LATE MIOCENE FLORAS FROM THE SETO GROUP IN AICHI AND GIFU PREFECTURES

Introduction

The Late Tertiary Seto Group interbedding the high-alumina clay-bearing deposits is typically distributed in the environs of Seto, Aichi Prefecture, and of Tajimi, Gifu Prefecture, and further extends southward in the distribution via the east of Nagoya City towards the Chita Peninsula. The clay has been well known as one of the important materials for the porcelain, the so-called "Setomono". These clay-bearing deposits abundantly include well-preserved plant remains such as seeds, fruits, cones and leaves. We principally owes the floras of the Seto Group to continuous investigation of the later Dr. Miki. Following the discovery of three-needle pine with large cone (Miki, 1939), Miki (1941) described a number of plant remains from the porcelain clay beds, accompanying many new genera and new species. He named this plant-bearing sediments the "*Pinus trifolia* bed", and dated it as Early Pliocene age, judging from floristic composition and component. It has been well known in the world that the genus *Metasequoia* was first established in this paper. Furthermore, his supplementary studies or revisions for his earlier works were continuously done (Miki, 1948, 1952, 1955, 1956, 1957, 1961, 1963, 1965, 1968, 1970). Beside Miki's works, there are few reports on Late Tertiary floras of Tokai district (Aichi and southern Gifu Prefectures). Yoshino (1971) described a palynoflora from the "Pliocene" Yadagawa Formation distributed in the north of Nagoya City. Nasu (1972) who summarized Pliocene and Pleistocene floras of Kinki and Tokai districts, briefly described palynofloras of the Seto Group.

The Seto Group has provided an important floristic sequence of the Upper Tertiary in central Honshu. Miki's investigations were principally based on reproductive organs such as seed, endocarp and cone, and were few on leaf remains. No other leaf floras from the Upper Tertiary in Tokai district have been described up to the present, except for a short note on the Latest Miocene flora of the Chita Peninsula by Onoe et al. (1986). An assemblage represented by reproductive organs is frequently different in composition from that of leaf remains in a fossil flora. It is probably due to the fact that heavy reproductive organs such as seed, fruit, and cone need higher energy to be transported by river water than leaf remain. The seed assemblage is usually more diverse in composition and component than the leaf assemblage, although some characteristic plants of leaf assemblage of same age are lacking.

Late Tertiary floras of Japan have been largely based on leaf remains. The "*Pinus trifolia* bed" flora was sometimes difficult to estimate its age and climatic implication in comparison with other leaf floras of same age. As Miki (1941) described, leaf remains are frequently included in the Seto porcelain beds. Accordingly, it is the principal purpose of my investigation to clarify the leaf assemblage of the Seto Group.

Geologic Occurrence

Neogene sediments are widely distributed on Mesozoic granitic rocks and Pre-Tertiary sediments in the southern Gifu and eastern Aichi Prefectures. The Neogene was deposited on denudated basement rocks with low relief, and they show considerable lateral change in lithology. A number of stratigraphic investigations have been reported by various authors,

