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595. FOSSIL SPORES AND POLLEN GRAINS FROM THE NEOGENE DEPOSITS IN NOTO PENINSULA, CENTRAL JAPAN—IV

A PALYNOLOGICAL STUDY OF THE LATE MIOCENE TSUKADA MEMBER*

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能登半島新第三系産化石胞子・花粉—IV；中新世後期塚田層の花粉学的研究： 能登半島に広く分布する新第三系に関する花粉学的研究のうち，今回は，その第IV報として，能登半島北端の輪島市に発達する中新世後期の塚田含珪藻泥岩層についての花粉学的研究の結果を報告する。

塚田層は輪島市の一本松公園付近と宅田付近に，局部的に発達する含珪藻泥岩を主体とする累層である。本層は硬質頁岩の薄層によって，上部層と下部層とに2分される。上部層は泥岩よりなり，下部層は砂岩薄層を夾在する泥岩よりなっている。

塚田層の13層準からの16試料と，他に，参考までに洪積世後期の稲舟段丘堆積物からの1試料，中新世中期の地層からの2試料（粟蔵層—1試料，縄又層—1試料）について分析し，各層準毎の化石群集の構成・変化の内容を明らかにし，これらの分析結果に基づいて，塚田層堆積時の古気候・古地理的条件・地質時代について考察した。

(1) 塚田層堆積時の古地理的条件： 本層からの花粉の構成は，upland 系の植物をいくらか含んではいるが，mixed-slope・riparian 要素を主体とする。本層に含まれている化石珪藻の構成内容や岩相などからの資料をも併せて判断すると，本層の堆積盆地は，入口の広い入江が直接外海に面しており，その入江の奥の，出入りの多い水域であった，と推定される。本層と同時代といわれる能登半島中央部の和倉層・聖川層からの花粉構成は，寒冷系の要素が塚田層のそれの1/2〜1/3である。このことは，和倉層・聖川層の堆積域が半島中央部の，入江や湾奥で，北方からの風や海流の影響を直接うけないような環境であったのに対して，塚田層の堆積域では，比較的直接うけるような環境下であった，と推定される。

(2) 塚田層堆積時の古気候： 温暖系の植物の花粉の頻度は10%で，和倉層の30%や台島期の砂子坂層・山戸田層のそれらが50〜60%であるのに比較すると，かなり低率である。本層の主体をなすのは温帯系の要素で，60〜70%を占めている。本層の下部と上部とを比較すると，下部に，温暖系要素が多い。本層では，寒冷・冷涼系要素は，温暖系要素に対してよりも，むしろ温帯系要素と正の相関々係を示す。

塚田層と同時代といわれる和倉層・聖川層の花粉構成に比較すると，細かな点では違いがあるが，大局的には同じである，と判断され，塚田層堆積当時の古気候は，現在の北陸地区の気候に殆んど同じか，若干冷涼か位であろう。

(3) 塚田層の地質時代： 本層からの花粉群集は，大局的には中新世後期の和倉層・聖川層，鮮新世前期の荻の谷層の花粉群集に酷似し，本層の地質時代もこれらの地層の時代に対比されよう。

藤　則雄

Introduction

Diatomaceous deposits occur at different stratigraphical horizons in the Neogene system of the Noto Peninsula, Ishikawa Prefecture, Central Japan. These diatomaceous deposits are classified into four horizons which range in age from the Middle to Late Miocene. The writer has been studying the fossil pollen grains and spores found from these diatomaceous deposits, and a part of the

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results appeared concerning the Late Miocece Wakura diatomaceous mudstone Member (the first report; FUJI, 1969a), the Middle Yamatoda diatomaceous mudstone Member (the second report; FUJI, 1969b), and the Late Miocene Hijirikawa diatomaceous mudstone Member (the third report; FUJI, 1970).

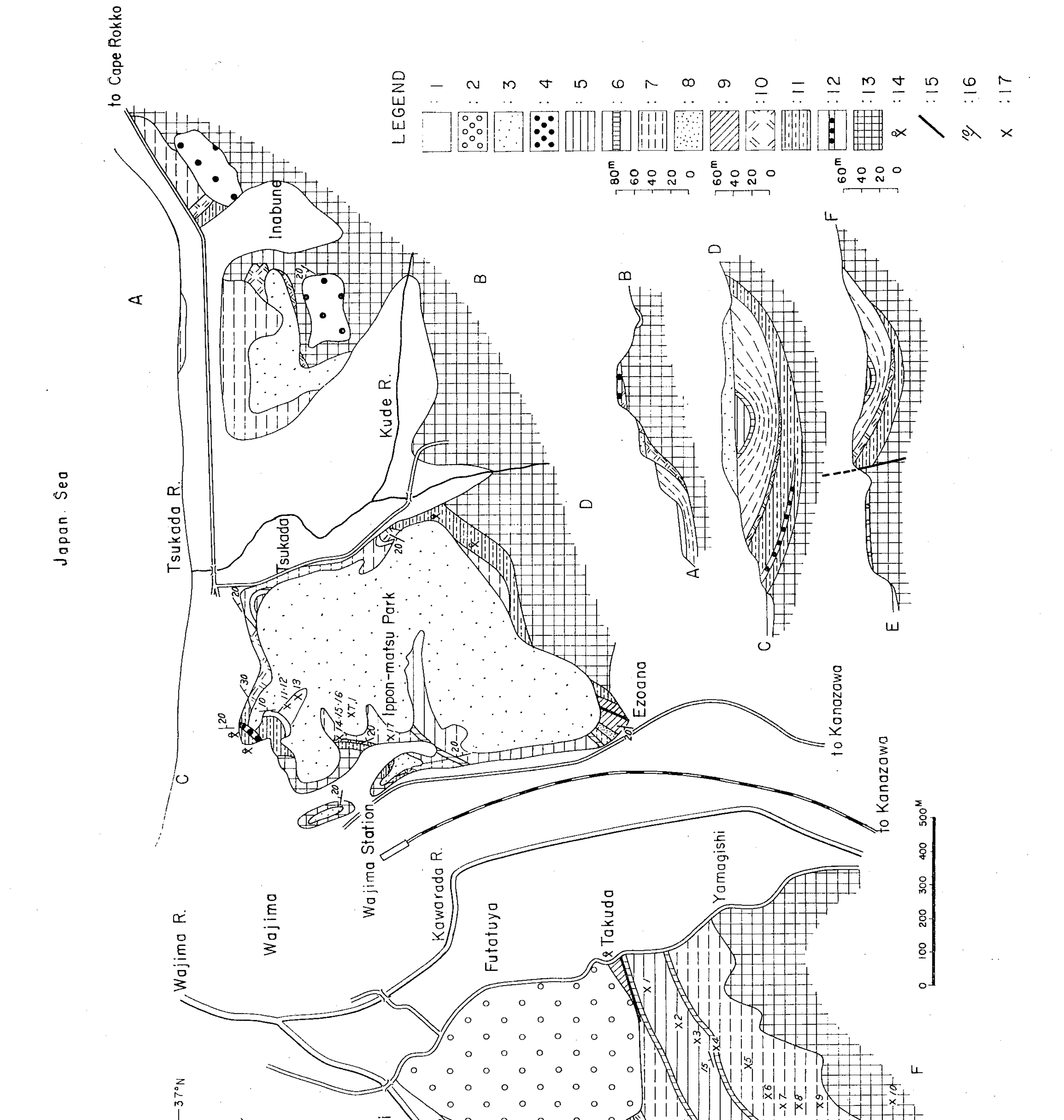
The present report, the fourth of the series, records the result of palynological analysis of the Late Miocene Tsukada diatomaceous mudstone Member, a unit which is distributed locally in Wajima City in the northern part of Noto Peninsula, Ishikawa Prefecture.

The scope of the study, based on the microfossils, is to make a systematic description of the microfossils, and to interpret the paleoclimatic condition and paleogeographical environment under which the Tsukada Member was deposited during the Otokawa stage of the Late Miocene age. Further, an attempt is made for correlation and comparison of the conditions and environment of the Tsukada Member with the Wakura, Hijirikawa and I'izuka diatomaceous members distributed in Noto Peninsula.

Acknowledgements

Here the writer wishes to record his sincere thanks to Professor Kotora HATAI of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University for his kind advice during the course of the writer's palynological researches and for reading the manuscript. Thanks are due to Dr. Seiji SUGIURA, Professor of the Department of Earth Sciences, Faculty of Science, Kanazawa University, who kindly discussed with the writer a few problems on the clay minerals found from the Tsukada diatomaceous mudstone Member. Appreciation is expressed to Professor Yoshio KASENO of the Department of Earth Sciences, Faculty of Science, Kanazawa University, for his advice and information on the stratigraphy and paleogeography of the Wajima area during the Late Miocene age. Thanks are due to Mr. Nobuomi MATSU'URA of the Kanazawa Girl's Senior High School, Kanazawa, for his suggestions on sampling for palynological investigation and information on the stratigraphy of the Tsukada Member. Acknowledgements are also due to Dr. Wataru ICHIKAWA, Professor Emeritus of the Kanazawa University for information on the diatom assemblage found from the Tsukada Member and for its paleoecological implications. Finally, the writer expresses his appreciation to the Ministry of Education of the Japanese Government for support from the Science Expenditure Funds.

Text-fig. 1. Geological map of the Wajima area, central part of Noto Peninsula, Central Japan (Compiled by FUJI, 1969; after; N. MATSU'URA, 1955; N. FUJI, 1968) 1: Alluvial deposits, 2: Lower terrace deposits, 3: Middle terrace deposits, 4: Upper terrace deposits, 5: Upper mudstone part of the Tsukada Member, 6: Siliceous sandy tuff, 7: Lower mudstone part of the Tsukada Member, 8: Coarse-grained sandstone part of the Tsukada Member, 9: Wajima-zaki Member, 10: Awakura Member, 11: Wajima Member, 12: *Operculina* calcareous sandstone, 13: Nawamata Member, 14: animal fossils, 15: fault, 16: strike and dip, 17: plant fossils.


to Cape Rokko
LEGEND
Japan Sea
Tsukada R.
Tsukada
Inabune
Kude R.
Ippon-matsu Park
Ezoana
to Kanazawa
to Kanazawa
Wajima Station
Kawarada R.
Wajima R.
Wajima
Futatuya
Takuda
Yamagishi
Horimachi
Fugeshi R.
Wajima
Nanao
Toyama
Kanazawa
37°N
137°E
0 100 200 300 400 500M

Outline of the geology

Many diatomaceous muddy deposits of Neogene age are distributed widely in the central and northern parts of the Noto Peninsula. They are mainly composed of homogeneous silty mudstone characterized with abundant fossil microorganisms, especially diatoms and silicoflagellates. In the Wajima area of the northwestern part of the peninsula, the diatomaceous deposits are distributed very locally, and their rock-facies are variable. In the Wajima area where the Late Miocene Tsukada Member is distributed the Neogene deposits are classified into two formations and five members in ascending order as follows; the Anamizu Formation, the Nawamata coarse-grained sandstone and mudstone Member, Wajima sandstone, sandy mudstone and tuffaceous mudstone alternation Member, Awakura sandy tuff Member, Wajima-zaki sandstone Member, Tsukada diatomaceous mudstone Member and the Late Pleistocene terrace deposits.

Some opinions about the stratigraphical succession of the Neogene deposits in the Wajima area were stated by many stratigraphers, namely, Yanosuke OTUKA (1946), Nobuomi MATSU'URA (1955, MS) and Yoshio KASENO (1963). The writer studied the stratigraphy of this area in the spring and summer seasons of 1967, and collected some samples for palynological investigation in the spring season of 1968. The other samples were obtained from a well drilled in this area for the research on the diatom earth distributed widely in the Noto Peninsula. The sampling localities and stratigraphical horizons of the materials from the Tsukada Member are shown in Text-figs. 1 and 2.

According to the writer's geological survey, these stratigraphical units are as mentioned below, in ascending order.

The Anamizu Formation: This formation is not only distributed in the Wajima area, but also widely in the northwestern and central parts of Noto Peninsula. It is generally classified in the northwestern part of Noto Peninsula into andesitic lava and andesitic pyroclastic rocks intercalated with dacitic pyroclastic rocks and thin basaltic lava. The stratigraphical succession of this formation is different in different localities, and also most of these rocks are disturbed by crustal movements such as faults and folds.

