace [VII Plain (ENDO, 1968); Kugino Plain (NAGAOKA, 1986)] is represented by the depositional surface of the Kugino Formation (ENDO, 1968). However, field evidence clearly shows that a gravel bed is separated from the Kauto pyroclastic flow deposits by unconformity. This leads to an conclusion that the higher terrace [VII Plain (ENDO, 1968); Kugino Plain (NAGAOKA, 1986)] is represented by the depositional surface of this gravel bed which also unconformably overlies the Kakuto pyroclastic flow deposits. Therefore the upper part of the Kugino Formation above the Kakuto pyroclastic flow deposits are newly designated here as the higher terrace deposits. This formation is mainly composed of intensely weathered cobbles and boulders, illustrating a typical feature of so-called "kusari reki". Its thickness is extremely variable, very thin in the Urushinobaru, and a few meters in the Odamoto areas.

Older ejecta from Kirishima volcano; Osumi pumice fall deposits; Ito pumice flow deposits; Younger ejecta from Kirishima volcano. [The stratigraphic divisions follow KINO and OTA (1976)]: The Older ejecta from Kirishima volcano, which is equivalent to the Older Hyuga loam Member (ENDO, 1963), is mainly composed of reddish brown

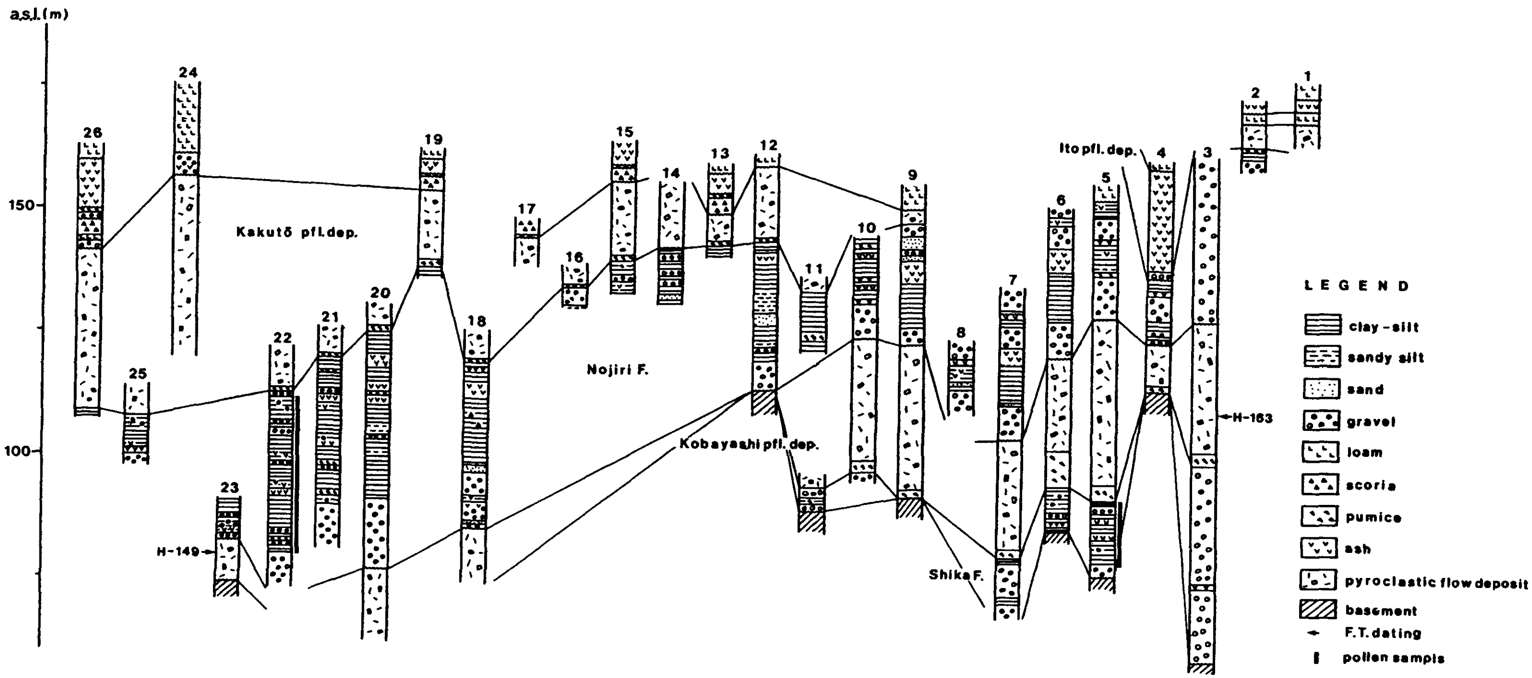


Fig. 21. Columnar sections of the Nojiri-Takaoka area.

scoria fall deposits formed by a dozen of fall units. The Osumi pumice fall deposits are composed of pumice lapilli with thickness of several tens centi-meters. They are widely tracable under the Ito pumice flow deposits and are correlated with the Osumi pumice fall deposits (ARAMAKI, 1968). The Ito pumice flow deposits, equivalent to YFP (ENDO, 1968), are composed of ash flow deposts which are occasionally welded. This deposts range in thickness between a few and scores of meters. The Younger ejecta from Kirishima volcano is correlated with the Younger Hyuga loam Member (ENDO, 1963). They consist of loamy pumice fall deposits and ashes. And, they mantle Quaternary geographical surfaces, excepting the alluvial plain.

Pollen samples are collected from the Shika Formation in the valley of 1.2 km south-west of Kugino [Site 5 (Fig. 19, 21)] and the Nojiri Formation in the valley of 1 km southeast of Sakaibyu [Site 22 (Fig. 19, 21)].

4-3-2. Fission Track Dating of the Kobayashi Pumice Flow Deposits

Samples are collected from three sites: Two sites are in the study area [Column No. 3, 23 (Fig. 19, 21)] and the other is from the Uebaru area in Tano city. The ages are dated by the external surface-internal detector method by HAYASHI (1982). (The laboratory works were mainly carried out by Dr. Hayashi.) The method is briefly explained below.

Purified zircon grains are mounted in a PFA sheet and etched in a eutectic melt of NaOH+KOH at 230°C for about 48 hours. The etched zircons are then irradiated with thermal neutron for 15 min. in the R.S.R. hole of the TRIGA Mark II reactor at Rikkyo University. After the irradiation, spontaneous tracks are counted. And then zircons are etched again under the same conditions for 30 hours to count induced tracks.

The fission track ages of the Kobayashi pumice flow deposits given by this method are 0.43±0.08 Ma (H-148), 0.41±0.09 Ma (H-149) and 0.51±0.09 Ma (H-163) (Table 4). These data lead to a chronological estimation that the age of the Kobayashi pumice flow deposits are between 0.41 Ma and 0.51 Ma.

Table 4. Fission track dating of the Kobayashi pumice flow deposits.

Sample	Number of grains	ΣNs	ρs	ΣNi	ρi	Nd	Φ	U	F	Age(Ma)
H-148	56	31	7.45±1.33	1700	4.09±0.10	1350	3.98±0.17	102	1.08	0.43±0.08
H-149	46	24	6.73±1.73	1402	3.93±0.10	1350	3.98±0.17	99	1.19	0.41±0.09
H-163	72	37	9.14±1.32	1717	4.24±0.10	1350	3.98±0.17	107	1.22	0.51±0.09

ΣNs:Number of spontaneous tracks, ρs:Spontaneous track density ($X10^3/cm^2$), ΣNi:Number of induced tracks, ρi:Induced track density ($X10^5/cm^2$), Nd:Number of tracks of mica detector, Φ:Neutron fluence ($X10^{14}$), U:Uranium content (ppm), F:F value after Hayashi(1982).

4-3-3. Pollen Analysis

Seven pollen zones are discriminated from the Shika and Nojiri Formations. These are the Ks (Fig. 22) and the NjI~NjVI (Fig. 23) zones in ascending order.
Sk Zone (Shika Formation, Sample No. Kmy 1~15): Dominance of *Ulmus-Zelkova*, *Fagus* and *Alnus* characterize this zone. Their frequency is generally high, although

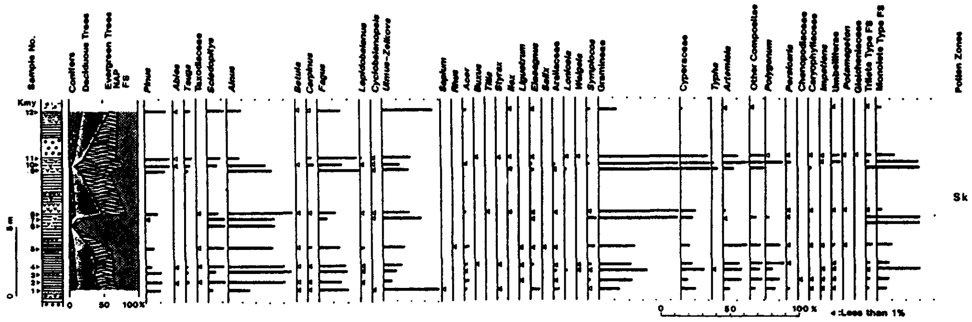


Fig. 22. Pollen diagram of the Shika Formation in the Nojiri-Takaoka area. The samples are collected from the columnar section No. 5 (Kugino) shown in the Fig. 21.

fluctuate irregularly between 10 and 40%. Among conifers *Pinus* continuously appears with slight fluctuations. *Sciadopitys* consistently occurs with frequency of about 10%. Evergreen taxon is not detected except for *Cyclobalanopsis* which appears with frequency of less than 1%. Herbs are abundant in general. Of them Gramineae is well represented and becomes dominant in the middle. Other important components of herbs are Cyperaceae, *Artemisia* and Other Compositae.

Nj I Zone (Nojiri Formation, Sample No. Iz 1~13): A large number of *Castanopsis* and *Cyclobalanopsis* characterizes this zone. Especially *Castanopsis* reaches the largest number with frequency between 65 and 85%. Other than evergreen taxa, AP and NAP are very small in occurrence, and *Pinus, Sciadopitys, Lepidobalanus, Liquidambar,* Gramineae and Cyperaceae only sporadically occur. *Gleichenia* consistently occurs, although fern spores are rare as a rule.

Castanopsis pollen was examined by a scanning electron microscope. It is collected from two horizons, Iz 5 and 9, and the collected samples are acetolized, and then used for the examination. The electron microscipic examination revealed that all *Castanopsis* pollen observed are possessed of "temari-like pattern" (MIYOSHI, 1982) and their trangled-sringy-rugulose elements of exine were about 0.1 μm in width. This feature quite agrees with that of *Castanopsis cuspidata* (MIYOSHI, 1981, 1982, 1983). In other words most of *Castanopsis* pollen within this zone are identifiable with *Castanopsis cuspidata.*

Nj II Zone (Nojiri Formation, Sample No. Iz 14~20): *Castanopsis* drastically decreases to a few percent. While, *Cyclobalanopsis* increases up to 50% and a combination of *Cyclobalanopsis* with *Sciadopitys* and *Alnus* characterizes this zone. *Abies, Tsuga* and *Lepidobalanus* also slightly increase and *Liquidambar* reaches its maximum value with frequency of about 10%. Herbs are mainly composed of Gramineae and Cyperaceae but are commonly low in frequency excepting the uppermost part. Fern spores abruptly increase at the basal part and show a trend of upward increase.

Nj III Zone (Nojiri Formation, Sample No. Iz 21~30): *Cyclobalanopsis* decreases and *Fagus* and *Ulmus-Zelkova* sharply increase and characterize this zone. *Pinus* and *Tsuga* increase slightly and *Sciadopitys* decreases to a few percent. *Tilia, Betula* and *Carpinus* consistently occur and *Liquidambar* almost disappears. Main components of herbs are characterized by Gramineae and Cyperaceae with high frequency.

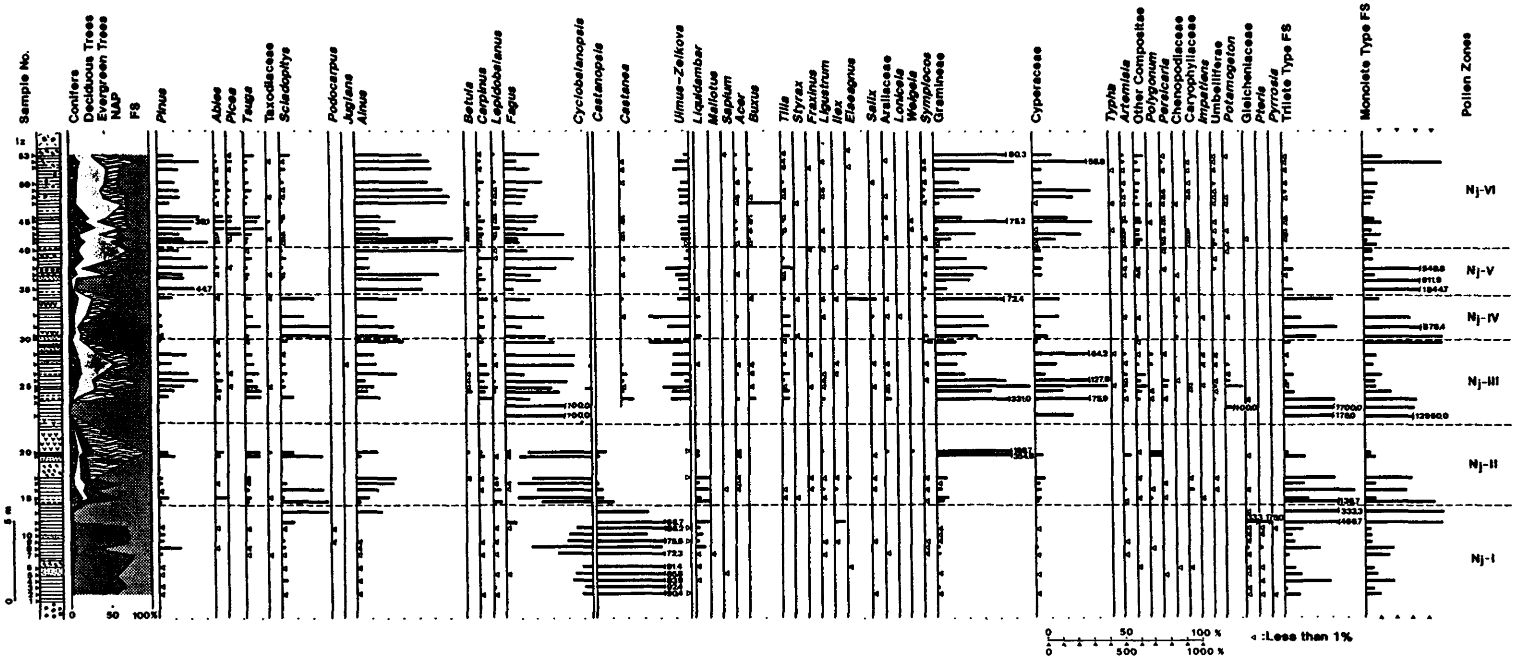


Fig. 23. Pollen diagram of the Nojiri Formation in the Nojiri-Takaoka area. The samples are collected from the columnar sections No. 22 (Sakenbyu) shown in the Fig. 21.