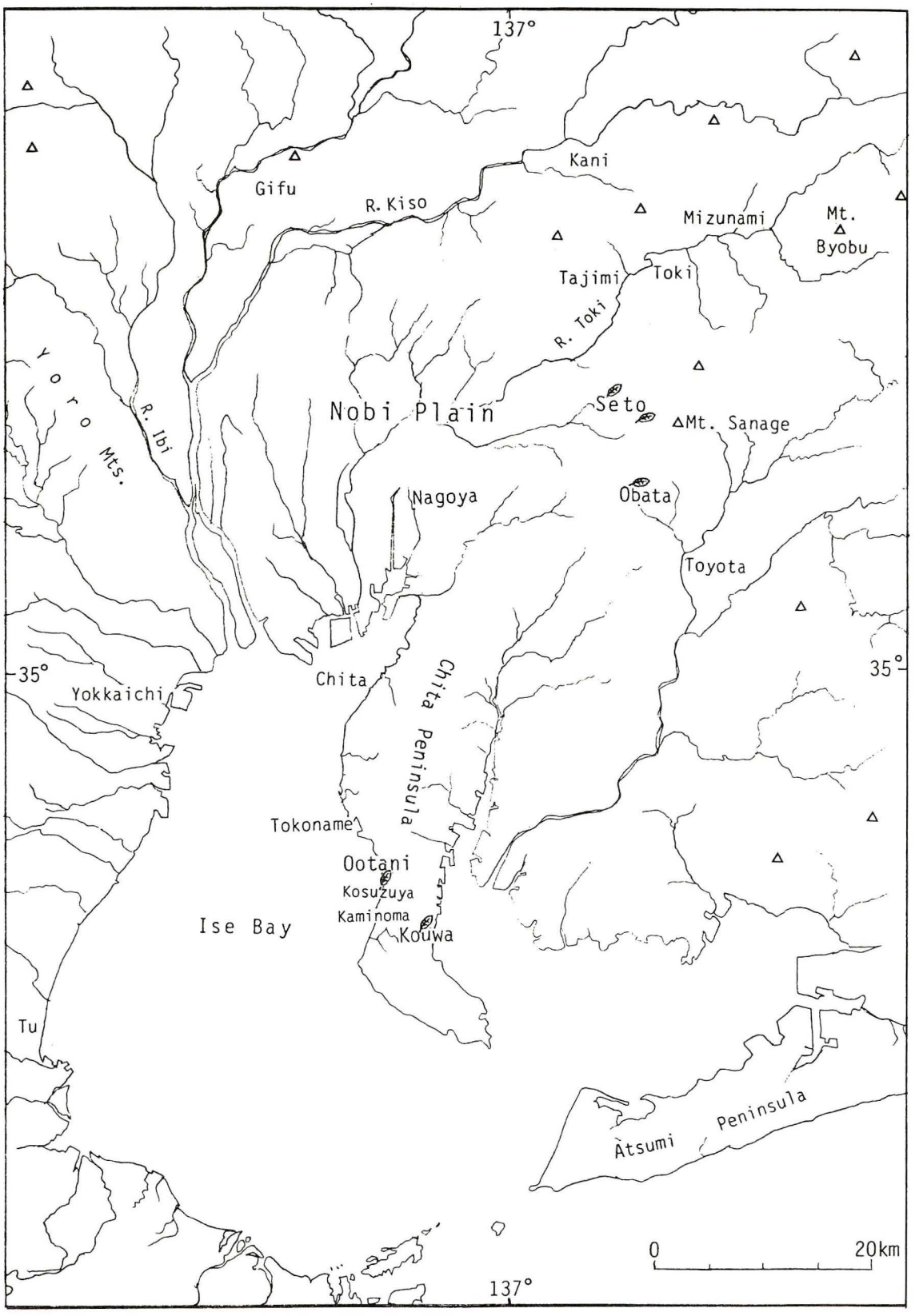

Fig. 15. Localities of Seto plants

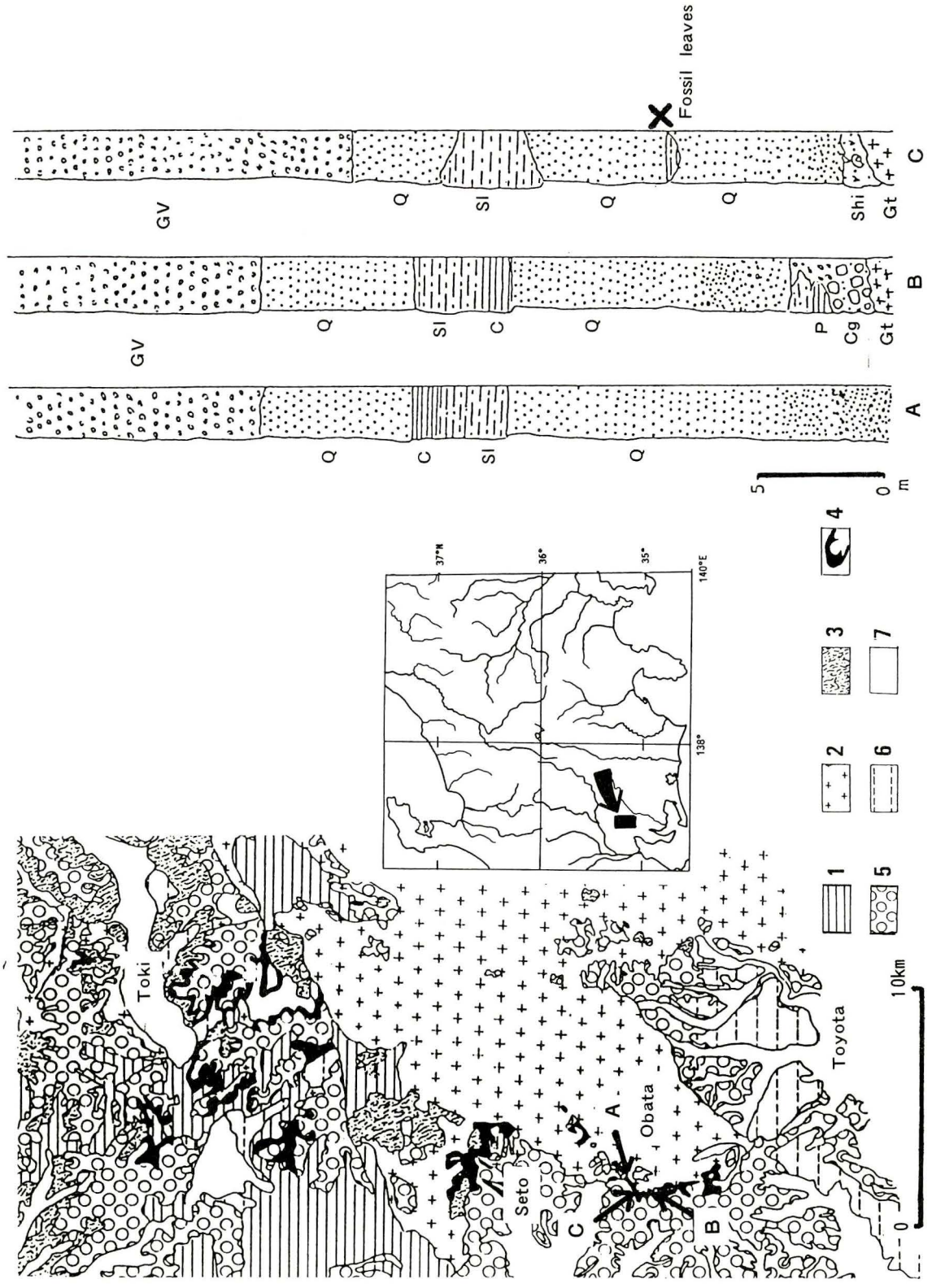

Fig. 16. Geological Map of the Seto Group, Aichi and Gifu Prefectures After Todo Collaborative Research Group (1985)

1: Paleozoic and Mesozoic sediments 2: Granites and Nohi rhyolites 3: Mizunami Group 4: Seto and Tokiguchi porcelain clay Formations 5: Yadagawa Formation and Toki gravel beds 6: Terrace 7: Alluvium Columnar sections of Obata area; A: The 3rd Hotoku mine B: The 2nd Hotoku mine C: Ito mine P: *Pinus trifolia* Gt: Granites Shi: Shinano Formation Cg: Conglomerate C: Clay Q: Quartz sand Sl: Siltstone Gv: Gravel

and the detailed stratigraphy, correlation and age-assignments for the Neogene have been proposed (Akamine, 1954 ; Kuwahara, 1971 ; Ishida and Yokoyama, 1969 ; Yokoyama, 1969 ; Itoigawa, 1971 ; Makinouchi, 1975, 1985 ; Toudo Collaborative Research Group, 1985 ; etc.). Most of the authors agree recently that the Neogene sediments are subdivided into two groups, the Mizunami and Seto Groups. The Mizunami Group typically develops in Toki-Mizunami area, and locally in Kani and Iwamura areas in Gifu Prefecture. It is largely of shallow-sea origin excepting for its basal part of terrestrial sediments which includes lignite seams. The Mizunami Group usually contains a number of molluscan and foraminiferal fossils and also sometimes plant fossils ; it is assigned to late-Early and early-Middle Miocene in age (Tsuchi, 1986). In the southern part of the Chita peninsula, the Morozaki Group develops. This group is correlated with the Mizunami Group and is of deep-sea origin, judging from molluscan fossils.

The Seto Group is widely distributed from Toki area through Seto area to the Chita Peninsula in the eastern margin of the Nobi Plain. The Group covers the Miznami and Morozaki Groups with disconformity, but it overlies directly on the basement rocks with an onlap relation in most areas. The Seto Group is subdivided into two formations in lithology (Akamine, 1954 ; Toudo Collaborative Research Group, 1985) : the lower is composed mainly of quartz sand, carbonaceous clay, quartz-grain bearing clay and lignite (the Seto or Tokiguchi porcelain clay Formations), and the upper is mostly composed of sand and gravel (the Yadagawa and Toki Formations). The Seto porcelain clay Formation contains many plant remains in carbonaceous clay, represented by *Pinus trifolia* as described by Miki (1939, 1941). The southward extension of the Seto Group has been discussed by many authors (Kuwahara, 1971 ; Itoigawa, 1971 ; Makinouchi, 1975 ; others), because the Group or its coeval formations are different in lithology and discontinuous in areal distribution. However, most of the authors concluded that the Seto porcelain clay Formation is lacking in Chita Peninsula, and only the upper part of the Seto Group develops there, consisting of sand, gravel, tuff, clay and lignite. The equivalent of the upper Seto Group is named the Yadagawa Formation in the west of Nagoya and the Tokoname Formation in the Chita Peninsula.

The Seto Group has been considered to be of Pliocene in age by most authors, accepting Miki's dating for "*Pinus trifolia* bed" flora. However, Tanai (1961), in his comprehensive study of Neogene floras throughout Japan, asserted that Miki's "*Pinus trifolia* bed" flora is of Late Miocene to Early Pliocene in age, because it is closely similar in floristic composition to most of Late Miocene leaf floras of other regions.

There are unfortunately no radiometric dating for the Seto porcelain clay Formation including plant assemblage. However, some fission-track dating was done for the upper Seto Group in the Chita Peninsula. Makinouchi et al. (1983) gave the fission-track ages to some volcanic ash beds which are intercalated in the Yadagawa Formation of the Chita Peninsula : 4.2 ± 0.4 Ma for the middle level tuff (the Ootani volcanic ash bed), and 5.2 ± 0.8 Ma or 7.6 ± 0.6 Ma for the lowest tuff (the Kofu volcanic ash bed), although values of the Kofu bed are somewhat questionable due to thermal events. Hayashi et al. (1985) recalculated statistically the fission-track ages of some rocks already published by various authors, and they showed the recalculated age of the Tokoname Formation : 5.2 ± 0.41 Ma for the Ootani bed, 5.59 ± 0.36 Ma for the Kaminoma bed and 7.02 ± 0.4 Ma for the Kofu bed. I cannot determine which age is reliable between these two authors' dating. However, even if we accept either value of the fission-track ages which were presented by them, the Yadagawa Formation is assigned to be Latest Miocene to Early Pliocene in age. The Seto porcelain clay Formation is stratigraphically underlies the Yadagawa Formation as asserted by Kuwahara (1971) and others ; it is concluded to be of Late Miocene age, and is probably dated as 8 or 9 Ma.

