Mem. Fac. Lit. & Sci., Shimane Univ.,
Nat. Sci., 8, pp. 91-104, March 10, 1974

Pliocne and Pleistocene Pollen Zone in Kinki and Tokai Districts

—— For the Basis of the Plio-Pleistocene Pollen Stratigraphy in Central and Southwestern Japan ——

Ikuo ONISHI
Department of Geology, Faculty of Literature and Science, Shimane University.
(Received November 5, 1974)

I. Introduction

The subdivisions of the Pleistocene time were usually carried out on the basis of climatic oscillation. Therefore, the study of the vegetational changes is one of the most important means for divisions of that time. The detailed vegetational histories were already confirmed in several parts of the world. And the successions of the stages of the cold and warm climates during the Pleistocene were proposed.

The Plio-Pleistocene is the time when occurred the floral displacement from Tertiary elements to living ones. Based on these floral changes, the Plio-Pleistocene boundary problems have been discussed at many times.

In Japan, these studies are most advanced in Kinki district. Investigations on the Plio-Pleistocene seed flora have been accumlated since 1933, when Miki presented the detailed floral list in the Province of Yamashiro. Few years after, he distinguished some particular floras, on the basis of the frequencies of the extinct and exotic genera and species. The disappearing horizon of the particular species, such as *Metasequoia*, was confirmed by several workers, together with the progresses of geological survey of the Osaka group. Especially, checking up the modes of the disappearance of Tertiary elements that florished during the lowermost part of the Osaka group, Itihara (1960 and 1961) discussed the Plio-Pleistocene boundary in that group.

In addition to the macrofloras, pollen analytical studies on the Osaka group were started by Shimakura (1956) and succeeded by several workers. At present, the outline of the floral successions in Kinki district can be given.

The writer has studied the pollen floras of the Pliocene and Pleistocene strata in Kinki and Tokai districts. In this paper, he wishes to present the pollen evidences and attempts to establish the pollen zone in these districts. Several warkers already proposed the pollen zones from some districts of Japan. These zones are based on the stratigraphic distribution of the combinations of some particular pollen taxa. The writer defines those combinations as the poleln assemblages and the horizons that are represented by the set of some pollen assemblages as the pollen zones. It is the advantage of the writer's method that one can clearly discern the evolutional shifts of flora from the floral changes which caused by climatic oscillation.

Pollen Preparation

Untill 1970, the writer had treated the pollen samples by the method which was proposed by Shimakura (1957). The outline is as follows;

Deflocculation by 10% KOH→Treating with mixed acid of HCl and HNO_3→ Concentration on a watch glass→HF treatment→Erdtman's acetolysis method→ Mounting with glycerin jelly.

Since 1970, the method was altered as the following;

KOH treatment→When the calcium carbonate contents are high, HCl and KOH treatments→Concentration→Gravity separation by saturated solution of $ZnCl_2$→ Acetolysis→Mounting.

Acknowledgment. This work was begun as the graduate work of Kyoto University. The writer is indebted to Professor K. Nakazawa for constant guidance and critical reading of the manuscript. Particular thanks are due to Dr. S. Ishida for his much help and kind advice throughout this study.

Thanks are also due to Professor T. Kamei and many members of Research Group on the Quaternary of Japan for the discussions of the ploblems.

II. Stratigraphic Notes

The Pliocene and Pleistocene series in Kinki and Tokai districts are composed of two units (Itihara, 1960). The older one is called the second Setouchi supergroup that deposited in the second Setouchi inland sea (Ikebe, 1956), suffered the tectonic movement and left the dissected hilly surface called the Setouchi level. The younger one is the marine and river terraces and "Alluvial deposits" that preserve clear depositional surfaces.

The second Setouchi supergroup is composed of the Osaka, Kobiwako, Agé and Seto groups from west to east. The tephrochronologic correlation among these four groups was attempted by several workers (Takaya, 1963, Yokoyama, 1971, Mori, 1971a, etc.). The results are summarized by Research Group for Cenozoic Strata in Kinki and Tokai Districts (1973).

Terraces are divided into the three terrace groups, i.e. the high, middle and low ones (Itihara, 1960), by means of the hight of the depositional surface, the degree of the surface dissection, the thickness of the reddish soil, the degree of the weathering, the sedimental environment, e.g. marine or fluviatile, and the absolute ages.

By means of the radiocarbon measurements, it is clarified that the so-called "Alluvial deposits" are referred to the uppermost Pleistocene and the Holocene (Itihara and Kigoshi, 1962).

III. Pollen Data

Pollen analysis were carried out on the peat and mud samples obtained from 23 localities. Sampling horizons are as the followings (fig. 1a and b).

