LATE MIOCENE AND PLIOCENE FLORAS IN NORTHWESTERN KWANTO DISTRICT

Introduction

In western part of Kwanto district north of the Kwanto mountains Neogene sedimentary and volcanic rocks are distributed. The northern distribution of the Neogene is in mountainous terrain on the west of the Ashio Mountains, and the late Tertiary is mainly distributed north and west of Numata City in the central to the north of Gunma Prefecture. The southern distribution of the Neogene is in the hills trending NWW-SEE along the northern margin of the Kwanto mountains from the west of Takasaki City of Gunma Prefecture to the south of Kumagaya City of Saitama Prefecture. The Neogene in the northwestern margin of the Kwanto Plain forms mountainous terrain that partly takes a part of the watershed of Central Japan. Except for some basal formations, the sediments of Early and Middle Miocene are of marine origin. The marine sediments in the early stage of Late Miocene age shift into terrestrial sediments in the middle to late stages of Late Miocene age and also in Pliocene age. Volcanism increased in violence in latest Miocene to Pliocene age, and some lacustrine sediments were accumulated in the western marginal area the Kwanto Plain.

A few Miocene flora have been reported from western Kwanto district. Some fossil leaf assemblages were reported by some authors: the Kabutoiwa (Upper Motojuku), the Itahana and the Yagii flora (Yagi, 1931; Suzuki et al., 1970; Ozaki et al., 1981; Homma, 1987). But no species has been yet described, except for 7 species from the Kabutoiwa flora. Plant fossils from several formations in northwestern Kwanto district were collected by me during 1983 and 1984. There are now on hand enough plant fossils to discuss the floral composition and paleoecology of the Late Miocene and Pliocene forests in northwestern Kwanto district, although my collection is not so large as might be desired.

The Itahana Flora

Geologic Occurrence

Miocene and Pliocene sediments are distributed at the northwest of Kwanto mountains : in the south to west of Takasaki City of Gunma Prefecture. Fujimoto and Kobayashi (1938) divided these sediments into five formations: the Ushibuse, Kanohara, Tomioka, Itahana and Akima Formations in ascending order as shown in Table 2. They considered these formations are in conformable relations each other. However, as shown in Table 2, the Tomioka Formation is further subdivided into 3 to 5 formations by later various authors ; all of these formations were treated as the Tomioka Group. Some authors (Kizaki, 1965; others) claimed that the Akima Formation overlies the Itahana Formation unconformably. The Tomioka Group is largely of marine origin, including molluscan and foraminifer fossils which are useful for age-determination (T. Saito, 1963; Matsumaru, 1967; Ujiie and Hatsukari, 1973; Takayanagi et al., 1978.). The Itahana Formation overlies the marine Yoshii Formation, which contains