Table 43. The Species Reported from the Seto Porcelain Clay Formation by Miki

Family	Species	Material
Osmundaceae	*Osmunda japonica* Thunb.	L
Pinaceae	*Keteleeria davidiana* Beiss.	FLT
	Keteleeria robusta Miki	FLT
	Picea koribae Miki	F
	Picea latibracteata Miki	F
	Pinus armandi Fr.	F
	Pinus fujiii (Yasui) Miki	FL
	Pinus parviflora Sieb. & Zucc.	F
	Pinus trifolia Miki	FLT
	Pseudolarix kaempferi Gord.	FLT
	Pseudotsuga subrotunda Miki	F
	Tsuga longibracteata Chang	FL
	Tsuga rotundata Miki	FT
	Tsuga oblonga Miki	F
Taxodiaceae	*Cunninghamia konishii* Hayata	T
	Glyptostrobus pensilis Koch	FST
	Metasequoia japonica (Endo) Miki	FT
	Protosequoia primaria Miki	FT
	Sequoia sempervirens Endl.	FST
Cephalotaxaceae	*Cephalotaxus biumbonata* Miki	F
Schisandraceae	*Schisandra megasperma* Miki	S
Magnoliaceae	*Magnolia salicifolia* Maxim.	SL
	Michelia sp.	S
Lauraceae	*Cinnamomum macropodum* Miki	SL
	Lindera sericea Blume	LS
	Lindera citriodora Hemsl.	L
	Machilus pasanifolia Miki	SL
	Parabenzoin praecox Nakai	F
	Umbellularia japonica Miki	L
Nymphaeaceae	*Brasenia schreberi* Gmel.	S
	Eoeuryale brasenioides Miki	S
	Nuphar akashiensis Miki	S
Menispermaceae	*Sinomenium acutum* Rehd. & Wils.	S
	Stephania periporosa Miki	S
Theaceae	*Camellia sasanqua* Thunb.	F
	Schima plioceca Miki	F
	Stewartia obovata Miki	F
Tiliaceae	*Tilia costata* Miki	FL
Cucurbitaceae	*Lissopepon melothroidea* Miki	S
	Trichosanthes kirilowii Maxim.	S
Hamamelidaceae	*Corylopsis* sp.	S
	Distyliopsis parrotioides Miki	F
	Fortunearia sinensis Rehd. & Wils.	FS
	Liquidambar cf. *L. formosana* Hance	FL
Eucommiaceae	*Eucommia ulmoides* Oliver	F
Rosaceae	*Amelanchier* cf. *A. asiatica* Endl.	L
Caesalpiniaceae	*Gleditsia* cf. *G. macracantha* Desf.	T
Fabaceae	*Dalbergia* sp.	L
	Wisteria ligniata Miki	FL
Rutaceae	*Fagara ailanthoides* Engl.	S
Meliaceae	*Melia* cf. *M. japonica* G. Don	F
Anacardiaceae	*Poupartia polymeris* Miki	F
Aceraceae	*Acer buergerianum* Miq.	FL
	Acer diabolicum Blume	F
	Acer palmatum Thunb.	SL
	Acer rubrum Linn. var.	L
Sabiaceae	*Meliosma radiocosta* Miki	S
	Meliosma rigida Sieb. & Zucc.	S
	Sabia japonica Maxim.	S

Staphyleaceae	*Euscaphis japonica* Kant.	S
Rhamnaceae	*Berchemia racemosa* Sieb. & Zucc.	S
	Paliurus nipponicus Miki	F
Vitaceae	*Ampelopsis leeoides* Planch.	S
	Cayratia megasperma (Miki) Miki	S
	Cayratia orbitalis Miki	S
	Tetrastigma tazimiensis Miki	S
	Vitis brachypoda Miki	S
	Vitis labruscoidea Miki	S
	Vitis rotundata Miki	S
	Vitis thunbergii Sieb. & Zucc.	S
Oleaceae	*Fraxinus japonica* Blume	F
	Syringa sp. (?)	L
Cornaceae	*Cornus controversa* Hemsl.	F
	Cornus kousa Buerger, ex Hance	F
Nyssaceae	*Nyssa pachycarpa* Miki	F
	Nyssa rugosa Miki	F
	Nyssa sylvatica Marsh.	F
Alangiaceae	*Alangium begoniifolium* (Roxb.) Baill.	F
	Alangium macrocarpum Miki	F
Elaeagnaceae	*Elaeagnus* sp.	L
Lythraceae	*Lagerstroemia* sp.	F
Trapaceae	*Eotrapa tetrasepala* (Miki) Miki	F
	Hemitrapa trapelloidea Miki	F
	Trapa dolichocarpa Miki	F
	Trapa mammillifera Miki	F
	Trapa maximowiczii Korsh.	F
	Trapa pulvinipoda Miki	F
Ulmaceae	*Zelkova* cf. *ungeri* Kovats.	L
Juglandaceae	*Carya ovatocarpa* Miki	F
	Carya striata Miki	F
	Carya ventricosa Unger	F
	Cyclocarya paliurus (Batal) Illjinsk.	F
	Juglans megacinerea Chaney	F
Betulaceae	*Alnus japonica* Sieb. & Zucc.	F
	Betula adstigmata Miki	FL
	Carpinus japonica Blume	FL
	Carpinus tschonoskii Maxim	FL
	Corylus ligniatus Miki	L
	Ostrya stenocarpa Miki	F
Fagaceae	*Castanopsis oligospina* Miki	F
	Cyclobalanopsis sp.	FL
	Fagus grandifolia Ehrh.	FL
	Fagus japonicoides Miki	FL
	Lithocarpus glabra Nakai	F
	Quercus chenii Nakai	FL
	Quercus rubroidea Miki	F
Salicaceae	*Salix* sp.	L
Euphorbiaceae	*Aleurites fordioides* Miki	S
	Mallotus protojaponicus Miki	SL
	Sapium sebiferum Roxb. var.	S
Buxaceae	*Buxus japonica* Muel.	SL
Ericaceae	*Enkianthus* sp.	F
	Pieris japonica Don	F
	Rhododendron ovatocarpa Miki	F
Styracaceae	*Meliodendron multipterium* (Miki) Miki	F
	Meliodendron nipponicum Miki	F
	Rehderodendron elliptica Miki	F
	Styrax laevigata Miki	F
	Styrax obassioidea Miki	F
	Styrax rugosa Miki	F
	Styrax shiraiana Makino	F

Symplocaceae	*Symplocos lancifolia* Sieb. & Zucc.	F
	Symplocos myrtacea Sieb. & Succ.	F
	Symplocos tricarpa Miki	F
Caprifoliaceae	*Viburnum japonicum* (Thunb.) Spreng.	S
Trapellaceae	*Trapella lissa* Miki	F
	Trapella primaria Miki	F
Gramineae	*Bambusoidea nipponica* Miki	TL

L : leaf F : fruit or cone S : seed T : twig and others

"*Pinus trifolia* bed" Flora from the Seto Porcelain Clay Formation

Based on the plant remain collection from the Seto porcelain clay Formation at 13 localities of Seto-Tajimi region, Miki (1941) described 83 species, which are distributed in 37 families and 62 genera. The plant assemblages in each locality are somewhat different in composition, but they were probably due to the mining condition of each clay pit at that time when the late Dr. Miki visited. However, *Pinus trifolia* was collected from 12 localities. Miki (1941) described the plant remains were collected from lignite-bearing clay. On the basis of additional specimens and taxonomical revision continued since 1941, Miki (1963) summarized the floristic list of the *Pinus trifolia* bearing flora. He proposed 3 new genera, 13 new species and 1 new combination in his paper ; but it is regrettable these proposed new genera and species are nomen nudum in the sense of the present International Code of Botanical Nomenclature. His further taxonomical studies on plant remains of this region continued until 1970. Summarizing the plant remains described by Miki (1939-1970) from the Seto Group, there are 93 genera and 128 species. These 128 species are 1 fern, 19 conifers, 104 dicots and 1 monocot. They are listed in Table 43, in which the fossil organs of each species are indicated.

The specimens recorded as new species by Miki are chiefly reproductive organs such as seed, fruit and endocarp, excepting in the case of *Metasequoia*. Among numerous new species, the ones described on the basis of leaves are only three, *Corylus ligniatus, Wisteria ligniata* and *Umbellularia japonica*.

Nasu (1972) mentioned that pollen assemblage from the Seto porcelain clay Formation is characterized by small occurrence of conifers (each genus less than 10%), predominant evergreen *Quercus* (max. 75%) and a meagre quantity of *Alnus* (max. less than 2%). These tendency of the microfossils well match to those of the leaf assemblage from the Formation.

Leaf Assemblage from the Seto Porcelain Clay Formation

Fossil localities of Seto-Tajimi region recorded by Miki were as many as 16, and most of them were in the porcelain clay pits. To collect fossils at some localities is now impossible, because most of clay pits have changed or abandoned their mining sites. I was able to collect leaf fossils from the Itoh Mine in Obata-machi, Toyota City. Obata, one of Miki's localities, seems to correspond to the Hohtoku Mine area at Ohara of Obata-machi, Toyota City, Aichi Prefecture. The Itoh Mine is at the north of the third pit of the Hohtoku Mine and at the west of the second pit of the Hohtoku Mine.

The Seto porcelain clay Formation around the Itoh and Hohtoku Mines in Obata area is 20 to 30 m thick, which unconformably overlies Mesozoic and Paleogene granitic rocks or Early Miocene Shinano Formation. The Shinano Formation, locally accompanied with conglomerate, lies unconformably on granitic rocks of large relief and is correlated with the Mizunami Group in Tajimi region by the molluscan fauna (Otsuka et al., 1976). The Seto porcelain clay Formation in this area is subdivided into three members : the upper and lower members consisting mainly of coarse-grained quartz sandstone facies and the middle member

of fine-grained siltstone facies. The upper member is covered by the conglomerate of the Yadagawa Formation with disconformity. As shown in the columnar sections of Fig. 16, the basal part of the basal member in Obata area reveals remarkable lateral changes in lithology. The basal coarse-grained quartz sandstone member at the Itoh Mine is a bed intercalated with lenticular siltstone of about 1 m thick, in which I collected leaf fossils. The middle member of 2.5-4 m thick is composed of sandy claystone or siltstone which locally grades into Kibushi clay. The upper member of several meters thickness consists mainly of massive quartzose coarse-grained sandstone.