The fine-grained sandstone and siltstone intercalated in the pyroclastic rocks of this formation yielded many fragments of plants, namely, at Konogi, Ikuru and Soyama near Anamizu *Metasequoia occidentalis, Glyptostrobus europaeus, Acer* sp., *Lindera* sp., *Machilus* sp. and *Hemitrapa* sp., and also small foraminifers from the medium- or fine-grained sandstone. *Bunolophodon* was found from the tuffaceous sandstone exposed at Hosoya (SHIKAMA, T., 1936).

Dacite developed very locally at Okamoto, In'nai and Okazuka near Wajima is intercalated with a welded tuff bearing dacitic tuff, and is about 85 meters in thickness.

Basalt occurs very locally at Okazuka, Yokoji and Kirita, and lithologically is an olivine two pyroxene basalt. The lava is about 10 meters in thickness. The stratigraphical relationship between the dacite and basalt is uncertain.

Andesite, overlain with unconformity by the dacite and basalt above-mentioned, is generally classified into two pyroxene andesite, hypersthene andesite, augite andesite and their agglomerates. Two pyroxene andesite is distributed widely in the eastern and southern parts of Wajima City and is more extensive compared with the other volcanic rocks above-noted.

.... unconformity ....

The Nawamata sandstone and mudstone alternation Member: This member is distributed widely in the northwestern part of Noto Peninsula, namely, in the area from Wajima City to Monzen Town and the coastal area of western Noto Peninsula. The distribution of this member is about 7 km in breadth from north to south, and the principal geological structure in and around the surveyed area is the undulated folding structure of repeated anticlinal and synclinal structures which trend in ENE–WSW direction.

The member overlies with unconformity dacitic pyroclastic rocks intercalated with some welded tuff layers and basalts. These belong to the upper part of the Anamizu Formation in the area from the south of Wajima Station to Nawamata. On the other hand, in the area of Nawamata, the pyroclastic rocks and andesite of the Anamizu Formation are overlain by the member with unconformity.

The rock-facies of this member is composed generally of an alternation of dark brown or bluish green medium- or coarse-grained sandstone and dark grayish brown or bluish gray mudstone partly intercalated with thin conglomerate layers.

The member yielded many fossil plants as *Metasequoia japonica*, *Liquidambar formosana*, *Fagus* sp., *Platanus* sp., *Marles* sp., *Cedrela* sp., *Ficus* sp., *Benzoin umbellatum*, siliceous wood stumps. No marine fauna has been found from this member.

This member attains about 500 meters in maximum thickness.

——— conformity ———

The Awakura sandy tuff Member: This member is distributed very locally in the Wajima area, namely, Ippon-matsu Park, Ezoana, Koise and Wajima-zaki. The type locality of the member is an outcrop north of Ippon-matsu Park in Wajima City.

The upper part and lower part of the member are correlated respectively with the Awakura tuff Member and the upper part of the Wajima sandstone Member named by the late Y. ÔTUKA (1946).

The rock-facies of this member is composed of pumiceous tuff, pumice-bearing tuffaceous sandstone, sandy pumiceous tuff and medium- or fine-grained sandstone partly intercalated with thin hard coarse-grained sandstone. This member is composed of a pumiceous facies.

The Awakura Member overlies with conformity the Wajima-zaki Member. The member is variable in thickness, that is, measuring about 40 meters at the Ippon-matsu Park and about 10 meters at Wajima-zaki.

——— conformity ———

The Wajima-zaki sandstone Member: This member is distributed only at Wajima-zaki Cape in the north part of Wajima City, therefore, it was named as the Wajima-zaki sandstone Member by MATSU'URA (1955, MS).

The member is classified into three parts lithologically, namely, the lower part is composed mainly of hard calcareous sandstone intercalated with some nodule layers and attaining about 35 meters in thickness, the middle part is of homogeneous calcareous fine-grained sandstone of about 30 meters in thickness, and the upper part consists of glauconitic coarse-grained sandstone with dark colored pebbles and attains about 5 meters in thickness.

The member yielded fossil animals, especially pelecypods and brachiopods etc. These fossils are as follows:

Lower part: *Chlamys* sp., *Balanus* sp., *Gryphus* cfr. *davidsoni*, *G.* cfr. *hanzawai* HATAI, *G.* sp., *Laqueus* cfr. *rubellus* (SOWERBY), *L.* sp., and also plant fragments.
Middle part: *Linthia nipponica* YOSHIWARA, *Isurus hastalis* (AGASSIZ), *Dentalium* sp., *Balanus* sp., and plant fragments.
Upper part: *Chlamys crassivenia* (YOKOYAMA), *Lucinoma acutilineata* (CONRAD), *L.* sp., *Turbonilla* sp., and plant fragments.

Based on *Linthia nipponica* YOSHIWARA found from the middle part, the member is correlated with the Tsukada Member. This view is supported from rock-facies, which is similar to that of the Tsukada Member, and by that the upper part of the Wajima-zaki Member consists of glauconitic sandstone.

This member is stratigraphically equivalent to the lower part of the Tsukada Member.

— interfingering with the Tsukada Member —

The Tsukada diatomaceous mudstone Member: This member is distributed very locally at Ippon-matsu Park and Tsukada in the southeastern part of Wajima City. The type locality of the member is in the Tsukada area east of the Ippon-matsu Park.

The member is classified into two parts by the siliceous shale layer or thin sandy tuff layer.

The lower part is of coarse-grained sandstone and calcareous; it contains many nodules. It yielded some marine molluscan fossils as *Gryphus* sp., *Laqueus* sp., *Linthia nipponica* and *Isurus hastalis* etc., and is about 40 meters in thickness.

The upper part is light yellowish brown (weathered part) or dark greenish blue (fresh part), homogeneous, massive diatomaceous mudstone intercalated with some thin calcareous nodules and dark colored glauconitic fine-grained sandstone layers. The megafossils are rare in the upper part, but comprised such as, *Chlamys crassivenia* and *Lucinoma acutilineata* etc. Microfossils such as diatoms, sponge spicules, spores and pollen grains are common, that is, the homogeneous massive mudstone of the upper part yielded. *Actynoptychus undulata* A.S., *Coscinodiscus actinochilus* EHR., *C. centralis* EHR., *C. elegans* GREV., *C. gigas* EHR., *C. lineatus* EHR., *C. marginatus* EHR., *C. aculus* EHR., *C. perforatus* EHR., *C. radiatus* EHR., *Grammatophora aceanica* (EHR.) GRUN.

The thickness of the upper part is about 20 meters, and that of the lower part about 40 meters.

.... unconformity ....

The Inabune terrace deposits: The Inabune terrace deposits are composed of clay, and sand and gravel. The Inabune terrace is classified into three terrace levels according to height above sea level, namely, (1) high terrace, (2) middle terrace and (3) lower terrace. The high terrace is distributed locally in the areas west of Inabune and northwest of Nishi-ôno, and its height is about 80 meters above the present sea level.

The middle terrace is distributed in the areas west of Inabune and the Ippon-matsu Park, and is about 30 to 50 meters above the present sea level in height.

The lower terrace is distributed at Takuda and Futatsuya, and its height is about 20 meters above the present sea level. From the viewpoint of height of these terraces the lower and middle terrace deposits are correlated with the Late Pleistocene age, perhaps the Hiradoko transgression age in the Hokuriku district or the Shimosueyoshi age in the Kwanto district.

The Neogene deposits in the Wajima area show gently folded structure, and there are two synclinal basins and anticlinal structure, namely,

(1) Kônosu-Kekachi anticline which has NE–SW trend in the southern part of the Wajima area,
(2) Wajima-Warabino "buried" anticline,
(3) Tsukada syncline,
(4) Wajima-zaki syncline.

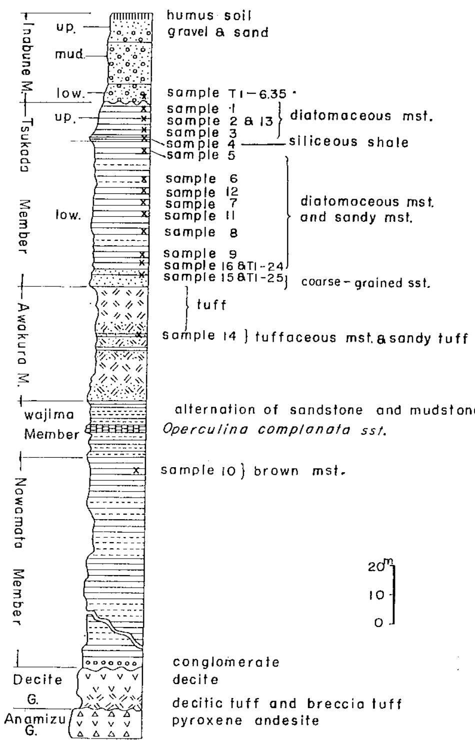
Palynological research

(1) Foreword

The writer has been studying the Neogene system which occurs in Noto Peninsula, especially the diatomaceous deposits, and has already summarized on the fossil pollen and spore assemblage of the Late Miocene Wakura (FUJI, 1969a), Middle Miocene Yamatoda (FUJI, 1969b), and Pliocene Oginoya and Late Miocene Hijirikawa (FUJI, 1969c) members.

The present paper is the fourth report of the series.

The purpose of the present study is to interpret the significance of the pollen grains and spores found from the samples collected from the Late Miocene Tsukada Member, mainly in terms of paleoclimatic condition and paleogeographical environment.



Text-fig. 2. Columnar section showing the sampling horizons of the Tsukada, Awakura and Nawamata members and Inabune deposits.

(2) Sampling

The samples analysed in the present investigation were collected by the writer in the spring season of 1968. The other three samples (abbreviation: T-1) were obtained from a well drilled for the research of the diatom earth which is distributed locally in the Wajima area. The samples treated in connection with the present research are 19 samples in total. The localities and stratigraphical horizons in the Tsukada Member of these samples are shown in Text-figs. 1, 2 and 3.

Of the samples collected from some outcrops, one sample consisted of three to five pieces of rock ever collected at random along the length of one meter, measured parallel to the stratification of the member.

(3) Preparation of materials and method of study

The preparation of the materials and method of study for the palynological investigation are the same as described in the previous papers (FUJI, 1969a and 1969c).

All of the slides containing the specimens registered in the present research are deposited in the collection of the Institute of Earth Science, Faculty of Education, Kanazawa University (register abbreviation: EKZJ), Kanazawa, Ishikawa Prefecture, Central Japan.

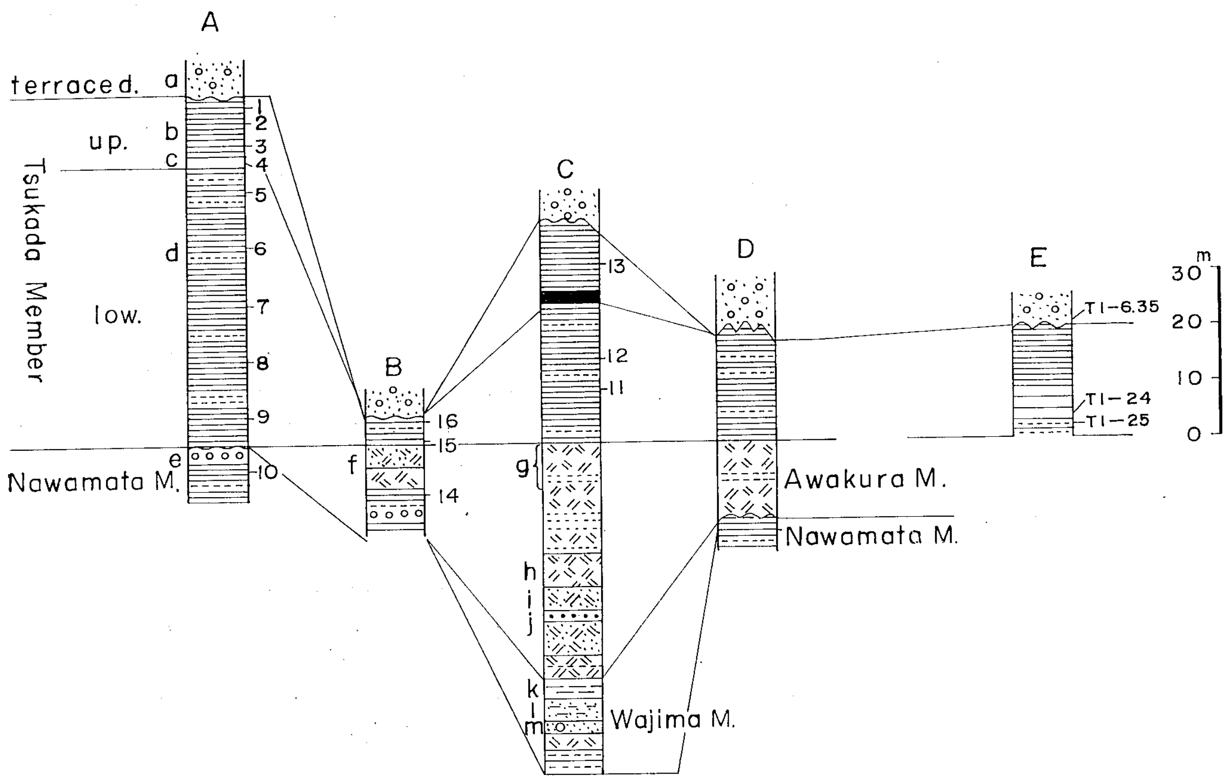
(4) Description of the assemblages

The assemblage of the fossil pollen grains and spores found from the analysed 19 samples is shown in Text-figs. 4 and 5, and is explained as follows in descending order.