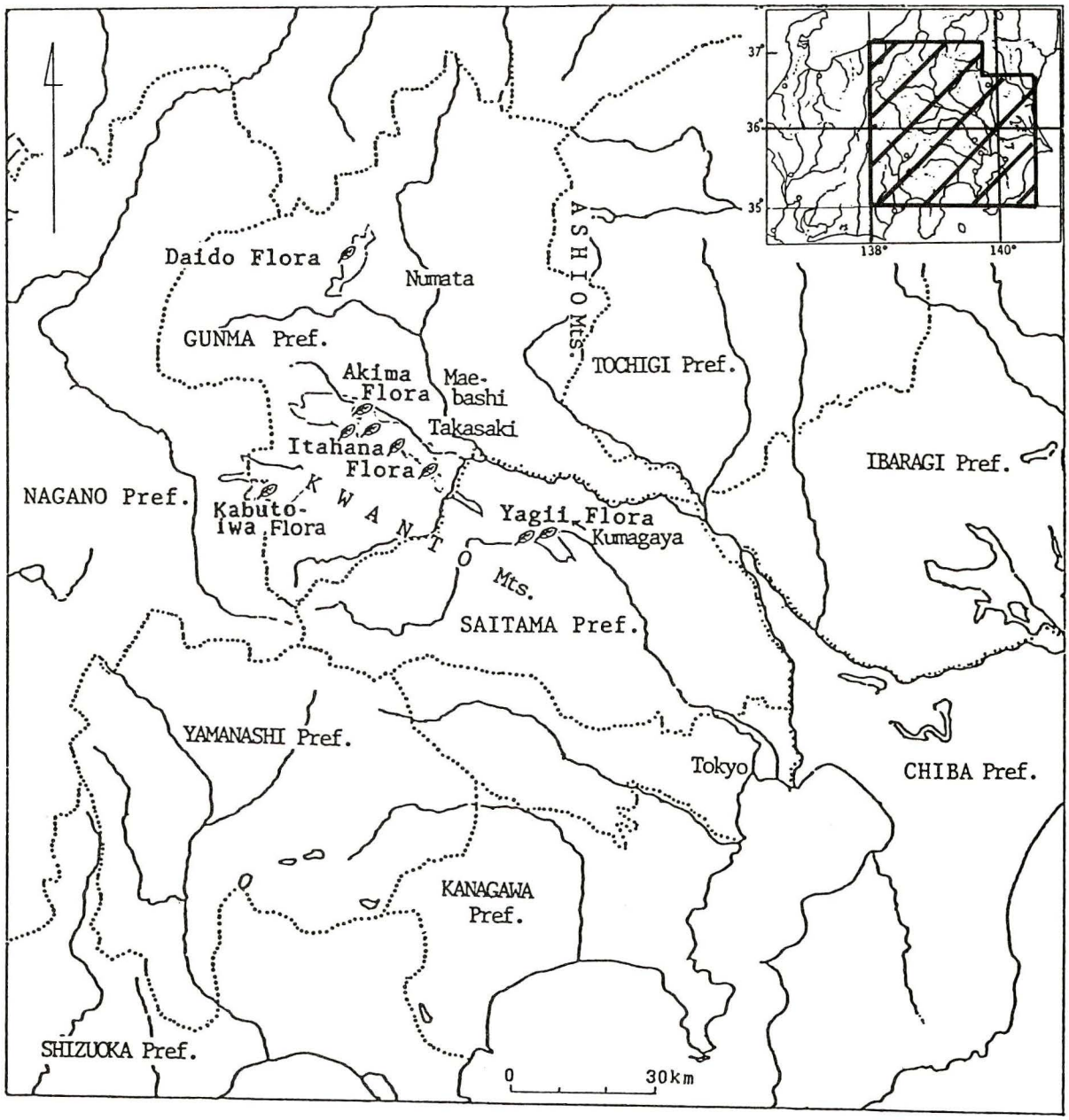


Fig. 2. Distribution of floras in Kwanto district.

Table 2. Correlation table of some studies on the Neogene sequences in south and western Takasaki City, Gunma Prefecture, Central Japan

	Hujimoto·Kobayashi (1938)	Watanabe (1952)	Kizaki (1965)	Matsumura (1967, '77)	Takayanagi et al. (1976)	Takayanagi et al. (1978)	Chiji·Konda (1978)	Nomura et al. (1981)
PLIOC.	Akima F.	Akima F.	Akima F.	Akima F.				Akima F.
Late	Itahana F.	Itahana F.	Itahana F.	Itahana F.	Itahana F.	Itahana F.	Itahana F.	Itahana F.
Middle	Tomioka F.	Yoshii F.	Yoshii F.	Yoshii F.	Haraichi F.	Haraichi F.	Yoshii F.	Yoshii F.
				Niwaya F.		Niwaya F.	Niwaya F.	
		Fukushima F.	Fukushima F.	Harata-jino F.	Ono F.	Sogi F.	Harata-jino F.	Fukushima F.
						Harata-jino F.		
Early		Idozawa F.	Idozawa F.	Idozawa F.	Idozawa F.	Idozawa F.	Idozawa F.	Idozawa F.
			Obata F.	Obata F.			Obata F.	Obata F.
	Kanohara F. / Ushibuse F.	Shimonita F.	Ushibuse F.	Ushibuse F.	Nukabe F.	Nukabe F.	Ushibuse F.	Ushibuse F. / Shimonita F.