Systematic Representation

Based on leaf collection from the Itoh Mine, the Seto leaf assemblage in the Obata district is composed of 31 families, 49 genera and 62 species. There are 5 conifers, 3 monocotyledons, and the remainder are dicotyledons. As indicated in Table 44, the largest family is the Fagaceae with 3 genera and 7 species; next come the Lauraceae with 4 genera and 5 species, the Betulaceae with 3 genera and 5 species, the Pinaceae with 4 genera and 4 species, the Aceraceae with 1 genus and 4 species, and the Ulmaceae, Theaceae and Fabaceae with 3 species each. The remaining families have 2 species or less, and most of them are represented by a single species. The following genera are predominant in number of species; *Quercus* and *Acer* with 4 species each, and *Carpinus* with 3 species. *Cinnamomum, Ulmus, Fagus* and *Populus* have 2 species each, and the remainders are represented by one species.

It is considered that Miki's Obata locality is close to the leaf fossil locality, although the precise site is uncertain. The following 23 genera and 30 species were reported by Miki (1933-1970) from the Obata locality: *Alangium begoniifolium* (Roxb.) Baill., *Benzoin umbellatum* Rehd., *Brasenia schreberi* Gmel., *Carpinus tschonoskii* Maxim., *Carya ovatocarpa* Miki, *C. striata* Miki, *Distyliopsis parrotioides* Miki, *Eoeuryale brasenioides* Miki, *Eotrapa tetrasepala* (Miki) Miki, *Fagus ferruginea* Ait., *F. japonicoides* Miki, *Fortunearia sinensis* Rehd. & Wils., *Glyptostrobus pensilis* Koch, *Hemitrapa trapelloidea* Miki, *Keteleeria davidiana* Beiss., *Meliosma rigida* Sieb. & Zucc., *Nyssa pachycarpa* Miki, *N. sylvatica* Marsh., *Paliurus nipponicus* Miki, *Pinus fujiii* (Yasui) Miki, *P. trifolia* Miki, *Protosequoia primaria* Miki, *Stephania periporosa* Miki, *Styrax laevigata* Miki, *S. rugosa* Miki, *Symplocos myrtracea* Sieb. & Zucc., *Trapa dolichocarpa* Miki, *T. mammillifera* Miki, *Trapella lissa* Miki and *T. primaria* Miki.

Most of these species were based mainly on reproductive organs. Except conifers, *Benzoin, Carpinus* and *Fagus* are based also on the leaves, and their related species are found in my leaf collection. Among the species from the Obata area there are only 5 allied or common species between the seed assemblage by Miki and leaf assemblage by me: 2 species of *Fagus* and 1 species each of *Carya, Lindera* and *Paliurus*. *Fagus japonicoides* Miki was reported in 1963 without description although it was treated as *F. japonica* up to that time by him.

The Seto leaf assemblage consists of both cool temperate and warm temperate or subtropical plant families. The Pinaceae, Ulmaceae, Juglandaceae, Betulaceae, Salicaceae, Rosaceae and Aceraceae are typically temperate families. The Lauraceae, Menispermaceae, Sabiaceae, Hamamelidaceae, Theaceae, Pittosporaceae and Fabaceae are, in general, warm temperate or subtropical to tropical families. Three species of the Fagaceae are evergreen oaks, and 5 species of the Lauraceae include 4 evergreen plants. The Seto leaf assemblage is concluded to consist mainly of warm temperate families and to have slightly less number of the cool temperate families.

In the whole species reported by Miki from the Seto porcelain clay Formation, the ratio of the entire-margined species to the total broad-leaved species is 30/92 that makes up 32.6 per cent, and that of the evergreen broad-leaved species to the total is 16/92 and 17.4 per cent. On the other hand, in the leaf flora collected from the Itoh mine by me, the ratio of the entire-margined broad-leaved species to the total broad-leaved species in Obata district is 20/57

Table 44. Systematic List of Families and Species

Pinaceae	*Keteleeria davidiana* Beiss.
	Pinus trifolia Miki
	Pseudotsuga tanaii Huzioka
	Tsuga miosieboldiana Ozaki
Taxodiaceae	*Glyptostrobus* sp.
Lauraceae	*Actinodaphne* sp. cf. *A. lancifolia* Meisn.
	Cinnamomum sp. cf. *C. camphora* Sieb.
	Cinnamomum sp. cf. *C. japonicum* Sieb.
	Lindera sp. cf. *L. miyataensis* Huzioka & Uemura
	Persea sp. cf. *P. thunbergii* Kosterm.
Menispermaceae	*Cocculus* sp. cf. *C. trilobus* DC.
Sabiaceae	*Meliosma oldhami* Maxim.
Hamamelidaceae	*Liquidambar miosinica* Hu & Chaney
	Fortunearia kabutoiwana Ozaki
Ulmaceae	*Ulmus protojaponica* Tanai & Onoe
	Ulmus subparvifolia Nathorst
	Zelkova ungeri Kovats
Juglandaceae	*Carya miocathayensis* Hu & Chaney
Fagaceae	*Castanea miocrenata* Tanai & Onoe
	Fagus palaeojaponica Tanai & Onoe
	Fagus stuxbergii (Nathorst) Tanai
	Quercus protoacuta K. Suzuki
	Quercus protoaliena Ozaki
	Quercus protosalicina K. Suzuki
	Quercus sp. aff. *Q. glauca* Thunb.
Betulaceae	*Betula* sp.
	Carpinus heigunensis Huzioka
	Carpinus miocenica Tanai
	Carpinus sp. cf. *C. turczaninowii* Hance
	Ostrya aizuana K. Suzuki
Elaeocarpaceae	*Elaeocarpus florinii* Tanai
Theaceae	*Eurya* sp.
	Stewartia hokiana Ozaki
Tiliaceae	*Tilia* sp.
Sterculiaceae	*"Ficus" tiliaefolia* Heer
Salicaceae	*Populus hokiensis* Ozaki
	Populus kobayashii K. Suzuki
Ericaceae	*Vaccinium* sp.
Styracaceae	*Halesia* sp.
	Styrax sp. cf. *S. japonica* Sieb. & Zucc.
Pittosporaceae	*Pittosporum* sp. cf. *P. illicioides* Makino
Saxifragaceae	*Deutzia* sp.
Rosaceae	*Malus* sp.
Fabaceae	*Cladrastis aniensis* Huzioka
	Lespedeza sp.
	Wisteria fallax (Nathorst) Tanai & Onoe
Haloragaceae	*Myriophyllum* sp.
Cornaceae	*Cornus megaphylla* Hu & Chaney
Aquifoliaceae	*Ilex subcornuta* Huzioka & Uemura
Euphorbiaceae	*Sapium hokianum* Ozaki
Rhamnaceae	*Paliurus protonipponicus* K. Suzuki
Vitaceae	*Vitis naumannii* (Nathorst) Tanai
Aceraceae	*Acer nordenskioeldii* Nathorst
	Acer prototrifidium Tanai
	Acer sp. cf. *A. chiharae* Huzioka & Nishida
	Acer tricuspidatum Bronn.
Oleaceae	*Fraxinus* sp.
	Syringa sp. cf. *S. pekinensis* Rupr.
Potamogetonaceae	*Potamogeton* sp.
Cyperaceae	*Carex* spp.
Poaceae	*Bambusites* sp.

(35.1%) and that of the evergreen broad-leaved species is 14/57 (24.6%). Thus, the proportion of the entire-margined species somewhat differs between the two assemblages, but that of evergreen broad-leaved species in the "seed" assemblage is somewhat higher than in the leaf assemblage.

Assumed Habits and Leaf Characters

Table 45 shows the probable habits of the Seto plants as judged from their most similar living plants and from the texture of fossil leaves. Fifty-four trees make up 67.5 percent of the total taxa, 10 small trees or shrubs make up 12.5 percent, 5 vines perform 6.3 pecent, 10 aquatic herbs make up 12.5 percent and terrestrial herb is represented by a single taxon. The Seto plants were predominantly arboreal as the percentage of trees to shrubs make up 80.0 percent.

