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Pollen Flora of the Tsunozu Group in Shimane Prefecture, Japan

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I. Introduction

In the San-in district the Plio-Pleistocene deposits widely distribute in the area facing to the Japan Sea. They are called the Tsunozu group in Shimane Prefecture. The Tsunozu group typically distributed in the hilly-land neighbouring Gôtsu and Tsunozu (the stratotype), and partly in the hills around Mt. Ôe-takayama. The Tsunozu group, according to Imamura (1964), is composed of marine and non-marine sediments and is correlated to the lower part of the Osaka group of Kinki district. In the Tsunozu group, *Stegodon* sp. and plant fossils, such as *Pseudolarix*, *Glyptostrobus*, *Sequoia*, *Cunninghamia*, *Metasequoia*, *Nyssa*, and *Paleodavidia*, were discovered (Imamura, 1964; Miki, 1950 etc.). It is very characteristic that *Stegodon* and some elements of *Pinus trifolia* flora,[1] as mentioned above, have coexisted at certain time of the geologic past. This coexistence shows that the deposition of the Tsunozu group began with the Pliocene age.

In this paper the writer describes the results of the pollen analysis of the Tsunozu group and will verify the floral changes in the Plio-Pleistocene age in Shimane Prefecture.

II. Pollen Analytic Method

Pollen analysis was made on 64 smaples of mainly clay and rarely lignite and fine sand in Tsunozu region, and 33 samples in the other regions. Preparation was followed to the Shimakura's method (Shimakura, 1956); pollen

1) *Pinus trifolia* flora is the flora contained in Miki's (1948) *Pinus trifolta* bed, i. e., the Seto group in Aichi and Gifu Prefectures, central Japan. In this flora, the following plants are enumerating : *Ginkgo biloba, Pinus trifolia, P. fujiii, Keteleeria davidiana, Pseudolarix kaempferi, Picea koribai, Tsuga longibracteata, Glyptostrobus pensilis, Sequoia sempervirens, Metasequoia japonica, M. disticha, Cunninghamia konishii, Carya striata, C. ventricosa, Nyssa pachycarpa, N. sylvatica, N. rugosa, Palaeodavidia multipterium, Liquidambar formosana, Hemitrapa trapelloidiana, Ilex cornuta, Juglans megacinerea.*

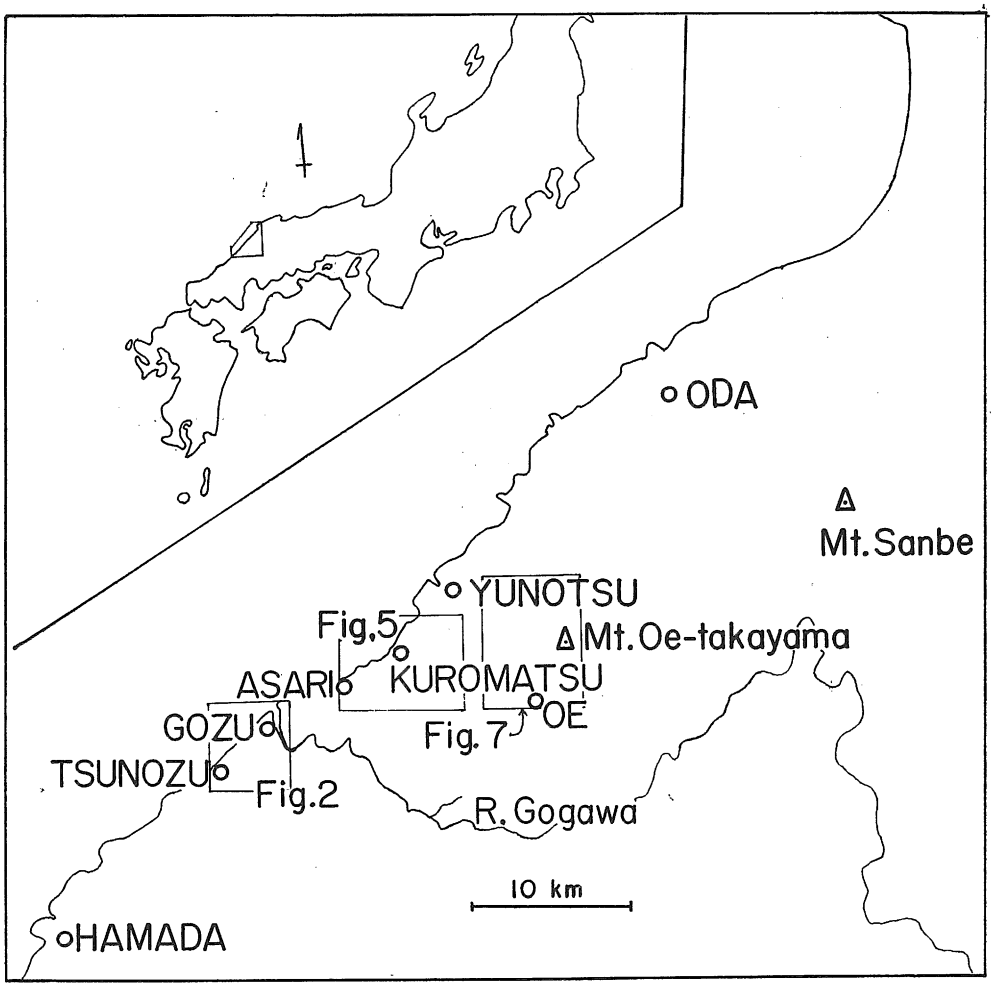

Fig. 1 Index map

grains were extracted from samples after the succeeding treatments of KOH, $HCl+HNO_3$, KOH, HF, and Acetolisis, and were mounted on slide glass with glycerol jelly. About 200 grains of the arboreal pollen were identified and counted under the microscope of 400 times.

In the Tsunozu group, 52 taxa of pollen were discovered, in which 33 arboreal taxa and 19 non-arboreal ones were discriminated. The results are shown in the pollen diagram of the Text-figures 4 and 9.

In these figures the percentage of the arboreal taxa represents their ratios to the total amounts of the arboreal pollen (ΣAP), and the percentage of the non-arboreal taxa is the ratios to the total amounts of pollen grans (ΣP). Pollen grains of representative taxa are also shown in the Plates.

III. Pollen Analysis in the Tsunozu Region

a. Sampling Localities and the Geologic Setting

The Tsunozu group was studied recently by the Tsunozu Research Group (unpublished), and by which the following natures were clarified. In the Tsunozu region, the Tsunozu group overlies unconformably the basement granitic rocks and takes almost horizontal structure. It is about 60 m in toal thickness. It is mainly composed of alternations of sand and mud layers, and is intercaled by gravel layers, lignite beds, and a thin volcanic ash layer. There are four marine clay beds of several meters thick, which are called as M 1, M 2, M 3, and M 4, respectively, in ascending order. Plant fossils, such as *Pseudolarix*, *Glyptostrobus*, *Sequoia*, *Liquidambar* etc., were reported by Miki (1950 and 1957) at the galley of Tsunozu. The horizon of this locality may situate the lignite beds between M 1 and M 2. Moreover plant fossils, such as *Picea koribai*, *Fagus* sp., *Pterocarya* cf. *palirurus*, *Berchemia* sp., *Stephania* sp., *Lindera* sp.?, and *Cornus controversa*, all of them were identified by Dr. S. Kokawa, were reported by the Tsunozu Research Group from the lignite bed just beneath of M 4.