Itahana flora

Lucinoma-Turritella assemblage (Iwasaki, 1970). The *Anadara-Dosinia* assemblage in the lower part of the Itahana Formation changed to the *Ostrea* assemblage in the middle part, and marine molluscs are entriely absent in the upper part. The molluscan fossil occurrence suggests that the Itahana Formation was deposited in marine to terrestrial environments.

The Fujiki (Baba) tuff in the upper part of the Yoshii (Haraichi) Formation is dated as 11.6±0.4 Ma (K-Ar age) by Shibata et al. (1979). As the *Globigerina nepenthes* Datum plane is placed around this tuff, the Itahana Formation beginning at about 200 m above the tuff, is considered to be younger than Blow's N. 15 (Chiji & Konda, 1978; Tsuchi et al., 1979). Thus the base of the Itahana Formation is considered to correlate with the base of the Late Miocene. I entrusted Teledyne Isotopes Co. with the measurement of andesite pebbles from tuff breccia in the uppermost part of Itahana Formation, and obtained a value of 6.4±2 Ma. Nomura and Kosaka (1987) reported a fission track value, 8.13±1.64 Ma for a tuff bed from the upper part of the Itahana Formation.

The Itahana Formation is characterized by a cyclic facies mainly composed of conglomerate-sandstone-siltstone in the ascending order. Conglomerates are considerably predominant with thick beds in the upper part than in the lower. The Itahana Formation is subdivided into two members by the lithological composition; the lower and upper members are bounded by a pumice tuff bed. The tuff bed of about 10 m thickness was named as "Tate tuff" by Takayanagi et al. (1978), which is situated stratigraphically at about 400 m above the base of the Formation in the eastern area. The tuff bed is locally accompanied by lignite seams above it. Plant fossils are obtained from the fine-grained rocks through the Itahana Formation, and they are listed in Table 3. The principal localities are shown in Fig. 3 and their stratigraphic horizons are shown in Fig. 4 and Fig. 5.

Locality A: A small, weathered sandstone outcrop along the roadside at a pass north of Miyanoiri, Shimogokan, Annaka City. The plant-bearing sediments are in the middle part of the lower member of the Itahana Formation. A small amount of leaf and seed fossils occurs from the standstone, although poorly preserved.

Locality B: Right bank of the Gokan River, west of Kido-mura, Kamigokan, Annaka City. Plant fossils occur tuffaceous siltsone, which is hollowed by erosion near the river bed. Tuffaceous siltstone grades upward into thick sand and gravel beds of 2 m thickness, which comprise Oyster bed with abundant *Glycymeris cisshuensis* Makiyama and *Chlamys kaneharai* (Yokoyama). The plant-bearing rocks are in the sandstone-rich facies of the middle part of the lower member. Well-preserved leaves occur commonly, and those of *Lindera* and *Bambusites* are especially abundant: the former occupies 32% and the latter 27% of the total specimens collected.

Locality Ca: A cliff of the golf practice ground southwest of the Irino Station of Joshin Railway at the eastern end of Yoshii-machi. Plant fossils occur in siltstone several meters above the Tate tuff. The total specimens identified are poor, but they include such evergreen trees as *Actinodaphne* and *Cinnamomum* together with a number of *"Ficus"*. Localities C, Cb and D are stratigraphically situated above the Tate tuff and around the middle lignite beds.

Locality Cb: In the valley south of the Self-Defense Forces Base, at the southern end of Yoshii-machi. Plant-bearing rocks are fine- to medium-grained sandstone, which is immediately above the Tate tuff. Plant fossils are poor in preservation.

Locality D: A weathered outcrop south of Kami-hanataka, Takasaki City. Plant fossils are aggregated like a swept-up heap in a fine-grained sandstone below the Tate tuff. *Phragmites* ? and *Alnus* occupy nearly two-thirds of the total specimens. Miki (1956, 1970) reported the following species from Hanataka area: *Vitis rotundata* Miki, *Cayratia orbitalis* Miki, *Glyptostrobus, Metasequoia, Stephania* and *Machilus pasanifolia* Miki.