Sample T-1-6.35:

This sample which belongs to the Inabune terrace deposits belongs to the lowermost horizon of the deposits. It was taken from the well drilled at Locality No. T-1 situated in Ippon-matsu Park about 500 meters east of Wajima Station of the Japanese National Railway Nanao Line, Wajima, Ishikawa Prefecture. Depth of the sample is 6.35 meters below the present ground surface. The sample is fairly weathered and is a light yellowish brown decomposed clayey mud. The lower part of the Inabune terrace deposits distributed in Ippon-matsu Park becomes the decomposed clayey mud at almost all part of the outcrop and these deposits are probably derived from the Tsukada diatomaceous mudstone Member. The decomposed mud has been used as "Jinoko" which is a kind of powder painted on the Japanese lacquer-ware named as "Wajima-nuri".

The fossil pollen grains and spores



Text-fig. 3. Columnar sections showing the sampling horizons and the relationship between them. A : Takuda area, B : Wajima Hospital, C : Ippon-matsu Park, D : Inabune area, E : Locality No. T-1 (the well drilled) in Ippon-matsu Park, 1, 2, 3, ... 15, 16, T1-6.35, T1-24, T1-25 : sampling horizons (refer to Text-fig. 2) ; a : sand, mud and gravel of the Pleistocene terrace deposits, b : mudstone, c : hard siliceous shale, d : fine- and medium-grained sandstone, e : conglomerate, f : tuffaceous sandstone with nodules, g : alternation of sandstone and tuff, h : tuff, i : tuffaceous sandstone, j : hard coarse-grained sandstone, k : micaceous sandy mudstone, l : tuffaceous sandy mudstone, m : *Operculina* calcareous sandstone.

found from the sample are less than 200 specimens in total. The writer, therefore, can not carry out right statistical treatment in connection with the sample. This sample yielded ; Gymnosperm-five genera ; Dicotyledon-six genera and two subgenera ; Monocotyledon-one family and one genus; Pteridophyta-two genera ; two indeterminable grains. Among them, *Pinus*, Nympaeaceae, *Inapertipollenites* and *Inapertisporites* are abundant, and *Picea*, *Abies*, *Tsuga*, evergreen and deciduous *Quercus*, *Alnus*, *Zelkova* and *Nuphar* are common. The grains such as Taxodiaceae, *Fagus*, *Betula*, *Juglans*, *Acer*, *Myriophyllum*, *Tilia*, *Lycopodium* and *Osmunda* are rare in a relative frequency.

Sample 1 :

The composite sample from Locality No. 1, situated at about 100 m west of Takuda, was examined for the present study. Locality No. 1 (Text-fig. 1) belongs to the uppermost horizon of the upper part of the Tsukada Member. The sample yielded, Gymnosperm-five genera (37%) ; Dicotyledon-11 genera and two subgenera (49%) ; Monocotyledon-two families (6%) ; spore-three genera (8%).

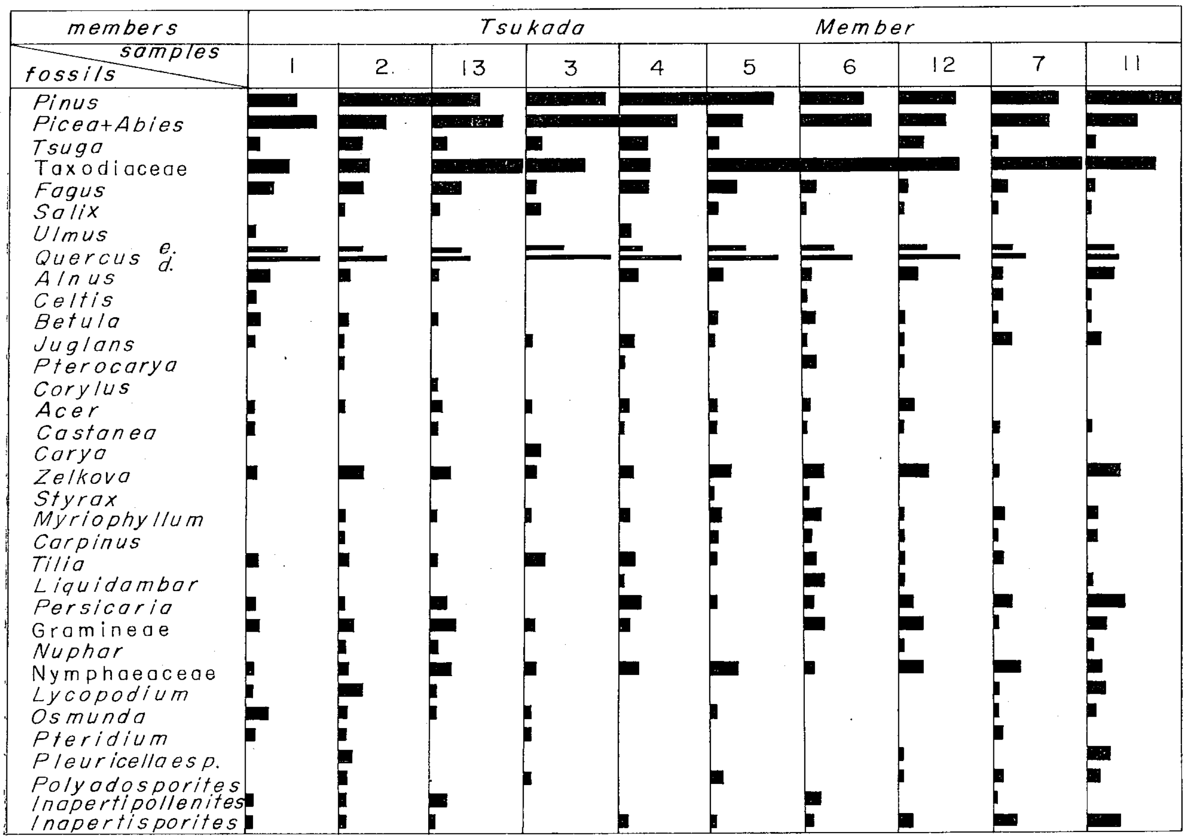
Among these groups, deciduous *Quercus*, *Picea*, *Abies* and *Pinus* are abundant and amount to 42% of the total frequency. The fossil pollen grain of deciduous *Quercus* totals 16%. Taxodiaceae and evergreen *Quercus* are common (ranging from 6 to 9%), both 9%. *Tsuga*, *Fagus*, *Ulmus*, *Alnus*, *Celtis*, *Betula*, *Juglans*, *Acer*, *Castanea*, *Zelkova*, *Tilia*, *Persicaria*, Gramineae, Nympaceae, *Lycopodium*, *Osmunda*, *Pteridium*, *Inapertipollenites* and *Inapertisporites* are rare.

As shown in some text-figures, plants having different habitats are distinguished among the treated composite sample. All of these genera which are representative plant of a warmer temperate and subtropical region, are denoted by the component "B", amounting to 11%. The cooler temperate plants denoted by "C" reach 58% of the total. Whereas the other elements denoted by "A" amount to 31%.

Sample 2:

The mixed sample was collected from an outcrop of Locality No. 2 (Text-fig. 1), where is situated at about 200 m just west of Takuda. It belongs to the middle horizon of the upper part of the Tsukada Member.

The sample yielded; Gymnosperm-five genera; Dicotyledon-12 genera and two subgenera; Monocotyledon-two families and one genus; spores-six genera. Among them, *Pinus* is very abundant, showing the highest concentration (20%) in this composite sample. The genus



Text-fig. 4. Pollen diagram (1) of the Tsukada Member.
Numbers refer to Text-figs. 1, 2 and 3.

Quercus is classified into two types, one is of large size and other of small size, based on the diameter of the pollen grain, and the latter belongs to the evergreen type. *Picea*, *Abies* and deciduous *Quercus* are abundant, ranging from 10 to 19%. Taxodiaceae is common, and the other pollen grains such as *Tsuga*, *Fagus*, evergreen *Quercus*, and *Zelkova* are rare. Gymnosperm, Dicotyledon, Monocotyledon and spore group are 41%, 41%, 6% and 12%, respectively.

The component "A", "B" and "C" are respectively 27, 6 and 67%.

Sample 13:

As shown in Text-fig. 1, the mixed sample was collected from Locality No. 13, at about 500 m northeast of the Wajima Station, Ippon-matsu Park. The horizon of the sample is similar to the horizon of Sample 2 above-mentioned. From the mixed sample, Taxodiaceae, *Picea* and *Abies* are very abundant, and the pollen grain of Taxodiaceae is the highest frequency in the sample. *Pinus* is common, amounting to 10%. The others are rare. Gymnosperm, Dicotyledon, Monocotyledon and spores contain respectively four genera and one family (49% in total), 11 genera and two subgenera (36%), one genus and two families (10%), and three genera (5%).

The component "A", "B" and "C" are respectively 31, 8 and 61%.

Sample 3:

The sample from Locality No. 3 situated at about 100 m just southwest of Locality No. 2, Takuda, occupies stratigraphically the lowermost horizon of the upper part of the Tsukada Member. In the sample, *Picea* and *Abies* are very abundant, its frequency being 28%. The deciduous *Quercus*, *Pinus* and Taxodiaceae are abundant, and evergreen *Quercus* is common. The other genera and families shown in Text-fig. 4 are rare.

Gymnosperm, Dicotyledon, Monocotyledon and spores are respectively 55% (four genera and one family), 38% (eight genera and two subgenera), 3% (two families) and 4% (three genera).

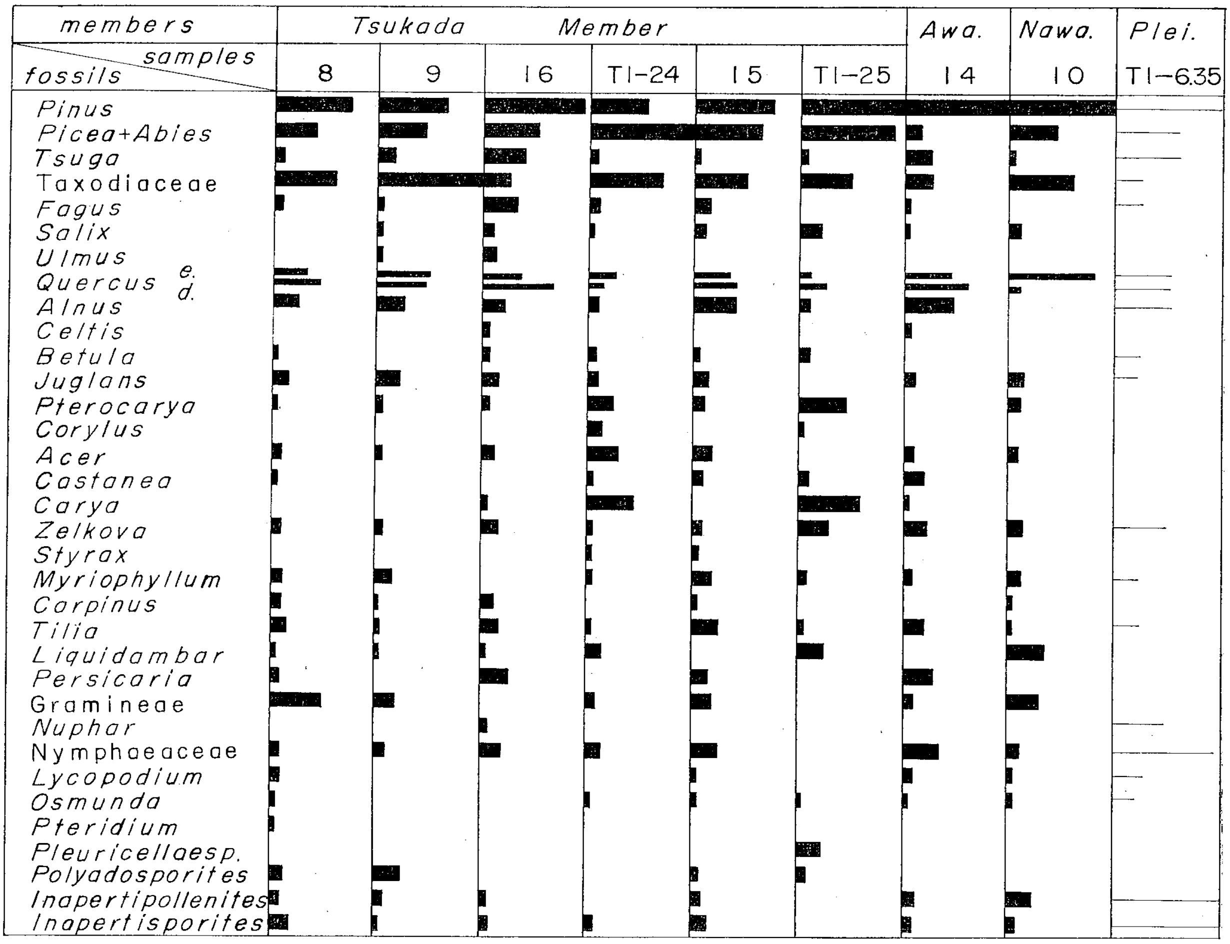
The element "A" amounts to 27%, element "B" to 9%, and element "C" to 64%. The non-arboreal pollen grains denoted by NA amounts only to 7% in total, and the arboreal pollen grains 93%.