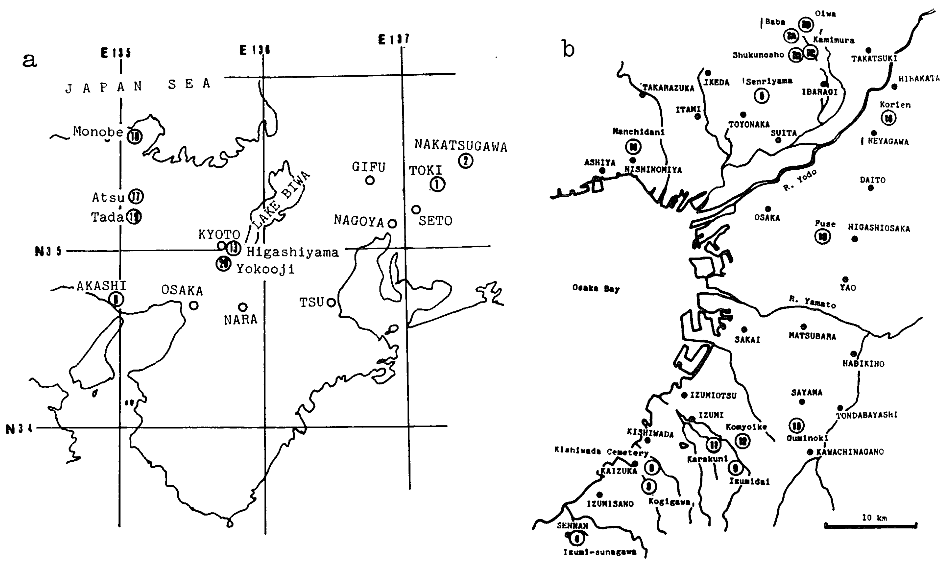

Fig. 1. Locality Map.

a) The Seto Group

1) **Tokiguchi**, Toki City, Gifu Prefecture (fig. 2)

Two samples (**ST–1** and **2**) from the clay bed were analyzed. From the same horizon, the occurrence of *Pinus trifolia* was reported (Miki, 1941), and this bed was correlated to the Seto ceramic clay (Fujii, 1968).

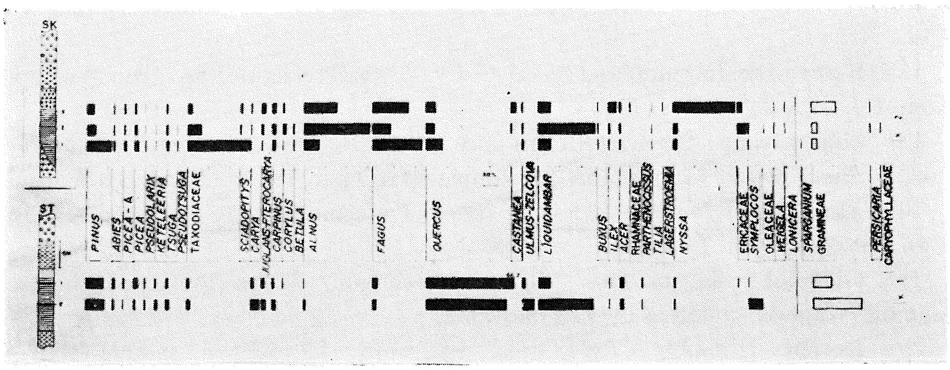

Fig. 2. Pollen Diagram (I); The Seto Group.

2) **Naeki**, Nakatsugawa City, Gifu Prefecture (fig. 2)

Three samples (**SK–1** to **3**) were collected from a clay bed which unconformably overlies on the basement granitic rocks. The clay bed is overlain by the pumice-bearing volcanic ash layer of about 5 m. thick. This ash layer is asserted to correlate to the Togo volcanic ash around Nagoya City (Mori, 1971b). So the sampling horizon may correspond to the upper part of the Mizuno formation.

b) The Osaka Group

The samples which cover almost all horizons of the Osaka group except **Ma 9** and **10** are analyzed. Sampling localities and sample numbers are as follows (fig. 1 and 3).

3) **Kogigawa**, Kaizuka City, Osaka Prefecture (fig. 4): 16 samples (**Kog–1** to **16**).

4) **Izumi-sunagawa**, Sennan City, Osaka Prefecture (fig. 5A): 3 samples (**IS–1**, **2** and **4**).

5) **Senriyama** hills, Toyonaka and Suita Cities, Osaka Prefecture (fig. 5B): 9 samples (**Sen–1** to **9**).

6) **Kishiwada** Cemetery, Kishiwada City, Osaka Prefecture (fig. 5D): 12 samples (**Kis–1** to **16**).

7) **Ibaragi** City, Osaka Prefecture (fig. 5C)

(a) Baba: 2 samples (**Bab–1** and **2**).

(b) Oiwa: 2 samples (**Oiw–1** and **2**).

(c) Fukui-kamimura: 4 samples (**Kam–1** to **4**).

(d) Shukunosho: 2 samples (**Iba–1** and **2**).

8) **Akashi** area, Okubo in Akashi City and Maiko in Kobe City, Hyogo Prefecture (fig. 5E): 6 samples (**Ak–1** to **25**).

9) **Izumidai**, Izumi City, Osaka Prefecture (fig. 5F): 14 samples (**Izu–1–1** to **3–4**).

10) **Fuse** boring core in Higashiosaka City, Osaka Prefecture (fig. 5C): 1 sample (**FuB–1**).

11) **Karakuni**, Izumi City, Osaka Prefecture (fig. 6A): 29 samples (**Kar–1–1** to **5–5**).

12) **Komyo-ike**, in Izumi and Sakai Cities, Osaka Prefecture (fig. 6B): 14 samples (**Kom–2–1** to **8–1**).

13) **Higashiyama**, the western entrance of the Higashiyama tunnel of the New Tokaido Line, Kyoto City (fig. 5A): 6 samples (**Hig–1** to **12**), collected by S. Ishida.

14) **Manchidani**, Nishinomiya City, Hyogo Prefecture (fig. 5C): 4 samples (**Nis–1** to **4**), collected by M. Furutani.

15) **Guminoki**, Sayama-cho, Minamikawachi-gun, Osaka Prefecture (fig. 5C): 1 sample (**Gum–1**), collected by T. Yokoyama.

16) **Korien**, Hirakata City, Osaka Prefecture (fig. 5C): 1 sample (**Hir–1**), collected by T. Yokoyama.