Nj IV Zone (Nojiri Formation, Sample No. Iz 31~34): *Fagus*, *Ulmus-Zelkova* and *Alnus* are dominant successively from the underlying zone. *Sciadopitys* also becomes prominent in occurrence. *Pinus* and *Abies* become scarce or absent.
Nj V Zone (Nojiri Formation, Sample No. Iz 35~40): Dominance of *Fagus*, *Ulmus-Zelkova* and *Alnus* is common to the underlying zone. While, *Sciadopitys* decreases to a few percent and *Pinus* increases again to more than 20% in frequency. *Abies* begins to appear sporadically in this zone.
Nj VI Zone (Nojiri Formation Sample No. Iz 41~53): This zone is also dominated by *Fagus*, *Ulmus-Zelkova* and *Alnus*, although they slightly decrease their abundance comparing with the underlying zone. Replaing with these taxa, conifers such as *Pinus*, *Abies*, *Picea* and *Tsuga* gradually increase in frequency. Especially, *Picea* consistently occurs with the maximum frequency of more than 10% and it characterizes this zone. *Alnus* reaches the leargest abundance in this formation with frequency of 50% and over. Among herbs, Other Compositae, *Persicaria* and Umbelliferae are discriminated other than the dominant Gramineae and Cyperaceae.

4-4. Hilly Land of the Miyazaki Coastal Plain

The Miyazaki coastal plain distributed through the area from Miyazaki City to Tsuno Town is composed of the Pleistocene terraces and alluvial plain (Fig. 24, 25). The Pleistocene terraces develop topographically between 30 and 200 m above the sea

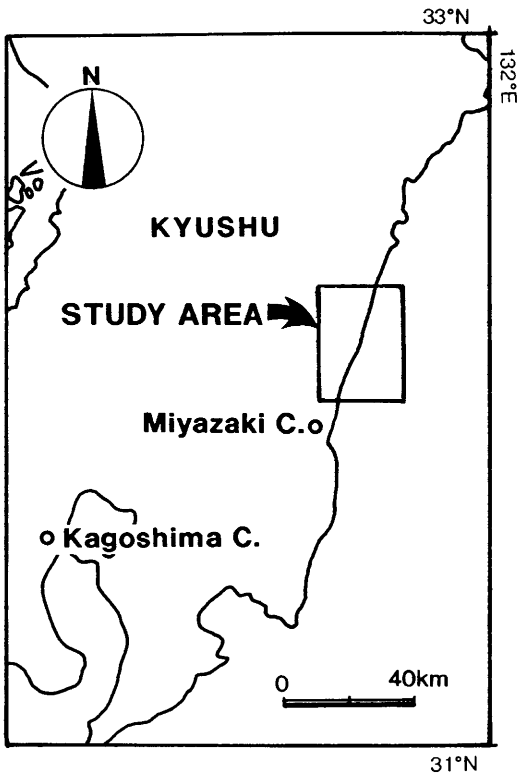


Fig. 24. Index map of the study area of the Miyazaki coastal plain.

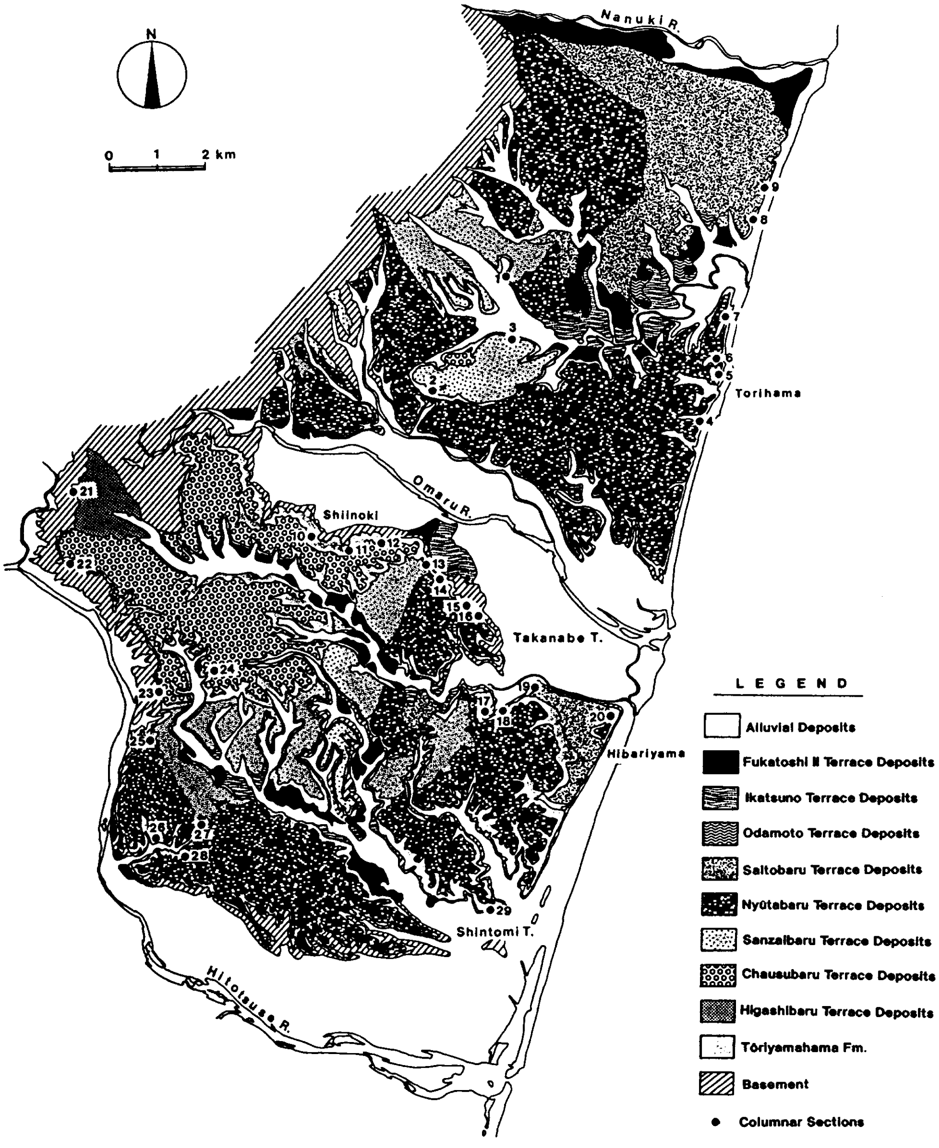


Fig. 25. Geological map of the Miyazaki coastal plain.

level. They are geologically constructed by Pleistocene deposits which are divided into two units, the lower, the Tôriyamahama Formation (OTUKA, 1932), and the upper, the terrace deposts. The Tôriyamahama Formation yields many pollen fossils from the intercalted silt beds and fills valleys which cut into the pre-Quaternary strata.

4-4-1. Geological Setting and Samples

The Pleistocene deposits in this area are composed of the Tôriyamahama Formation and the terrace deposits. The Quaternary geology and geomorphology of

Table 5. Correlation of the Quaternary of the Miyazaki coastal plain.

Otsuka (1930)	Endo (1968) Rs. Hitotsuse–Omaru	Endo (1968) Rs. Omaru–Nanuki	Endo and Suzuki (1986)	This Study
Alluvium	Alluvial deposits	Alluvial deposits	Flood plain deposits, coastal plain deposits and terrace deposits / Burried deposits under alluvial plain	Alluvial Deposits
	River terrace deposits / River terrace deposits / River terrace deposits	River terrace deposits / River terrace depoists / River terrace deposits	Fukatoshi II Terrace Deposits	Fukatoshi II Terrace Deposits
			Ito Pyroclastic Flow Deposits / Fukatoshi I Terrace Deposits	
	River terrace gravel bed	Nanuki fan Gravel	Ikatsuno Terrace Deposits	Ikatsuno Terrace Deposits
			Okadomi Terrace Deposits	Okadomi Terrace Deposits
Hibariyama Fm.	Gravel bed	Toyohama fan Gravel	Saitobaru Terrace Deposits	Saitobaru Terrace Deposits
Nyutabaru Fm.	Nyutabaru Gravel Mem.	Kawaminamibaru Gravel bed	Nyutabaru Terrace Deposits	Nyutabaru Terrace Deposts
			Baba Terrace Deposits	
Sanzaibaru Fm.	Sanzaibaru Grvel Mem.	Kokkobaru & old dissected fan Gravel	Sanzaibaru Terrace Deposits	Sanzaibaru Terrace Deposits
Chausubaru Fm.	Chausubaru Gravel Mem.	Remnant of Pl. VII Gravel bed	Chausubaru Fm. / Shiinoki Mem.	Chausubaru Terrace Deposits
Toriyamahama Fm.	Pre-Chausubaru Gravel Mem.	Toriyamahama Fm.	Omarugawa Fm. / Toriyamahama Fm.	Higashibaru Terrace Deposits
		Nanukigawa Fm.	Higashibaru Terrace Deposits	Toriyamahama Fm.
			Undivided higher deposits	

this area have been well documented and their details are summarized by a correlation chert in Table 5.

Geological features of the Tôriyamahama Formation which is palynologically analized are briefly noted here.

Tôriyamahama Formation: The Tôriyamahama Formation comprises sands and gravel with intercalations of bluish gray silts of marine origin. In the area of Chausubaru-Azebaru, this formation attains to the maximum thickness of about 20 m without intercalations of bluish gray silt beds. On the contrary, in the east of Chausubaru, it reaches between 30 and 45 m thick and comprises bluish gray silt beds. The upper part of this formation is accompanied by a white ash bed of a few meters thick, which serves as a key bed for the field mapping. This ash bed is comparable with the Hanakiri tuff which is dated as 0.48±0.12 Ma by fission track dating method (ENDO and SUZUKI, 1986).

Pollen samples of the Tôriyamahama Formation are collected at Tôrihama, Kawaminami Town (Column No. 5) (Fig. 26-1), Shiinoki, Kijô Town (Column No. 10) (Fig. 26-2), Hibariyama, Takanabe Town (Column No. 20) (Fig. 26-2) and Tonokôri, Saito City (out of the mapped area).

4-4-2. Pollen Analysis

Four sampling sites are hereafter grouped into 3 areas for convenience, namely the Shiinoki-Hibariyama, Tôrihama, and Tonokôri areas. Pollen sequence of the Tôriyamahama Formation in the Shiinoko-Hibariyama area is divided into 4 pollen zones, Tb I~III and Si zones (Fig. 27, 28) in ascending order. Pollen records from the Tôriyamahama Formation in the Tôrihama area are classified into 3 pollen zones, Th I~III zones (Fig. 29, 30) in ascending order. The To zone (Fig. 31) is recognized in the Tnokôri area.

Shiinoki-Hibariyama Area

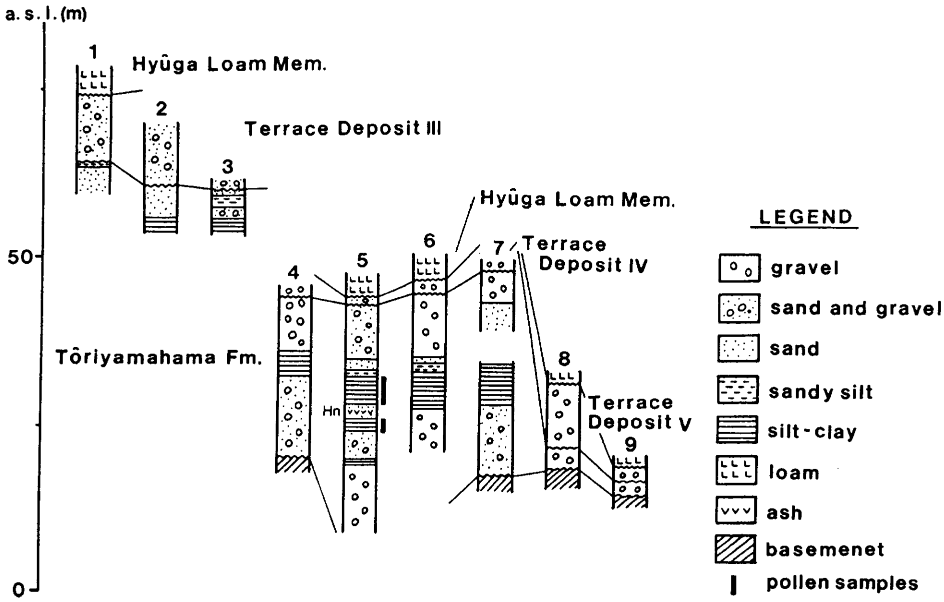


Fig. 26-1. Columnar sections of the Tôrihama area in the Miyazaki coastal plain.

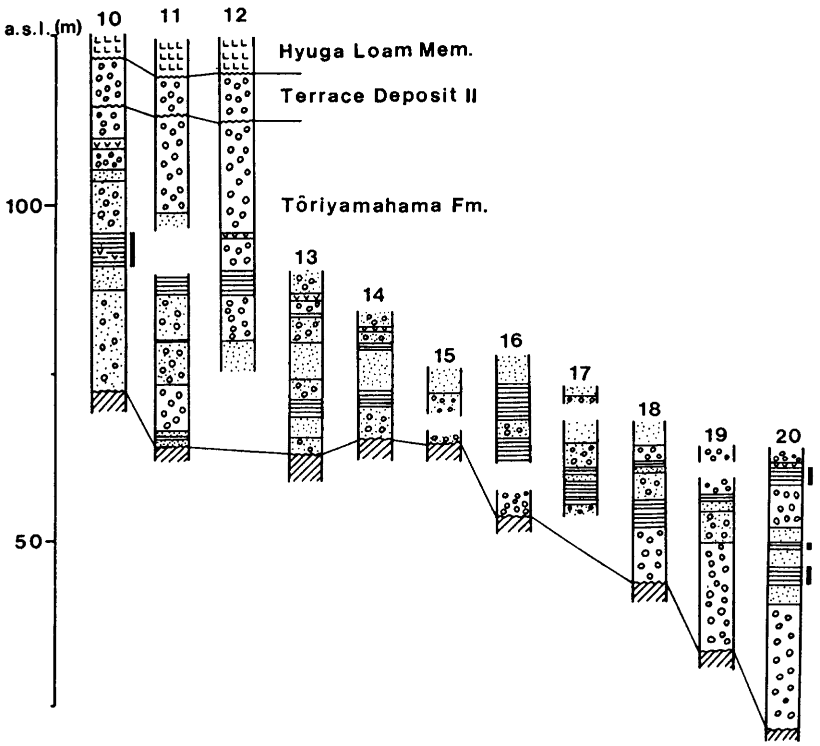


Fig. 26-2. Columnar sections of the Shiinoki-Hibariyama area in the Miyazaki coastal plain.