The sampling localities and columnar sections are shown in the Text-figures 2 and 3.

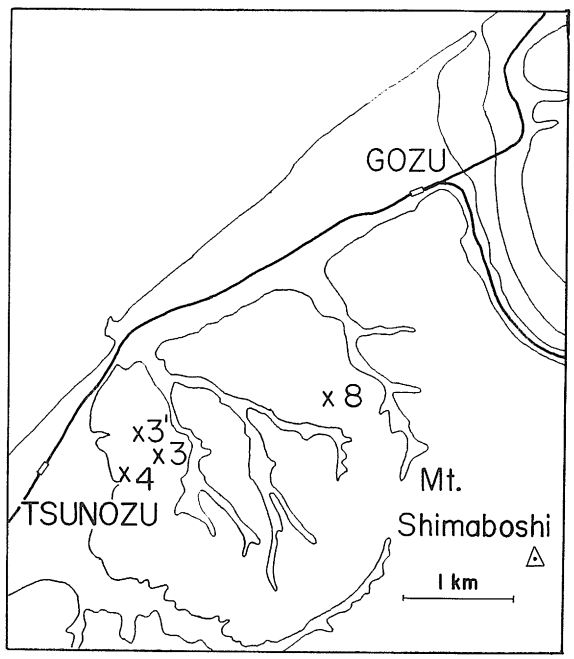

Fig. 2 Locality map of the Tsunozu region

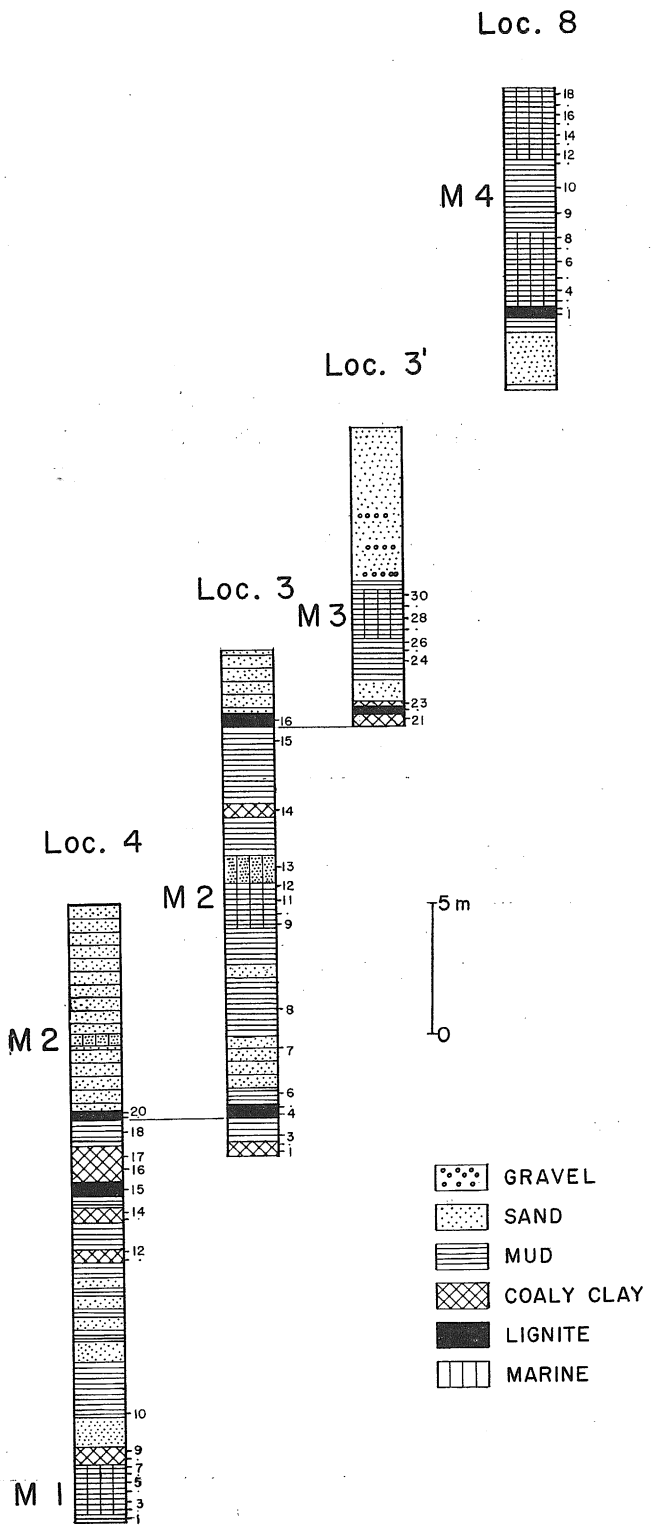

Fig. 3 Columnar sections of the Tsunozu region

b. Description of Data

The pollen features of the Tsunozu group are as follows.

M 1 and its above and below

The pollen diagram is marked at the base by the sharp peak of *Alnus*, which reaches to 83 percent of the total arboreal pollen. At the same level the non-arboreal pollen, especially *Persicaria* and Gramineae, also has a high percentage (47% to the total pollen). Among the arboreal pollen, *Liquidambar* and *Ilex* are common.

Above this basal feature, *Pinus*, Taxodiaceae, and *Liquidambar* pollen rise steeply, and there are smaller pollen maxima of *Fagus* and *Quercus*.

A few grains of *Pseudolarix*?, *Keteleeria*, *Tsuga*, *Juglans-Pterocarya*, *Carpinus*, *Castanea-Castanopsis*, *Ulmus-Zelkova*, *Ilex*, *Tilia*, and *Elaeagnus* are found.

Among the herbs, Gramineae, *Persicaria*, and Compositae are common.

Lignites and coaly clays between M 1 and M 2

The pollen diagram of this horizon is characterized by the excess of *Alnus* at the middle and the upper parts. At the same time the non-arboreal pollen rises from 30 to 93 percent of the total pollen.

By means of the pollen composition, this horizon can be divided into three parts.

The lowerpart: *Quercus* and *Largerstroemia* have sharp peaks. It is distinctive that *Largerstroemia* pollen, which occurred only occasionally in the other levels, rises over 20 percent through this horizon.

Common pollens also are *Pinus*, *Picea*, Taxodiaceae, and *Liquidambar*. A few grains of *Pseudolarix*?, *Keteleeria*, *Juglans-Pterocarya*, *Carpinus*, *Alnus*, *Fagus*, *Ulmus-Zelkova*, *Ilex*, *Tilia*, and *Elaeagnus* are found.

Among the non-arboreal pollen, *Persicaria* and Gramineae are dominant, and the Compositae are common.

The middle part: The non-arboreal pollen has less higher percentage than that of the lower and the upper parts.

Alnus pollen shows extremely high percentage (70-90%) and the most of other arboreal pollen curves decrease. *Picea*, *Pseudolarix*?, *Keteleeria*, Taxodiaceae, *Juglans-Pterocarya*, *Carpinus*, *Ulmus-Zelkova*, and *Liquidambar* decrease to a few percent.

The non-arboreal pollen is composed mainly of *Persicaria*, and the pollen grains of the Gramineae and Compositae are inferior in number in comparison with the lower and the upper parts.