Locality E: An outcrop at Shimotakabettou of Annaka City. Plant-bearing rocks are tuffaceous siltstone, which corresponds to the upper part of the Tate tuff.

Locality F: An earth-digging site north of Zuirinji, Nakaakima, Annaka City. Plant-

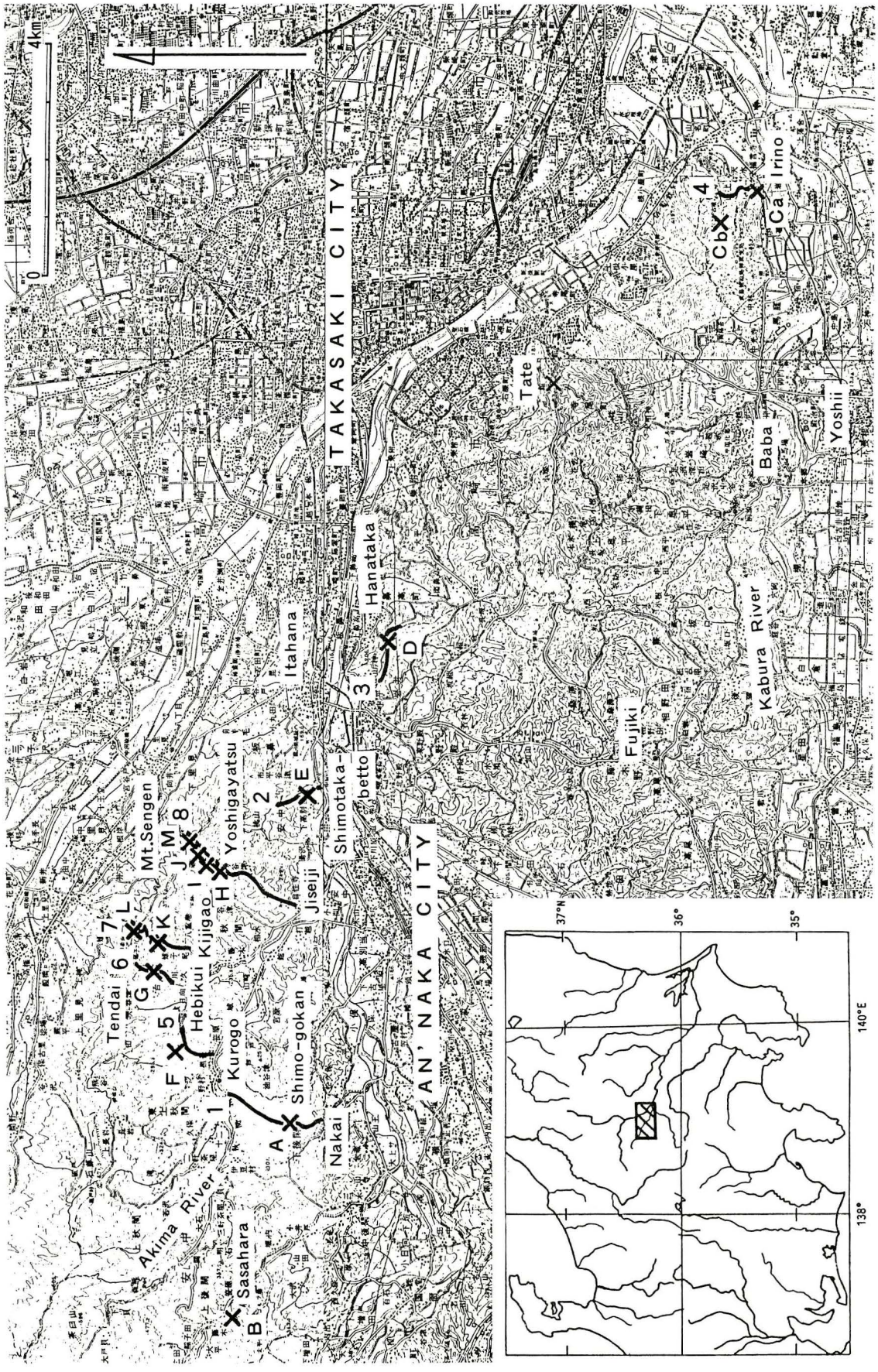


Fig. 3. Localities of the Itahana and Akima floras in Gunma Prefecture.