Sample 4:

As shown in Text-fig. 1, the mixed sample, which was collected from Locality No. 4, at about 50 m southwest of Locality No. 3, Takuda, was treated for the present study. The horizon of Locality No. 4 belongs to the lowermost of the upper part of the Tsukada Member. The rockfacies of the sample is a siliceous shale lithologically and many field geologists classify the Tsukada Member into the upper and lower parts by the siliceous shale.

The composite sample yielded; Gymnosperm-four genera and one family (42%); Dicotyledon-12 genera and two subgenera (50%); Monocotyledon-two genera (6%). Among them, *Pinus* is very abundant and amounts to 20% of the total frequency, being the highest per centage in the composite sample. *Picea*, *Abies* and deciduous *Quercus* are abundant. *Tsuga*, Taxodiaceae, *Fagus* and *Persicaria* are common, and the other pollen grains such as *Ulmus*, evergreen *Quercus*, *Alnus*, *Juglans*, *Pterocarya*, *Acer*, *Castanea*, *Zelkova*, *Myriophyllum*, *Tilia*, *Liquidamber*, *Persicaria*, Gramineae and Nympaeaceae are frequent, amounting to about 40% in the total frequency.

The component "A", "B" and "C" are respectively 27, 7 and 66%.



Text-fig. 5. Pollen diagram (2) of the Tsukada, Nawamata and Awakura Members, and the Pleistocene Inabune deposits. Numbers refer to Text-figs. 1, 2 and 3.

Sample 5:

The mixed sample from Locality No. 5, situated at about 80 m southwest of Locality No. 4, Takuda, occupies stratigraphically the uppermost horizon of the lower part of the Tsukada Member.

The composite sample yielded; Gymnosperm-four genera and one family, amounting to 43%; Dicotyledon-13 genera and two subgenera, amounting to 49%; Monocotyledon-one family, being five per cent; spores-three genera, being three per cent. Among them, Taxodiaceae is very abundant and the highest per cent (20%) in the total frequency. Deciduous *Quercus* and *Pinus* are abundant, being respectively 14 and 13%. *Picea*, *Abies* and evergreen *Quercus* are common. *Tsuga*, *Salix*, *Alnus*, *Betula*, *Juglans*, *Acer*, *Castanea*, *Zelkova*, *Stylux*, *Myriophyllum*, *Carpinus*, *Tilia*, *Persicaria*, Nympaceae, *Osmunda*, *Polyadosporites* and *Inapertisporites* are rare, amounting to about 35% in the total frequency of these pollen grains and spores.

The element "A" amounts to 17%, element "B" to 8% and element "C" to 75%.

Sample 6:

This sample is from an outcrop of Locality No. 6 (Text-fig. 1), situated at about 1,300 m southwest of the Wajima Station of the National Railway Nanao

Line and about 50 m west of Locality No. 5, Takuda. From sample 6, which occupies stratigraphically the upper horizon of the lower part of the Tsukada Member. Taxodiaceae is very abundant and is found in 20% of the total frequency. *Picea*, *Abies*, *Pinus* and deciduous *Quercus* are abundant, ranging from 10 to 19%. This sample yielded, Gymnosperm-three genera and one family (45% of the total); Dicotyledon-16 genera and two subgenera (48%); Monocotyledon-two families (5%); spores-one genus (2%). Among them, it is noteworthy that the pollen grains of *Liquidambar* are found from this horizon of the Late Miocene.

On the other hand, the element "A" amounts to 23%, element "B" to 13%, and element "C" to 64%. And from the viewpoint of the palynological environment, the upland and mixed-slope elements are abundant.

Sample 12:

Sample 12 belongs stratigraphically to the middle horizon of the lower part of the Tsukada Member, and was collected from the highest level of an outcrop of Locality No. 12, situated at about 550 m nort east of the Wajima Station, and at northern side of Ippon-matsu Park. The horizon of Sample 11 mentioned below situates the lowermost level of this outcrop and the interval between these two horizons is about 20 m.

Taxodiaceae is abundant, being 13% of the total frequency. *Pinus*, deciduous *Quercus*, *Picea* and *Abies* are abundant, ranging from 10 to 13%. This sample yielded, Gymnosperm-four genera and one family, being about 40% in the total frequency; Dicotyledon-14 genera and two subgenera, amounting to 46%; Monocotyledon-one genus and two families, about 10%; spore-three genera and amounts to 5%.

On the other hand, the element "A" amounts to 22%, element "B" to 9% and element "C" to 69%. And also, the non-arboreal grains are about 20%, and the arboreal pollen grains about 80% of the total frequency.

Sample 7:

The composite sample from Locality No. 7, situated at about 100 m southwest of Locality No. 6, was examined for the present study. Locality No. 7 belongs to the middle horizon of the lower part of the Tsukada Member.

The composite sample yielded, Gymnosperm-four genera and one family (46%); Dicotyledon-12 genera and two subgenera (34%); Monocotyledon-two families (7%); spores-6 genera (13%).

The element "B" which is representative plants of a warmer temperate and subtropical region amounts to 5%. The cooler temperate plants denoted by "C" reach 73% of the total frequency. Whereas the other element "A" amounts to 22%.

Among them, Taxodiaceae, *Pinus*, *Picea* and *Abies* are abundant in the relative frequency, and Taxodiaceae amounts to 19% in the total frequency.

Sample 11:

As shown in Text-fig. 1, the mixed sample was collected from Locality No. 11 at about 1200 m northeast of Locality No. 1 and northern end of Tsukada-machi.

The horizon of the sample belongs to the middle horizon of the lower part of the Tsukada Member. From the composite sample, *Pinus*, Taxodiaceae, *Abies* and *Picea* are abundant in frequency, namely, *Pinus* is very abundant (20%) and the other pollen grains range from 11 to 15%. Both type of *Quercus*, *Alnus*, *Zelkova*, *Persicaria* and *Inapertisporites* are common, and *Tsuga*, *Fagus*, *Salix*, *Celtis*, *Betula*, *Juglans*, *Castanea*, *Myriophyllum*, *Carpinus*, *Liquidambar*, Gramineae (small type), *Nuphar*, Nymphaeceae, *Lycopodium*, *Osmunda*, *Pleuricellaesporites* and *Polyadosporites* are rare.

Among them, Gymnosperm-one family and four genera, being 43% in the total frequency; Dicotyledon-12 genera and two subgenera, amounting to 44% ; Monocotyledon-two families and one genus, being 8% ; spores-five genera, being 5% of the total frequency.

The elements " A ", " B " and " C " are 25, 11 and 64% respectively.

Sample 8:

The sample is from an outcrop of Locality No. 8 (Text-fig. 1), where is situated at about 60 m southwest of Locality No. 7 of Takuda-machi. It belongs to the lower horizon of the lower part of the Tsukada Member. The rock-facies of the sample is dark bluish greenish gray homogeneous diatomaceous mudstone with very fine-grained sand and silt.

This sample yielded; Gymnosperm-one family and four genera, being 36% in the total frequency; Dicotyledon-13 genera and two subgenera, being 41%; Monocotyledon-two families, amounting to 12%; spores-six genera, being 12%. Among them, *Pinus*, Taxodiaceae and Gramineae (small grain type) are abundant, respectively 15, 12 and 10%. *Picea*, *Abies*, deciduous and evergreen *Quercus* are common, ranging from 6 to 9%.

The elements " A ", " B " and " C " are 18, 11 and 71% of the total frequency.

Sample 9:

The sample was collected from Locality No. 9 situated at about 100 m southwest of Locality No. 8 of Takuda, and belongs to the lower horizon of the lower part of the Tsukada Member.

Among these pollen grains and spores, Taxodiaceae, *Pinus* and *Picea-Abies* are very abundant, being 20%, amount to 13 and 10% respectively. *Tsuga*, evergreen *Quercus* and deciduous *Quercus* are common.

The sample yielded ; Gymnosperm-four genera and one family, being 45% of the total frequency ; Dicotyledon-12 genera and two subgenera, being 41% ; Monocotyledon-two families and amounting to 6% ; spores-three genera, being 8%.

The elements " A ", " B " and " C " are found 27, 13 and 60% respectively from the composite sample.

Sample 16:

This sample is from an outcrop of Locality No. 14 (Text-fig. 1) which is situated at about 50 m east of the Wajima Hospital and at western end of the Ippon-matsu Park.

From Sample 16, which occupies stratigraphically the lowermost horizon of the lower part of the Tsukada Member, *Pinus* is found in 19% of the total frequency. Deciduous *Quercus*, *Pinus* and *Abies* are abundant. *Tsuga*, *Fagus*, evergreen *Quercus* and *Persicaria* are common in relative frequency, ranging from 6 to 9%.

This sample yielded, Gymnosperm-one family and four genera, being 41% ; Dicotyledon-15% ; Monocotyledon-one genus and one family, being 4% ; spores-two genera, amounting to 3%.

The elements " A ", " B " and " C " are 29, 10 and 61% respectively.

Sample T-1-24:

This sample was taken from 24 m in depth of the well drilled at Locality No. T-1 situated at Ippon-matsu Park.

The sample from this boring-core is a light yellowish brown clayey siltstone, and the horizon of the sample belongs to the lowermost horizon of the lower part of the Tsukada Member.

This composite sample yielded, Gymnosperm-one family and four genera (47%); Dicotyledon-15 genera and two subgenera (45%); Monocotyledon-two families (5%) and spores-two genera (3%). Among them, Taxodiaceae, *Pinus* and *Abies* type pollen grains are abundant, *Acer* and *Carya* are common. The other grains such as *Tsuga*, *Fagus*, *Salix*, *Quercus*, *Betula* and *Corylus* etc. are rare in a relative frequency.

As shown in some text-figures plants having different habitats are distinguished among the treated composite sample. The element "A", "B" and "C" are respectively 27, 9 and 64%, and also the non arboreal pollen grains (NAP) and the arboreal pollen grains (AP) are 8 and 92%.

Sample 15:

This mixed sample is from an outcrop of Locality No. 14 (Text-fig. 1) which is same to the outcrop of the locality collecting Samples 14 and 16. Namely, Sample 16 was collected from the upper part (the lower horizon of the lower part of the Tsukada Member) of this large outcrop, Sample 15 from the middle part (the lowermost horizon of the lower part of the Tsukada Member) and also Sample 14 from the lower part (the middle horizon of the Awakura Member). The rock facies of this sample is a light brownish gray coarse-grained sandstone intercalated with thin dark bluish greenish gray mudstone layer.

The mixed sample yielded; Gymnosperm-one family and four genera (37% in the total); Dicotyledon-14 genera and two subgenera (48%); Monocotyledon-two families (9%); spores-five genera (6%). *Pinus* is abundant, being 15% of the total frequency. The element "A", "B" and "C" are 23, 9 and 68% respectively, and the arboreal pollen grain (AP) and non arboreal pollen grain are (NAP) 80 and 20%.