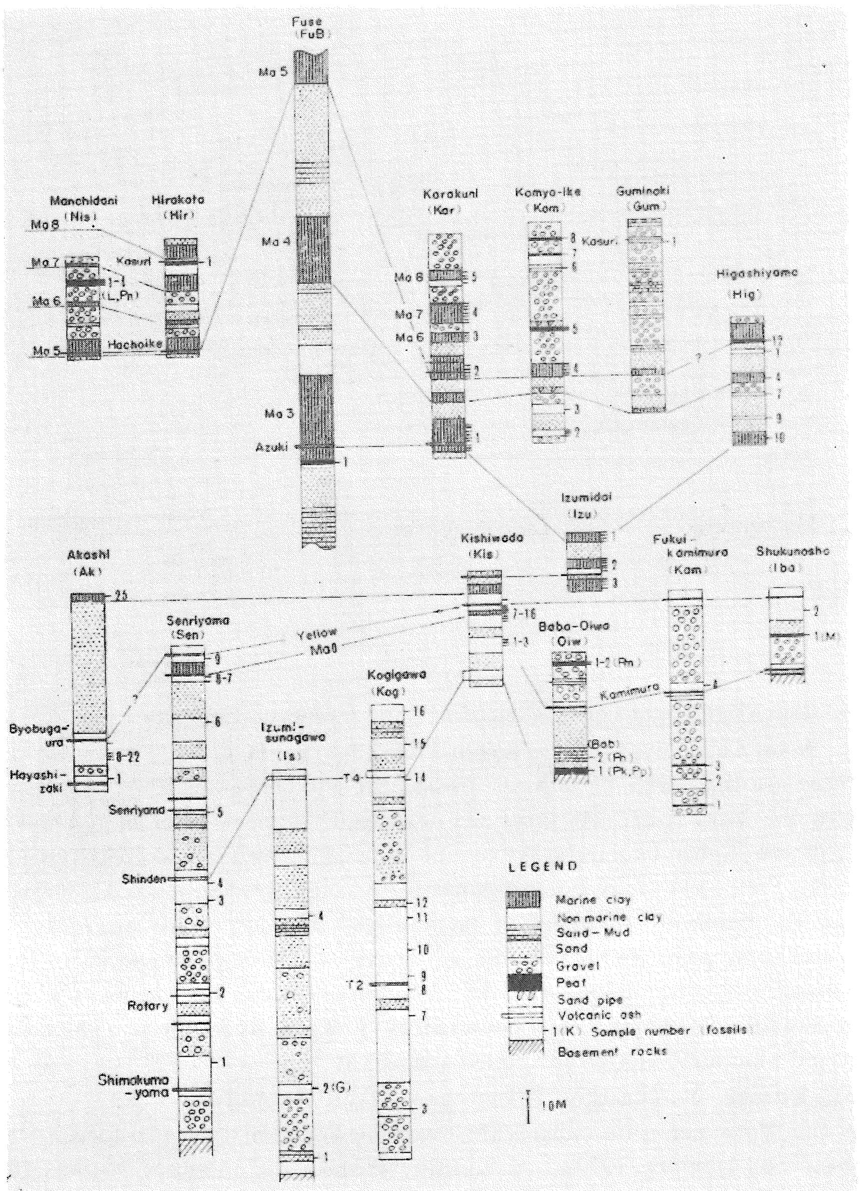

Fig. 3. Columnar Sections and Sampling Horizons of the Osaka Group.
Fossil; G: Ginkgo biloba, L: Larix gmelini, M: Metasequoia disticha, Pk: Picea koribai, Pm: Picea maximowiczii, Pn: Pinus koraiensis, Pp: Pterocarya paliurus.

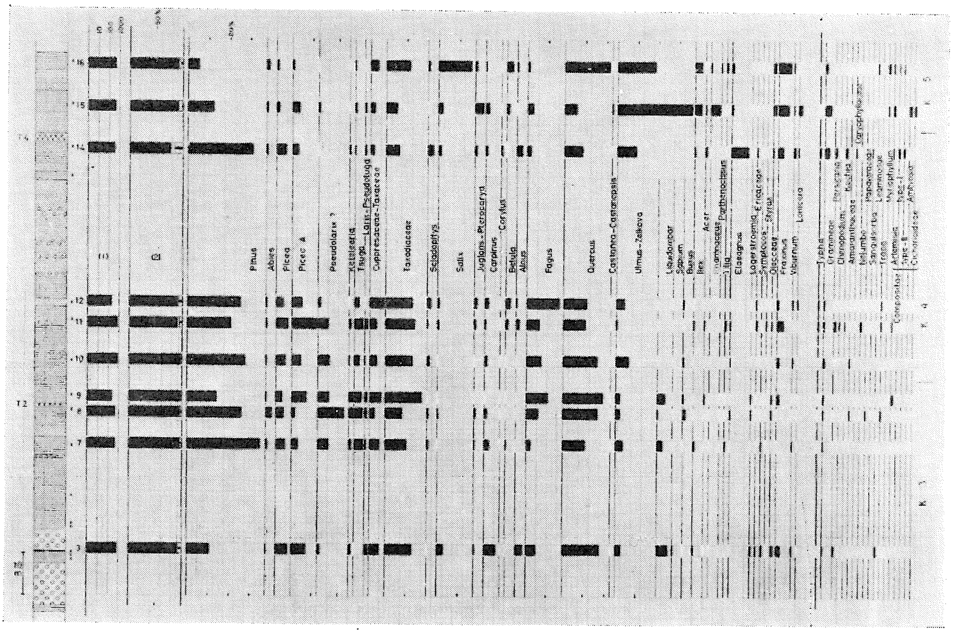

Fig. 4. Pollen Diagram (II); Kogigawa.