The upper part: The upper part is characterized by having a extremely excess of the non-arboreal pollen, which is more than 70 percent of total. *Persicaria* pollen exceeds 50 percent, and the Gramineae are over than 10 percent.

In the lower half of this part, *Picea* pollen is dominant. In the middle half,

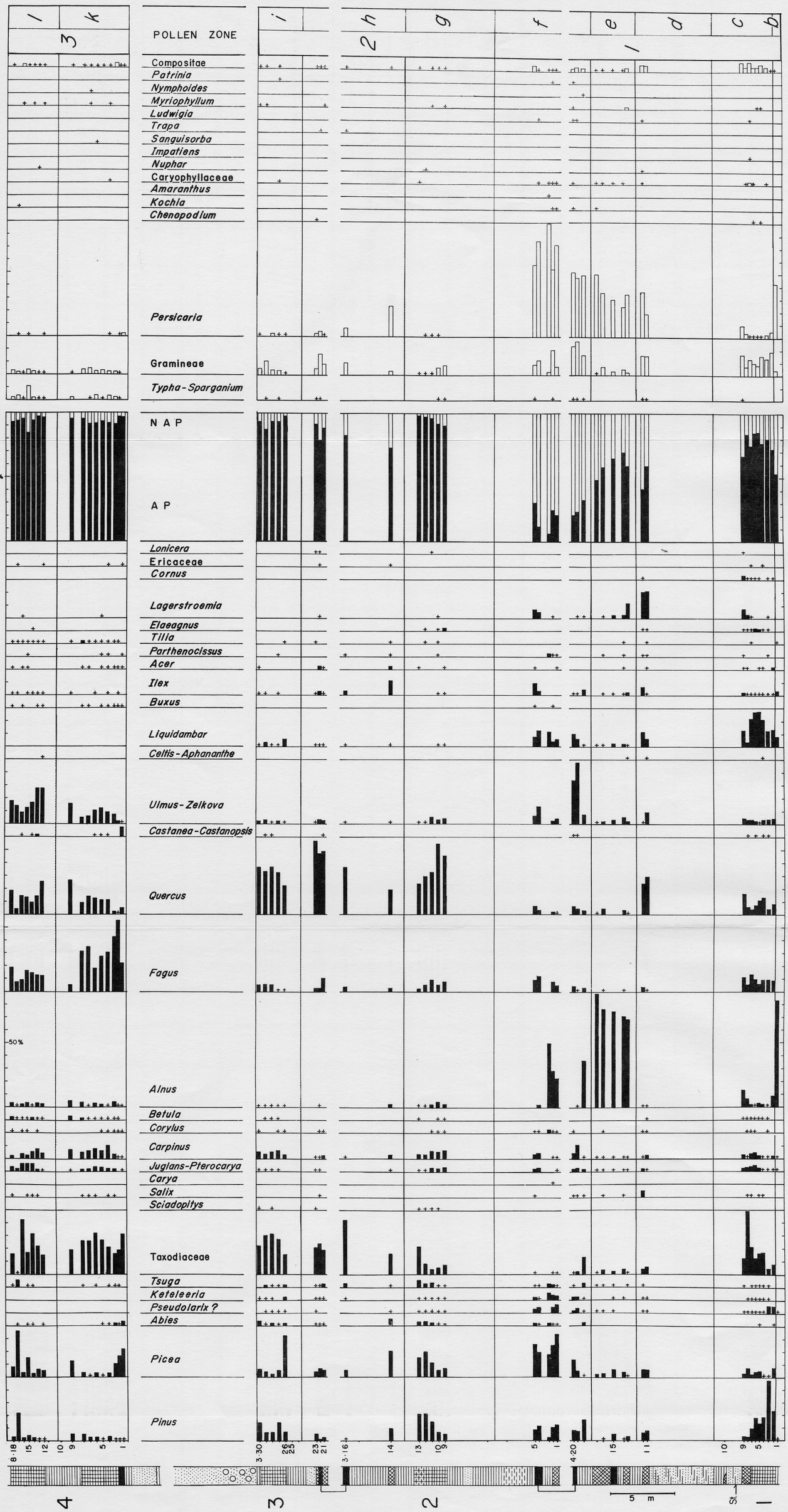

Fig. 4 Pollen diagram of the Tsunozu region.

Alnus shows a sharp peak, while *Picea* decreases. In the upper half, *Ulmus-Zelkova* shows a sharp peak, *Alnus* disappears practically and *Picea* increases. *Pinus*, *Pseudolarix*?, and *Keteleeria* are common. A few grains of *Fagus*, *Quercus*, and *Liquidambar* are also present. Some pollen grains of *Carya* are found for the first time.

M 2

The non-arboreal pollen is lower than 10 percent of total pollen, especially in the upper half the figure is lower than 5 percent.

Quercus pollen is dominant, and *Pinus*, *Picea*, Taxodiaceae, *Carpinus*, and *Fagus* are common. A few pollen grains of *Abies*, *Pseudolarix*?, *Keteleeria*, *Tsuga*, *Sciadopitys*, *Juglans-Pterocarya*, *Ulmus-Zelkova*, and *Liquidambar* are also found.

Among the non-arboreal pollen, the Gramineae are common.

Lignites and coaly clays between M 2 and M 3

The non-arboreal pollen has relatively high percentage (10-30%) in the upper half of the Tsunozu group.

Among the arboreal pollen, *Quercus* and Taxodiaceae are dominant, and *Pinus*, *Picea*, and *Ilex* are common. A few grains of *Tsuga*, *Carpinus*, *Ulmus-Zelkova*, *Liquidambar*, *Pseudolarix*?, and *Keteleeria* are found.

M 3

Quercus and Taxodiaceae are dominant, and *Pinus*, *Picea*, *Carpinus*, *Fagus*, and *Liquidambar* are common. Some pollen grains of *Abies Juglans-Pterocarya*, *Alnus*, *Ulmus-Zelkova*, *Pseudolarix*?, and *Keteleeria* are also found.

In sample Loc. 3-30, the spores of *Ceratopteris* are identified.

The lower part of M 4 and lignite bed lying beneath M 4

Fagus and Taxodiaceae (*Metasequoia* pollen is comprised[2]) are dominant, and *Quercus*, *Ulmus-Zelkova*, *Alnus*, and *Picea* are common. *Pinus*, *Juglans-Pterocarya*, *Betula*, *Alnus*, *Buxus*, *Ilex*, *Acer*, and *Tilia* are constantly contained. *Pseudolarix*?, *Keteleeria*, and *Liquidambar* are not found in this horizon.

The upper part of M 4

The pollen grains of *Fagus*, *Quercus*, *Ulmus-Zelkova*, and Taxodiaceae (*Metasequoia* is comprised) are dominant, and *Picea*, *Juglans-Pterocarya*, and *Carpinus*, are common. A few grains of *Pinus*, *Betula*, *Alnus*, *Buxus*, *Ilex*, and *Tilia* are found.

There is a sharp peaks of conifer trees, such as *Picea*, *Pinus*, and *Tsuga*, in the upper part of M 4 (Loc. 8-17). In this level the Taxodiaceae curve decreases.

2) The pollen of *Metasequoia* is able to distinguish from the other genera of Taxodiaceae in its smaller size of grains (Tai, 1963 and 1966, and Ueno, 1951).