Sample T-1-25:

This sample was taken from 25 m in depth of the well drilled at Locality No. T-1 situated at Ippon-matsu Park.

The sample is a light brown siltstone, being correlated with a horizon between the horizon of Sample 15 and that of Sample 14. The horizon of Sample T-1-25 is the lowermost horizon of the lower part of the Tsukada Member.

The sample yielded; Gymnosperm-one family and four genera (49%); Dicotyledon-11 genera and two subgenera (52%); Monocotyledon-two families (9%) and spores-three genera (8%).

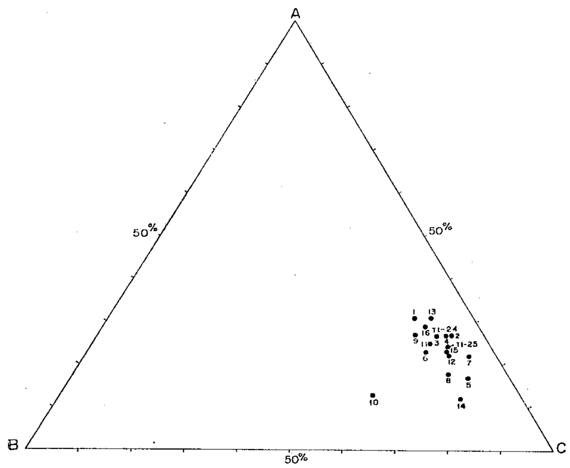
Among them, *Pinus*, *Abies* and *Picea* pollen grains are very abundant, Taxodiaceae and *Castanea* are abundant. Deciduous *Quercus*, *Juglans* and *Zelkova* are common, the other pollen grains and spores are rare in a relative frequency.

As shown in some text-figures the element "A", "B" and "C" are respectively 23, 9 and 68%, and the non arboreal pollen grains (NAP) and the arboreal pollen grains (AP) are 8 and 92% respectively.

Sample 14:

This mixed sample was collected from the outcrop of Locality No. 14 (Text-fig. 1) which is located at the back of the Wajima Hospital near the Wajima Station. The sample is belonging to the middle horizon of the Awakura Member.

The composite sample yielded; Gymnosperm-one family and four genera (33% in the total frequency); Dicotyledon-12 genera and two subgenera (50%); Monocotyledon-two families (9%); spores-four genera (8%). *Pinus* is very abundant,



Text-fig. 6. Pollen Diagram (3): Triangular diagram showing the relationship between cold and cool, temperate and warm climate elements found from several samples of the Tsukada, Awakura, Nawamata Members and Inabune Deposits. Numbers refer to Text-figs. 1, 2 and 3.

being 20%.

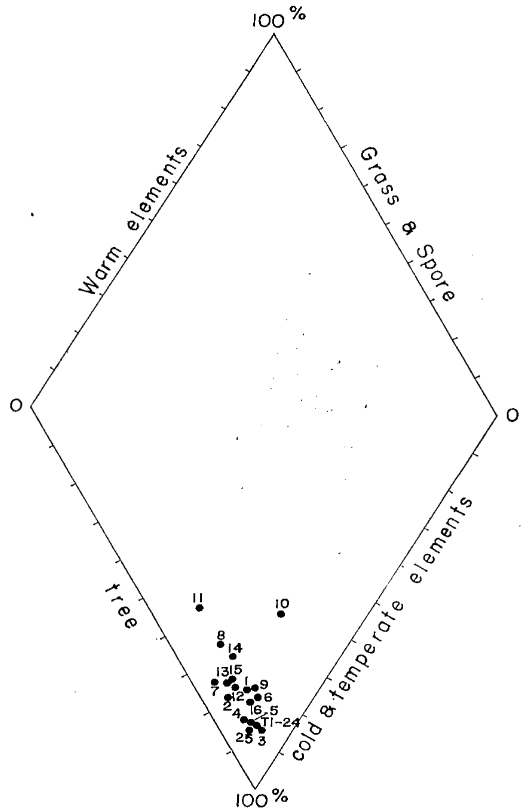
The component "A", "B" and "C" are 12, 12 and 76% respectively and the arboreal pollen grains (AP) and non arboreal pollen grains (NAP) are 77 and 23% respectively.

Sample 10:

This sample was collected from Locality No. 10 at about 200 m south of Locality No. 9, Takuda. The mixed sample is belonging to the uppermost horizon of the Nawamata Member, being a dark brown mudstone.

The composite sample yielded; Gymnosperm-one family and four genera (42% in the total frequency); Dicotyledon-9 genera and two subgenera (42%); Monocotyledon-two families (8%) and spores-four genera (8%).

The element "A", "B" and "C" are 13, 28 and 59% respectively, and non arboreal pollen grains (NAP) and arboreal pollen grains (AP) are respectively 17 and 83%.



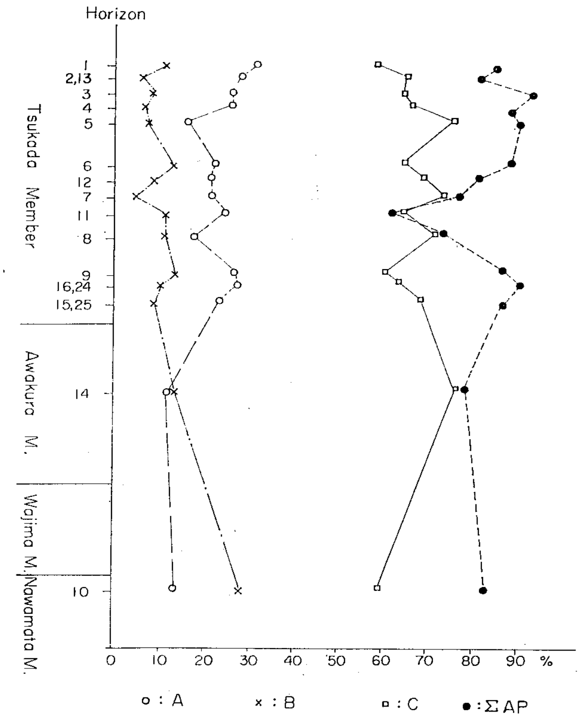
Text-fig. 7. Pollen diagram (4): Quadrilateral diagram showing the paleoclimatic condition and paleoecological environment. Numbers refer to Text-figs. 1, 2 and 3.

(5) Discussion

A general interpretation is made of the physical conditions that prevailed during the growth of the sedimentary basin in which the flora was buried on the basis of an analysis of the fossil spores and pollen grains. In this section, the writer will give a discussion on the paleoclimatic condition, paleogeographical environment and geological age of the stratigraphical units based upon the palynological and field researches.

(a) Paleoclimatic condition

On the basis of the analysis of the pollen grain and spore assemblage the general characters of the paleoclimatic



Text-fig. 8. Pollen diagram (5) : Figure showing the relationship among cold and cool (A in Text-figs. 6 and 8), temperate (C) and warm (B) climate elements. Numbers refer to Text-figs. 1, 2, 3, 6 and 13. AP : arboreal pollen grains.

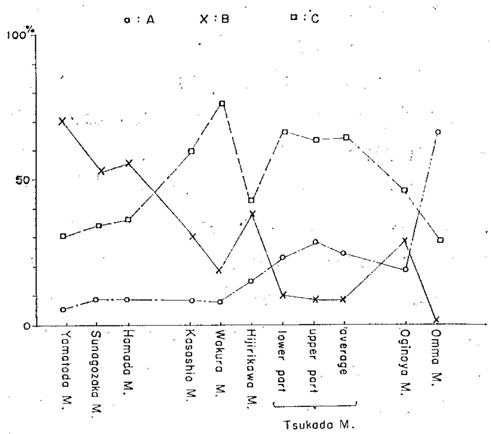
condition can be presented. The methods for analysing the assemblages for paleoclimatic interpretation have been proposed by some palynologists and paleobotanists. As shown in the triangular diagram (Text-fig. 6), quadrilateral diagram (Text-fig. 7) and pollen diagram (Text-fig. 8), the warm and subtropical plants denoted by "B" in some text-figures of this paper as *Liquidambar* and *Metasequoia* are yielded much less from the Tsukada Member than those from the Yamatoda and Sunagozaka members which are correlated with the Daijima age. That is to say, the Sunagozaka and Yamatoda members contain from 60 to 80% of the total frequency, and the Tsukada only 9%. This result is closely similar to those from the fossil pollen grain and spore assemblage from the Wakura diatomaceous mudstone Member (FUJI, 1969a) which is distributed in the central part of Noto Peninsula. As shown in Text-figs. 8 and 9, the warm climate elements from the lower part of the Tsukada Member show higher frequency than those from the upper part, namely, the lower part amounts to 10% whereas the upper part to only 8%. Throughout the member the change of the warm climate elements is a negative reciprocity to the cold and cool climate elements such as *Picea*, *Abies*, *Betula* and *Fagus* etc. That is to say, the warm climate elements are common a relative frequency mentioned above, the cold and cool climate elements 23 and 29% respectively. If we examine fully the relationship between the two climate elements denoted by A and B, the relationship is not always a negative reciprocity. For instance, in the change between Sample nos. 5 and 4, the cold and cool climate elements are found respectively to comprise 17% (Sample No. 5) and 27% (Sample No. 4), the warm climate elements B 8% (Sample No. 5) and 7% (Sample No. 4), and also the temperate climate elements C 75% (Sample No. 5) and 66% (Sample No. 4). Namely, the change of the cold and cool climate elements relates rather directly to the temperate climate elements than to the warm climate elements.

According to the writer's researches, as shown in the triangular and quadrilateral diagrams (Text-figs. 12 and 13), and pollen diagrams (Text-figs. 9 and 11), though the warm and subtropical plants found from the Tsukada Member show higher frequency than those from the Omma Member, they are numerically much less than those from the Hijirikawa, Wakura and Kasashio members which are correlated to the Tsukada

Member. The warm and tropical plants are found abundantly from the Middle Miocene Yamatoda, Sunagozaka and Hamada members. Though the Tsukada, Wakura, Kasashio and Hijirikawa members belong to the same age, the Late Miocene Epoch, the component of the pollen-floras from the other members is different from that of the Tsukada Member.

This result may be related closely to the paleoenvironment under which the Tsukada Member was deposited. That is to say, judging from the palynological results, litho-facies, poor contents of planktonic foraminifers, fossil diatom floras and diversity in the thickness of the deposits of the Hijirikawa and Wakura members, the paleogeographical environment under which the Tsukada Member was deposited was an open embayment facing the open sea. The sea under which the other members except the Tsukada Member were deposited seem to have been a closed embayment probably connected with the lagoon of that age. And as a consequence of the paleogeographical environment mentioned above those localities seem to have not been subjected to the influence of a cold current and/or north wind. As a natural course of the event, though the plants which are exotic conifers such as *Cunninghamia*, *Taiwania*, *Metasequoia* and *Glyptostrobus* and evergreen broad-leaved tree such as *Liquidambar* seem to have remained as a relict in the central part of Noto Peninsula where the Hijirikawa, Wakura and Kasashio members are locally distributed, those plants seem to have been affected by current and/or wind of the northern part (Tsukada area) of the peninsula.

Comparison between the fossil plants and the living equivalents whose climatic requirements are known is frequent-



Text-fig. 9. Pollen diagram (6) : Figure showing the cold and cool (A in Text-figs. 2, 3, 6 and 13), temperate (C) and warm (B) climate elements found from the Neogene System in the Hokuriku region.

ly used for climatic analysis of a fossil flora. Where the modern relationships are known definitely, this method is probably useful for acquring accurate information. The Neogene species are comparatively modernized in morphological features, so it is not difficult to compare them with their living equivalents with some exceptions. The genera composing the Neogene floras in the Japanese Islands are mostly distributed now in East Asia, and nearly all of the temperate Dicotyledons genera in the fossil flora are now growing in the Japanese Islands. The exotic coniferous genera are found throughout the Neogene floras of the Japanese Islands, and they are now mostly living in China, and some of them are known in the western part of North America.