Of seven conifers, only one *Glyptostrobus europaeaus* was deciduous. Referring to the abscission habit of the broad-leaved members of the flora, the herbs can be omitted from consideration, but we include several angiosperms which have not been assigned specific status, and whose leaf characters indicate whether they were evergreen or deciduous. Among 57 angiosperms, the following 14 taxa may be assumed to have had an evergreen habit as judged from the thick texture of their leaves, and from the abscission regime of their living equiva-

Table 45. Assumed Growth Habit and Leaf Characters of the Seto Plants

Species	Growth Habit	Leaf Characters
Glyptostrobus europaeus	Tree	DC
Keteleeria ezoana	Tree	EC
Pinus trifolia	Tree	EC
Pinus fujiii	Tree	EC
Pseudotsuga tanaii	Tree	EC
Protosequoia primaria	Tree	EC
Tsuga miosieboldiana	Tree	EC
Acer sp. cf. *A. chiharae*	Tree	Ds
Acer nordenskioeldii	Tree	Ds
Acer prototrifidium	Tree	Ds
Acer tricuspidatum	Tree	Ds
Actinodaphne sp. cf. *A. lancifolia*	Tree	Ee
Alangium begoniifolium	Tree	De
Betula sp.	Tree	Ds
Carpinus sp. cf. *C. turczaninovii*	Tree	Ds
Carpinus heigunensis	Tree	Ds
Carpinus miocenica	Tree	Ds
Carya miocathayensis	Tree	De
Carya ovatocarpa	Tree	De
Carya striata	Tree	De
Castanea miocrenata	Tree	Ds
Cinnamomum sp. cf. *C. camphora*	Tree	Ee
Cladrastis aniensis	Tree	De
Cornus megaphylla	Tree	De
Elaeocarpus florinii	Tree	Es
Eurya sp.	Tree	Es
Fagus palaeojaponica	Tree	Ds
Fagus stuxbergii	Tree	Ds
Fortunearia kabutoiwana	Tree	Ds
Fraxinus sp.	Tree	Ds
Halesia sp.	Tree	Ds
Liquidambar miosinica	Tree	Ds
Malus sp.	Tree	Ds
Meliosma sp. cf. *M. oldhami*	Tree	Ds
Nyssa pachycarpa	Tree	De
Nyssa ovatocarpa	Tree	De
Ostrya aizuana	Tree	Ds
Persea sp. cf. *P. thunbergii*	Tree	Ee
Populus hokiensis	Tree	Ds
Populus kobayashii	Tree	Ds
Quercus sp. af. *Q. glauca*	Tree	Es
Quercus protoacuta	Tree	Ee
Quercus protoaliena	Tree	Ds
Quercus protosalicina	Tree	Es
Sapium hokianum	Tree	De
Stewartia hokiana	Tree	Ds
Styrax sp. cf. *S. japonica*	Tree	Ds
Styrax laevigata	Tree	Ds
Styrax rugosa	Tree	Ds
Symplocos myrtacea	Tree	Es
Tilia sp.	Tree	Ds
Ulmus protojaponica	Tree	Ds
Ulmus subparvifolia	Tree	Ds
Zelkova ungeri	Tree	Ds
Cinnamomum sp. cf. *C. japonicum*	ST or Shrub	Ee
Deutzia sp.	ST or Shrub	Ds
Eurya sp.	ST or Shrub	Es
Ilex subcornuta	ST or Shrub	Es
Lespedeza sp.	ST or Shrub	De
Lindera cf. *miyataensis*	ST or Shrub	De
Paliurus protonipponicus	ST or Shrub	Ds
Pittosporum sp. cf. *P. illicioides*	ST or Shrub	Ee
Syringa sp. cf. *S. pekinensis*	ST or Shrub	De
Vaccinium sp.	ST or Shrub	Ds
Cocculus sp. cf. *C. trilobus*	Vine	De
Kadsura protojaponica	Vine	Es
Stephania periporosa	Vine	De
Vitis naumannii	Vine	Ds
Wisteria fallax	Vine	De
Carex spp.	Terr. Herb	
Brasenia schreberi	Aqua. Herb	
Eoeuryale brasenioides	Aqua. Herb	
Eotrapa tetrasepala	Aqua. Herb	
Hemitrapa trapelloidea	Aqua. Herb	
Myriophyllum sp.	Aqua. Herb	
Potamogeton sp.	Aqua. Herb	
Trapa dolichocarpa	Aqua. Herb	
Trapa mammillifera	Aqua. Herb	
Trapella lissa	Aqua. Herb	
Trapella primaria	Aqua. Herb	
Bambusites sp.		
Distyliopsis parrotioides		
"Ficus" tiliaefolia		De

ST : Small Tree Terr. : Terrestrial Aqua. : Aquatic D : Deciduous C : Conifer s : Serrata broad-leaf e : Entire broad-leaf

lents: *Actinodaphne* sp. cf. *A. lancifolia*, *Cinnamomum* sp. cf. *C. camphora*, *Cinnamomum* sp. cf. *C. japonicum*, *Elaeocarpus florinii*, *Eurya* sp., *Ilex subcornuta*, *Meliosma rigida*, *Kadsura protojaponica*, *Persea* sp. cf. *P. thunbergii*, *Pittosporum* sp. cf. *P. illicioides*, *Quercus protoacuta*, *Quercus protosalicina*, *Quercus* sp. aff. *Q. glauca* and *Symplocos myrtacea*.

Numerical Representation

The following quantitative appraisal of the Seto flora is based on a count of 231 specimens. Among the 62 Seto fossil species, 5 ones are numerous, making up more than 5 per cent each, and these species occupy nearly a half of the total specimens. No species is especially dominant in the number of specimen. 27 species having more than 1 per cent comprise 82.3 per cent of the total. These predominant plants appear to have lived in the forests near the depositional sites and/or to have occupied the topographic circumstances suitable for transporting their leaves to sites of deposition. It may be considered that the topography around the depositional sites was hilly and mountain slopes. This topographic inference is also consistent with the fact that the plant-bearing Seto porcelain clay Formation in the Obata area is largely composed of coarse-grained sandstone and that the flora has few plants lived in typical swamp flat, except *Glyptostrobus* listed by Miki. Among the predominant species, *Quercus* sp. aff. *Q. glauca, Cinnamomum* sp. cf. *C. camphora, Persea* sp. cf. *P. thunbergii, Actinodaphne* sp. cf. *A. lancifolia* and *Quercus protosalicina* were considered to be evergreen broad-leaved trees. Although these evergreen trees may be at a disadvantage for shedding their leaves, they show relative high scores in leaf record. They appear to have formed evergreen forest from the lake borders to lower slopes along with *Quercus protoacuta* and *Elaecarpus*. *Paliurus protonipponicus* may have formed the understory of the above trees along with several evergreen shrubs such as *Cinnamomum* sp. cf. *C. japonicum, Eurya* sp., *Ilex subcornuta* and *Pittosporum* cf. *illicioides*. *Fagus stuxbergii* must have formed deciduous broad-leaved mountain slope forests of the Seto forest together with the other deciduous trees represented by meagre percentage such as *Betula* sp., *Malus* sp., *Ostrya aizuana, Stewartia* and *Styrax*. Some

Table 46. Numerical Representation of the Seto Species

Species	Number of specimens	Percentage
Carpinus miocenica	17	7.4
Paliurus protonipponicus	16	6.9
Quercus aff. *glauca*	16	6.9
Acer nordenskioeldii	15	6.5
Fagus stuxbergii	13	5.6
Cinnamomum cf. *camphora*	9	3.9
Pseudotsuga tanaii	9	3.9
Carex spp.	8	3.5
Populus kobayashii	8	3.5
Tilia sp.	8	3.5
Liquidambar miosinica	7	3.0
Populus hokiensis	7	3.0
Syringa sp. cf. *S. pekinensis*	6	2.6
Ulmus protojaponica	6	2.6
Bambusites sp.	5	2.2
Zelkova ungeri	5	2.2
Lindera cf. *miyataensis*	4	1.7
Persea cf. *thunbergii*	4	1.7
Actinodaphne cf. *lancifolia*	3	1.3
Carpinus heigunensis	3	1.3
Carpinus cf. *turczaninowii*	3	1.3
Cocculus cf. trilobus	3	1.3
Fagus palaeojaponica	3	1.3
Halesia sp.	3	1.3
Lespedeza sp.	3	1.3
Quercus protoaliena	3	1.3
Quercus protosalicina	3	1.3
"Ficus" tiliaefolia	2	0.9
Acer prototrifidium	2	0.9
Acer cf. *chiharae*	2	0.9
Betula sp.	2	0.9
Castanea miocrenata	2	0.9
Cinnamomum cf. *japonicum*	2	0.9
Myriophyllum sp.	2	0.9
Potamogeton sp.	2	0.9
Quercus protoacuta	2	0.9
Sapium hokianum	2	0.9
Ulmus subparvifolia	2	0.9
Wisteria fallax	2	0.9
Acer tricuspidatum	1	0.4
Carya miocathayensis	1	0.4
Cladrastis aniensis	1	0.4
Cornus megaphylla	1	0.4
Deutzia sp.	1	0.4
Elaeocarpus florinii	1	0.4
Eurya sp.	1	0.4
Fraxinus sp.	1	0.4
Ilex subcornuta	1	0.4
Malus sp.	1	0.4
Ostrya aizuana	1	0.4
Pittosporum cf. *illicioides*	1	0.4
Stewartia hokiana	1	0.4
Styrax cf. *japonica*	1	0.4
Tsuga miosieboldiana	1	0.4
Vaccinium sp.	1	0.4
Vitis naumannii	1	0.4
	231	100.3

evergreen conifers, *Pseudotsuga tanaii, Tsuga miosieboldiana* and *Keteleeria davidiana,* may have formed conifer forest in some places or sporadically lived on slopes between the evergreen and deciduous forests. The other trees such as *Acer, Populus, Tilia, Liquidambar, Ulmus, Buxus, Zelkova, Lindera* and *Carpinus,* seem to be main members of valley forest, judging mainly from the living equivalents.