IV. Pollen Flora in the Other Regions

The Tsunozu group distributes also in the Kuromatsu-Asari and the Ôe regions. In each region, there is a marine clay bed embedded in non-marine sediments. Some important plant fossils are reported from these sediments. As there is no excellent key bed, the horizons of these sediments are not yet settled clearly.

a. The Kuromatsu-Asari Region

In coastal area on the Kuromatsu-Asari region there is a marine clay bed of 1 to 3 meters thick. The marine clay bed is embedded in the alternating beds of non-marine clays, sands, and gravels. Sampling localities and columnar sections are shown in the Text-figures 5 and 6.

In this region the following plant fossils have been reported by Miki (1950, 1952, 1955, 1956, 1957, and 1958).

At the galley near the Asari railway station:

Pseudolarix, Glyptostrobus, Picea koribai, Nelumbo, Meliodendron, Trapa deformata, Trapa mammilifera.

At the galley of Yabu in Hazumi:

Pseudolarix kaempferi, Pseudotsuga subrotunda, Cryptomeria, Cunninghamia, Sequoia, Cephalotaxus obovata, Pterocarya paliurus, Nyssa pachycarpa, Paleodavidia multipterium, Meliodendron.

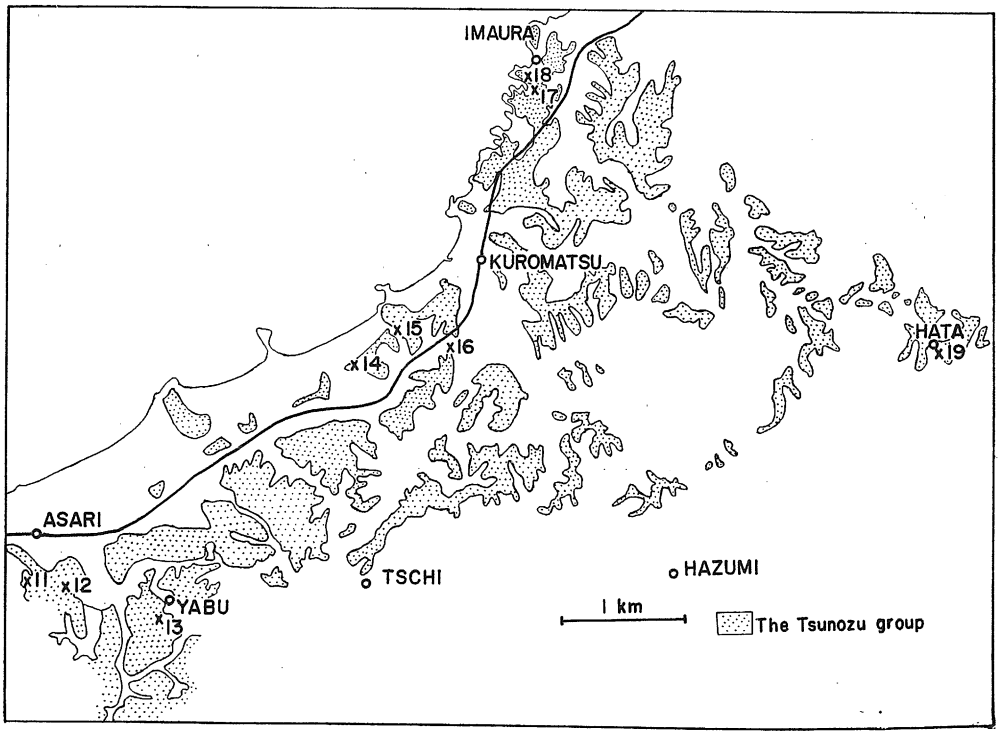

Fig. 5 Locality map of the Kuromatsu-Asari region

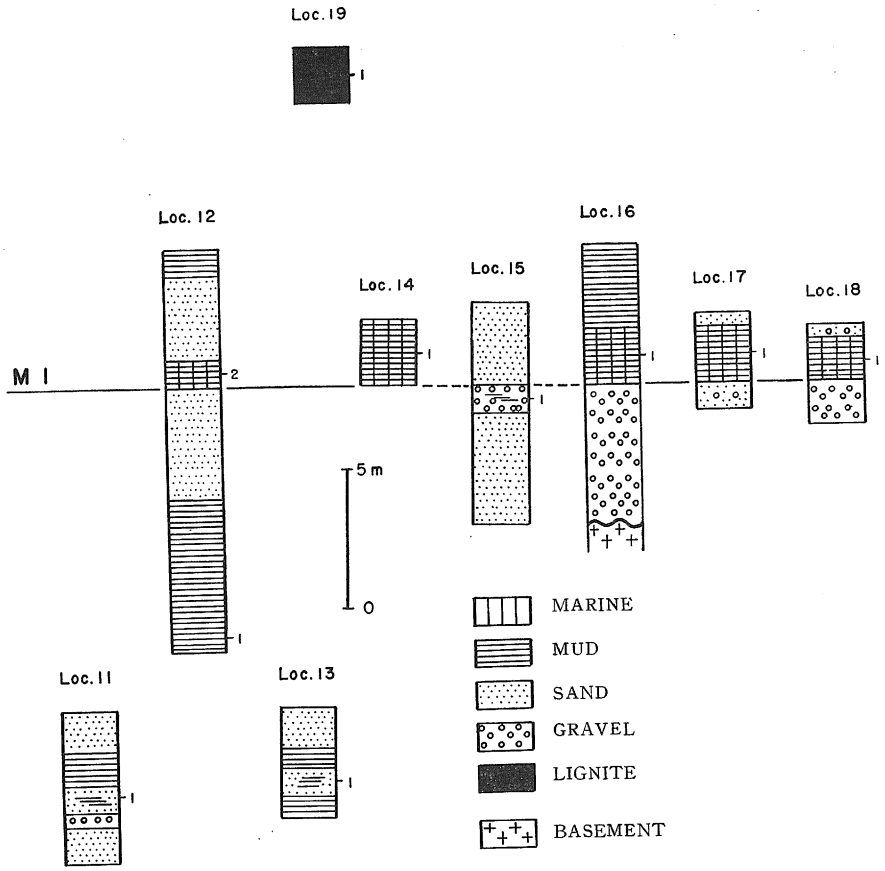

Fig. 6 Columnar sections of the Kuromatsu-Asari region

The horizons of these fossiliferous strata may situate the level below the marine clay.

Pollen spectra from the samples below the marine clay are characterized by the dominant or common occurrence of the pollen of *Pinus*, *Picea*, Taxodiaceae, *Fagus*, and *Quercus*. A few grains of *Pseudolarix*?, *Keteleeria*, and *Liquidambar* are found. Some samples (Loc. 11-1 and Loc. 13-1) contain *Nyssa* pollen.

In the marine clay bed, *Pinus*, *Fagus*, *Quercus* and *Liquidambar* pollen are dominant or common. A few grains of *Pseudolarix*? and *Keteleeria* are found. In some samples (Loc. 17-1 and Loc. 18-1), *Carya* pollens are discovered.

The lignite bed (Loc. 19-1) which lies above the marine clay, shows high percentage (about 60%) of the non-arboreal pollen. *Persicaria* pollen is about 50 percent, and the Gramineae are about 10 percent.

The pollen of *Pinus*, Taxodiaceae, *Fagus*, and *Ulmus-Zelkova* are dominant,

and *Quercus* and *Liquidambar* are common. There are a few grains of *Pseudolarix*? and *Keteleeria*.