The Tsukada pollen-flora consists mainly of the temperate genera with some warm and cold—cool climate elements. The dominant genera among the temperate flora are *Alnus*, *Castanea*, *Quercus*, *Zelkova*, *Acer*, *Pterocarya* and *Juglans* etc. Their modern equivalent species are mostly distributed in the

Japanese Islands proper, especially in the northern part of Honshû and Hokkaido. Further, the pollen-flora from the Tsukada Member contains the exotic conifers such as *Metasequoia* and exotic broad-leaved Dicotyledons as *Liquidambar*, though they are not abundant in number of specimens and species and may be the relicts which survived from the previous Middle Miocene Epoch. Thus, according to the present writer's investigation, the pollen flora from the Tsukada Member is composed of a mixed, mainly temperate and some warm and cold climate elements in floristic composition as already described in the previous part of this paper.

From the viewpoint of leaf character analysis reported on the Late Miocene floras from various localities in the Japanese Islands, these pollen-floras are related to the present temperate or somewhat warm temperate forest now growing in the central and southern parts of the Japanese Islands, and they seem to have grown under a warm

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Explanation of Plate 35

Fig. 1. *Tilia*, polar view, 25μ; Locality No. 9, Takuda, Wajima City; the lowest horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20194.

Fig. 2. *Tilia*, polar view, 36μ; 24 m in depth of the well drilled in Locality No. T–1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20195.

Fig. 3. *Tilia*, polar view, 32μ; Locality No. 9, Takuda, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20196.

Fig. 4. *Tilia*, polar view, 29μ; Locality No. 2, Takuda, Wajima City; the middle horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20197.

Fig. 5. *Tilia*, polar view, 24μ; Sample 13 from Locality No. 13, Ippon-matsu Park, Wajima City; the middle horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20198.

Fig. 6. Cf. *Fagus*, oblique equatorial view, 38μ; Locality No. 9, Takuda, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20199.

Fig. 7. *Juglans*, polar view, 37μ; Locality No. 9, Takuda, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20200.

Fig. 8. *Juglans*, polar view, 42μ; Locality No. 2, Takuda, Wajima City; the middle horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20201.

Fig. 9. *Juglans*, polar view, 40μ; 24 meters in depth of the well drilled in Locality No. T–1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20202.

Fig. 10. *Inapertipollenites*, polar view, 45μ; Locality No. 6, Takuda, Wajima City; the upper horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20203.

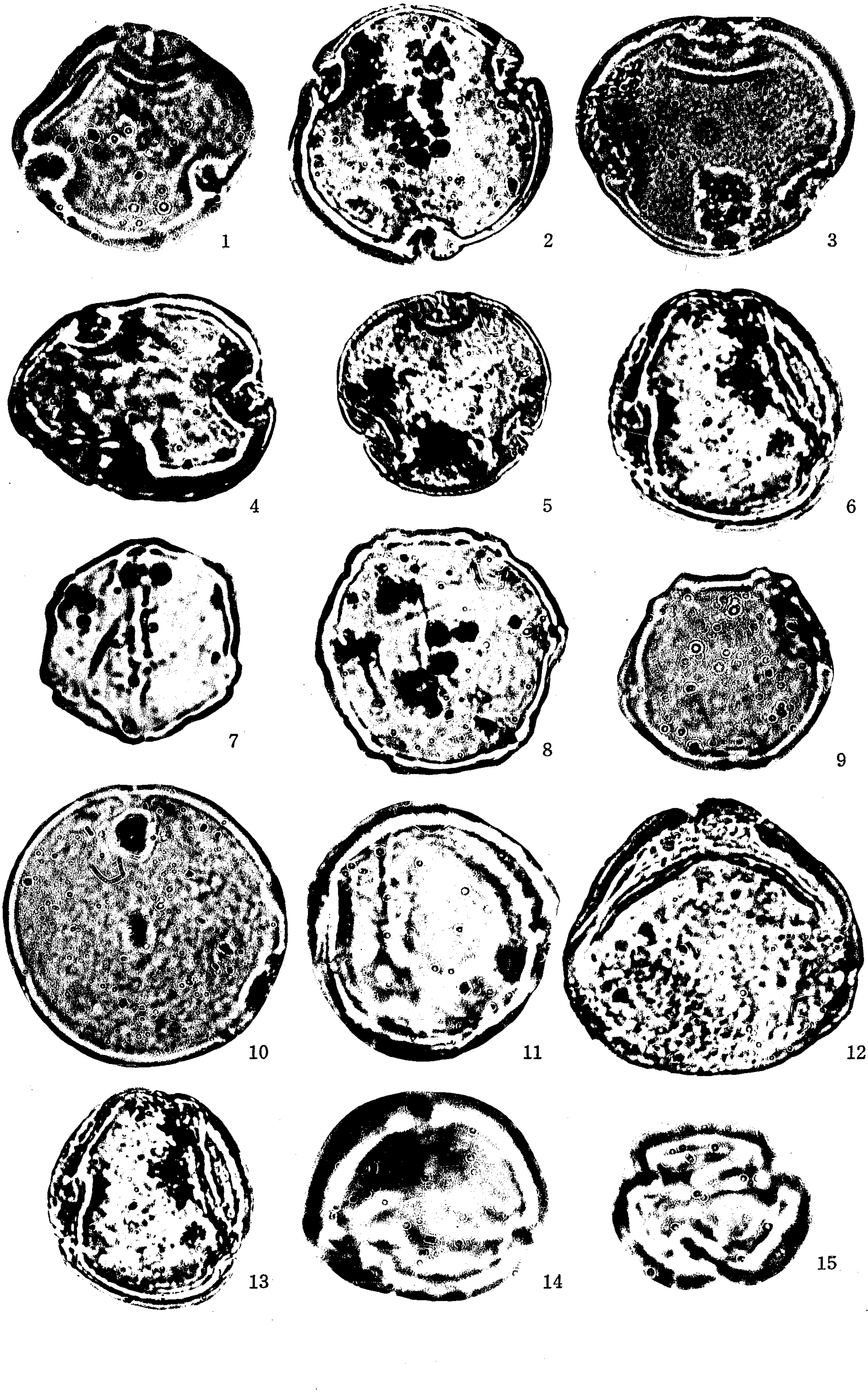
Fig. 11. *Fagus*, oblique equatorial view, 43μ; Locality No. 1, Takuda, Wajima City; the uppermost horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20204.

Fig. 12. *Carya*, oblique polar view, 46μ; Locality No. 1, Takuda, Wajima City; the uppermost horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20205.

Fig. 13. Cf. *Fagus*, oblique equatorial view, 36μ; Locality No. 9, Takuda, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20206.

Fig. 14. *Fagus*, polar view, 30μ; Locality No. 2, Takuda, Wajima City; the middle horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20207.

Fig. 15. *Salix*, oblique polar view, 36μ; Locality No. 8, Takuda, Wajima City; the lower horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20208.



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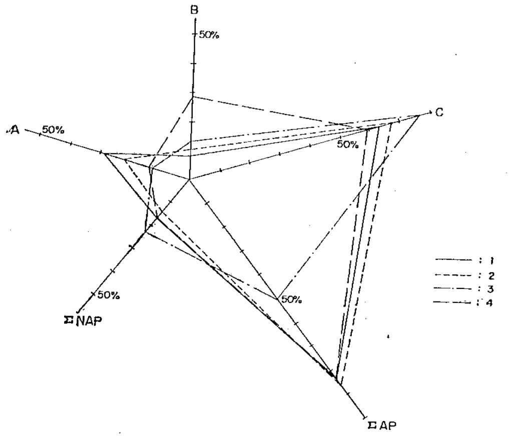
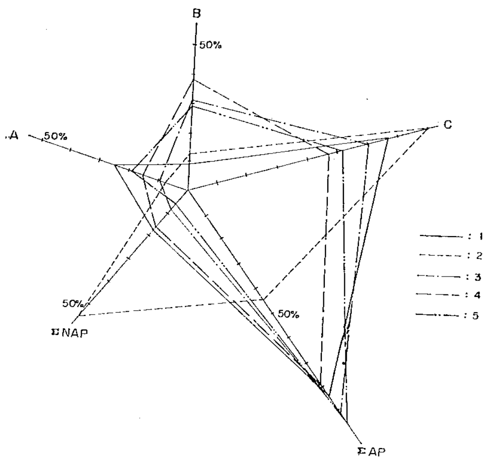


Text-fig. 10. Pollen diagram (7): Pentagonal diagram showing the relationship among cold and cool (A), temperate (C) and warm (B) climate elements, NAP and AP found from the upper part of the Tsukada Member (1), the lower part of the Tsukada Member (2), Awakura (3) and Nawamata (4) members.



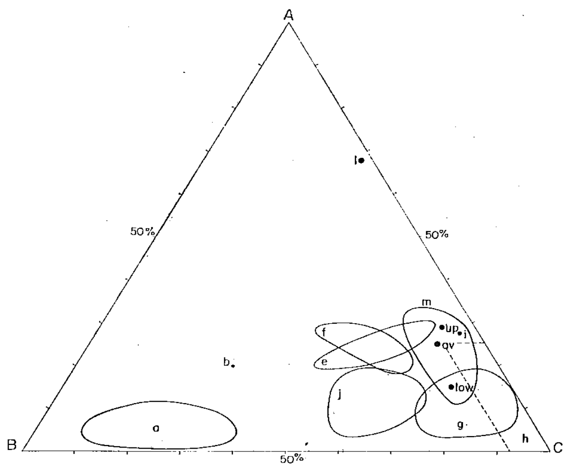
Text-fig. 11. Pollen diagram (8): Pentagonal diagram showing the relationship among cold and cool (A), temperate (C) and warm (B) climate elements, arboreal pollen grains (AP) and non arboreal pollen grains found from the Tsukada (1), Wakura (2), Kasashio (3), Hijirikawa (4) and Oginoya (5) members.

temperate climatic condition. However, the reduction of warm and subtropical plants evidently indicates that the temperature had lowered in comparison with that of the Middle Miocene Yamatoda and Sunagozaka members (FUJI, 1969b).

The Tsukada pollen-flora somewhat resembles the forest now growing in the central or northern parts of the Japanese Islands. The floristic composition of the fossil floras of this stage, the Latest Miocene, varies with the localities, so that the climate at that time shows local difference. From the viewpoint of the result, the Tsukada pollen-flora seems to have differed from the other pollen-floras of the same time, such as Hijirikawa and Wakura floras.

(b) Paleogeographical environment

To facilitate the considerations on the probable paleogeographical environments under which the ancient plants grew, the modern equivalents of the fossil species can be grouped according to their



Text-fig. 12. Pollen diagram (9): Triangular diagram showing the relationship among cold and cool (A), temperate (C) and warm (B) climate elements found from the Yamatoda (a), Sunagozaka (b), Hojuji (e), I'ida (f), Wakura (g), Nakayama-toge (i), Hijirikawa (j) and Omma (l) members, and the upper part (up), lower part (low) of the Tsukada Member, and average per cent (av) of the Tsukada Member.

habitats into four types of upland, mixed-slope, stream-side or riparian, and lake or marshy elements.

The Tsukada pollen-flora is composed mainly of mixed-slope or mixed-slope—riparian plants in the frequency of specimens, and contains upland—mixed-slope plants. That is to say, the Tsukada pollen-flora seems to represent a mixed-slope to riparian assemblage.

On the other hand, judging from the lithofacies, poor contents of the other microfossils such as diatoms and planktonic foraminifers and diversity in the thickness of the Tsukada Member, the basin in which the member was deposited seems to have been an open embayment with a wide mouth facing the open sea. The spread of the sedimentary basin and paleogeographical outline are shown in Text-figs. 14 and 15.

Explanation of Plate 36

Fig. 1. Deciduous *Quercus*, equatorial view, 26μ; Locality No. 8, Takuda, Wajima City; the lower horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20209.

Fig. 2. Evergreen *Quercus*, equatorial view, 23μ; Locality No. 6, Takuda, Wajima City; the upper horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20210.

Fig. 3. Deciduous *Quercus*, equatorial view, 28μ; Sample 16 from Locality No. 14, Ippon-matsu Park, Wajima City; EKZJ coll. cat. no. 20211.

Fig. 4. Evergreen *Quercus*, equatorial view, 22μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20212.

Fig. 5. Deciduous *Quercus*, equatorial view, 27μ; 24 m in depth of the well drilled at Locality No. 1, Ippon-matsu Park, Wajima City; EKZJ coll. cat. no. 20213.

Fig. 6. Evergreen *Quercus*, equatorial view, 23μ; Sample 13 from Locality No. 13, Ippon-matsu Park, Wajima City; the middle horizon of the upper part of the Tsukada Member; EKZJ coll. cat. no. 20214.

Fig. 7. Deciduous *Quercus*, equatorial view, 29μ; Sample 15 from the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20215.