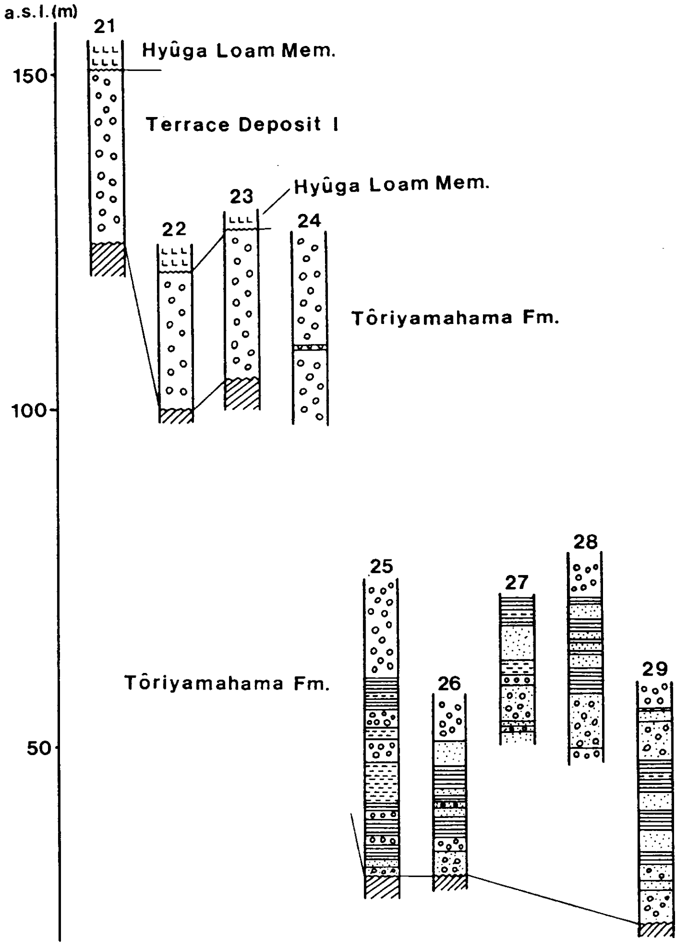


Fig. 26-3. Columnar sections of the Tonokôri area in the Miyazaki coastal plain.

Tb I Zone (Sample No. Hb 1): The sum of *Abies* and *Tsuga* reaches more than 90%. Besides these taxa, *Pinus*, *Fagus* and *Ulmus-Zelkova* and only detected. Herbs are small in amount, and each taxon shows a frequency of less than 1%. The Monolete type usually holds about 80% of the total fern spores.

Tb II Zone (Sample No. Hb 2~13): Mixture of coniferous and deciduous taxa characterizes this zone. Conifers mainly comprise *Abies* and *Tsuga*, in association with *Pinus* and *Picea*. Deciduous taxa mainly consist of *Fagus* and *Ulmus-Zelkova*. *Carpinus* and *Lepidobalanus* consistently present but low in frequency. Herbs are dominated by Gramineae. Fern spores are characterized by those of the Monolete type.

Tb III Zone (Sample No. Hb 14~21): This zone is also characterized by the mixture of conifers and deciduous taxa. *Abies* and *Tsuga* decrease, while *Pinus* and *Picea* become increasable. Deciduous taxa are characterized by *Fagus* with frequency of 30~50% and subordinately accompanied by *Ulmus-Zelkova* and *Carpinus* at a few

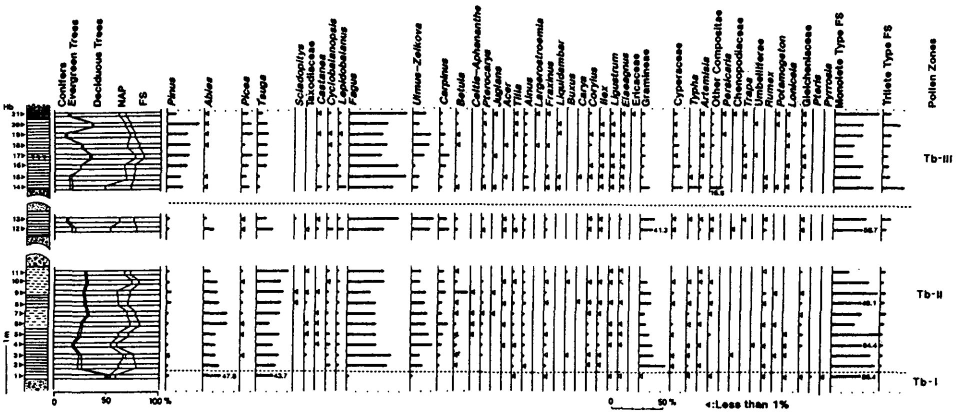


Fig. 27. Pollen diagram of the Tôriyamahama Formation. The samples are collected from the columnar section No. 20 (Hibariyama) shown in the Fig. 26-2.

percent in frequency. Herbs are very low in frequency as a rule. Cyperaceae and Other Compositae are present at a few percent. Other taxa of herbs are all less than 1%.

Si Zone (Smaple No. Si 1~13): *Cyclobalanopsis* becomes prominent and mixes with coniferous and deciduous taxa. *Cyclobalanopsis* reaches more than 50% in the lower part. Conifers mainly comprise *Pinus*, *Abies* and *Tsuga*. They are also accompanied by *Picea* as a minor element. Deciduous taxa mainly involve *Fagus* and *Lepidobalanus*. Excepting Gramineae with a few percent, each taxon of herbs shows less than 1% in frequency.

Tôrihama Area

Th I Zone (Sample No. Th 1~3): This zone is characterized by mixture of coniferous and deciduous taxa. Conifers are mainly composed of *Pinus*, *Abies* and *Picea*, while deciduous taxa are of *Fagus*, *Llepidobalanus*, and *Alnus*. Among herbs Gramineae becomes very prominent at the horizon of Th 2 and 3. *Typha* and *Artemisia* are other important herbaceous elements with a few percent in frequency.

Th II Zone (Sampe No. Th 4~6): Deciduous taxa such as *Fagus*, *Lepidobalanus*, *Ulmus-Zelkova*, *Carpinus* and *Alnus* account for more than 80% of arboreal pollen and they characterize this zone. Besides *Pinus* which shows 10~30% in frequency, conifer and evergreen broad leaved taxa are trivial. Herbs are mainly composed of Gramineae, Cyperaceae, and *Typha* with frequency between 10 and 20% in general, while Gramineae exceptionally reaches 55% at a horizon of Th 4. Fern spores mainly comprise those of Monolete type.

Th III (Sample No. Th 7~11): Mixture of coniferous and deciduous taxa characterizes this zone. Conifers are mainly composed of *Pinus*, *Abies* and *Picea* with frequency of about 10%, respectively. Deciduous taxa mainly comprise *Lepidobalanus*, *Betula*, and *Pterocarya* and *Fagus* and *Carpinus* as the minor elements. Herbs are dominated by Cyperaceae and *Artemisia*. Of them the former is remarkable with frequency of about 60%. *Potamogeton* characteristically presents in relatively high frequency.

Th IV Zone (Sample No. Th 12~24): This zone is also characterized by mixture of coniferous and deciduous taxa. *Pinus* increases up to 30% in the upper part, and

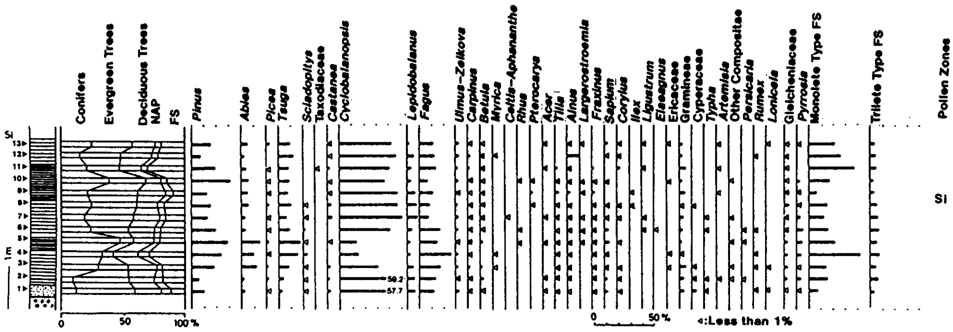


Fig. 28. Pollen diagram of the Tôriyamahama Formation. The samples are collected from the columnar section No. 10 (Shiinoki) shown in the Fig. 26-2.

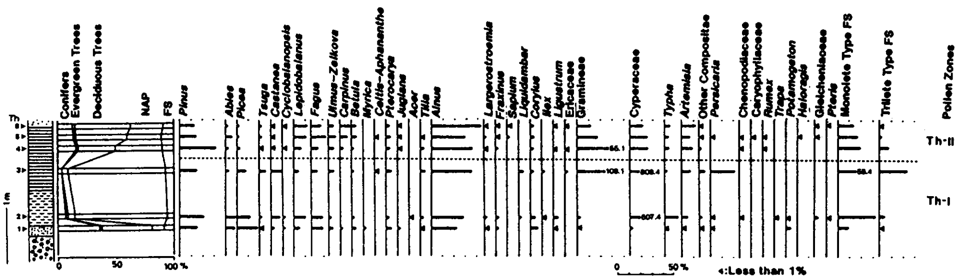


Fig. 29. Pollen diagram of the Tôriyamahama Formation. The samples are collected from the columnar section No. 5 (Tôrihama) shown in the Fig. 26-1.

Tsuga decrease slightly to 10%. *Betula* and *Pterocarya* decrease, while *Fagus*, *Alnus*, and *Lepidobalanus* sharply increase. Herbs drastically decrease their influence and most of them except for Gramineae uniformly show less than a few percent. Fern spores mainly comprise Monolete type and reach more than 80% at the horizon of Th 19.

Tonokori Area

To Zone (Sample No. Tn 1~23): This zone is characterized by the mixture of coniferous, deciduous and evergreen taxa. Conifers are composed mainly by *Pinus*, *Tsuga* and *Abies*. Deciduous taxa comprise *Fagus* which normally occurs at about 20% and occasinally reaches 50%. A few percent of *Ulmus-Zelkova*, *Carpinus* and *Largerstroemia* are also present as minor elements. Evergreen taxa chiefly consist of *Cyclobalanopsis* which normally occurs at about 10% but occasinally decreases to less than 1%. Herbs are very small in amount as a rule. Fern spores contain Monolete and Trilete types with the frequency of about 10%. Of them *Gleichenia* shows the most dominant occurrence.

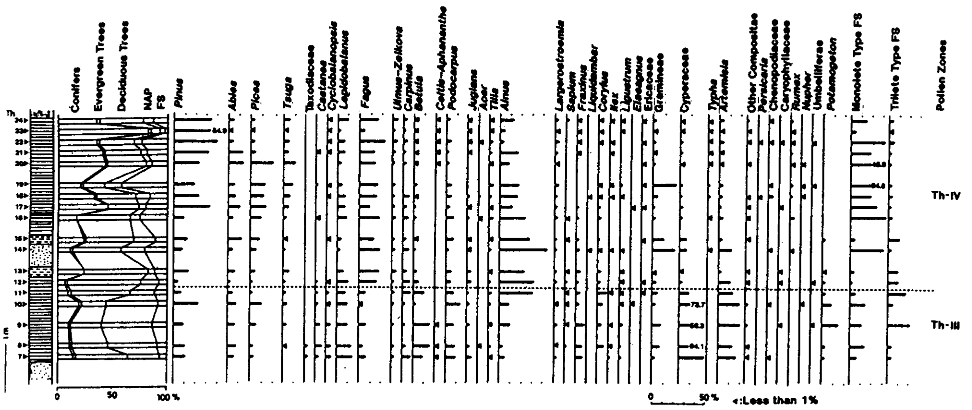


Fig. 30. Pollen diagram of the Tôriyamahama Formation. The samples are collected from the columnar section No. 5 (Tôrihama) shown in the fig. 26-1.

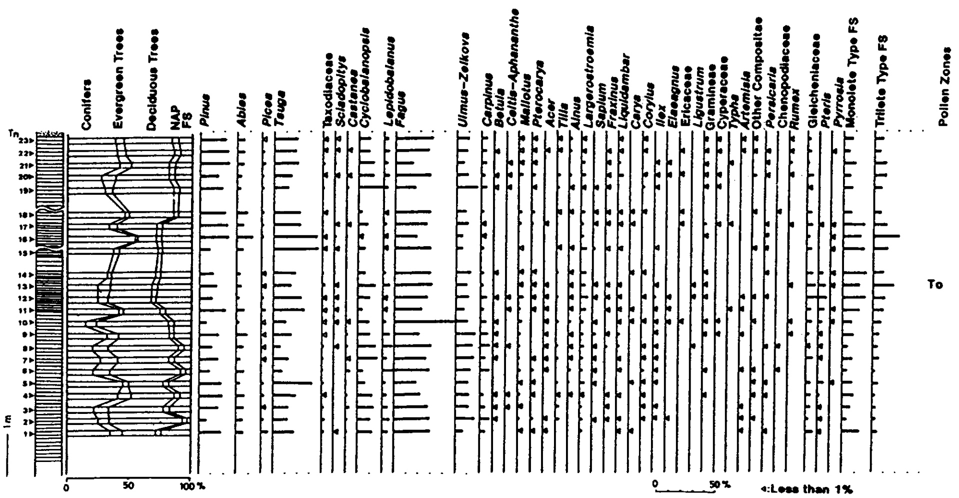


Fig. 31. Pollen diagram of the Tôriyamahama Formation. The samples are collected from Tonokôri (Kuronuki) in Saito City. This site is not included in the geological map shown in the Fig. 25.

5. Discussion

5-1. Paleovegetation and Paleoclimate

5-1-1. YF Core Samples from the Chikugo Plain

YFP-1 Zone: Combination of the temperate deciduous taxa characterized by *Tsuga* and *Ulmus-Zelkova* and evergreen coniferous taxa well suggests that a pan-mixed forest widely prevails in the age of this zone.

YFP-2 Zone: The reconstructed paleovegetation of this zone shows temperate deciduous forest which contains *Fagus* and *Ulmus-Zelkova* is associated with a small amount of *Cyclobalanopsis*. This vegetation reveals that the climate of this zone is characterized by the lower cool temperate zone.

YFP-3 Zone: Temperate deciduous forest continuously prevails in this zone. This forest contains *Abies*, Taxodiaceae and *Pinus* and it completely lacks *Cyclobalanopsis*. This vegetation suggests that the temperature slightly decreases and the climatic condition is comparable with the middle part of the cool temperate zone.

YFP-4 Zone: The reconstructed vegetation is characterized by mixture of conifers, deciduous trees and evergreen trees, which suggest slight increase of temperature comparing with the foregoing zone.

YFP-5 Zone: The paleovegetation developed in the time span of this zone is characterized by the temperate deciduous forest which mainly comprises *Fagus, Carpinus* and *Ulmus-Zelkova*. This vegetation is associated with the lower part of the cool temperate zone. Therefore it is highly probable that the temperature decrease slightly.

YFP-6 Zone: Mixed forest of coniferous and deciduous trees reappears in this zone. Temperature slightly decreases and then the climate is represented by the upper part of the cool temperate zone.