The proportion of the evergreen broad-leaved species to the total broad-leaved species is 14/62 that makes up 22.6 percent, and that of the entire-margined species is 22/62 and 35.5 percent.

Following leaves were collected by Miki from the Obata locality: *Fortunearia* sp., *Glyptostrobus* sp., *Keteleeria davidiana* Beiss., *Meliosma rigida* Sieb. et Zucc. and *Pinus trifolia* Miki.

Distribution of the Allied Living Species

Table 47 shows the most allied living species of the Seto species and their distribution in East Asia. The following table indicates the total number of species in each forest zone and the percentages for the cumulative number of species in all zones.

Zone	1	2	3	4	5	6	7	Sum
No. of Species	9.0	29.5	42.0	31.0	18.5	1.0	0.0	133.0
Percentage	8.3	22.3	31.6	23.3	15.3	0.8	0.0	100.0

In the cumulative number of species, the upper warm temperate forest zone (zone 3) is largest with 42 species, taking up 31.6 per cent of the total. Next come the lower cool temperate forest zone (zone 4) with 31 species (23.3%) and the lower warm temperate forest zone (zone 2) with 29.5 species (22.3%). The distribution of the living species allied to the Seto fossil species indicates that the Seto flora bears a close resemblance to the upper warm temperate zone forest which corresponds to the modern evergreen oak forest of East Asia.

Assumed Habitat

Table 48 shows the assumed habitat of the Seto leaf flora. Only two species belong to the aquatic community, and their similar modern plants are confined to areas of shallow water, although many water plants were reported from the Seto porcelain clay Formation by Miki. Almost all of the water-loving species appear to have lived mainly to well-drained, moist, valley sites such as stream banks, damp swales, and moist flats near the sites of deposition, considering from small number of the swamp species. These riparian or valley forests are largely composed of deciduous hardwoods, and are mixed with a few evergreen broad-leaved trees such as *Actinodaphne* cf. *lancifolia, Persea* cf. *thunbergii* along with a shrub, *Ilex subcornuta.* Some of more abundant trees of the flora, such as *Carpinus miocenica, Acer nordenskioeldii, Populus kobayashii, Tilia* sp., *Liquidambar miosinica, Populus hokiensis, Syringa* cf. *pekinensis* and *Zelkova ungeri,* probably found their most luxuriant growth in this community, along with *Carex* spp., and *Bambusites* sp. Many species of the riparian or valley communities were not confined to the lake-shore and valley flat but also occupied lower slope in the region. The lower slope forest has a marked relationship to the evergreen forest of lower elevation, though the forest contains a number of temperate deciduous hardwood trees. Some of the abundant trees of the flora, such as *Quercus* aff. *glauca, Cinnamomum* cf. *camphora, Paliurus protonipponicus, Liquidambar,* maples and hornbeams, probably found their most luxuriant growth in the lower slope forest. The forest at higher elevation above the lower slope forests was the deciduous broad-leaved forest dominated by *Fagus stuxbergii* ; it contains conifers such as *Keteleeria davidiana, Pseudotsuga tanaii* and *Tsuga mioseiboldiana.*

Summary

The Seto porcelain clay leaf flora composed of 62 species, 31 families and 49 genera occurs

Table 47. Distribution of the Most Allied Living Species

Fossil species	Most Allied living species	1	2	3	4	5	6	7
Cinnamomus cf. *camphora*	*C. camphora* Sieb.	*	*	—	—	—	—	—
Cinnamomum cf. *japonicum*	*C. japonicum* Sieb.	*	*	*	—	—	—	—
Cocculus cf. *trilobus*	*C. trilobus* DC.	*	*	*	—	—	—	—
Elaeocarpus florinii	*E. sylvestris* (Lour.) Poir	*	*	*	—	—	—	—
Eurya sp.	*E. japonica* Thunb.	*	*	*	—	—	—	—
Glyptostrobus europeaeus	*G. pencilis* K. Koch	*	*	*	—	—	—	—
Kadsura protojaponica	*K. japonica* (L.) Dunal	*	*	*	—	—	—	—
Paliurus protonipponicus	*P. ramosissimus* (Lour.) Poir.	*	*	*	—	—	—	—
Persea cf. *thunbergii*	*P. thunbergii* Sieb. et Zucc.	*	*	*	—	—	—	—
Styrax cf. *japonica*	*S. japonica* Sieb. et Zucc.	*	*	*	*	—	—	—
Myriophyllum sp.	*M. spicatum* Linn.	*	*	*	*	*	*	—
Meliosma cf. *oldhami*	*M. oldhami* Maxim.	—	*	—	—	—	—	—
Acer prototrifidium	*A. buergerianum* Miq.	—	*	*	—	—	—	—
Actinodaphne cf. *lancifolia*	*A. lancifolia* Meisn.	—	*	*	—	—	—	—
Carya miocathayensis	*C. cathayensis* Sarg.	—	*	*	—	—	—	—
Ilex subcornuta	*I. cornuta* Lindl.	—	*	*	—	—	—	—
Keteleeria ezoana	*K. davidiana* (Franch.) Beiss.	—	*	*	—	—	—	—
Quercus protosalicina	*Q. salicina* Blume	—	*	*	—	—	—	—
Quercus aff. *glauca*	*Q. glauca Thunb.*	—	*	*	—	—	—	—
Sapium hokianum	*S. sebiferum* (Linn.) Roxb.	—	*	*	—	—	—	—
Tilia sp.	*T. kiusiana* Mak. et Shirasawa	—	*	*	—	—	—	—
Ulmus subparvifolia	*U. parvifoia* Jacq.	—	*	*	—	—	—	—
Fortunearia kabutoiwana	*F. sinensis* Rehd. et Wils.	—	*	*	*	—	—	—
Liquidambar miosinica	*L. formosana* Hance	—	*	*	*	—	—	—
Quercus protoacuta	*Q. acuta* Oerst.	—	*	*	*	—	—	—
Quercus protoaliena	*Q. aliena* Blume	—	*	*	*	—	—	—
Cornus megaphylla	*C. controversa* Hemsl.	—	*	*	*	*	—	—
Lespedeza sp.	*Lespedeza* sp.	—	*	*	*	*	—	—
Wisteria fallax	*W. floribunda* (Willd.) DC.	—	*	*	*	*	—	—
Zelkova ungeri	*Z. serrata* Makino	—	+	*	*	—	—	—
Pittosporum cf. *illicioides*	*P. illicioides* Makino	—	—	*	—	—	—	—
Acer nordenskioeldii	*A. palmatum* Thunb.	—	—	*	*	—	—	—
Acer tricuspidatum	*A. pycnanthum* K. Koch	—	—	*	*	—	—	—
Carpinus heigunensis	*C. tschonoskii* Maxim.	—	—	*	*	—	—	—
Carpinus cf. *turczaninowii*	*C. turczaninovii* Hance	—	—	*	*	—	—	—
Fagus palaeojaponica	*F. japonica* Maxim.	—	—	*	*	—	—	—
Pseudotsuga tanaii	*P. japonica* Shirasawa	—	—	*	*	—	—	—
Tsuga miosieboldiana	*T. sieboldii* Carr.	—	—	*	*	—	—	—
Acer cf. *chiharae*	*A. mono* Maxim.	—	—	*	*	*	—	—
Castanea miocrenata	*C. crenata* Sieb. et Zucc.	—	—	*	*	*	—	—
Lindera cf. *miyataensis*	*L. umbellata* Thunb.	—	—	*	*	*	—	—
Populus hokiensis	*P. sieboldii* Miq.	—	—	*	*	*	—	—
Vaccinium sp.	*V. smallii* A. Gray	—	—	*	*	*	—	—
Ostrya aizuana	*O. japonica* Sarg.	—	—	+	*	*	—	—
Carpinus miocenica	*C. laxiflora* Blume	—	—	+	*	+	—	—
Betula sp.	*Betula* sp.	—	—	—	*	*	—	—
Cladrastis aniensis	*C. platycarpa* (Maxim.) Makino	—	—	—	*	*	—	—
Fagus stuxbergii	*F. crenata* Blume	—	—	—	*	*	—	—
Malus sp.	*Malus* sp.	—	—	—	*	*	—	—
Stewartia hokiana	*S. pseudo-camellia* Maxim.	—	—	—	*	*	—	—
Syringa cf. *pekinensis*	*S. pekinensis* Rupr.	—	—	—	*	*	—	—
Ulmus protojaponica	*U. davidiana* Planch. var. *japonica* (Rehd.) Nakai	—	—	—	+	*	—	—
Vitis naumannii	*V. coignetiae* Pulliat	—	—	—	+	*	—	—