Fig. 8. Indeterminable pollen grain (?), 34μ; Locality No. 8, Tsukada, Wajima City; the lower horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20216.

Fig. 9. Cf. *Ilex*, oblique polar view, 26μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20217.

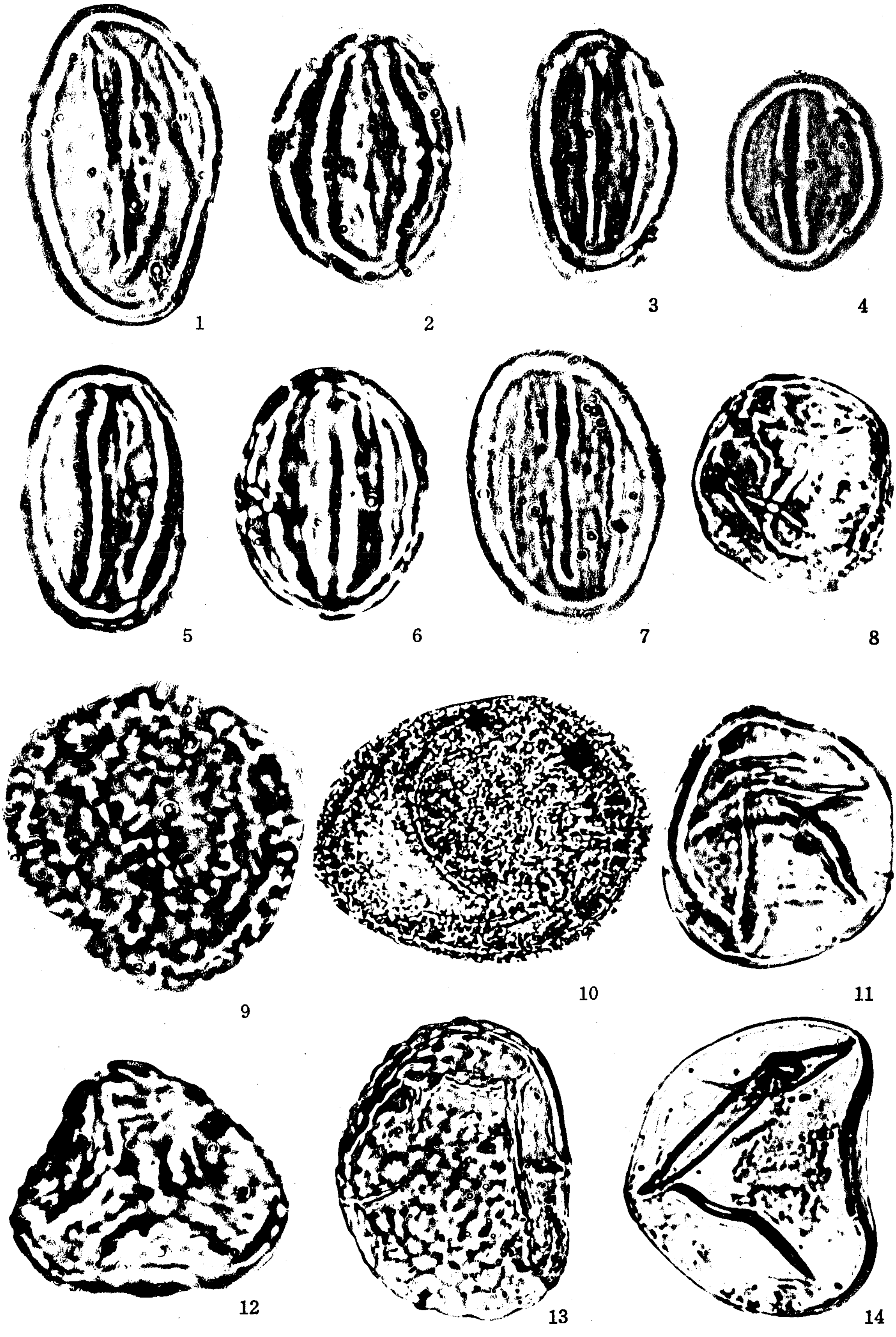
Fig. 10. *Nuphar* (?), equatorial view, 46μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20218.

Fig. 11. Aff. *Carya*, oblique polar view, 40μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower par of the Tsukada Member; EKZJ coll. cat. no. 20219.

Fig. 12. Gleicheniaceae, 38μ; Locality No. 5, Takuda, Wajima City; the uppermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20220.

Fig. 13. *Osmunda*, 48μ, lateral view; Locality No. 12, Ippon-matsu Park, Wajima City; the middle horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20221.

Fig. 14. Cf. Monolete type spore, 38μ, lateral view; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20222.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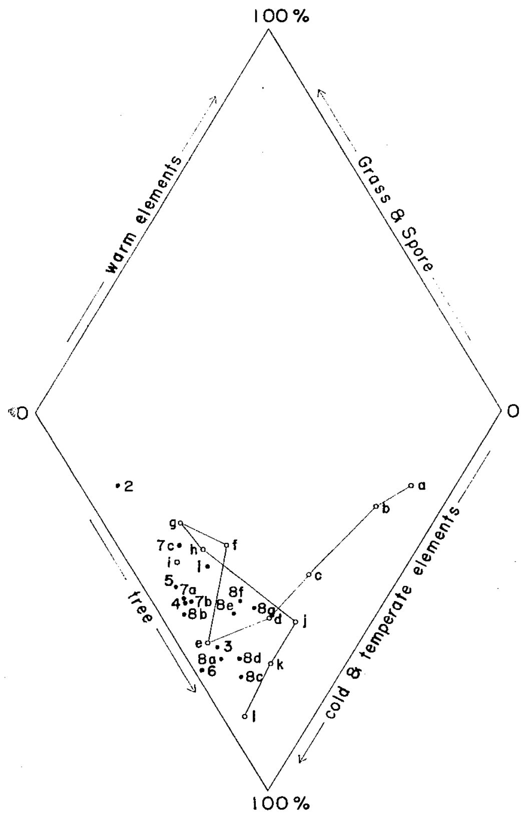
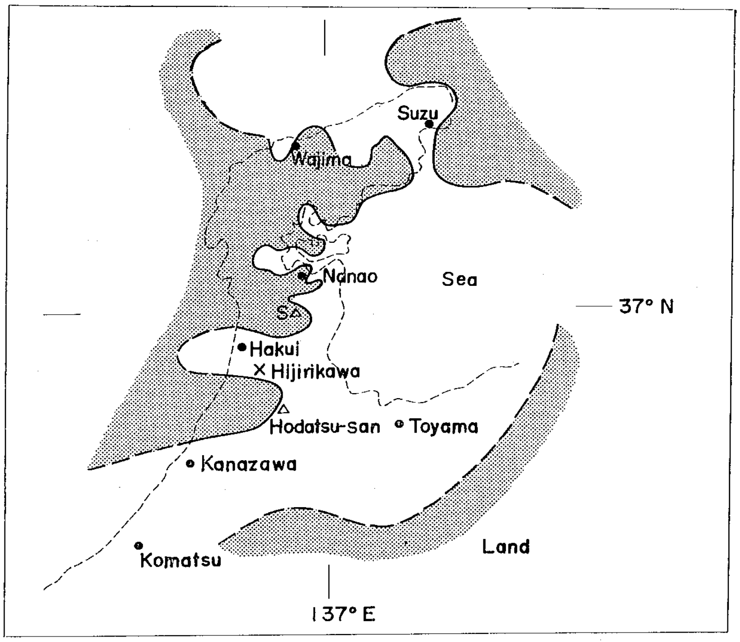


Text-fig. 13. Pollen diagram (10) : Quadrilateral diagram showing the paleoclimatic condition, paleoecological environment, tree pollen grains (AP) and grass pollen grains & spores (NAP) from the Yamatoda (a) ; Pollen grain from the Sunagozaka (b), Higashi-in'nai (c), Najimi (d), Hojuji (e), I'ida (f), Wakura (g), I'izuka (h), Nakayama-toge (i), Hijirikawa (j), Takakubo (k) and Omma (l) members. Numbers refer to Text-figs. 1 and 3 in the writer's previous paper (1969a).



Text-fig. 14. The paleogeographical map during the Otokawa Stage of the Late Miocene Epoch in the Hokuriku region (After Y. KASENO, 1963).

(c) Geological age

The correlation and age determination of the Neogene floras have been frequently done by use of some characteristic fossils and assemblages in the Japanese Islands. TANAI (1963) classified the Neogene floras of Japan into six types as described already in the writer's previous papers (FUJI, 1969a, b, c).

In generic composition the Tsukada pollen-flora is very similar to the Mitoku-type flora. The Mitoku-type flora contains a few exotic elements which are found abundantly in the Yamatoda and Noroshi floras. The exotic elements are commonly found in the Late Miocene floras of Europe and in the western region of the United States of America where the modernized plants of these exotic elements are abundant.

Thus, in comparison with various floras of the Tertiary in the Japanese Islands and from the viewpoint of stratigraphical evidences and paleontological data, the Tsukada pollen-flora is correlated with the Mitoku-type flora, and the member seems to be geochronologically of the Late Miocene or Earliest Pliocene epoch.

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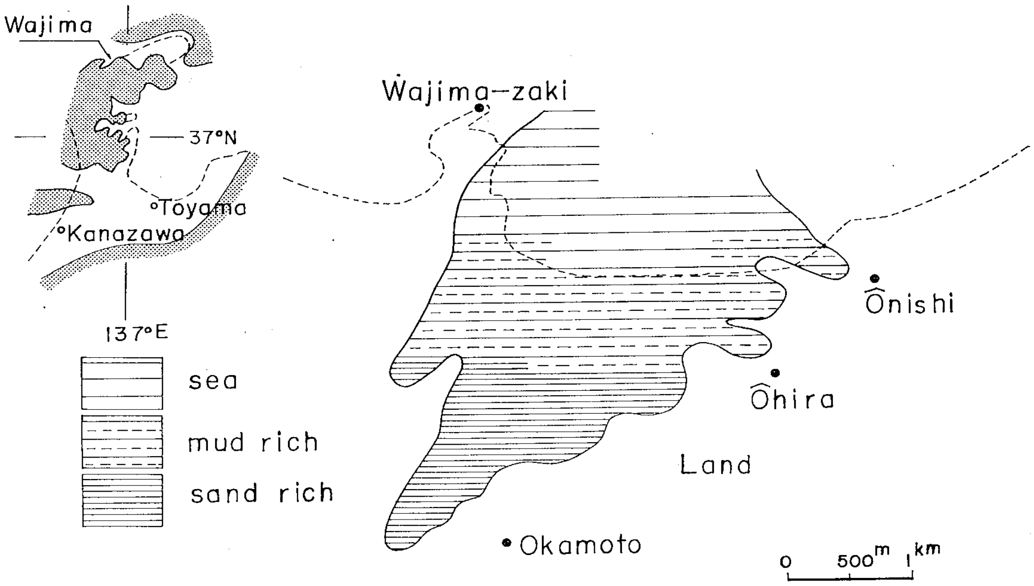


Text-fig. 15. The paleogeographical map during the sedimentation of the Tsukada Member in the Otokawa Stage of the Late Miocene Epoch in the Wakura area of Noto Peninsula, Central Japan (after Y. KASENO, 1963).

Explanation of Plate 37

Fig. 1. *Picea*, lateral view, 70μ; Locality No. 5, Takuda, Wajima City; the uppermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20223.

Fig. 2. *Picea*, lateral view, 82μ; Locality No. 7, Takuda, Wajima City; the middle horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20224.

Fig. 3. *Picea*, lateral view, 67μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20225.

Fig. 4. Taxodiaceae, Cf. *Metasequoia*, oblique lateral view, 22μ; Sample 14 from the outcrop of Locality No. 14, Ippon-matsu Park, Wajima City; the middle horizon of the Awakura Member, Sample 14 was collected from the tuffaceous mudstone of the Awakura Member; EKZJ coll. cat. no. 20226.