YFP-7 Zone: Both evergreen and deciduous trees flourish in this zone. High frequency of *Cyclobalanopsis* suggests considerable increase of temperature and general shift of climate towards the temperate condition. These may imply that this zone is apparently comparable with an interglacial phase.

YFP-8 Zone: Mixed forests of conifers and deciduous trees prevails again. This vegetation suggests slight decrease of temperature towards the middle part of the cool temperate zone.

YFP-9 Zone: The vegetation is mainly composed of deciduous trees with a low density of evergreen broad leaved trees and belong to the temperate forest. This vegetation suggests that temperature slightly increases, although the climate is still comparable with the cool temperate zone. This zone represents the onset of an interglacial phase.

YFP-10 Zone: Evergreen broad leaved trees further increase in density and mix with deciduous trees. This fact easily suggests the continuous rise of temperature.

YFP-11 Zone: Deciduous trees become dominant again. This vegetational change suggests a decrease of temperature to the middle part of the cool temperate zone.

5-1-2. Ôita Area

5-1-2-1. Nyû and Tsurusaki Hills

Kt I Zone: Conifers characterized by *Pinus, Abies* and *Picea* are dominant in this zone. Of them, *Picea* is prevalent at the maximum pollen frequency of 25%. This genetic composition strongly suggests that the vegetation is represented by the subarctic forest and the climate belongs to the subarctic zone. This fact suggests that this zone represents one of glacial phases.

Kt II Zone: Conspicuous mixture between the subarctic and temperate elements well indicate that the vegetation changes to the pan-mixed forest. This vegetation suggests a slight rise in temperature and the climate is considered to be the intermediate between subarctic and cool temperate zones. Therefore this zone is in the transitional phase from a glacial to an interglacial phase.

Kt III Zone: The vegetation is replaced by elements of the cool temperate forest which comprises *Ulmus-Zelkova*, *Carpinus*, *Fagus* and *Lepidobalanus*. Temperature continuously increases and climate changes to the upper part of the cool temperate zone.

Kt IV Zone: The reconstructed vegetation of this zone shows a typical temperate forest which normally contains of *Fagus*, *Ulmus-Zelkova*, *Lepidobalanus*, and *Carpinus*. This vegetation is closely comparable with that of the cool temperate zone.

Sm I Zone: *Pinus* forest flourishes in this zone. However, this forest is characterized by the substituted community and the potential natural vegetation is represented by subarctic forest which mainly contains *Abies*, *Picea* and *Tsuga*. Small amount of deciduous trees associated with cool temperate zone accompany them. This combination suggests that the climate is comparable with the lower part of the subarctic zone which gives a vivid account of a glacial phase.

Sm II Zone: Mixed vegetation composed of conifers and deciduous trees prevails in this zone. Conifers mainly consist of *Sciadopitys*, *Cryptomeria* and *Tsuga*. Deciduous trees are characterized by *Fagus* and *Ulmus-Zelkova*. Relatively high frequency of *Sciadopitys* implies that the vegetation is associated with the intermediate condition between the warm temperate and cool temperate zones. This suggests that this zone represents an interglacial phase.

Tk I Zone: The vegetation mainly consisting of *Fagus* and *Ulmus-Zelkova* is considered to be wholly temperate forest. Conifers such as *Pinus*, *Abies*, and *Tsuga* are accompanied by them. This association suggests that the climate belongs to the lower part of the cool temperate zone.

Tk II Zone: The reconstructed vegetation is the conifers-deciduous-evergreen broad leaved forest which mainly contains *Abies*, *Tsuga*, *Fagus* and *Cyclobalanopsis*. This composition suggests an intermediate condition between the cool and warm temperate zones.

Tk III Zone: The characteristic vegetation dominated by both *Fagus* and *Cyclobalanopsis* prevails in this zone. This vegetation suggests that the climatic condition is nearly the same as the preceding zone. Slight inscease in temperature is inferable from high frequency of *Cyclobalanopsis*. This inference also suggests that this zone represents an interglacial phase. Temporary decrease of *Cycloblanopsis* and increase of conifers at the horizon of Tk 34 suggest that this interglacial stage contains a stadial of a lesser scale.

Tk IV Zone: The vegetation characterized by a decrease of *Fagus* and *Cyclobalanopsis* and an increase of conifers such as *Abies* and *Tsuga* well represent an transitional phase. The conifers-deciduous-evergreen broad leaves forest flourishes as the whole. This suggests that the climatic condition is considered to be at the onset of a glacial period.

Sr Zone: Temperate forest with the following main elements as *Fagus*, *Ulmus-Zelkova*, *Lepidobalanus* and *Carpinus* flourishes in this zone. Limited but continuous occurence of *Cyclobalanopsis* suggests that the climate belongs to the lower part of the cool temperate zone.

Ny Zone: It is generally concluded that the temperate forest also developes in this zone. *Cyclobalanopsis* sporadically occurs in the lower half of this zone, but it becomes very scarce in the upper part and, in turn, *Picea* is detected. This vegetational change indicates a gradual climatic shift from the lower to the upper part of the cool temperate zone.

Ok Zone: *Fagus* and *Ulmus-Zelkova* are dominant in this zone and the combination of these genera implies that the vegetation belongs to the temperate forest. This zone also contains *Cyclobalanopsis* with low density. These facts well support that the climatic condition is represented by the lower part of the cool temperate zone.

5-1-2-2. KB Core

KB I Zone: Both deciduous and coniferous trees prevail in this zone. Deciduous trees comprise *Fagus*, *Ulmus-Zelkova* and *Lepidobalanus*, and conifers chiefly consist of *Tsuga* and *Cryptomeria*. This combination suggests that the climate of this zone is in harmony with the lower part of the cool temperate zone.

KB II Zone: The vegetational character is nearly the same as the underlying zone, where the deciduous trees are mixed with the conifers. A slight difference of this zone from the underlying one, however, is realized in the prominence of *Cryptomeria*. These lead to an recogniton that the climatic condition of this zone becomes more humid than the preceding zone, while the temperature does not essentially change.

KB III Zone: The vegetation is almost very similar to the preceding two zones, however, *Cryptomeria* becomes almost absent. This change of composition suggests that the precipitation decreases in this zone, while cool temperate condition has been continued.

KB IV Zone: Deciduous-evergreen broad leaved forest flourishes in this zone. Deciduous trees comprise *Fagus*, *Lepidobalanus* and *Ulmus-Zelkova*, and evergreen broad leaved trees are represented by *Cyclobalanopsis*. These generic composition suggests the intermediate stage of climatic condition between the warm and cool temperate zones.

KB V Zone: The former vegetation is replaced by a temperate forest mainly composed of *Fagus*, *Ulmus-Zelkova* and *Lepidobalanus*. This vegetaion suggests that the temperature slightly decreases and climatic condition becomes to be equivalent to the middle part of the cool temperate zone.

5-1-2-3. OB Core

OB I Zone: The following genera such as *Fagus*, *Ulmus-Zelkova*, *Carpinus* and *Alnus* are dominant in this zone. These generic elements suggest that the vegetation is equivalent to the temperate forest which is well comparable with the middle part of the cool temperate zone.

OB II Zone: Subarctic forest composed of *Abies*, *Picea* and *Tsuga* with such subordinate temperate elements as *Fagus*, *Ulmus-Zelkova* and *Carpinus* flourish in this zone. This combination suggests that the vegetation is characterized by the pan-mixed forest which is comparable with an intermediate condition between the subarctic and cool temperate zones.

OB III Zone: The former vegetation is generally replaced by the temperate forest characterized by *Fagus, Ulmus-Zelkova, Carpinus* and *Lepidobalanus*, though small amount of conifers still remain. This vegetation indicates that the temperature slightly increases and the climate becomes to be involved in the lower part of the cool temperate zone.

OB IV Zone: The pan-mixed forest reappears in this zone, and the temperature is considered to be cooler than that of the preceding zone. The climatic condition is comparable with the intermediate one which is involved between the subarctic and cool temperate zones.

5-1-3. Nojiri-Takaoka Area

Sk Zone: Temperate forest dominated by *Fagus, Ulmus-Zelkova* and *Alnus* prevails in this zone. And, this forest comprises *Sciadopitys, Tsuga* and *Cyclobalanopsis* as the minor elements. This generic composition suggests a specific assignment of *Fagus* and *Tsuga*. They are *Fagus japonica*, and *Tsuga sieboldii.* These vegetational data imply that the climatic condition is involved between the cool and warm temperate zones and annual temperature may be slightly lower than that of present.

Nj I Zone: The vegetaion of the preceding zone is replaced by the evergreen broad leaved forest mainly characterized by *Castanopsis, Cyclobalanopsis* and incidental inclusion of *Podocarpus*. This vegetation is similar to that of the Hypsithermal interval in the Holocene time. It is presumable from these vegetational data that the climate is slightly warmer than that of the present.

Nj II Zone: The evergreen broad leaved forest mainly composed of *Cyclobalanopsis* flourishes in this zone. While, *Catanopsis* decreases and conifers such as *Sciadopitys, Abies* and *Tsuga* reappear. The northern limits of distribution of *Catanopsis* and *Cyclobalanopsis* are respectively consistent with the 2°C and 1°C isothermal line of monthly mean temperature in the coldest month (Yoshioka, 1954, 1956). The vegetational condition in the Nj-II zone characterized by *Cyclobalanopsis* suggests a slightly cooler climate than that of the Nj-I zone which is dominated by *Castanopsis.* Finally, it is also inferred that the decrease of summer temperature permits the invasion of the conifers such as *Sciadopitys, Abies* and *Tsuga.*

Nj III Zone: The dominant genera of this zone are represented by *Fagus* and *Ulmus-Zelkova* and following genera such as *Abies, Tsuga, Carpinus* and *Betula* are subordinately accompained by them. This combination suggests that the vegetational condition is comparable with the upper part of the cool temperate zone and the temperature is notably lower than the preceding zone.

Nj IV Zone: The reconstructed vegetation of this zone is the mixed forest composed of cool temperate elements with *Sciadopitys* and *Tsuga* as subordinate elements. This vegetation is quite similar to that of the Sk zone. The climate becomes warmer than that of the preceding zone and it is referable to the lower part of the cool temperate or intermediate conditions between the cool and warm temperate zones.

Nj V Zone: The forest characterized exclusively by the cool temperate elements flourishes in this zone. This implies that the climatic condition becomes cooler comparing with the preceding zone.

Nj VI Zone: The vegetation is still associated with the cool temperate zone, though, fair amount of conifers such as *Abies* and *Picea* are accompanied by them. Therefore, *Picea* detected in this zone is considered to be originated from *Picea polita*. The generic combination indicates that the climate is inferred to be comparable with the upper part of the cool temperate zone, while the temperature apparently continues to decrease.

5-1-4. Hilly Land of the Miyazaki Coastal Plain

Tb I Zone: The reconstructed vegetation is represented by a mixed forest, comprising *Abies* and *Tsuga*. This vegetation clearly suggests that the climate is under an intermediate condition between the cool and warm temperate zones.

Tb II Zone: The temperate elements such as *Fagus*, *Ulmus-Zelkova* and *Carpinus* are dominant and conifers are accompanied by them as minor elements. This vegetation is compared with the middle part of the cool temperate zone.

Tb III Zone: The temperate forest is continuously predominant in this zone. Relatively high frequency of *Picea* suggests a slight decrease of temperature and the climatic condition of the lower part of the cool temperate zone.

Si Zone: Conifers, deciduous and evergreen trees flourish together in this zone, and this suggests the intermediate climatic condition between the cool and warm temperate zones.

Th I Zone: Some subarctic and cool temperate elements are mixed with each other in this zone. The warm temperate element is absolutely absent. This vegetation is considered to be comparable with the pan-mixed forest, and it suggests that the climatic condition is the intermediate between the subarctic and cool temperate zones. Therefore this zone represents one of a glacial phase.

Th II Zone: The cool temperate elements such as *Fagus*, *Lepidobalanus*, *Ulmus-Zelkova* and *Carpinus* take place in this zone. This suggests that the climate becomes slightly warmer than that of the preceding zone and is comparable with the middle part of the cool temperate zone.

Th III Zone: Conifers such as *Pinus*, *Abies* and *Picea* reappear in this zone, and they are mixed with the cool temperate deciduous forest. Relatively large number of *Cyclobalanopsis* suggests that these conifers are not subarctic elements. Therefore, the climatic condition is comparable with the lower part of the cool temperate zone.

Th IV Zone: A mixed forest characterized by cool temperate elements and subarctic conifers flourishes in this zone. The warm temperate elements are very scarce. Therefore the vegetation in this zone is considered to be the pan-mixed forest. This vegetation suggests that the climate becomes cooler again to be comparable with the intermediate condition between the subarctic and cool temperate zones.

To Zone: The vegetation is also characterized by a mixed forest composed of the temperate elements and conifers. However, the presence of *Cyclobalanopsis* suggests that the vegetation is not the pan-mixed forest but the intermediate one between the temperate and warm temperate forests. The climate becomes obviously warmer than that of the preceding zone. It is highly probable that this zone represents one of interglacial phases.

5-2. Some Problems on the Paleovegetation

5-2-1. The Age of the Extirpation of *Liquidambar*

Liquidambar pollen is detected from 9 pollen zones among 48 pollen zones established in the study areas. These are YFP 1, 2, 4, 9, Tk III, Ok, Tb III, Th I, and Th III zones. *Liquidambar* was believed to be extirpated in the Early Pleistocene, though, NISHIMURA (1980) and NASU (1980) suggested that *Liquidambar* reappeared in the Middle Pleistocene. The reappearance is chronologically assinged to the Sannôdai loam Member in the Kantô area (NISHIMURA, 1980) and Ma 6 to 7 Formation of the Ôsaka Group in Kinki area (NASU, 1980). In the pollen records from the subsurface Quaternary strata in the Nôbi plain, *Liquidambar* was also detected in the lower part of the Middle Pleistocene Ama Formation (YOSHINO *et al.*, 1980). Moreover, *Liquidambar* can be traceble in the pollen spectra from up to the P 8 zone of the Middle Pleistocene of the Senshu Group (FURUTANI, 1984). In this study, however, *Liquidambar* pollen is detected not only from the Middle Pleistocene but also from the Ok zone of the Late Pleistocene. The Ok zone is compared with the Riss-Würm interglacial. Therefore, *Liquidambar* survived as a relict after the reappearance in the Middle Pleistocene up to the Late Pleistocene in Kyushu district. This is attributable to the warmth of Kyushu district. Finally, it is probable that *Liquidambar* has completely extirpated from Kyushu district by the cold climate prevailed in the Last Glacial age.