On account of the occurrence of common pollen grains of *Liquidambar* and a few grains of *Pseudolarix*? and *Keteleeria*, the marine clay bed may be

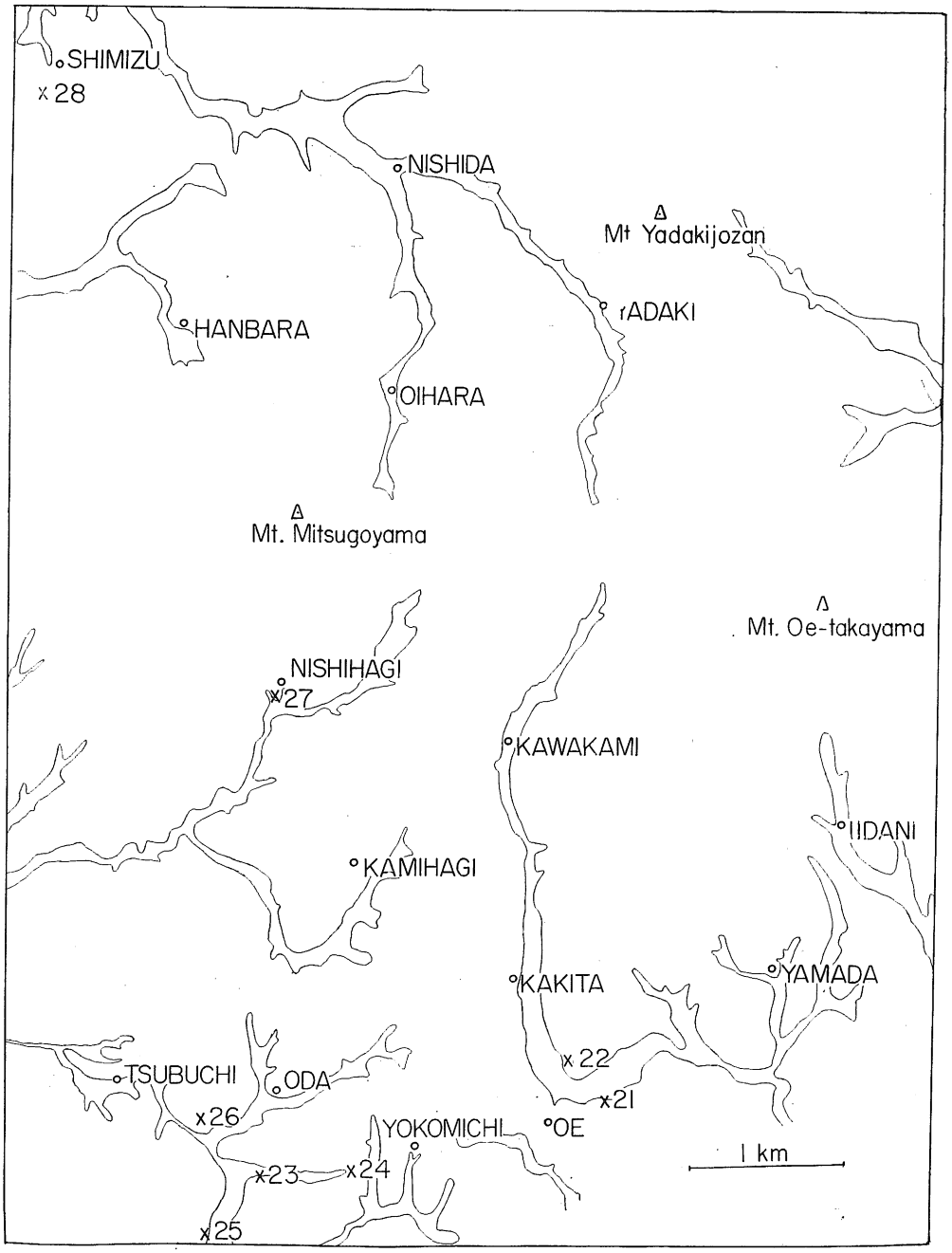

Fig. 7 Locality map of the Oe region

correlated to M 1 of the Tsunozu region. This correlation is also supported by the facts that the high percentage of the non-arboreal pollen and the total percentage of *Pinus trifolia* flora.

b. The Ôe Region

The Ôe-takayama pyroclastic flow and fall deposits are embedded in the clastic sediments of the Tsunozu group in this region.

The stratigraphical succession of the group that established by the Tsunozu Research Group (1968, MS[3]) is as follows.

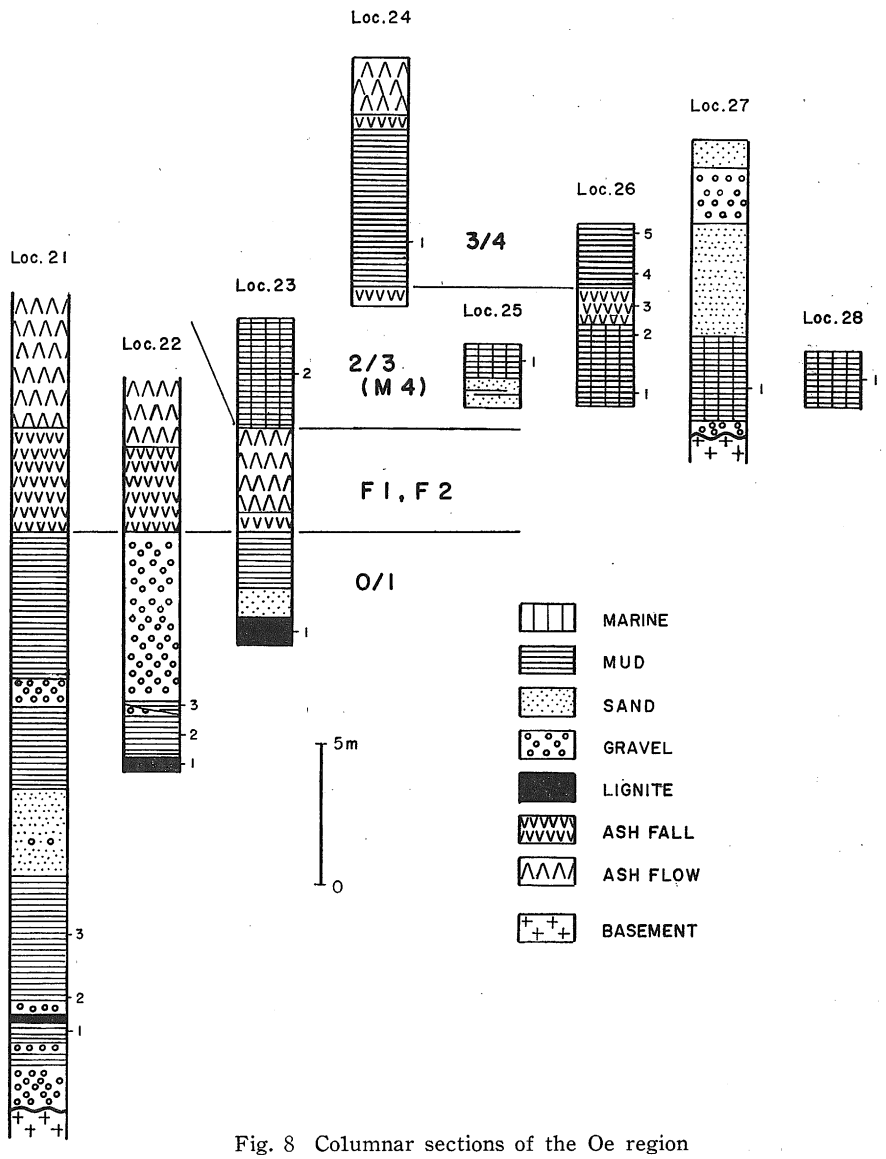

Fig. 8 Columnar sections of the Oe region

Pyroclastic flow deposit (**F4**)
Sand and non-marine clay (**3/4**)
Ash flow deposit (**F3**)
Marine clay (**2/3**)
Ash flow deposits (**F2** and **F1**)
Gravels, sands, and non-marine clays with lignite beds (**0/1**)