c) The Middle and Upper Pleistocene and Holocene Deposits

17) **Atsu**, Fukuchiyama City, Kyoto Prefecture (fig. 6C):

There are five levels of terraces around the Fukuchiyama basin, at the middle course of the Yura river. As there are developed the thick layer of red soil at the surface of the higher two terraces, i.e. the Hito and Osadano terraces (Okada and Takahashi, 1969), they may be correlated to the high terrace in Osaka basin. The Osadano formation is composed of unconsolidated muds, sands and gravels, and intercalates some peats and a volcanic ash layer. At Monobe, 6 species of the temperate forest elements, such as *Juglans sieboldiana*, *Fagus microcarpa* (?), *Quercus serrata* and *Buxus japonica*, are collected by S. Ishida and others. Three samples of peat and mud are collected for pollen analysis at Atsu.

18) **Kurobe**, Yasaka-cho, Takeno-gun, Kyoto Prefecture:

In the Yosa peninsula, there are distributed the marine Pleistocene deposits (Sakamoto and Uemura, 1972). At Kurobe, 45 species of molluscs, such as *Dendrostrea paulucciae*, were reported from the Kurobe formation. Some plant remains as *Pinus thunbergii*, *Fagus* sp., etc. have also been collected by S. Ishida and others. The Kurobe formation is correlated to the middle terrace deposits (Kinki Group, 1969). Seven samples collected from 4 localities are analyzed by the writer (Onishi, 1974).

19) **Tada**, Kasuga-cho, Hikami-gun, Hyogo Prefecture (fig. 6D):

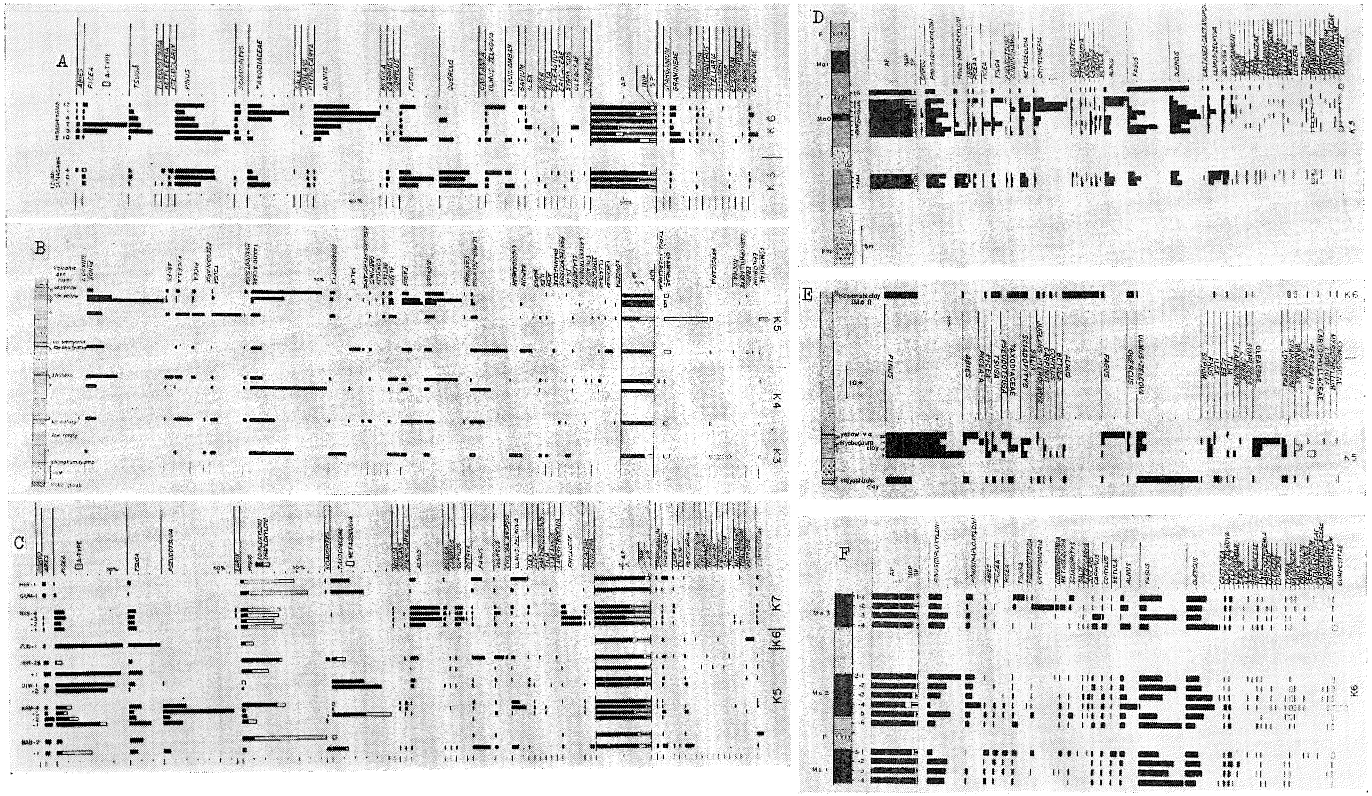

Fig. 5. Pollen Diagram (III); A: Izumisunagawa and Higashiyama. B: Senriyama Hills. C: Ibaragi and the Other Sites. D: Kishiwada. E: Akashi. F: Izumidai. (Pm=Pumice volcanic ash, Y=Yellow volcanic ash, P=Pink valconic ash)