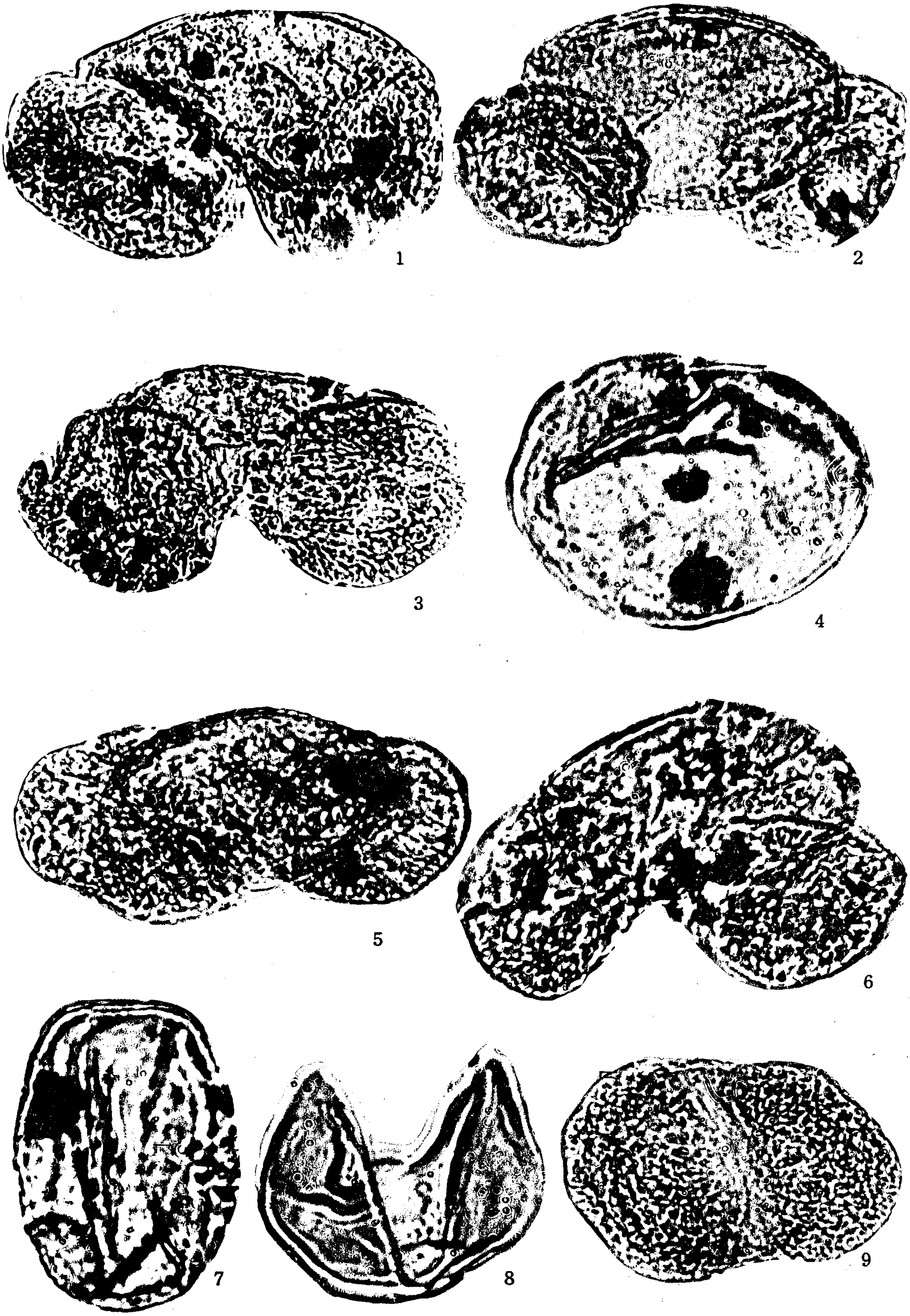
Fig. 5. *Picea*, lateral view, 70μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20227.

Fig. 6. *Abies*, lateral view, 82μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20228.

Fig. 7. *Tricolpropollenites* type pollen grain, gen. indet, equatorial view, 46μ; Locality No. 7, Takuda, Wajima City; the middle horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20229.

Fig. 8. Taxodiaceae, lateral view, 38μ; Sample 15 from the lowermost horizon of the lower part of the Tsukada Member, Locality No. 14, Ippon-matsu Park, Wajima City; EKZJ coll. cat. no. 20230.

Fig. 9. *Abies*, oblique ventral view, 98μ; 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; the lowermost horizon of the lower part of the Tsukada Member; EKZJ coll. cat. no. 20231.



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Anamizu	穴水
Awakura	粟蔵
Daijima	台島
Ezoana	蝦夷穴
Hamada	浜田
Hijirikawa	聖川
Hiradoko	平床
Hokuriku	北陸
Ikuru	伊久留
Inabune	稲舟
In'nai	院内
Ippon-matsu	一本松
Ishikawa	石川
Jinoko	地の粉
Kanazawa	金沢
Kasashio	笠師保
Kirita	桐田
Ko-ise	小伊勢
Konogi	此木
Kwanto	関東
Mitoku	三徳
Nanao	七尾
Nawamata	縄又
Nishi-ôno	西大野
Noroshi	狼煙
Noto	能登
Omma	大桑
Okamoto	岡本
Okazuka	岡塚
Otokawa	音川
Soyama	曽山
Sunagozaka	砂子坂
Takuda	宅田
Tsukada	塚田
Wajima	輪島
Wajima-nuri	輪島塗
Wajima-zaki	輪島岬
Wakura	和倉
Warabino	蕨野
Yamatoda	山戸田
Yokohama	横浜
Yokoji	横地

Explanation of Plate 38

Fig. 1. Photograph showing contact of pollen grain body and bladders of *Picea* from Locality No. 9, Takuda, Wajima City; ×600; EKZJ coll. cat. no. 20232; A: bladder, B: pollen grain body, C: contact part.

Fig. 2. Photograph showing sporoderm pattern of pollen grain body of *Picea* from Locality No. 9; ×880; EKZJ coll. cat. no. 20233; A: bladder, B: pollen grain body.

Fig. 3. Microphotograph showing contact of pollen grain body and bladders of *Picea* from 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu Park, Wajima City; ×640; EKZJ coll. cat. no. 20234; C & D: bladder, E: pollen grain body; F: contact area.

Fig. 4. Photomicrograph showing sporoderm pattern, especially sexine, of bladder of *Abies* from 24 m in depth of the well drilled at Locality No. T-1; ×640; EKZJ coll. cat. no. 20235; D: bladder, E: body.

Fig. 5. Photomicrograph showing sporoderm pattern of pollen grain body and marginal ridge of *Abies* from horizon above mentioned; EKZJ coll. cat. no. 20236; ×640; E: pollen grain body, M: marginal ridge.

Fig. 6. Photomicrograph showing contact of bladders and pollen grain of *Abies* from horizon refered to Fig. 4; ×800; EKZJ coll. cat. no. 20237; C: bladders, D: contact area.

Fig. 7. Photograph showing colpus of the deciduous *Quercus* from Sample 15 of Locality No. 14, Ippon-matsu Park, Wajima City; ×1360; EKZJ coll. cat. no. 20238.

Fig. 8. Photomicrograph showing pollen aperture of *Tilia* from Locality No. 9, Takuda, Wajima City; EKZJ coll. cat. no. 20239; ×1200.

Fig. 9. Photomicrograph showing pollen aperture of *Tilia* from locality above mentioned; ×1200; EKZJ coll. cat. no. 20240.

Fig. 10. Photomicrograph showing pollen grain aperture of *Tilia* from Locality No. 9, Takuda, Wajima City; ×1040; EKZJ coll. cat. no. 20241.

Fig. 11. Photomicrograph showing pollen aperture of *Tilia* from Locality No. 9; ×1200; EKZJ coll. cat. no. 20242.

Fig. 12. Photomicrograph showing pollen grain aperture of *Tilia* from 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu, Wajima City; ×1200; EKZJ coll. cat. no. 20243.

Fig. 13. Photomicrograph showing pollen aperture of Cf. *Tilia* from 24 m in depth of the well drilled at Locality No. T-1; ×800; EKZJ coll. cat. no. 20244.

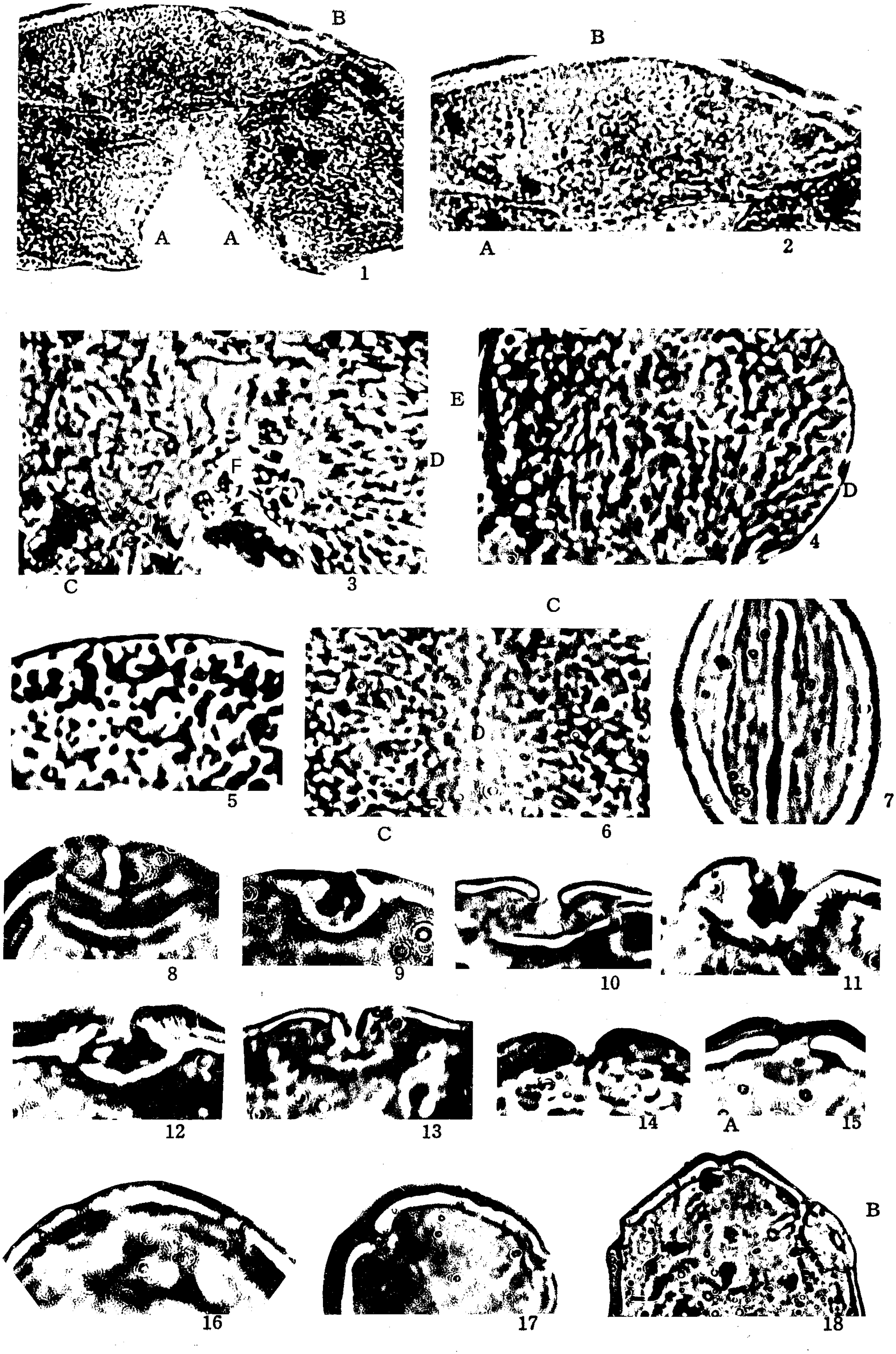
Fig. 14. Photomicrograph showing pollen aperture of *Carya* from Locality No. 1, Takuda, Wajima City; ×800; EKZJ coll. cat. no. 20245.

Fig. 15. Photomicrograph showing pollen aperture of *Carya* from Locality No. 1; ×800; EKZJ coll. cat. no. 20246.

Fig. 16. Photomicrograph showing pollen aperture of *Inapertipollenites* type pollen grain showing in Fig. 10, from Locality No. 6, Takuda, Wajima City; ×1040; EKZJ coll. cat. no. 20203.

Fig. 17. Photomicrograph showing pollen aperture of *Inapertipollenites* type pollen grain showing Fig. 10; ×480; EKZJ coll. cat. no. 20203.

Fig. 18. Photograph showing pollen aperture of *Juglans* from 24 m in depth of the well drilled at Locality No. T-1, Ippon-matsu, Wajima City; ×480; EKZJ coll. cat. no. 20247; A: profile of aperture, B: oblique view of aperture of *Tilia*.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