1) Subtropical forest zone 2) Lower warm temperate forest zone 3) Upper warm temperate forest zone
4) Lower cool temperate forest zone 5) Upper cool temperate forest zone 6) Subalpine forest zone 7) Alpine forest zone

in a siltstone bed of the Seto porcelain clay Formation of Seto Group in the Obata area south of Seto City in Aichi Prefecture. The Seto porcelain clay Formation consists mainly of quartz

Table 48. Assumed Habitat of the Seto Plants

Species	1	2	3	4
Myriophyllum sp.	*			
Potamogeton sp.	*			
Glyptostrobus sp.	*	*		
Ulmus protojaponica	*	*		
Ulmus subparvifolia	*	*		
Acer tricuspidatum		*		
Bambusites sp.		*		
Ilex subcornuta		*		
Populus kobayashii		*		
Sapium hokianum		*		
Zelkova ungeri		*		
"Ficus" tiliaefolia		*		
Acer nordenskioeldii		*	*	
Acer prototrifidium		*	*	
Acer cf. *chiharae*		*	*	
Actinodaphne cf. *lancifolia*		*	*	
Carex spp.		*	*	
Carpinus heigunensis		*	*	
Carpinus miocenica		*	*	
Carya miocathayensis		*	*	
Cladrastis aniensis		*	*	
Cornus megaphylla		*	*	
Deutzia sp.		*	*	
Liquidambar miosinica		*	*	
Malus sp.		*	*	
Persea cf. *thunbergii*		*	*	
Populus hokiensis		*	*	
Styrax cf. *japonica*		*	*	
Syringa cf. *pekinensis*		*	*	
Tilia sp.		*	*	
Wisteria fallax		*	*	
Castanea miocrenata			*	
Cinnamomum cf. *camphora*			*	
Cinnamomum cf. *japonicum*			*	
Elaeocarpus florinii			*	
Eurya sp.			*	
Fortunearia kabutoiwana			*	
Halesia sp.			*	
Lespedeza sp.			*	
Paliurus protonipponicus			*	
Pinus trifolia			*	
Pittosporum cf. *illicioides*			*	
Quercus protoacuta			*	
Quercus protoaliena			*	
Quercus protosalicina			*	
Quercus aff. *glauca*			*	
Vaccinium sp.			*	
Carpinus cf. *turczaninowii*			*	*
Betula sp.				*
Fagus palaeojaponica				*
Fagus stuxbergii				*
Keteleeria davidiana				*
Lindera cf. *miyataensis*				*
Ostrya aizuana				*
Pseudotsuga tanaii				*
Stewartia hokiana				*
Tsuga miosieboldiana				*

1 : Aquatic or Marsh 2 : Riparian or Valley 3 : Lower Slope 4 : Mountain Slope

sandstone and porcelain clays, unconformably rests on the pre-Neogene basement rocks and/or marine Early Miocene Mizunami Group, and unconformably underlies the Yadagawa Formation of Latest Miocene and Pliocene age. The Seto porcelain clay Formation is of lacustrine origin.

Abundant occurrence of evergreen *Quercus* and *Paliurus* together with common occurrence of *Cinnamomum* characterize Seto porcelain clay leaf flora. The Seto porcelain flora has an affinity with the modern warm-temperate broad-leaved forests in north-central Honshu, Japan. The Seto porcelain clay leaf flora is composed of three communities : wet riparian or valley, mesic lowland, and well-drained mountain. The slope forest was dominated by beech and conifers. The ratio of entire-margined broad-leaved species is 35.5 percent.

Plant Fossils from the Yadagawa Formation

Several plant fossils were reported from the lignite-bearing sediments in Ueno, Sakashita-cho, Kasugai City of Aichi Prefecture by Miki (1948). This plant-bearing bed (Loc. 84 in Miki, 1948) is at the lower horizon of the Yadagawa Formation unconformably overlying the Seto porcelain clay Formation (Mori, 1971). Miki (1948) identified the following species at Loc. 84 : *Glyptostrobus pensilis, Metasequoia disticha, Sequoia sempervirens, Juglans cinerea, Fagus japonica, Quercus acutissima, Fortunearia sinensis, Liquidambar formosana, Styrax japonica,* and *Styrax rugosa*. Considering from the fact that these plants were based mainly on fruit, cone and seed, and also from their assumed habitat which are marsh or riparian (excluding *Fagus* and *Quercus*), these fossils were deposited probably near the river bank, and were dominant

members of the lowland and lower slope forests near the sites of deposition. Compared the floristic composition with the Seto porcelain clay flora, this reproductive organ assemblage lacks evergreen broad-leaved species.

The microfossil record from 9 horizons between the Marune and Tougou volcanic ash beds of the lower part of the Yadagawa Formation reported by Yoshino (1971) adds many genera in this megafossil assemblage as follows:

List of Microfossils

Gymnospermae	Nyssaceae
Abies	*Nyssa*
Picea	Aquifoliaceae
Pinus+	*Ilex*+
Tsuga	Aceraceae
Pseudotsuga-Larix	*Acer*+
*Taxodiaeae++	Tiliaceae
Salicaceae	*Tilia*
Salix+	Ericaceae
Juglandaceae	Symplococaceae
**Juglans*+	*Symplocos*
Carya	Styracaceae
Betulaceae	**Styrax*
Carpinus+	Polygonaceae
Betula-Corylus+	*Persicarya*
Alnus++	Chenopodiaceae
Fagaceae	*Chenopodium*
**Fagus*++	Caryophyllaceae
Castanea	*Stellaria*
**Quercus*++	*Lychnis*
Castanopsis	Nymphaeaceae
Ulmaceae	*Nuphar*
Ulmus-Zelkova	Caprifoliaceae
Hamamelidaceae	*Lonicera*
Corylopsis	Compositae
**Liquidambar*+	

* : represented also by megafossils + : common ++ : dominant

Taxodiaceae is predominant in the microfossil assemblages and contains three species in megafossil. Accordingly, it must have been dominant or common members of the lower Yadagawa forest. *Fagus, Quercus, Liquidambar* and *Juglans* are recorded in the micro- and megafossil groups. These plants may be also dominant or common members of the forest. The five genera of the Pinaceae unrecognized as megafossils may be supposed to have been montane members of the forest whose winged pollen readily entered the depositional sites. A single evergren tree, *Castanopsis,* is recorded from only one locality with meagre representation; it may be subordinate member of the forest. All the lower Yadagawa plants were deciduous excepting *Castanopsis.*

According to Mori (1971), the plant-bearing sediments (Miki's Loc. 84) are just below the Tougou volcanic ash bed, which is the equivalent of the Ootani volcanic ash bed (5.24±0.41 Ma by Hayashi et al., 1985).

During Latest Miocene age when the Lower Yadagawa Formation was deposited, it was under unfavorable climate for the growth of evergreen broad-leaved trees, different from the warm temperate climate indicated by the "Seto porcelain clay" flora.