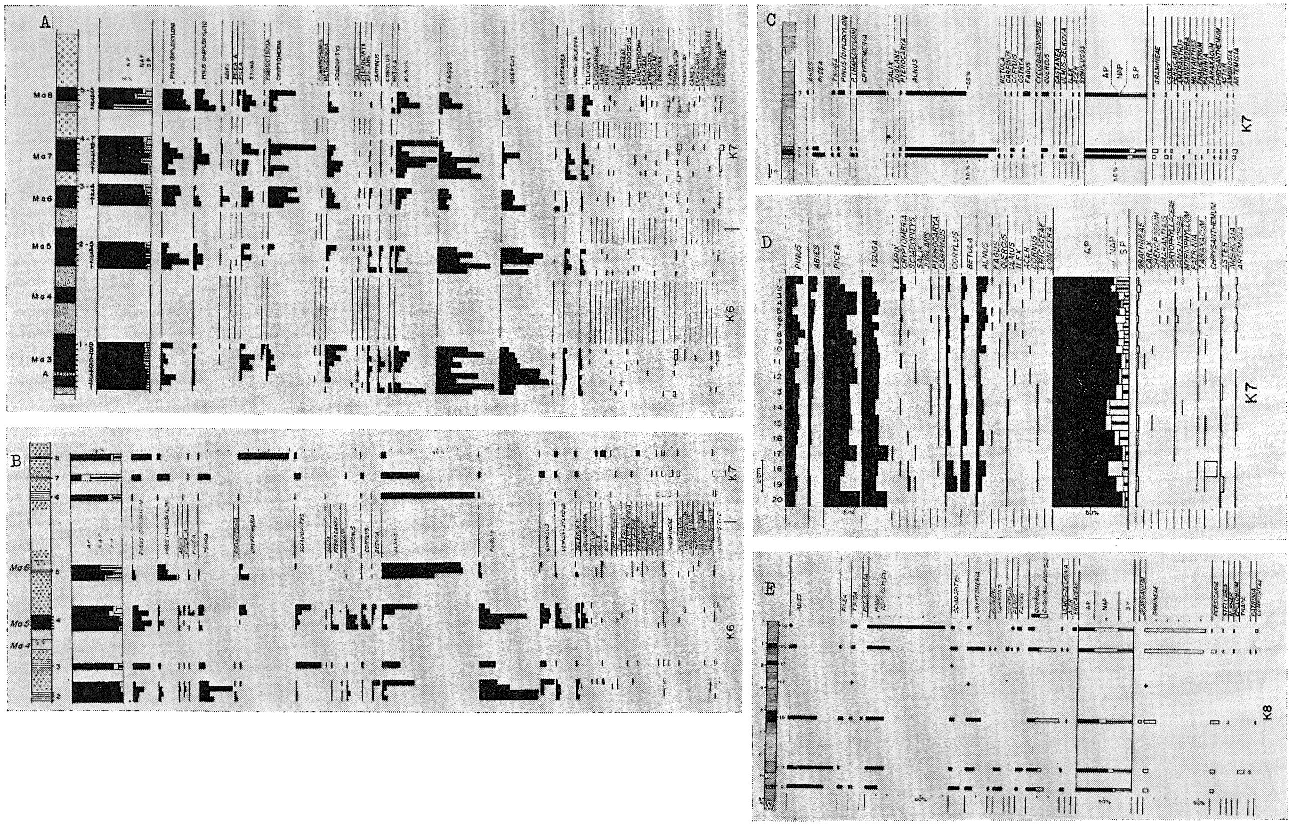

Fig. 6. Pollen Diagram (IV); A: Karakuni (A=Azuki volcanic ash). B: Komyo-ike. C: Atsu. D: Tada. E: Fushimi.

From a peat bed at Tada, 20 samples were gathered. This peat contains such subalpine forest elements as *Tsuga diversifolia*, *Oxycoccus* sp., etc., and is covered by gravel veneer of the lowest terrace. There are different opinions on the age of this peat. One asserts that it belongs to the low terrace (Okada and Takahashi, 1969) and the other assumes it to be assigned to the high terrace (Research Group of Quaternary Tectonic Movement in C-Zone of UMP, 1973). The results of the residual percentages of acetylbromide soluble substance (Itihara, Y. et al., 1966) and the Szaferowa's graphs of *Menyanthes* seeds (Kokawa, 1962a and b) of this peat differ from those of the peat in the Osadano formation at Atsu. The radiocarbon ages of $>32{,}000$ (GaK–944) and $24{,}900\pm450$ (TK–38) were reported from the same peat at Tada (Okada and Takahashi, 1969), so this peat seems to belong to the low terrace.

20) **Yokooji** swamp, **Fushimi**-ku, Kyoto City (fig. 6E):

S. Ishida and others collected 7 samples (**Fus–5** to **19**) from the open-cut of about 10 m. deep. At the base of this cut, there are the latest Pleistocene gravels of $12{,}340\pm220$ ^{14}C years B.P. (GaK–1453). Radiocarbon ages are obtained from 8 horizons, and the depositional ratio is calculated as 1 meter per 1,000 years (Ishida et al., 1969). Judging from this ratio, the following age for each sample may be estimated:

Fus–19	0.2 to 0.3×10^3 years B.P.
Fus–18	about 1.0×10^3 years B.P.
Fus–15	about 4.5×10^3 years B.P.
Fus–9	about 6.0×10^3 years B.P.
Fus–5	about 7.0×10^3 years B.P.

At the same horizon of **Fus–15**, the abundant leaves of *Cyclobalanopsis gilva* were reported (Ishida et al., 1969).

IV. Changes of Pollen Flora

a) Pollen Assemblages

Based on the features of each spectrum, the following 14 pollen assemblages are distinguished.