From the marine clay bed (**2/3**), some plant fossils, such as *Metasequoia*, *Cunninghamia konishii*, *Fagus*, and *Alnus* are discovered (Tsunozu Research Group, 1968, MS[3]). In the fall ash bed just beneath **F1**, the leaf of *Cryptomeria* is obtained (Tsunozu Research Group, 1968, MS[3]).

Sampling locaities and columnar sections are shown in the Text-figures 7 and 8.

The pollen spectra from lignite or non-marine clay beds of the horizon **0/1** have the high percentage of the arboreal pollen (more than 90%). There is a dominant or common occurrence of pollen grains of *Pinus*, *Picea*, Taxodiaceae (comprising *Metasequoia*), and *Fagus* in them. In these taxa, the Taxodiaceae pollen reaches 70 percent in some samples. *Fagus* pollen excesses *Quercus*. There is no pollen grain of *Pseudolarix*?, *Keteleeria*, and *Liquidambar*.

In the marine clay bed (**2/3**), the predominant arboreal pollen are found (more than 98%). Among arboreal pollen, *Pinus*, Taxodiaceae (comprising *Metasequoia*), and *Fagus* are dominant, and *Picea* and *Ulmus-Zelkova* are common.

In the non-marine clay bed of horizon **3/4**, more than 95 percent of the arboreal pollen are found. *Pinus*, Taxodiaceae (comprising *Metasequoia*) and *Fagus* are dominant, and *Picea* and *Ulmus-Zelkova* are common.

As there is no pollen grain of *Pseudolarix*?, *Keteleeria*, and *Liquidambar*, the marine clay may be correlated to M 4 of the Tsunozu region. This correlation may be supported by the facts that *Metasequoia* pollen is still contained in it and that *Fagus* pollen excesses *Quercus*.

V. Floral Changes in the Tsunozu Group

From the above data mentioned in the Chapters III and IV, floral changes in the Tsunozu group to be considered as follows.

a. The Disappearance of *Pinus trifolia* Flora

Pollen grains of some elements of *Pinus trifolia* flora, such as *Pseudolarix*?, *Keteleeria*, *Liquidambar*, *Nyssa*, and *Carya*, which commonly contained in M 1, are not found in M 4.

The total percentage of above-mentioned taxa which reaches 20 percent in

3) 大阪層群総研連絡紙 No. 3, pp. 13–15.

Pinus
Picea
Abies
Pseudolarix?
Keteleeria
Tsuga
Taxodiaceae
Sciadopitys
Salix
Carya
Juglans-Pterocarya
Carpinus
Corylus
Betula
Alnus
Fagus
Quercus
Castanea-Castanopsis
Ulmus-Zelkova
Celtis-Aphananthe
Liquidambar
Buxus
Ilex
Acer
Parthenocissus
Tilia
Elaeagnus
Lagerstroemia
Nyssa
Ericaceae
Weigela
Lonicera
ΣAP
ΣNAP
Typha-Sparganium
Gramineae
Lilium
Persicaria
Kochia
Amaranthus
Caryophyllaceae
Nuphar
Nelumbo
Impatiens
Trapa
Ludwigia
Myriophyllum
Menyanthes
Nymphoides
Patrinia
Compositae
POLLEN ZONE

50%

Oe Region

3/4
Loc. 24-1
Loc. 26-5
-4
-3
-2
-1

2/3 (M4)
Loc. 25-1
Loc. 27-1
Loc. 28-1
Loc. 23-2
-1

0/1
Loc. 22-3
-2
-1
Loc. 21-3
-2
-1

3
j

Kuromatsu-Asari Region

(M1)
Loc. 19-1
Loc. 17-1
Loc. 18-1
Loc. 16-1
Loc. 14-1
Loc. 12-2
-1
Loc. 15-1
Loc. 13-1
Loc. 11-1

f
c
/
a

Fig. 9 Pollen diagrams of the Ôe and Kuromatsu-Asari region

the horizon below M 2, while decreases to only few percent in M 2 and M 3. In M 4 and the horizon **0/1** of the Ôe region, no pollen grain of these taxa is found (Fig. 10).

The horizon from which the plant fossils of *Pseudolarix*, *Liquidamber*, *Nyssa*, and *Paleodavidia* are reported, situates the level below M 2.

Among the Taxodiaceae, *Sequoia*, *Glyptostrobus*, *Cunninghamia*, *Cryptomeria*, and *Metasequoia* are reported in the Tsunozu group. *Sequoia* and *Glyptostrobus*, which are found in the horizon below M 2, have not been reported from M 4. While *Metasequoia* and *Cunniughamia* are reported from M 4.

b. Floral zones of the Tsunozu Group

From the view-point of the sequence of disappearance of these elements of *Pinus trifolia* flora, the Tsunozu group is divided into three floral zones, whose characters are described in the following.

Zone 1

The horizon from the base to just beneath M 2, including M 1, is Zone 1. There are dominancy or common occurrence of pollen grains of *Liquidambar*, *Keteleeria*, and *Pseudolarix*? in this zone. Occasionally a few grains of *Nyssa* and *Carya* are also found. Among the Taxodiaceae, *Sequoia*, *Glyptostrobus*, *Cunninghamia*, and *Metasequoia* are contained.

Zone 2

The horizon from M 2 to M 3 is Zone 2. A few grains of *Pseudolarix*?, *Keteleeria*, and *Liquidambar* are found, but there is no pollen grain of *Nyssa* and *Carya* in this zone. This zone is regarded as the transitional zone from Zone 1 to Zone 3.

Zone 3

M 4 and the non-marine sediments between M 3 and M 4 consist of Zone 3. In this zone, no pollen grain of *Liquidambar*, *Pseudolarix*?, and *Keteleeria* is found. Among the Taxodiaceae, *Metasequoia*, *Cunninghamia*, and *Cryptomeria* are contained.

These floral zones are subdivided into 12 subzones (Fig. 10) by means of their pollen composition.

c. The Position of the Tsunozu Group in Comparison with the Plio-Pleistocene Floral Changes in Southwest Japan

The floral changes in the Plio-Pleistocene age are excellently established by the eminent studies of S. Miki and S. Kokawa in the Osaka group and its equivalents in Kinki district.

Miki (1948) divided the late Cenozoic plant-bearing bed in central Japan into 7 beds, i. e., *Pinus trifolia* bed, *Metasequoia* bed, *Paliurus* bed, and so on, in ascending order.