5-2-2. The Singular Dominance of Alnus

Alnus often becomes exclusively prominent in occurrence at many horizons in the Sk, Nj II~IV, Kt I~IV, and Sm II zones. In these horizons, fern spores also present in high frequency. From TSUJI *et al.* (1984) and HASE *et al.* (1985), the dominance of *Alnus* is attributed to the destruction of the vegetation by volcanic activity. The sediments above mentioned provide not only pollen but also a lot of volcanic materials. TAGAWA's study (1964) on the vegetation dynamics of the volcanic area clarified vegetational changes from a bare ground to a climax forest tracing 6 stages, viz., lichen and bryophyte stage, herbaceous stage, scrub stage, *Pinus* forest, *Cyclobalanopsis* forest and *Machilus* forest. When compared the reconstructed vegetations with this succession, the vegetation of the pollen zones with dominant fern spores are equivalent to the herbaceous stage (TAGAWA, 1964) and *Alnus* rich pollen zones correspond to the scrub stage (TAGAWA, 1964). Therefore, phenomena of exclusive dominance of *Alnus* or fern spores are considered to be caused by destruction of the vegetation by the volcanic activity.

5-3. Correlation

5-3-1. Correlation between the YF Core and the Senshu Group

In attempting to correlate the pollen zones described in the previous chapters, the YF core which shows the most continuous succession must serve for a standard. First, the author trys to compare the pollen records from the YF core samples with those of the Quaternary Senshu Group from the bottom of Ôsaka Bay (FURUTANI, 1984). The Senshu Group consists of highly successive sediments ranging from the Lower Pleistocene to the Holocene. FURUTANI (1984) described the pollen sequence of the group and discriminated P1 to P17 pollen zones which were further subdivided into 48 subzones. His work is elaborate and goes in detail and serve for a standard of the Quaternary pollen sequence in Japan. The Senshu Group is precisely correlated with the Ôsaka Group by several tephras. Nannofossils obtained from some horizons also confirm the dating. Therefore, the YF core may become a local time-scale after it is correlated with the Senshu Group by pollen records. This will make it easy to correlate the pollen zones among the previous sections with each other.

Among the pollen zones in the YF core, YFP 4, 7 and 10 zones are definitely correlated with the pollen zones in the Senshu Group. In zones below the P 13 zones (in the Senshu Group), Taxodiaceae consistently and characteristically occurs in high frequency. However, Taxodiaceae abruptly decreases to a few percent or is absent in this zone (FURUTANI, 1984). Quite similar pollen succession is recognized below and in the YFP 5 zone (in the YF core). Moreover, in the YFP 4 and P 14 zones, just before the drastic decrease, this taxon slightly increases in frequency by about 10%. This successive change of Taxodiaceae is very remarkable and this characteristic leads the correlation of the YFP 4 zone with the P 14 zone. The pollen assemblage of the P 14 zone is correlated with that of the Ma 2 Formation of the Ôsaka Group (FURUTANI, 1984), which was chronologically assigned to be 0.8±0.1 Ma (ISHIDA, 1970). In consequence, the age of the YFP 4 zone is approximately referred to be 0.8 Ma.

The YFP 7 zone (in the YF core) is characterized by the first temporary rise of *Cyclobalanopsis* after the dramatic decrease of Taxodiaceae. In this zone, *Cyclobalanopsis* form a mixed forest with deciduous trees mainly composed of *Fagus*. This feature is very similar to that of the P 12b zone (in the Senshu Group). This leads to the correlation of the YFP 7 zone with the P 12b. The pollen assmblages between the YFP 4 and YFP 7 zones include conifers such as *Pinus*, *Abies*, and *Tsuga*, and deciduous trees like *Fagus*, *Carpinus*, and *Lepidobalanus*. This generic composition is quite similar to that between the P 14 and P 12b zones in the Senshu Group. This fact supports the idea above mentioned. The strata in which the P 12b zone is established involves the Azuki tuff which is contained within the Ma 3 Formation of the Ôsaka Group. The pollen records of the P 12b zone are very similar to those of the Ma 3 Formation (FURUTANI, 1984). The Azuki tuff was dated as 0.84±0.07 Ma (NISHIMURA and SASAJIMA, 1970) by fission track dating method. Weighing the paleomagnetic stratigraphy, the age of the Ma 3 Formation is revised as 0.75±0.1 Ma (ISHIDA, 1970). Therefore, the age of the YFP 7 zone is considered to be about 0.75 Ma.

The YFP 10 zone (in the YF core) is characterized by the first slight increase and decrease of *Cyclobalanopsis* above the YFP 7 zone. This feature is also seen in the P 11b zone (in the Senshu Group). This agreement indicates that the YFP 10 zone is highly correlated with the P 11b zone. The pollen assemblages between the YFP 7 and YFP 10 zones are dominated by temperate deciduous elements accompanied by conifers such as *Pinus*, *Abies*, and *Tsuga*. Almost the same pollen assemblages are recognized in the pollen records between the P 12c and P 11a zones (in the Senshu Group). This concurrence of the pollen assemblage below the YF 10 and P 11b zones between a distant districts supports the correlation above mentioned. The P 11b zone in the Senshu Group accords with the base of *Gephyrocapsa oceanica* zone (OKAMURA and YAMAUCHI, 1984), which is assigned to 0.44 Ma (GARTNER, 1973). Consequently the YFP 10 zone is chronologically referred to 0.44 Ma.

5-3-2. Correlation of the Regional Pollen Zones

The KB I and KB II zones (in the KB core) are dominated by taxodiaceae. However, this taxon suddenly decreases to a few percent in the KB III zone (in the KB core) after a slight increase by about 10% in the KB II zone. The change of Taxodiaceae is also seen between the YFP 4 and YFP 5 zones as mentioned in the preceding chapter. It is easily suggested that the KB II zone is correlated with the YFP 4 zone. The KB I and YFP 3 zones are respectively just below the KB II and YFP 4 zones. And Taxodiaceae and deciduous trees coexist in the KB I and YFP 3 zones. The fact suggests that the KB I zone is correlated with the YFP 3 zone. The KB III, YFP 5, and 6 zones are pollen zones just after the decrease of Taxodiaceae, and they have almost the same palynological character which deciduous trees such as *Fagus*, *Ulmus-Zelkova* and *Lepidobalanus* occur with conifers. This fact suggests that the KB III zone is correlative with the YFP 5 and YFP 6 zones.

The KB IV zone (in the KB core) is characterized by the temporary increase of *Cyclobalanopsis* that immediately follows the drastic decrease of Taxodiaceae. And *Cyclobalanopsis* occurs with deciduous trees such as *Fagus* and *Ulmus-Zelkova* in the KB IV zone. This palynological feature of the KB IV zone quite resembles that of the YFP 7 zone. Accordingly the KB IV zone is naturally correlated with the YFP 7 zone.

Coexistence of *Fagus* and *Cyclobalanopsis* with subordinate occurrence of *Ulmus-Zelkova*, *Pinus*, and *Sciadopitys* characterizes the Tk III and IV zones (in the Nyû and Tsurusaki Hills) and as well the YFP 10 zones (in the YF core). In other words, the Tk III and IV zones have the same palynological character as that of the YFP 10 zone. Moreover, the fission track date (0.3~0.4 Ma) (HITAKA, personal communication) of Tpfl, pyroclastic flow deposits intercalated in the Takajô alternation Member, is not contradictory with the age of the YFP 10 zone (about 0.44 Ma). Several lines of accordance lead to the correlation of the Tk III and Tk IV zones with the YFP 10 zone. The common accordances are observed also in Si and To zones (in the Shiihoki-Hibariyama and Tonokôri areas). The Hanakiri tuff contained in the Tôriyamahama Formation in which the Si and To zones are established is dated as 0.48 Ma by the fission track dating method (ENDO and SUZUKI, 1986). This F. T. age is almost equal to the estimated age of YFP 10 zone. Therefore, the Si and To zones are also considered to be correlated with the YFP 10 zone.

The Th I~IV zones (in the Tôrihama area) are stratigraphically comparable with the Tb II~III zones (in the Tôrihama area). Of them, the Th III zone is correlated with the Tb II zone because of their similar palynological character. Both the Th IV and Tb III zones are characterized by the quite similar pollen assemblages featured by a rise of *Picea* and *Fagus* by a few percent and a decrease of *Cyclobalanopsis*. These characters suggest that the Th IV zone is correlated with the Tb III zone. The Tb I zone represents a *Abies-Tsuga* forest, however, the similar pollen assemblage is not seen in the section of the Tôhihama area. And, instead, between the Th II and Th III zones, there intercalated a sandy bed a few meters thick without pollen fossils.

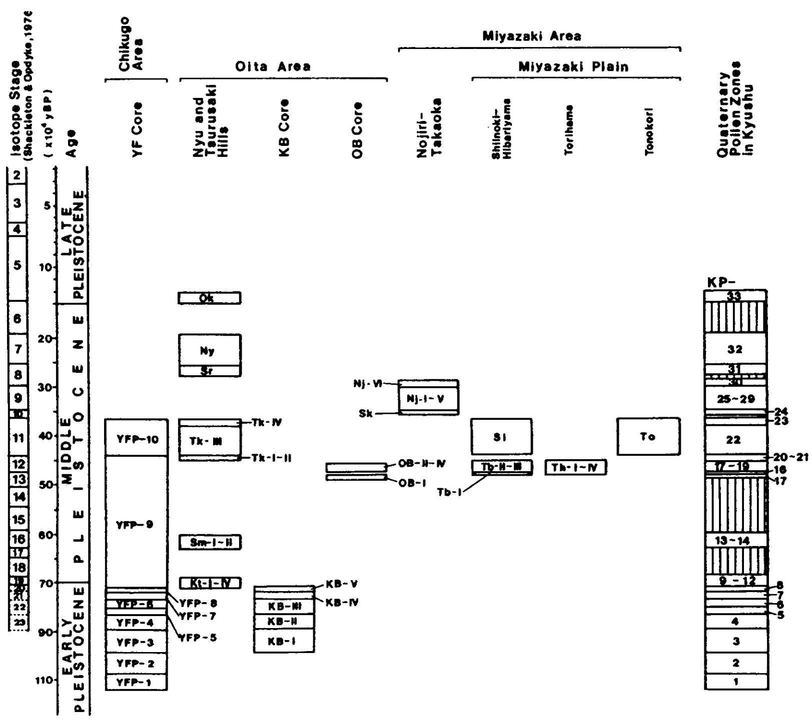


Fig. 32. Correlation of the regional pollen zones and reconstruction of standard pollen zones in Kyushu.

The Tb I zone may be included in this part.

The ON-I Formation in which the OB I to IV zones (in the OB core) are discriminated is composed mainly of alternation of sands and silts and does not contain pyroclastic flow deposts. The sand beds comprise black, medium to coarse grained sands which are characteristic to the Takajô alternation and Shimogôri sand and gravel Members. On the contrary, many pyrocrastic sediments are contained below the Hada pyroclastic rocks in the Nyû and Tsurusaki Hills. The ON-I Formation has a thickness of about 90 m. Taking these data into consideration, the ON-I Formation is presumable to be correlated with the strata between the Tpfl and the Hada pyroclastic rocks.

Conifers such as *Pinus*, *Abies* and *Cryptomeria* are dominant in association with *Fagus* and *Ulmus-Zelkova* accompany them in the OB IV zone (in the OB core) which is established in the upper part of the ON-I Formation. The palynological characters of the Tk I zone (in the Nyû and Tsurusaki hills) are similar to that of the OB IV zone. However, the Tk I zone represents a slightly warmer climate than that of OB IV zone, because the former yields smaller amount of *Picea* than the latter. It is highly probable that the Tk I zone is successively followed by the OB IV zone and represents the phase of increase in temperature after the glacial phase in the OB IV zone.

5-4. Reconstruction of the Generalized Pollen Zones

On the basis of the pollen analyses and the discussions stated in the preceding chapters, 33 Quaternary pollen zones have been established in Kyushu in the time span between 1.2 Ma and 0.12 Ma. Hereafter, they are designated as the KP-1 to KP-33 zones in ascending order. The characteristics of those zones are showen in Table 6 in regard to the pollen assemblage, paleovegetation and paleoclimate. However, these pollen zones do not form a completely continuous spectra and may include some time gaps. Therefore, the 33 pollen zones are not enough to explain the complete pollen sequencies in the Quaternary. Nevetheless, the pollen succession is almost satisfactory in the age between the later half of the Early Pleistocene and the beginning of the Late Pleistocene in Kyushu.

Table 6. The synthesized pollen zones in the Pleistocene in Kyushu and their characteristic pollen records, infered paleovegetation, and paleoclimate.

Synthesized Pollen Zones	Regional Pollen Zones	Characteristic Pollen Records	Vegetation	Climate (S – C – W)
KP- 33	Ok	*Fagus*, *Ulmus-Zelkova*, *Lepidobalanus*	Cool-temperate Forest	●
32	Ny	*Fagus*, *Carpinus*, *Ulmus-Zelkova*	Cool-temperate Forest	●
31	Sr	*Fagus*, *Carpinus*, *Ulmus-Zelkova*	Cool-temperate Forest	●
30	Nj-VI	*Fagus*, *Ulmus-Zelkova*, *Abies*, *Picea*, *Tsuga*	Cool-temperate Forest	●
29	Nj-V	*Fagus*, *Ulmus-Zelkova*	Cool-temperate Forest	●
28	Nj-IV	*Fagus*, *Ulmus-Zelkova*, *Sciadopitys*	Cool-temperate Forest	●
27	Nj-III	*Fagus*, *Ulmus-Zelkova*, *Tsuga*, *Abies*	Cool-temperate Forest	●
26	Nj-II	*Cyclobalanopsis*, *Sciadopitys*	Warm-temperate Forest	●
25	Nj-I	*Castanopsis*, *Cyclobalanopsis*	Warm-temperate Forest	●
24	Sk	*Fagus*, *Ulmus-Zelkova*, *Sciadopitys*	Cool-temperate Forest	●
23	YFP-10 / Tk-IV / St / To	*Fagus*, *Cyclobalanopsis*, *Pinus*, *Tsuga*	Temperate Forest	●
22	YFP-10 / Tk-III / St / To	*Cyclobalanopsis*, *Tsuga*	Temperate Forest	●
21	YFP-9 / Tk-II	*Fagus*, *Abies*, *Tsuga*	Temperate Forest	●
20	YFP-9 / Tk-I	*Fagus*, *Ulmus-Zelkova*, *Tsuga*, *Abies*, *Cryptomeria*	Cool-temperate Forest	●
19	YFP-9 / OB-IV / Tb-III – Tb-II / Th-IV – Th-I	*Abies*, *Picea*, *Tsuga*, *Cryptomeria*, *Fagus*	Pan-mixed Forest	●
18	YFP-9 / OB-III / Tb-III – Tb-II / Th-IV – Th-I	*Fagus*, *Carpinus*, *Lepidobalanus*, *Abies*, *Tsuga*	Cooltemperate Forest	●
17	YFP-9 / OB-II / Tb-III – Tb-II / Th-IV – Th-I	*Abies*, *Picea*, *Tsuga*, *Cryptomeria*, *Fagus*	Pan-mixed Forest	●
16	YFP-9 / Tb-I	*Abies*, *Tsuga*	Temperate Forest	●
15	YFP-9 / OB-I	*Fagus*, *Carpinus*, *Lepidobalanus*, *Ulmus-Zelkova*	Cool-temperate Forest	●
14	YFP-9 / Sm-II	*Fagus*, *Ulmus-Zelkova*, *Pinus*	Cool-temperate Forest	●
13	YFP-9 / Sm-I	*Pinus*, *Abies*, *Picea*, *Tsuga*	Sub-arctic Forest	●
12	YFP-9 / Kt-IV	*Lepidobalanus*, *Ulmus-Zelkova*, *Fagus*, *Carpinus*	Cool-temperate Forest	●
11	YFP-9 / Kt-III	*Ulmus-Zelkova*, *Lepidobalanus*, *Tsuga*	Cool-temperate Forest	●
10	YFP-9 / Kt-II	*Ulmus-Zelkova*, *Abies*, *Picea*, *Tsuga*	Pan-mixed Forest	●
9	YFP-9 / Kt-I	*Abies*, *Picea*	Sub-arctic Forest	●
8	YFP-8 / KB-V	*Fagus*, *Tsuga*, *Ulmus-Zelkova*	Cool-temperate Forest	●
7	YFP-7 / KB-IV	*Cyclobalanopsis*, *Fagus*	Temperate Forest	●
6	YFP-6 / KB-III	*Fagus*, *Tsuga*, *Abies*, *Ulmus-Zelkova*	Cool-temperate Forest	●
5	YFP-5 / KB-III	*Fagus*, *Carpinus*, *Lepidobalanus*, *Ulmus-Zelkova*	Cool-temperate Forest	●
4	YFP-4 / KB-II	Taxodiaceae, *Fagus*, *Ulmus-Zelkova*	Temperate Forest	●
3	YFP-3 / KB-I	*Fagus*, Taxodiaceae, *Ulmus-Zelkova*, *Abies*	Cool-temperate Forest	●
2	YFP-2	*Ulmus-Zelkova*, *Fagus*, Taxodiaceae, *Abies*	Cool-temperate Forest	●
1	YFP-1	Taxodiaceae, *Fagus*, *Ulmus-Zelkova*, *Abies*	Pan-mixed Forest	●