1) ***Cyclobalanopsis-Carya*** **assemblage**

It is characteristic of the Seto ceramic clay bed (**ST–1** and **2** in fig. 2). The spectrum of this assemblage shows the predominant frequency of *Quercus* (mainly *Cyclobalanopsis*). *Liquidambar*, *Pinus*, *Carya* and *Ulmus-Zelkova* are rather abundant. There are also small percent of *Keteleeria* and *Pseudolarix*.

It is considered that this assemblage was dirived from Seto flora.

2) ***Cyclobalanopsis-Podocarpus*** **assemblage**

Another warm climate is inferred from a spectrum of **Ma 8** in Hirakata hills (Tai, 1963). This spectrum is characterized by abundant pollen of *Cyclobalanopsis* and *Quercus* and is accompanied by *Pinus* and *Podocarpus*. This spectrum is classified into *Cyclobalanopsis-Podocarpus* assemblage. It seems that this assemblage was derived from *Syzygium* flora.

3) ***Cyclobalanopsis-Abies*** **assemblage**

It is represented by the pollen assemblage of the middle part of the Alluvial deposits (**Fus–5** to **15** in fig. 6E). The age is called "Climatic Optimum" and thought to be the warmest period during the Holocene. Pollen spectra of this assemblage are characterized by the high percentage of *Cyclobalanopsis*, *Quercus* and *Abies*. And it is considered that this assemblage was derived from Yokooji flora.

4) ***Quercus–Liquidambar*** **assemblage**

This assemblage is characteristic of the lowermost part of the Osaka group (e.g. **Kog–3, 7** and **9** in fig. 4). The spectrum of this assemblage shows the high percentage of *Quercus* including *Cyclobalanopsis* here, and not a few percent of *Liquidambar*, *Keteleeria* and *Pseudolarix* are contained. It seems that this assemblage was derived from Sennan flora.

5) ***Quercus*-Taxodiaceae assemblage**

Pollen grains called Taxodiaceae in this context may belong to *Sequoia* or *Glyptostrobus*, because of the coexistence of these macrofossils. Typical spectrum of this assemblage is characterized by predominance of Taxodiaceae and *Quercus* including *Cyclobalanopsis* (e.g. **Kog–10** or **11** in fig. 4) and is obtained from the upper half of the lowermost part of the Osaka group.

6) ***Fagus-Quercus*** **assemblage**

It is characterized by abundant pollen of *Fagus* and *Quercus* including *Cycclobalanopsis*. This assemblage is obtained from the marine clay beds of almost all horizons of the Osaka group (e.g. fig. 6A).

7) **Taxodiaceae-*Zelkova* assemblage**

The spectrum which is characterized by the predominance of *Ulmus-Zelkova* and accompanied by several percent of Taxodiaceae, *Quercus*, etc., belongs to this assemblage (e.g. **Sen–5** in fig. 5B). This assemblage, together with *Metasequoia-Picea* A assemblage, is the most common in the lower part of the Osaka group.

8) ***Metasequoia-Picea*** **A assemblage**

The spectrum of this assemblage shows the predominance of *Metasequoia* and the abundance of *Picea* A, *Fagus* and *Quercus*, and is typically found at about **Ma 0** horizon (e.g. **Sen–8** and **9** in fig. 5B). It is considered that this assemblage was derived from Kokawa's (1961) *Metasequoia* flora.

9) ***Fagus–Nyssa*** **assemblage**

The spectrum from the Yadagawa formation, the middle and upper parts of the Seto group, shows the high frequencies of *Fagus*, *Nyssa*, *Liquidambar* and Taxodiaceae, but *Carya* pollen is rare or absent (**SK–1** to **3** in fig. 1). Some similar spectra are reported from the middle and upper parts of the Seto group (Sohma, 1958 and Yoshino, 1971), the lower part of the Agé and Kobiwako groups (Shimakura, 1964 and 1966). These spectra are grouped into *Fagus-Nyssa* assemblage. The stratigraphic horizon of this assemblage corresponds to that of Shimagahara flora.

10) ***Fagus-Cryptomeria* assemblage**

This assemblage is characterized by the predominance of *Cryptomeria* and *Fagus* (e.g. **Kar–3–1** to **3–4** in fig. 6A) and is restricted within the upper part of the Osaka group and terrace deposits.

11) ***Fagus-Tsuga* assemblage**

This assemblage is represented by the spectrum that shows the high percentage of *Fagus* and *Tsuga* and is observable at the upper part of the Osaka group (**Kar–5–3**).

12) ***Diploxylon-Cryptomeria* assemblage**

The percentage of *Diploxylon*, *Cryptomeria* and Gramineae increases rapidly during the last millennium (**Fus–18** and **19** in fig. 6E). It is thought that this is caused by the artificial effects (Nakamura, 1967). *Diploxylon-Cryptomeria* assemblage is proposed for these association.

13) ***Picea-Cryptomeria* assemblage**

The abundant occurrence of *Picea maximowiczii* is reported at Oiwa (Ibaragi Research Group, 1966) at the horizon of Kamimura I cold age (Ishida et al., 1969). The pollen spectrum of this horizon (**Oiw–1** and **2** in fig. 5C) is characterized by the high percentage of *Cryptomeria*, *Picea* and *Haploxylon*. Some similar spectra are obtained from the peat beds at several sits (e.g. **Hir–1** and **Gum–1** in fig. 5C). These spectra are grouped into *Picea-Cryptomeria* assemblage.