Itihara (1960 and 1961) discussed the problem of extinction of *Metasequoia* flora in the Osaka group. He concluded that the lower part of the Osaka group was divided into two ages based on the *Metasequoia* flora. The upper half (the latter) of the group was the age of extinction of *Metasequoia* flora, and the

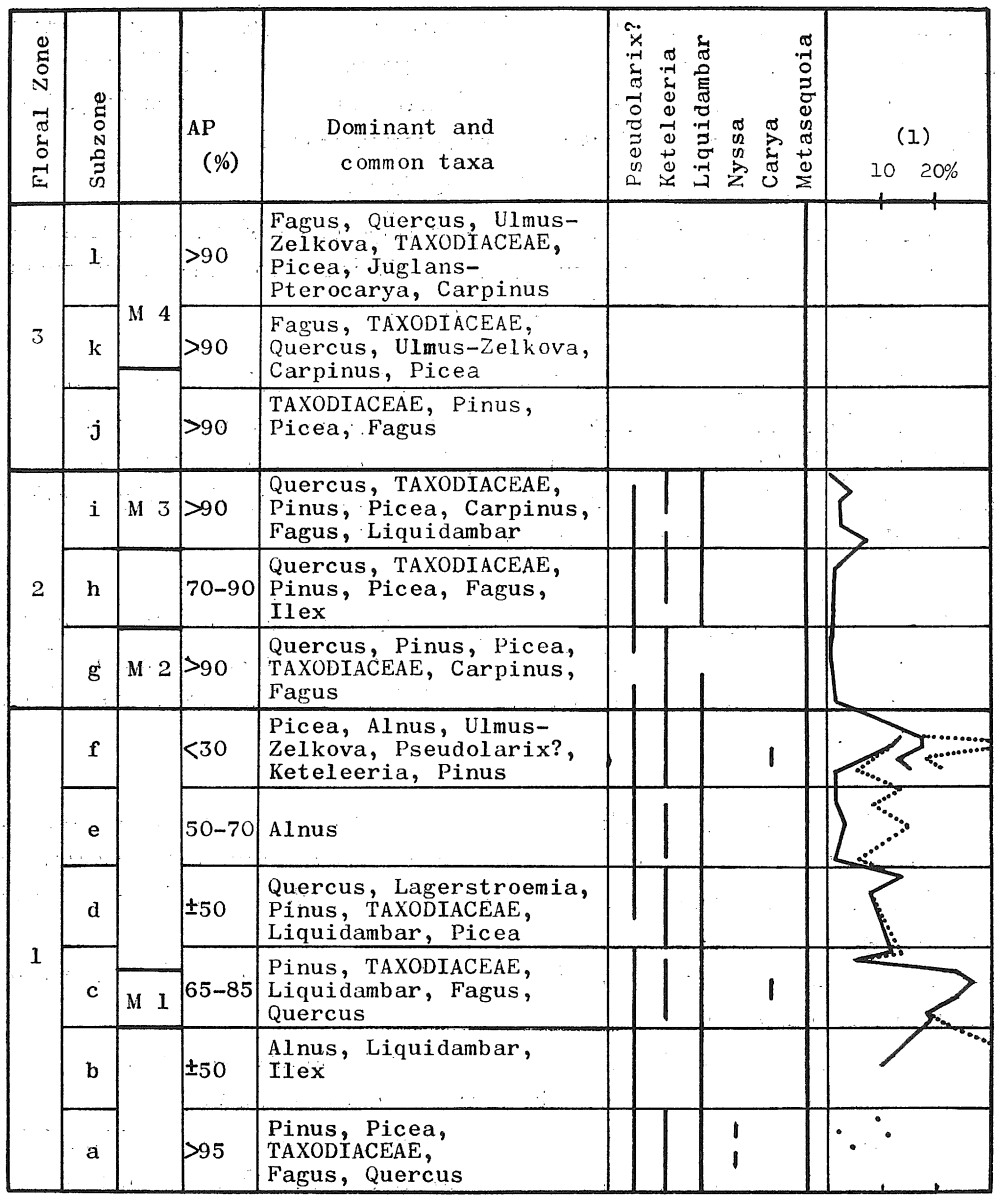

Fig. 10 Floral zones and subzones of the Tsunozu group, with the prosperity and decay of the some elements of *Pinus trifolia* flora
(1) solid line : (*Pseudolarix?*+*Keteleeria*+*Liquidambar*+*Nyssa*+*Carya*)/ΣAP
dotted line : (*Pseudolarix?*+*Keteleeria*+*Liquidambar*+*Nyssa*+*Carya*)/(ΣAP-*Alnus*)

lower (the earlier) was the age of flourish of the flora. He considered that the beginning of the age of extinction of *Metasequoia* flora should be assigned to the Plio-Pleistocene boundary in Japan.

In discussing the floral changes since the Pliocene in Kinki district, Kokawa (1964) recognized the following florae in ascending order.

1) *Pinus trifolia* flora which is contained in the Seto group.

2) Transitional flora between of the florae 1) and 3), which is reported from the lowermost part of the Osaka group.

3) *Metasequoia* flora of the lower part of the Osaka group.

4) *Paliurus nipponicus* flora of the upper part of the Osaka group.

In her studying the pollen flora of the Osaka group, Tai (1963 and 1966) divided the group into the following two zones.

2) *Fagus* Zone which corresponds with the upper part of the Osaka group.

1) *Metasequoia* Zone which corresponds with the lower part of the Osaka group.

The *Metasequoia* Zone, in its turn, was subdivided into two subzones: the upper and the lower *Metasequoia* Subzones. The pollen grains of *Keteleeria*, *Pseudolarix*?, and *Liquidambar* occurred in the lower *Metasequoia* subzone, while they were lacking in the upper *Metasequoia* one.

The pollen flora of the plant-bearing strata, which have been correlated to the Seto group, has analyzed by Shimakura in the Jigokudani formation (1963) and the Tsugeno group (1964) in Nara Prefecture and the Soni group (1964) in Mie Prefecture. In these strata, the occurrence of the pollen grains of *Carya*, *Nyssa*, and *Liquidambar* is rather common, while a few grains of *Hemitrapa*? are found.

The pollen flora of the lower parts of the Age and the Ko-Biwako groups has been studied by Shimakura (1964 and 1966). The pollen percentage of *Carya*, *Liquidambar*, and *Nyssa* are fairly high in the lowermost part of these groups. *Carya* and *Nyssa* pollen, however, decrease to a few percent in the upward course of the groups.

In the lowermost part of the Osaka group, the pollen grains of *Liquidambar*, *Pseudolarix*, and *Keteleeria* occurred, but, of *Nyssa* and *Carya* are not found (Tai and Ueno, 1965). From these pollen feature, this part of the group should be belonged to the lower *Metasequoia* subzone of Tai (1966).

The pollen feature of each flora is summarized as follows.

1) *Pinus trifolia* flora: the pollen grains of *Hemitrapa*? are found.

2) Transitional flora 1 : *Liquidambar* pollen is common, but *Nyssa* and *Carya* pollen are rare.

3) Transitional flora 2 : A few pollen grains of *Liquidambar*, *Pseudolarix*?, and *Keteleeria* are found. But there is no pollen grain of *Nyssa* and *Carya*.

4) *Metasequoia* flora: There found no pollen grain of *Nyssa*, *Carya*, *Liquidambar*, *Pseudolarix*?, and *Keteleeria*.