S: Sub-arctic Zone
C: Cool-temperate Zone
W: Warm-temperate Zone

5-5. Comparison of the Generalized Pollen Zones with the Global Climatic Change Curve

The Quaternary cyclic changes are also revealed by the measurments of $\delta^{18}O$ of planktonic foraminifers from some deep sea cores. EMILLIANI (1955) divided $\delta^{18}O$ curve based on the planktonic foraminifers into 14 stages and assinged the warmer stages to odd numbers and the cooler stages to even numbers. These isotopic stages were extended to 17 stages and dated by $^{230}Th/^{231}Pa$ method by EMILLIANI (1964). Further, Shackleton and OPDYKE (1976) extended EMILLIANI's curve (1964) and established 23 isotopic stages reinforced by the paleomagnetic stratigraphy. The $\delta^{18}O$ curve proposed by SHACKLETON and OPDYKE (1976) covers a long period from the Latest Pliocene to the Late Pleistocene and it has been considered to be one of the standard of the $\delta^{18}O$ succession which reflect the global climatic change.

In this section the author will attempt to compare the regional pollen zones establised in the preceding sections with the isotopic stages after 0.9 Ma (SHACKLETON and OPDYKE, 1976), taking the absolute ages and the climate estimated by the pollen assemblages into consideration. By this comparison the chronologic assignment of the pollen sequence will be expected to be more accurate. The climatic changes read from the $\delta^{18}O$ curve is globaly appricable, however, they show merely the relative climatic change. In other words, $\delta^{18}O$ curves can not serve for specifying the climate and vegetation prevailed in each stage. Relative climatic changes must be linked with definite climate and vegetation by the correlation above mentioned.

Age of the KP-4 zone is considered about 0.8 Ma based on the correlation with the Senshu Group. The KP-4 zone represents an interglacial phase with the time span of about 10×10^4 years by extrapolation from the age of the YFP 7 zone. These conditions are satisfied by the isotopic stage 23 on the $\delta^{18}O$ curve and, in consequence, the KP 4 zone is correlated with the isotopic stage 23.

Age of the KP-7 zone is estimated about 0.75 Ma also according to the correlation with the Senshu and Ôsaka Groups. The pollen assemblage of the KP-7 zone suggests an interglacial phase with and intermediate climate between the warm and cool temperate zones. The isotopic stage 21 satisfies these conditions. That leads to the correlation of the KP-7 zone with the isotopic stage 21.

The KP 5 and 6 zones are suggested to represent a relatively warm glacial period by their pollen assemblages consisting mainly of deciduous taxa. And the KP-4 zone is compared with the isotopic stage 23 and the KP-7 zone with the isotopic stage 21. Therefore, the KP-5 and 6 zones are comparable with the isotopic stage 22.

The KP-22 zone is referred to about 0.44 Ma and represents an interglacial phase as mentioned before. These suggest that this pollen zone is compared with isotopic stage 11. The climate of the Kp-20 and 21 zones is suggested to be an intermediate condition between the warm and the cool temperate zones and has the warming trend upward. Therefore, these zones are the transitional phase to KP-22 zone which represent an interglacial phase. The KP-20 and 21 zones are considered to be compared with the transitional part between the isotopic stage 12 and 11, because the KP-22 zone is correlative with isotopic stage 11.

The KP-17 and 18 zones represent a gradually warming climate from the upper to the middle part of the cool temperate zone. Thereafter, the climate becomes cooler to be nearly subarctic. That is to say, the KP-16~19 zones represent a glacial phase with an interstadial. Because the KP-22 zone is comparable with the isotopic stage 11, the KP-16~19 zones must correspond with the isotopic stage 12 which indicates an intensive cold period.

The pollen seemblage of the KP-24~30 zones suggest a cycle of climatic change with minor fluctuations as mentioned before. And, the time span of this climatic cycle is estimated to cover the time between 0.5 Ma and 0.3 Ma by fission track dating method. Therefore, this cycle of climatic change may be comparable with either of the cycles in the isotopic stage 10 to 8 or 12 to 10. The transitional pattern of the climate in the KP-24~30 zones is, however, very similar to that of the isotopic stages 10 to 8. Accordingly the KP-24 to 30 zones are regarded as equivalent to the isotopic stage 10 to 8; further in detail, the KP-24, KP-25 to 29 and KP-30 zones are respectively compared with the isotopic stage 10, 9 and 8.

The KP-32 zone represents an interglacial phase. Another interglacial phase immediately above this one is observed in the KP-33 zone, and is compared with the Last Interglacial as mentioned after wards. Therefore the KP-32 zone is assinged to the Mindel/Riss interglacial period. This assignment leads to the correlation of the KP-32 zone with the isotopic stage 7. The KP-31 zone represents a phase of increasing temperature, which is prior to the warm period of the KP-32 zone. Therefore the KP-31 zone is compared with the upper part of the isotopic stage 8.

The Oka mud Member contains sea shells and is considered to be marine in origin. The KP-33 zone established in the Oka mud Member represents a relatively warm period and corresponds with Riss/Würm interglacial period. Therefore the KP-33 zone is comparable with the isotopic stage 5.

According to the stratigraphic inspection, the KP-9 to 12 zones together are considered to represent a transitional phase which follows the interglacial phase of the KP-7 zone, which is compared with the isotopic stage 21. Therefore, the KP-9 to 12 zones are comparable with the isotopic stage 20 and 19.

The pollen assemblages suggest that the KP-13 and 14 zones represent a glacial and a warming transitional phases. Some sedimentary cycles are observed in the Maki sand and gravel and Shimôgori alternation Members. The KP-13 and 14 zones are established in a sandy part of the lower part of the latter member. The Tk III zone (in the Takajô alternation Member) equivalent to the KP-22 zone correspond to the isotopic stage 11 as mentioned before. Therefore, gravelly part in the upper, muddy part in the middle, and gravelly part in the lower parts of the Maki sand and gravel Member are considered to be respectively comparable with the isotopic stage 12, 13, and 14. The upper and lower parts of the Shimogôri alternation Member are respectively compared with the isotopic stage 15 and 16. The KP-13 and 14 zones are established in the sandy part in the lower part of the Shimogôri alternation Member. An ash layer in this member has been dated as 0.6±0.23 Ma by fission track dating method (TAKEMURA *et al.*, 1988). Consequently, the KP-13 and 14 zones are compared with the isotopic stage 16.

5-6. Comparison with Other Areas

In this chapter, the pollen zones described in the previous chapters will be compared with the pollen records from other areas. Subsequently, certain aspects of the Quaternary pollen sequence in Kyushu will also be referred to.

HASE and IWAUCHI (1988) examined both the pollen records and mega plant fossils from the Asono Formation in the Asono area, and the Hôsenji and Nogami Formations in the Kusu basin. They proposed the H I to V zones in the Lower Pleistocene Hôsenji Formation, the N I to VII zones in the Middle Pleistocene Nogami Formation, and the A I to VI zones in the Middle Pleistocene Asono Formation. From their study, Taxodiaceae suddenly decreases in the H II zone, and thereafter, the climate moves to a cold period in the H III and IV zones and it is improved in the H V zone (HASE and IWAUCHI, 1988). The Kawauchi pyroxine andesite included in the Hosenji Formation is dated as 0.7±0.2 Ma and 0.81±0.30 Ma by fission track dating method (HASE and IWAUCHI, 1988). Such climatic change in 0.7 to 0.8 Ma seen in the H I to V zones are comparable with that in the KP-4 to 6 zones.

Some fission track dates indicate that the N I to VII zones in the Nogami Formation and the A I to VI zones in the Asono Formation are considered to be involved in a time span between 0.5±0.3 Ma and 0.34±0.17 Ma, and the A I to VI zones and the N I to VII zones are correlated as a whole (HASE and IWAUCHI, 1988). The similar situation of the coexistence of *Fagus* and *Cyclobalanopsis* in the N II and KP-22 zones suggests that they are correlative to each other. The N I zone represents a cold period prior to the N II zone, therefore, the N I zone is compared with the KP-20 to 21 zones. The N I to VII zones and the A I to VI zones involved three cycle of climatic changes and the N II zone reveals the warmest period among the three. The next warm period, in the KP-25~29 zones, is considered to be warmer than that of the KP-22 zone. These suggest that the N I to VII zones and the A I to VI zones situate below the KP-25 zone in their horizon and are compared with KP-20 to 24 zones. While, precise correlation is not clear other than two zones above mentioned.

The pollen sequence mainly reflects the cyclic climatic change of relatively short wave length, probably dozones of thousands years. The pollen zones dealt in this study and those in HASE and IWAUCHI (1988) are established on the basis of this type of pollen succession. On the other hand, transition of pollen assemblage in a relatively long term, some hundreds of thousands years, have been simultaneously observed. Hereafter, this type of change is designated the long term transition.

TAI (1966) described the long term transition of the Quaternary pollen assemblages in the Ôsaka Group. She divided the Quaternary pollen assemblages into two groups and designated them, the *Metasequoia* and *Fagus* zones in ascending order according to their dominant taxon. Further, NASU (1970) subdivided her *Fagus* zone into the lower part, the *Fagus* zone, and the upper part, the Pinaceae zone. And he established the Pinaceae-*Tsuga* zone as a transitional zone between them. In the Quaternary of the Kantô area, *Fagus* is dominant between the Naganuma and Sannôdai loam Formations, and is replaced by Pinaceae above the Sannôdai loam Formation (NISHIMURA, 1980). Consequently, the long term transition in the pollen assemblage in the Kantô and Kansai areas is summarized as follows; the dominant taxa were *Metasequoia* in the lower, *Fagus* in the middle and Pinaceae in the upper parts. Comparing this pollen succession with that recognized in Kyushu (Fig. 33), the *Metasequoia* zone (TAI, 1966) is compared with the KP-1 to 4 zones because Taxodiaceae is dominant in these zones. However, Pinaceae is predominant in the zones between the KP-5 and KP-19 zones, and *Fagus* becomes prominent to take

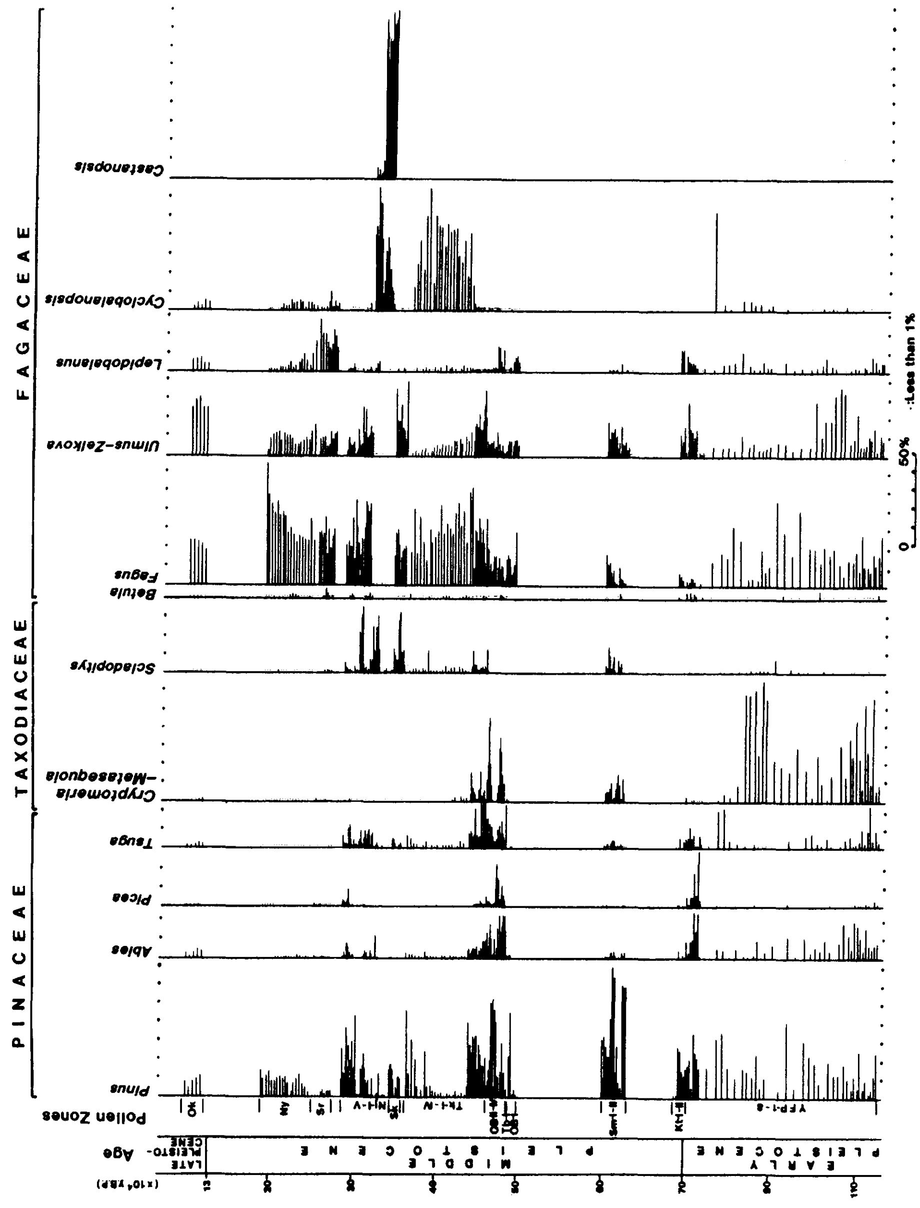


Fig. 33. Schematic pollen diagram which shows the pollen succession in the Quaternary age in Kyushu.

place of Pinaceae above the KP-19 zone. That is to say, the long term transition in pollen assemblages in the Quaternary of Kyushu is different from that in the Kantô and the Kansai areas.