14) ***Picea-Haploxylon* assemblage**

The spectra characterized by the predominance of *Picea*, *Haploxylon* and *Tsuga* are obtained from several localities, from where the macroflora of the subalpine conifer forest is reported (e.g. **Nis–1** to **4** in fig. 5C). These association are grouped into *Picea-Haploxylon* assemblage.

b) Pollen Zones

The stratigraphic distribution of these 14 pollen assemblages is shown in fig. 8. Based on the vertical occurrence of pollen assemblages, following 8 pollen zones are distinguished. The relation to the other floral subdivisions is shown in fig. 7.

Zone K1 The lowest zone, here termed zone **K1**, is characterized by *Cyclobalanopsis-Carya* assemblage. It corresponds to the Seto ceramic clay of the Seto group (fig. 2).

Zone K2 Zone **K2** is characterized by *Fagus-Nyssa* assemblage. It corresponds to the Yadagawa formation, the middle and upper parts of the Seto group (fig. 2).

Zone K3 Zone **K3** is characterized by *Quercus-Liquidambar* assemblage. It corresponds to the basal part of the Osaka group (fig. 4, 5A and 5B). *Picea-Haploxylon* assemblage also occurs in this zone (Nasu, 1968).

Zone K4 Below Pumice volcanic ash and above zone **K3** is zone **K4**. This zone is characterized by *Quercus*-Taxodiaceae and Taxodiaceae-*Zelkova* assemblage (fig. 4 and 5B).

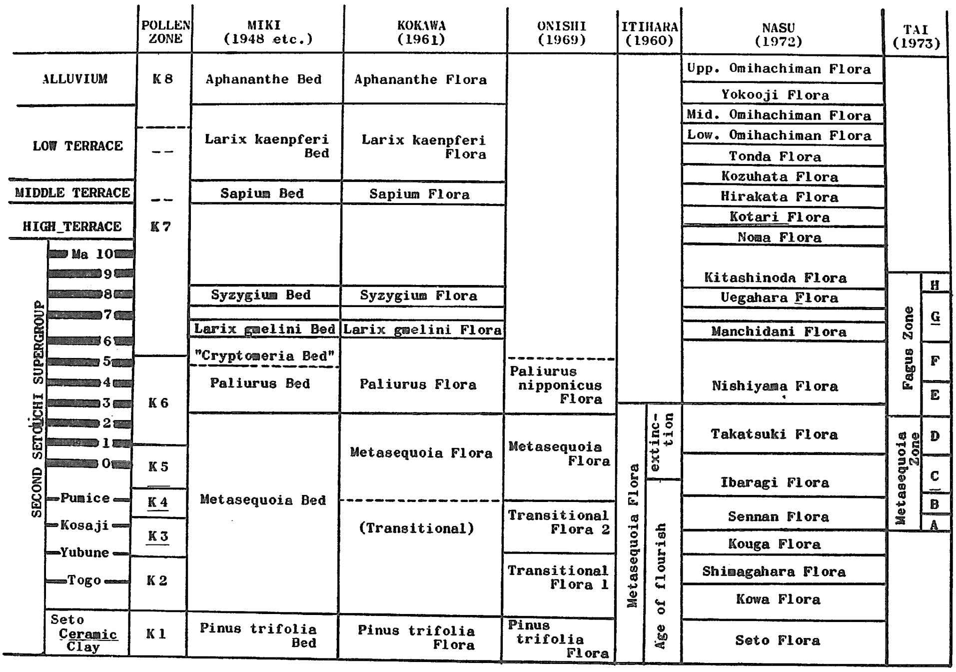

Fig. 7. Floral Subdivisions.

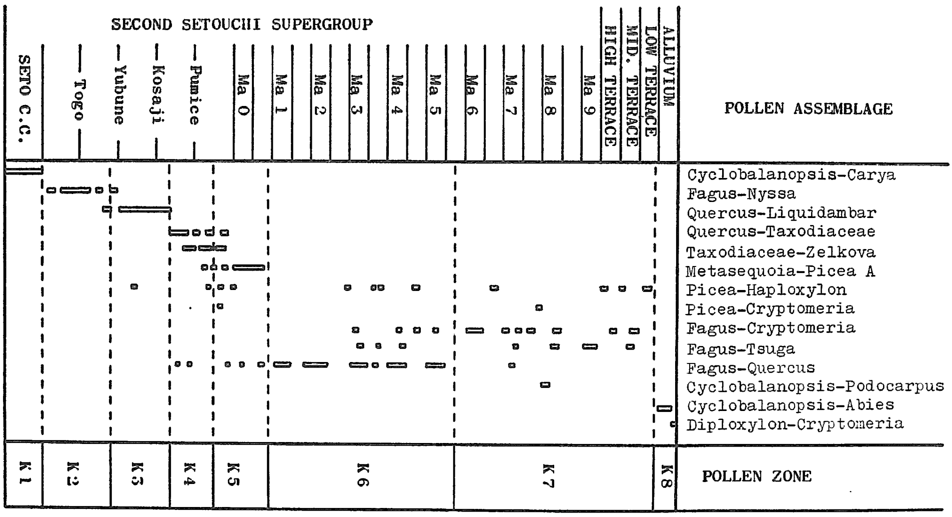

Fig. 8. Stratigraphic Distribution of Pollen Assemblages

Zone K5 Below **Ma 1** and above zone **K4** is zone **K5**, consisting of alternations of sands and muds including **Ma 0**. This zone is characterized by *Metasequoia-Picea* A assemblage. *Picea-Haploxylon*, *Picea-Cryptomeria* and *Fagus-Quercus* assemblages also occur in this zone (fig. 4 and 5B to E).