To compare the pollen feature of the Tsunozu group with that of the Osaka group, the flora in Zone 1 of the Tsunozu group may correspond to the Transitional flora 1, and the florae in Zone 2 and Zone 3 may correspond to the Transitional flora 2 and Metasequoia flora, respectively. The Plio-Pleistocene boundary in the Tsunozu group, as defined by Itihara (1960 and 1961) in the Osaka group, may situate on between Zone 2 and Zone 3.

		Miki (1948)	Itihara (1960, 1961)	Kokawa (1964)	Tai (1963, 1966)
The Osaka group	upper	*Paliurus* Bed		*Paliurus nipponicus* flora	*Fagus* Zone
	lower	*Metasequoia* Bed	Age of extinction of *Metasequoia* flora	*Metasequoia* flora	Upper *Metasequoia* Subzone
	lowermost		Age of flourish of *Metasequoia* flora	Transitional flora	Lower *Metasequoia* Subzone
		Pinus trifolia Bed		*Pinus trifolia* flora	

VI. Summary

1) In the Tsunozu group, 52 taxa of pollen were discovered, in which 33 arboreal and 19 non-arboreal taxa were discriminated.

2) From the view-point of the sequence of disappearance of some elements of the *Pinus trifolia* flora, such as *Nyssa*, *Carya*, *Liquidambar*, *Pseudolarix*, and *Keteleeria*, the group is divided into three zones.

3) By the pollen composition, these zones are subdivided into 12 subzones as showing in the Text-figure 9.

4) The floral changes in Kinki district, in ascending order, are summarized as follows. i) the *Pinus trifolia* flora, ii) the Transitional flora 1, iii) the Transitional flora 2, and iv) the *Metasequoia* flora. Zones 1, 2, and 3 of the Tsunozu group may correspond to the Transitional florae 1 and 2 and *Metasequoia* flora, respectively. The Plio-Pleistocene boundary, as defined by Itihara (1960 and 1961) should be drawn between Zone 2 and Zone 3.

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EXPLANATION OF PLATES

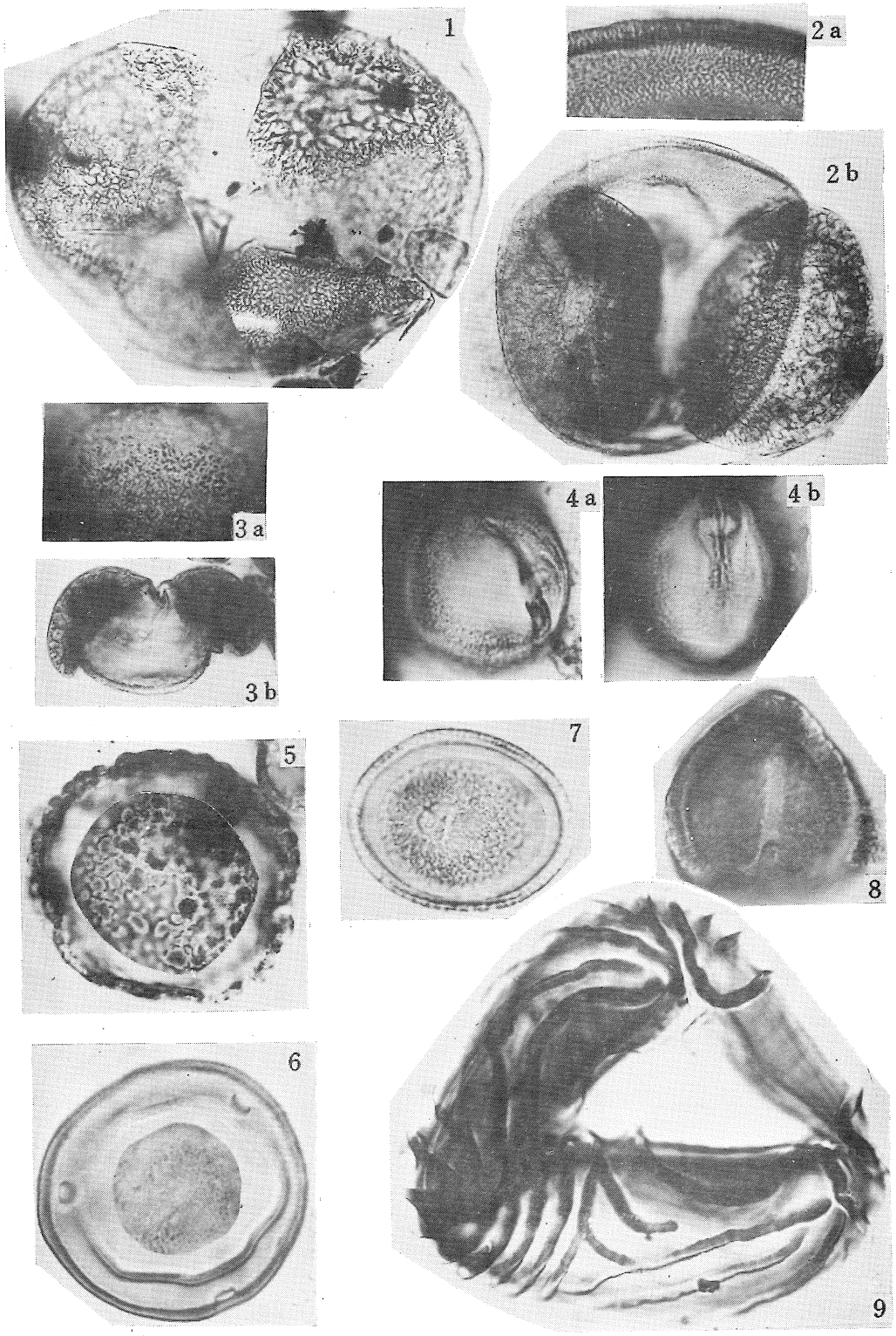
Plate 1

1. *Picea*, Loc. 8−18, ×400.
2. a, b. *Keteleeria*, Loc. 4−18, a ; ×1000, b ; ×400.
3. a, b. *Pseudolarix*, Loc. 4−2, a ; ×1000, b ; ×400.
4. a, b. *Nyssa*, Loc. 11−1, ×1000.
5. *Sciadopitys*, Loc. 4−5, ×1000.
6. *Carya*, Loc. 3−2, ×1000.
7. *Sparganium*, Loc. 4−19, ×1000.
8. *Largerstroemia*, Loc. 4−12, ×1000.
9. *Ceratopteris*, Loc. 3−30, ×500.

Plate 2

10. *Buxus*, Loc. 4−3, ×1000.
11. *Liquidambar*, Loc. 4−3, ×1000.
12. Caryophyllaceae, Loc. 4−5, ×1000.
13. a, b. *Acer*, Loc. 25−1, ×1000.
14. a, b. *Menyanthes*, Loc. 12−2, ×1000.
15. *Lilium*, Loc. 21−1, ×1000.
16. a, b. *Impatiens*, Loc. 4−7, ×1000.
17. a, b. *Nuphar*, Loc. 8−18, a ; ×1000, b ; ×400.
18. *Persicaria*, Loc. 4−5, ×1000.
19. *Chenopodium*, Loc. 4−3, ×1000.
20. *Trapa*, Loc. 8−18, ×400.
21. *Nymphoides*, Loc. 8−18, ×1000.

I. ONISHI : Pollen Flora of the Tsunozu Group Plate 1



I. ONISHI : Pollen Flora of the Tsunozu Group Plate 2