HASE and HATANAKA (1984) examined the pollen records from the Upper Pliocene and Plleistocene in the Southern Kyushu. On that occasion, they discriminated 5 pollen zones; these were the *Metasequoia* zone in the Nagano Formation, the *Fagus* zone in the Yamanokuchi, Kajiki and Kokubu Formations, the *Cryptomeria-Sciadopitys-Alnus* zone in the Ikemure and the Hieda Formations, *Cryptomeria* zone

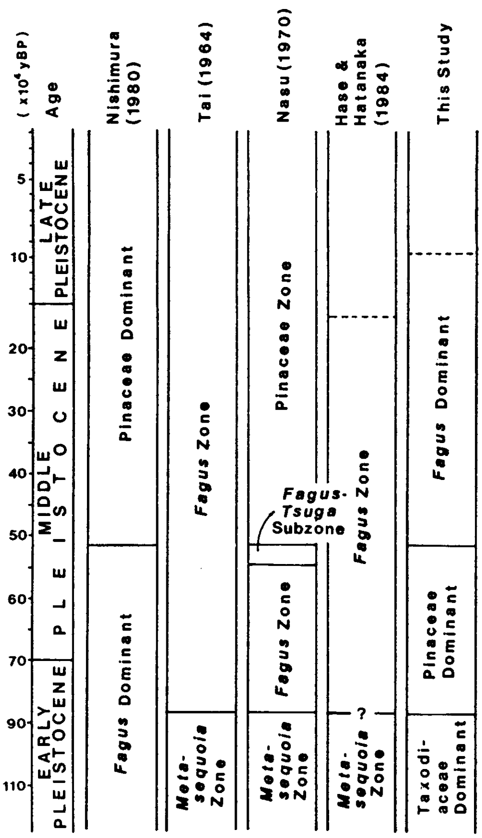


Fig. 34. Comparison of long term transitions of pollen assemblages.

in the Shinkai Formation, and the Pinaceae zone in the Mizozono and Sand and Gravel Formations. Among them, the *Metasequoia* zone (HASE and HATANAKA, 1984) is correlated with the KP-1 to 4 and *Metasequoia* zones (TAI, 1966) in the Ôsaka Group because they are all characterized by the dominant of Taxodiaceae. The fission track dates of the pyroclastic flow deposits in the Kajiki and Kokubu Formations in which the *Fagus* zone (HASE and HATANAKA, 1984) is recognized are 0.77±0.16 Ma and 0.63±0.20 Ma. Therefore, the *Fagus* zone is comparable with either of pollen zone between the KP-9 and KP-14 zones. The pollen spectra of the *Fagus* zone (HASE and HATANAKA, 1984), however, reveal far more Pinaceae than *Fagus* and this feature is also recognized in zones between KP-9 and KP-14 zones.

Thus, in the Quaternary pollen sequence in Kyushu, *Metasequoia* (Taxodiaceae) was dominant from the Latest Poilocene and later, and was replaced by Pinaceae at an age of about 0.8 Ma. And then *Fagus* became prominent at about 0.45 Ma and the situation continued at least until the beginning of the Late Pleistocene (Fig. 34).

6. Conclusion

Based on the careful examination of the litho stratigraphy and the pollen records from the Quaternary strata of the Chikugo, Ôita and Miyazaki area, the following conclusions are reached.

1) Thirty three pollen zones are recognized in the time span between 1.2 Ma and 0.1 Ma in Kyushu based on the synthetic correlation of the pollen sequence from the Quaternary strata distributed in the three areas in Kyushu (Fig. 32).

2) The long term transition confirmed in the pollen sequence in Kyushu is different from those in the Kantô and Kansai areas in the stratigraphic position of the *Fagus* zone. The long term transition in pollen assemblages in Kyushu is summarized as follows; Taxodiaceae was dominant from the Latest Pliocene to about 0.8 Ma. Pinaceae became dominant since about 0.8 Ma, and was replaced by *Fagus* at about 0.45 Ma. And *Fagus* continued to be prominent at least until the beginning of the Late Pleistocene.

3) The paleovegetation and paleoclimate are estimated from the pollen records. The results are summarized in the Table 6.

4) The extirpation of *Liquidambar* in Kyushu is considered to take place in the Würm Glacial Period.

5) The singular dominance of *Alnus* and fern spores is suggested to be caused by the destruction of the vegetation by volcanic activity.

References

ARAMAKI, S. (1969): Geology and Pyroclastic flow deposts of the Kakuto area, Kagoshima Prefecture. *Jour. Geol. Soc. Japan*, **75**, 425–442.

ARIAKE BAY RESEARCH GROUP(1965): Quaternary system of the Ariake and the Shiranui bay area, with special references to the Ariake soft clay. *Monograph* 11, Association for the Geological collaboration in Japan, 86 p.

EMILLIANI, C. (1955): Pleistocene temperatures. *Jour. Geol.*, **63**, 538–578.

——— (1964): Paleotemperature analysis of the Caribbean cores A 254-BR-C and CP-28. *Geol. Soc. Amer. Bull.*, **75**, 129–143.

ENDO, H. and SUZUKI, Y. (1986): Geology of the Tsuma and Takanabe district. *Quadrangle Series Scale 1:50,000 Kagoshima (15)* No. 68 and 69, Geological survery of Japan. 99p.

ENDO, H. (1958): On the terrace deposits in Nishimorogata gun Miyazaki Prefecture, Japan. *Mem. Fac. Liberal Arts & Educ. Miyazaki Univ.*, (4), 17–21.

——— (1963): Stratigraphical study on volcanic ash deposits covering the surface of terraces developed in the central part of Miyazaki prefecture, Kyushu, Japan. *Mem. Fac. Liberal Arts & Educ. Miyazaki Univ.*, (15–16), 29–52.

——— (1968): Geological study of the Miyazaki coastal plain, southeastern Kyushu, Japan. *Mem. Fac. Liberal Arts & Educ. Miyazaki Univ.*, (24), 17–64.

——— (1981): Relation between Kakuto pyroclastic flow deposits and geomorphic surfaces in southern Kyushu. *Mem. Fac. Educ. Nat. Sci.*, (49), 1–16.

FURUTANI, M. (1984): Pollen stratigraphy of the submarine strata at the Kansai international airport in Osaka bay. *Geological survey of the submarine strata at the Kansai international airport in Osaka bay, central Japan, Report of the calamity science instutute*, 91–116.

GARTNER, S. (1973): Absolute chronology of the late Neogene calcareous nannofossil succession in the equatorial Pacific. *Geol. Soc. Amer. Bull.*, **84**, 2021–2034.

HASE, Y. and HATANAKA K. (1984): Pollen stratigraphic study of the late Cenozoic sediments in southern Kyushu, Japan. *The Quat. Res.*, **23**, 1–20.

——— and IWAUCHI, A. (1985): Late Cenozoic vegetation and paleoenvironment of northern and central Kyushu, Japan. —Part 1. Asono area—. *Jour. Geol. Soc. Japan*, **91**, 753–770.

HATANAKA, K. (1985): Palynological study on the vegetational succession since the Würm

glacial age in Kyushu and adjacent areas. *Jour. Fac. Lit. Kitakyushu Univ. (Ser. B)*, **18**, 29–71.
HAYASHI, M. (1982): Statistical tests of the fission track dating by the grain by grain method. *Jour. Geol. Soc. Japan*, **88**, 691–197.
ISEKI, H. (1983): Alluvial plain. 145p., Tokyo university press, Tokyo.
ISHIDA, S. (1970): The Osaka Group —The cyclic sediments of lacustrine and bay in Plio-Pleistocene Japan—. *The Quat. Res.*, **9**, 101–112.
IWAUCHI, A. and HASE, Y. (1986): Late Cenozoic vegetation and paleoenvironment of northern and central Kyushu, Japan —Part 2. Ajimu-Innai area (upper Pliocene)— *Jour. Geol. Soc. Japan*, **92**, 591–598.
——— and ——— (1987): Late Cenozoic vegetation and paleoenvironment of northern and central Kyushu, Japan —Part 3. Southern part of Kusu basin. (lower and middle Pleistocene)— *Jour. Geol. Soc. Japan.* **93**, 469–489.
JIMBO, T. (1932): Pollen analytical studies of peat formed on volcanic ash. *Sci. Rep. Tohoku Imp. Univ. 4th ser. (Biol.)*, **7**, 129–132.
KINO, Y. and OTA, R. (1976): Geology of the Nojiri district. *Quadragle Series Scale 1:50,000 Kagoshima (15)* No. 75, Geological Survey of Japan, 45p.
MIYACHI, M. (1978): Pyroclastic flow deposits in the Hitoyoshi basin area, Kumamoto Prefecture, Japan. *Rep. Earth Sci. Dep. Gen. Educ. Kyushu Univ.*, (20), 9–17.
MIYOSHI, N. (1981): Pollen morphology of *Castanopsis*, *Pasania* and *Castanea* (Fagaceae). *Hikobia Suppl.*, **1**, 381–386.
——— (1982): Pollen morphology by means of scanning electron microscope. 4. Fagaceae (Angiospermae). *Bull. Hiruzen Res. Insti. Okayama University of Science*, (7), 55–60.
——— (1983): Pollen morphology of the genus *Castanopsis* (Fagaceae) in Japan. *Grana*, 22, 19–21.
NAGAOKA, N. (1986): The landform evolution of late Pleistocene in the Miyazaki plain south Kyushu, Japan. *The Qurt. Res.*, **25**, 139–163.
NAKAMURA, J. (1952): A comparative study of Japanese pollen records. *Res. Rep. Kochi Univ.*, **1**, 1–29.
——— (1967): Pollen analysis (Kafunbunseki). 232p., Kokin-shoin, Tokyo.
——— (1968): Palynological aspects of the Quaternary in Hokkaido, V. —Pollen succession and climatic change since the upper Pleistocene—. *Res. Rep. Tohoku Univ.*, **17**, 39–51.
——— (1975a): History of the Quaternary vegetation in Japan. *JIBP SYNTHESIS 1975 TOKYO*, **8**, 12–16.
——— (1975b): Changes in vegetation induced by human impact. *JIBP SYNTHESIS 1975 TOKYO*, **8**, 127–130.
———, KURODA, T. and MITSUHIO (1974): Sedimentological palynology, part 1. —Subsurface sediments from the western sea area off Kyushu and Shikoku—. *Bull. Geol. Surv. Japan*, **25**, 209–221.
NASU, T. (1970): Palynological study on the upper Osaka Group in Kinki district, Japan. *Earth Science*, **24**, 25–34.
——— (1980): Flora of Japanese middle Pleistocene. *The Quat. Res.*, **19**, 217–114.
NARUSE, Y. (1966): The Quaternary tephras to the east of Kirishima volcano. *Misc. Rep. Res. Inst. Natur. Resources*, (66), 15–33.
NISHIMURA S. (1980): The transition of pollen assemblage in the middle and upper Pleistocene sediments in Yokohama city, south Kanto, Japan. *Jour. Geol. Soc. Japan*, **86**, 275–291.
NISHIMURA, S. and SASAJIMA, S. (1970): Fission-track age of volcanic ash-layers of Plio-Pleistocene series in Kinki district, Japan. *Earth Science*, **24** 222–224.
NOI, H. (1985): Pollen stratigraphy of the Pleistocene series in Oita city, central Kyushu, Japan. *Sci. Rep. Dept. Geol., Kyushu Univ.*, **14**, 129–142.
——— (1988): Stratigraphy and pollen analysis of the middle Pleistocene series in the Nojiri-Takaoka area, Miyazaki prefecure, Japan. *Jour. Geol. Soc. Japan*, **93**, 897–907.
OKAGUCHI, M. (1976): Revision of the geolgoy of the Tsurusaki hills, Oita prefecure, Kyushu. —Fission track age determination of accesory zircon from pyroclastic rocks—. *The Quat. Res.*, **15**, 97–108.

OKAMURA, M. and YAMAUCHI, M. (1984): Detailed survery on nannofossils at the Kansai international airport in Osaka bay, central Japan. *Geological survery of the submarine strata at the Kansai international airport in Osaka bay, central Japan. Report of the calamity science institute*, 19–28.
ONISHI, I. (1965): Pollen analysis of the Sekinan and the Oita Groups in Oita city, central Kyushu. *The Quat. Res.*, **4**, 208–216.
——— (1978): Pliocene and Pleistocene pollen stratigraphy in central and southeastern Japan. *Mem. Fac. Sci. Kyoto Univ. Ser. Geol. & Mineral.*, **XLX**, 1–54.
ÔTUKA, Y. (1930): Some geological problem in the southeastern coast of Kyushu. *Geogr. Rev. Japan*, **6**, 496–522.
SHACKLETON, N. J. and OPDYKE, N. D. (1973): Oxygen isotope and paleomagnetic stratigraphy of equatorial Pacific core V 28–238: oxygen isotope temperature and ice volume on a 10^5 year and 10^6 year scale. *Quat. Res.*, **3**, 39–55.
——— and ——— (1976): Oxygen-isotope and paleomagnetic stratigraphy of Pacific core V 28–239, late Pleistocene to latest Pleistocene. *Geol. Soc. Amer. Mem.*, **145**, 449–464.
SOHMA, K. (1976): The present situation and problems on land paleoecology; C. Paleoclimate. *Land paleoecology—Monograph on paleoecology I—*, 63–80, Kyoritsushuppan, Tokyo.
SHUTO, T. (1953): Younger Cenozoic history of Oita district, Kyushu. *Jour. Geol. Soc. Japan*, **59**, 225–240, 372–384.
——— (1962): A revision of the Pleistocene stratigraphy in Kyushu —For the basis of interprovincial correlation— (Note on the Pleistocene history in Kyushu island II), *Jour. Geol. Soc. Japan*, **68**, 301–312.
———, ONISHI, I. and HITAKA, M. (1966): Quaternary geology of the Nyu hills, Oita prefecture, Kyushu, with special reference to the palaeolithic remains. *Mem. Fac. Sci. Kyushu Univ. Ser. K Geol.*, **XVII**, 331–346.
———, HITAKA, M. (1971): The alluvium at the Oita district, with special reference to the origin of Beppu bay. *Sci. Repts. Dept. Geol. Kyushu Univ.*, **11**, 87–104.
SUGITANI, T. (1983): Geomorphological development of the north Ariake bay lowland, Kyushu, since the last-interglacial epoch: Aquantiative study. *Geogr. Rev. Japan*, **56**, 403–419.
TAGAWA, H. (1964): A study of the volcanic vegetation in Sakurajima, south-west Japan. I. Dynamics of vegetation. *Mem. Fac. Sci. Kyushu Univ. Ser. E. (Biology)*, **3**, 165–228.
TAI, A. (1966): Pollen analysis of the core (OD-1) in Osaka city —The research of younger Cenozoic strata in Kinki province, V—. *Earth Science*, (83), 25–33, (84), 31–38.
TAKAHASHI, K., KAWASAKI, S. and FURUKAWA, H. (1968): Quaternary system under the bottom of the Ariake sea and Palynology. *Bull. Fac. Liberal Arts, Ngasaki Univ. Nat. Sci.*, **9**, 33–43.
———, ——— and ——— (1969): Palynological study of the Quaternary formations of the Ariake sea area. *Bull. Fac. Liberal Arts., Nagasaki Univ. Nat. Sci.*, **10**, 49–66.
TAKEMURA, K., DANBARA, T. and HORIE, S. (1988): Fission-track dating of the Oita Group, central Kyushu. *Abstracts*, The 95th Annual Meeting of the Geological Society of Japan.
TSUJI, S., MINAKI, M. and SUZUKI, M. (1984): Plant fossil assemblage of the last Pleistocene at Ninomiya cho, southern Tochigi prefecture, central Japan. *The Quat. Res.*, **23**, 21–29.
TSUKADA, M. (1963): Umbella Pine, *Sciadopitys verticillata*, -Post and present distribution in Japan—. *Science*, **142**, 1680–1681.
——— (1967): The last 12,000 years: A vegetation history of Japan. *Bot. Mag.*, **80**, 323–336.
——— (1974): Paleoecology II, Synthesis. 231p. Kyoritsu-shuppan, Tokyo.
YOSHINO, M., SAKAI, J. and NISHIMURA, S. (1980): Pollen fossils in boring cores from Saya and Tsushima in the Nobi plain, central Japan. *The Quat. Res.*, **19**, 163–171.
YOSHIOKA, H. (1954): Sociological studies of the forests in the Tohoku district 4, forest communities in the northern limits of *Shiia sieboldii*. *Bull. Soc. Ecol.*, **3**, 219–229.
——— (1956): Sociological studies of the forests in the Tohoku district (5) Forest communities in the northern limits of the forests of the evergreen oaks. *Sci. Repts. Art & Sci. Fukushima Univ.*, (5), 13–23.