Zone K6 From **Ma 1** to **Ma 5** is zone **K6**, consisting of alternations of marine clay and non-marine clay and sand. It is marked by *Fagus-Quercus* assemblage. *Fagus-Cryptomeria* and *Picea-Haploxylon* assemblages are accompanied (fig. 5A, C, E and F, and 6A and B).

Metasequoia zone is named by Tai in 1963 at Fukakusa and Hirakata. The upper limit of her *Metasequoia* zone is defined at the base of **Ma 3** by reason of the last appearance of macrofossil of *Metasequoia disticha* and her Taxodiaceae I pollen type. The pollen frequency of *Metasequoia* is rather low in the upper half of her *Metasequoia* zone and a few percent of *Metasequoia* pollen is observed even in **Ma 3**, so that the upper limit of her zone should not have any meaning.

Zone K7 From **Ma 6** to the low terrace deposits is zone **K7**. This zone is characterized by *Fagus-Cryptomeria* assemblage. *Cyclobalanopsis-Podocarpus*, *Fagus-Quercus*, *Fagus-Tsuga*, *Picea-Cryptomeria* and *Picea-Haploxylon* assemblages also occur in this zone (fig. 5C, and 6A to D).

Zone K8 The Holocene deposits belong to zone **K8**. It is represented by *Cyclobalanopsis-Abies* assemblage (fig. 6E).

V. Summary

1. In Kinki district, the studies of the Plio-Pleistocene seed flora have been accumlated since the 1930's. And the floral subdivisions have been proposed by several workers.

2. Pollen analysis is carried out on the samples covering almost all horizons of the Pliocene and Pleistocene deposits in Kinki and Tokai districts. The results are shown in fig. 2 and 4 to 6.

3. Based on the feature of each pollen spectrum, 14 pollen assemblages are distinguished. Judging from the contained taxa and the stratigraphic horizon, some pollen assemblages are connected with the macrofloras.

4. Based on the stratigraphic distribution of these pollen assemblages, 8 pollen zones, **K1** to **K8** in ascending order, are distinguished.

References

Fujii, N., 1968, *Report* no. 230, *Geol. Surv. Japan.*

Ibaragi Research Group, 1966, *Prof. S. Matsushita Mem. Vol.,* 117–130.

Ikebe, N., 1956, *Proc. 8th Pacif. Sci. Congr.,* **2**, 446–465.

Ishida, S., Onishi, I., Nasu, T. and Yokoyama, T., 1969, *Quat. Res. Japan,* **8** (2), 72.

ITIHARA, M., 1960, *Chikyu-Kagaku,* (49), 15–25.
————, 1961, *Jour. Inst. Polytechn., Osaka City Univ.,* **G**, **5**, 13–30.
———— and KIGOSHI, K., 1962, *Chikyu-Kagaku,* (58,) 65–72.
ITIHARA, Y., KURODA, N. and ITIHARA, M., 1966, *Ibid.,* (84), 1–5.
Kinki Group, 1969, *Quaternary System of Japan,* 331–354.
KOKAWA, S., 1961, *Jour. Biol., Osaka City Univ.,* **12**, 123–151.
————, 1962a, *Ibid.,* **13**, 87–97.
————, 1962b, *Quat. Res. Japan,* **2** (4/5), 180–187.
MIKI, S., 1941, *Jap. Jour. Bot.,* **11** (3), 237–303.
————, 1948, *Kobutsu to Chishitsu,* **2** (3), 105–144.
MORI, S., 1971a, *Prof. H. Takehara Mem. Vol.,* 99–111.
————, 1971b, *Jour. Geol. Soc. Japan,* **77** (10), 635–644.
NAKAMURA, J., 1967, *Pollen analysis.* Kokin Shoin, Tokyo.
NASU, T., 1968, *Jour. Geol. Soc. Japan,* **74** (2), 120.
————, 1972, *Biol. Soc. Yokyo,* **24** (1), 1–10.
OKADA, A. and TAKAHASHI, K., 1969, *Jour. Geogr. Tokyo,* **78** (1), 19–37.
ONISHI, I., 1969, *Chikyu-Kagaku,* **23** (6), 236–242.
————, 1974, *Mem. Fac. Lit. & Sci., Shimane Univ.,* Nat. Sci., **7**, 101–114.
Research Group for Cenozoic Strata in Kinki and Tokai Districts, 1973, *Chikyo-Kagaku,* **27** (2/3), 66–80.
Research Group of Quaternary Tectonic Movement in C-zone of UMP, 1973, *The Crust and Upper Mantle of Japanese Area,* part II, 135–137.
SAKAMOTO, T., and UEMURA, F., 1972, *Jour. Geol. Soc. Japan,* **78** (8), 415–416.
SHIMAKURA, M., 1956, *Jour. Nara Gakugei Univ.,* **6** (2), 57–64.
————, 1957, *Ibid.,* **7** (2), 35–42.
————, 1964, *Ibid.,* Nat. Sci., **12**, 37–50.
————, 1966, *Ibid.,* **14**, 25–39.
SOHMA, K., 1958, *Ecol. Rev. Sendai,* **14**, 289–290.
TAI, A., 1963, *Chikyu-Kagaku,* (64), 8–17.
————, 1973, *Mem. Fac. Sci., Kyoto Univ.,* Geol. & Min., **39** (2), 123–165.
TAKAYA, Y., 1663, *Mem. Coll. Sci., Kyoto Univ.,* **B**, **30** (2), Geol. & Min., 81–119.
YOKOYAMA, T., 1971, *Prof. H. Takehara Mem. Vol.,* 55–67.
YOSHINO, M., 1971, *Ibid.,* 129–136.