Plant Fossils from the Tokoname Formation

The Tokoname Formation unconformably overlying the Early Miocene Morozaki Group is distributed in the Chita Peninsula. The stratigraphy of the Formation is well defined by

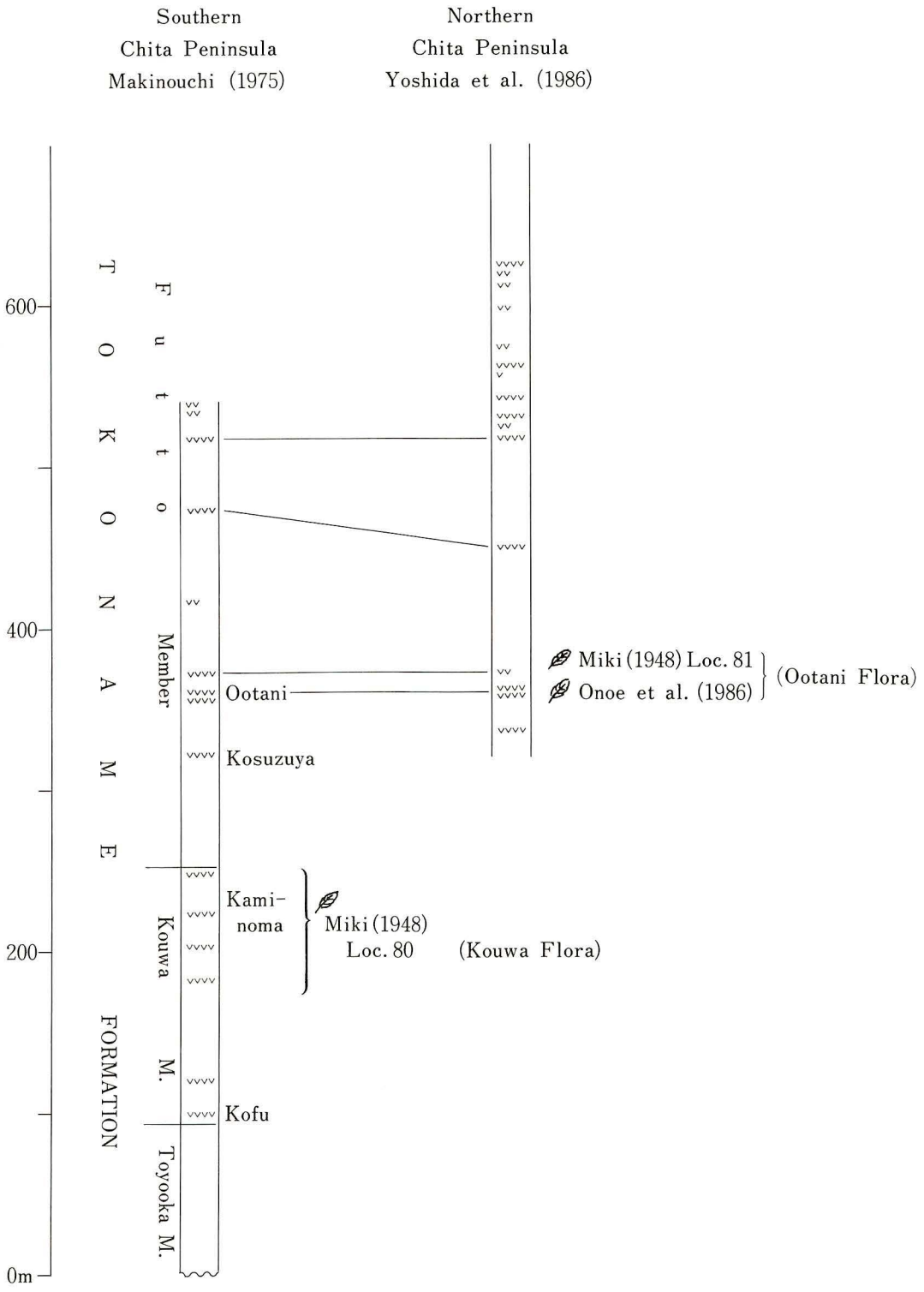

Fig. 17. Stratigraphy of the Seto Group in Chita Peninsula and Horizons of the Ootani and Kouwa floras
VVVV : Volcanic ash bed

Itoigawa (1971), Makinouchi (1975), Yoshida et al. (1986) and others, tracing many volcanic ash beds intercalated. Makinouchi divided the formation into the Toyooka, Kouwa and Futto Members in ascending order as shown in Fig. 17. Plant fossils such as reproductive organs were first reported from the Tokoname Formation by Miki (1948), and leaf fossils were recently reported by Onoe et al. (1986). Nasu (1972) gave a brief note on the pollen flora of the Lower Tokoname Formation.

The Ootani Flora

Miki (1948) reported *Glyptostrobus pensilis, Sequoia sempervirens, Sabia japonica, Nyssa sylvatica* and *Berchemia racemosa* from the lignite-bearing bed in Tokoname area, Tokoname City (Miki's Loc. 81). This plant-bearing bed is situated just above the Ootani volcanic ash bed (Onoe et al., 1986). Onoe et al. (1986) reported the leaf fossils from the basal part of the Ootani volcanic ash bed in Oosani area, Tokoname City as follows: *Salix* cf. *subfragilis, Quercus sinomiocenicum, Q. protoaliena, Q. protoserrata, Lindera miyataensis, Liquidambar protopalmata, Cladrastis* cf. *platycarpa, C.* cf. *shikokiana, Wisteria fallax, Acer* sp., *Paliurus protonipponicus,* Vitaceae gen. et sp. indet., *Alangium aequalifolium, Carex* sp. and *Pleioblastus* sp.

There are no common species between the fossils collected by Miki and Onoe et al. The leaf assemblage comprises a large number of *Salix, "Alangium"* and many elements of riparian forest, while Miki's collection contains *Glyptostrobus.* Therefore, the both assemblages may reflect the vegetation near a marshy area. Although the both assemblages are poor in species composition, they lack evergreen broad-leaved species. A pollen assemblage was reported from the lower part of the Tokoname Formation just below the Ootani volcanic ash bed by Nasu (1972); it contains abundantly *Glyptostrobus, Fagus, Alnus, Liquidambar,* deciduous *Quercus* and *Nyssa.* This pollen flora includes markedly less evergreen oak pollen and further dominat deciduous oak pollen, compared with the Seto porcelain clay flora.

The Kouwa Flora

Miki (1948) reported 24 species from the hill around Kouwa-cho in southern Chita Peninsula (at Loc. 80 and Loc. 80B). The specimens from Loc. 80A are considered to be obtained from the Alluvium clay bed. Although the precise site is uncertain, Onoe et al. (1986) estimated the horizon of Miki's Loc. 80B is in the upper part of the Kouwa Member as shown in Fig. 17

The Kouwa flora listed by Miki (1948) from Loc. 80 and Loc. 80B is as follows: *Pseudolarix kaempferi, Cunninghamia* sp., *Glyptostrobus pensilis, Metasequoia disticha, Sequoia sempervirens, Sciadopitys verticillata, Myrica rubra, Castanopsis cuspidata, Quercus stenophylla, Aphananthe aspera, Zelkova ungeri, Brasenia purpurea, Cinnamomum camphora, Nuphar japonicum, Illicium religiosum, Mallotus japonicus, Buxus japonica, Berchemia racemosa, Camellia japonica, Trapa anteformata, Trapa incisa, Pieris* sp., *Symplocos glauca, Symplocos prunifolia, Trapella antennifera.*

This assemblage contains many species of evergreen broad-leaved trees, and shows a close similarity to the composition of the extant evergreen broad-leaved forest of the warm temperate zone in East Asia.

Geologic Age of the Floras

The radiometric age suggests that the Ootani flora reported from the Ootani volcanic ash bed by Miki (1948) and Onoe et al. (1986) is Latest Miocene in age, and that the Kouwa flora reported by Miki (1948) may be slightly older in age (between 6.0 Ma and 6.4 Ma).

Summary

Among fossil floras from the Seto Group distributed in the Tokai district, the Seto porcelain clay leaf flora represents an early Late Miocene vegetation. It is composed of 62 species (31 families and 49 genera), and is characterized by well developed riparian and lower slope taxa. The plant remains were accumulated in an inland lake. The mixed broad-leaved evergreen and deciduous forest flourished around the lake. The Kouwa flora is characterized by rich evergreen broad-leaved species with many aquatic plants, although minor in the composition. The Kouwa flora shows a evergreen broad-leaved forest on lowland. The Latest Miocene Ootani flora from the Futto Member of the Tokoname Formation and its coeval assemblage from the Yadagawa Formation are dominated by riparian plants ; they are composed mainly of deciduous broad-leaved trees with some water-loving plants. These two leaf assemblages entirely lack evergreen broad-leaved species except a few evergreen pollen taxa. The Latest Miocene to the Early Pliocene vegetation considered to be so-called warm temperate deciduous forest.