Explanation of Plate 3

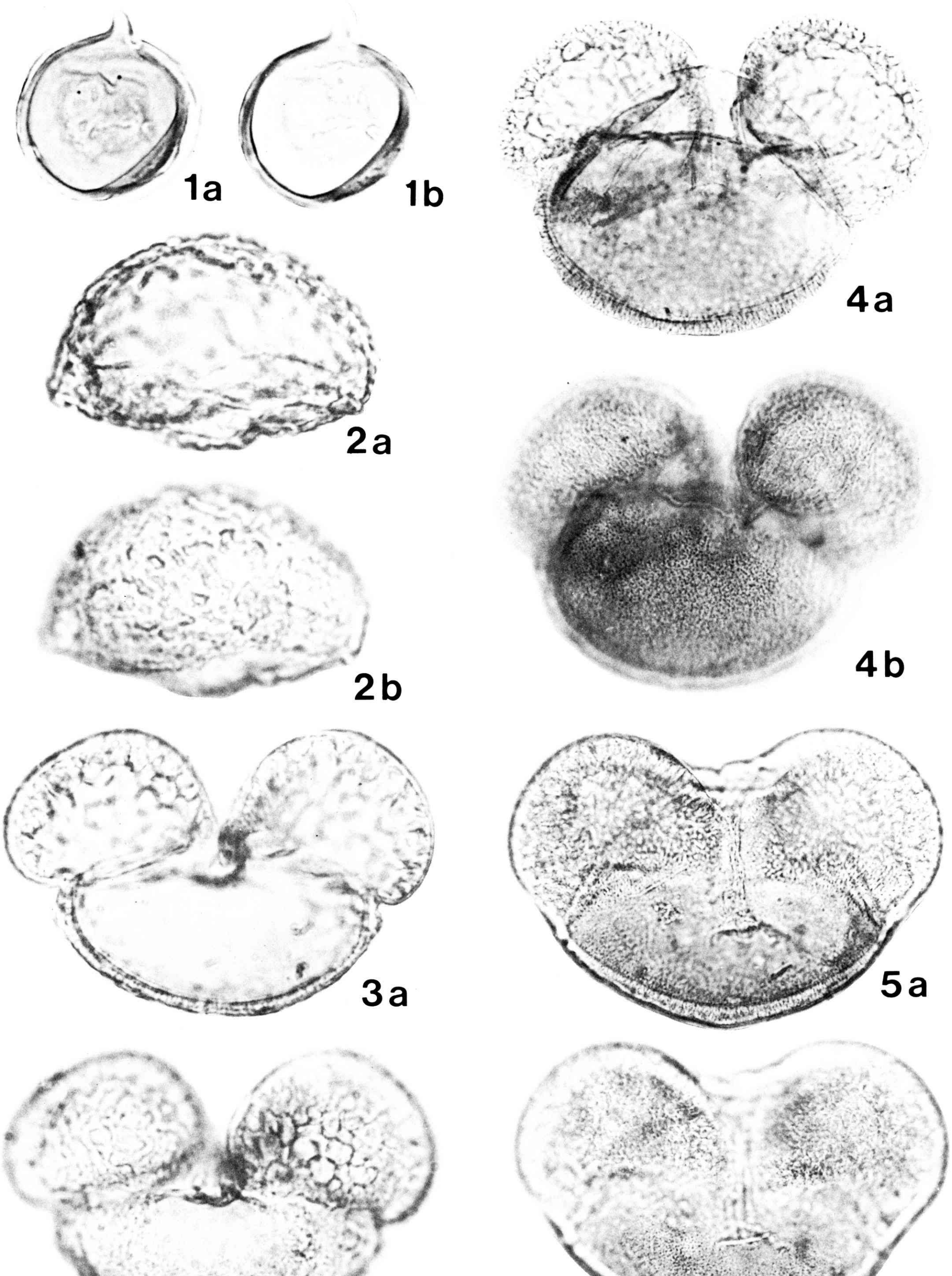
1.	Taxodiaceae	YF-26	X700
2.	*Sciadopitys*	Iz-17	—
3.	*Pinus*	Iz-20	—
4.	*Abies*	OB-24	X350
5.	*Picea*	Iz-42	—

Explanation of Plate 4

1.	*Tsuga*	YF-20	X350
2.	*Myrica*	YF-18	X700
3.	*Pterocarya*	YF-33	—
4.	*Betula*	Iz-20	—
5.	*Alnus*	YF-18	—
6.	*Castanopsis*	Iz-20	—
7.	*Cyclobalanopsis*	Iz-20	—
8.	*Lepidobalanus*	Iz-24	—
9.	*Ulmus-Zelkova*	YF-41	—
10.	*Celtis-Aphananthe*	Ia-20	—
11.	*Fagus*	YF-35	—
12.	*Carpinus*	YF-41	—

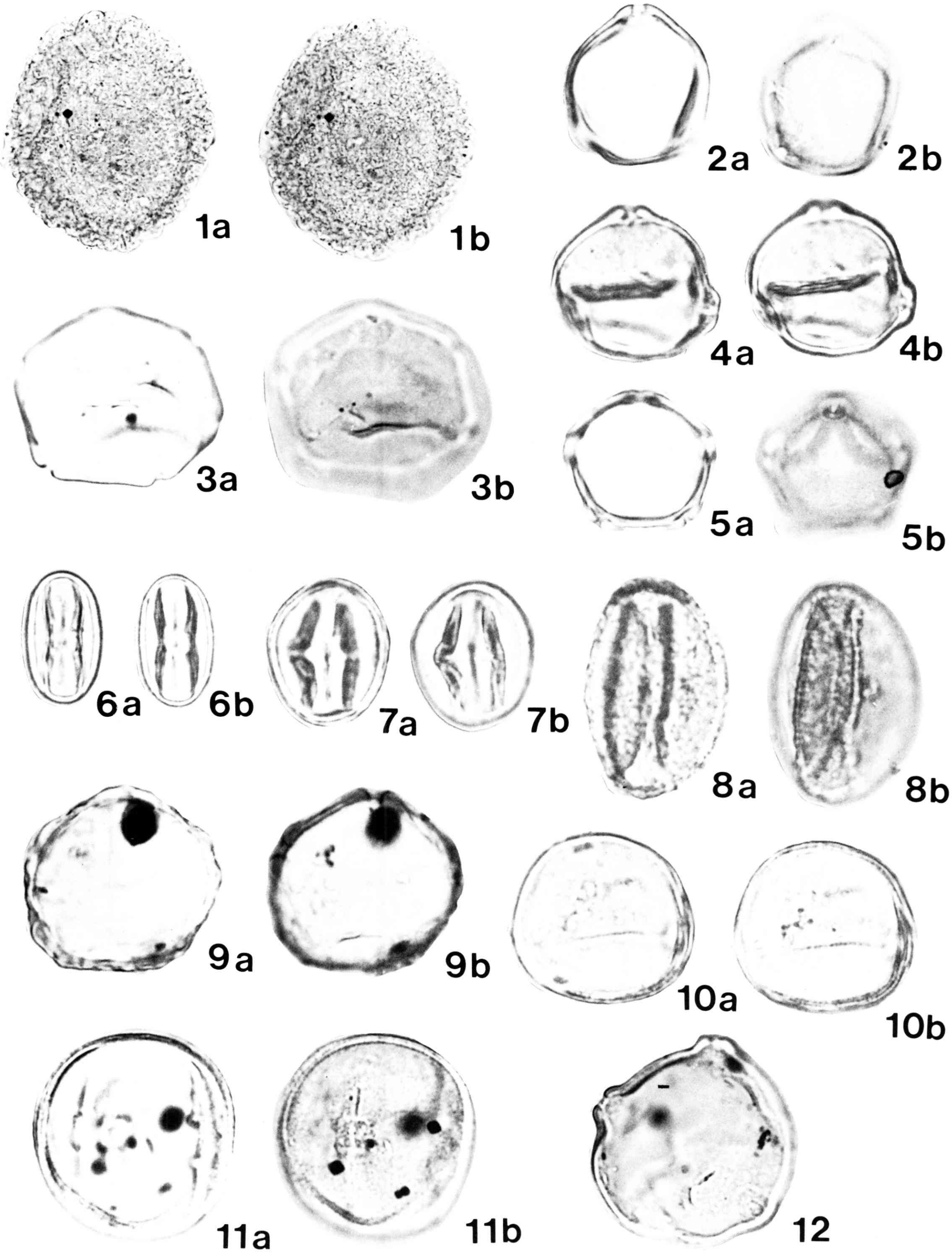
Explanation of Plate 5

1.	*Lagerostroemia*	YF-41	X700
2.	*Liquidambar*	YF-41	—
3.	*Tilia*	Iz-24	—
4.	*Ilex*	Iz-39	—
5.	*Buxus*	YF-26	—
6.	Gramineae	YF-26	—
7.	Cyperaceae	Iz-24	—
8.	*Elaeagnus*	Iz-42	—
9.	*Artemisia*	Kmy-3	—
10.	Caryophyllaceae	OB-12	—
11.	Compositae	OB-12	—
12.	*Persicaria*	OB-12	—



H. NOI: Palynological Study of the Quaternary in Kyushu

Plate 4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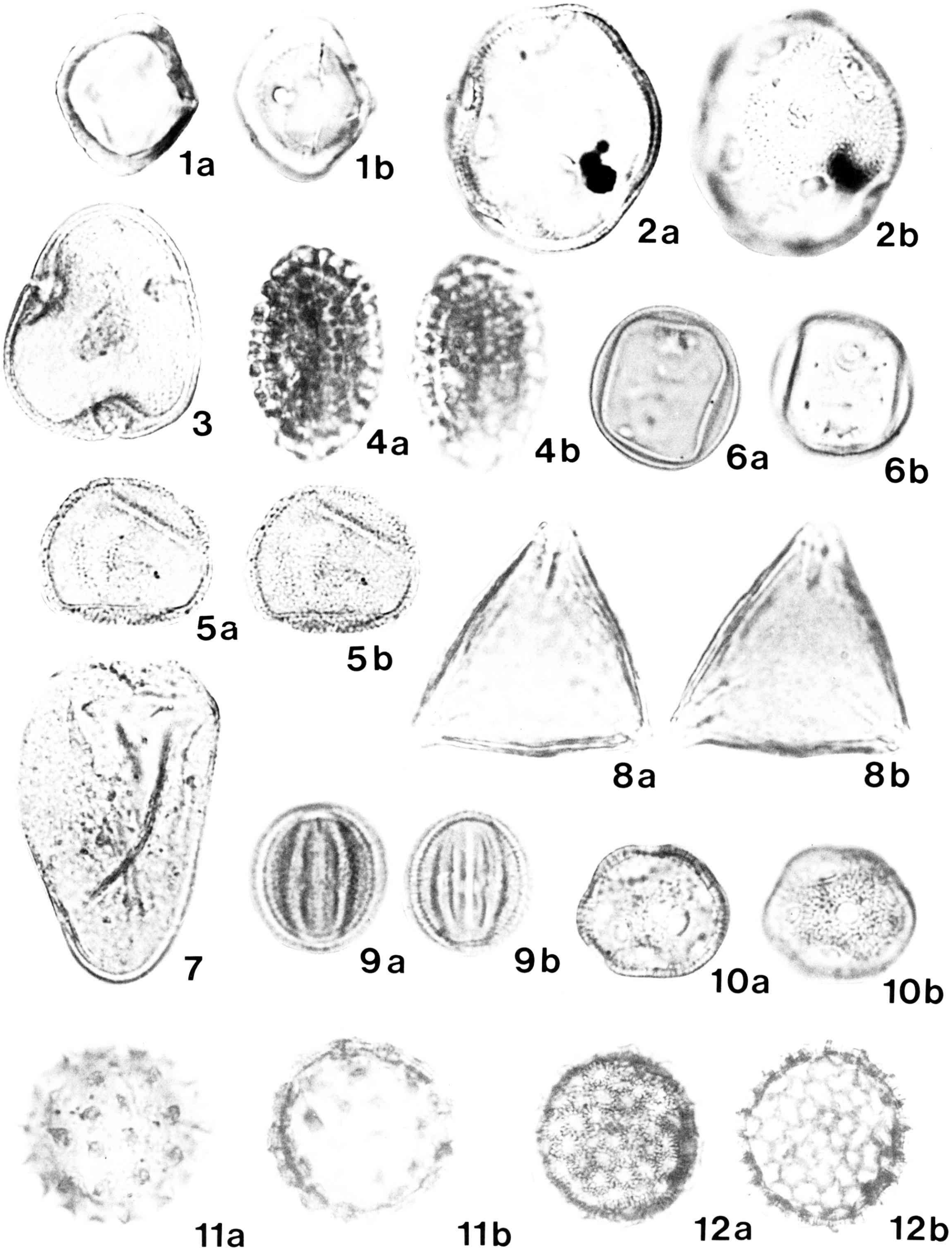

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