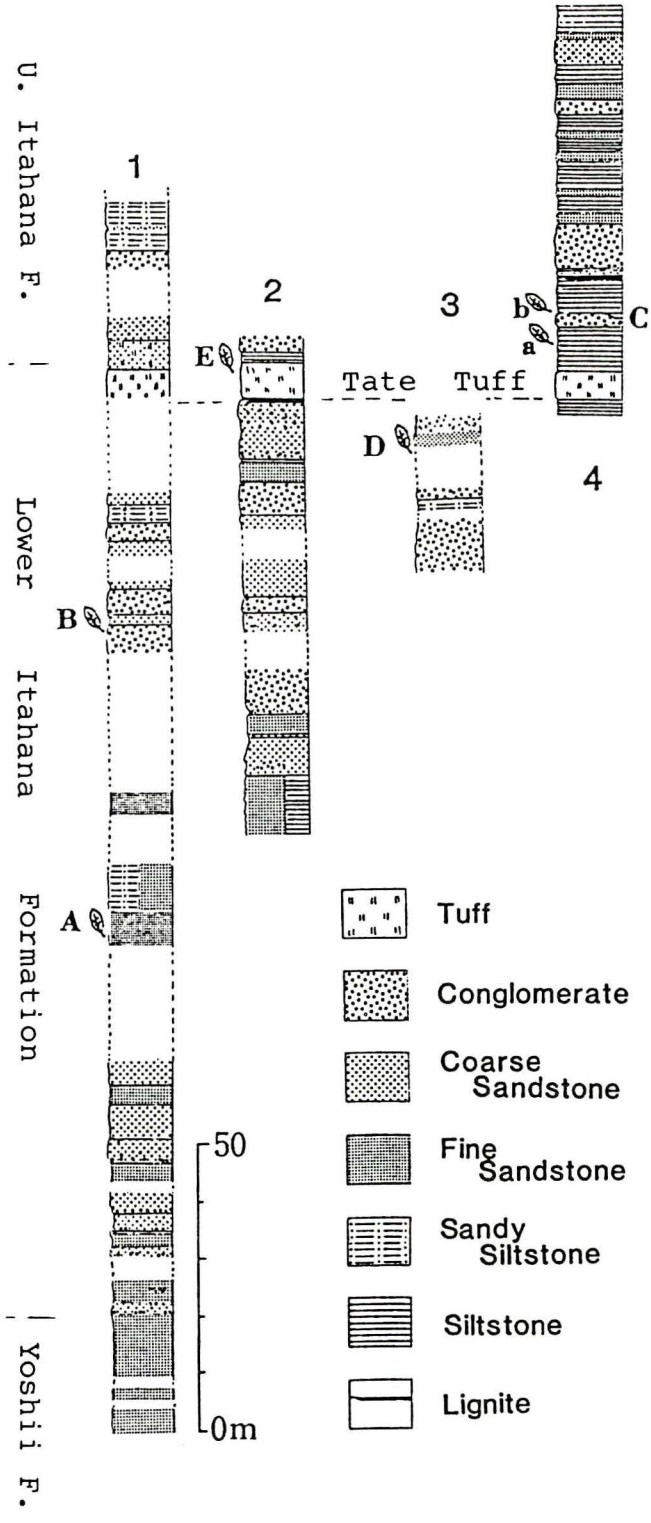


Fig. 4. Stratigraphic Relationships of Six Localities of the Lower Itahana Florule.
1: from Nakai to Kurogo in Shimogokan, Annaka City 2: around Yuzawa in Shimotakabettou, An'naka City 3: near Hanataka, Takasaki City 4: north of Irino, Takasaki City.

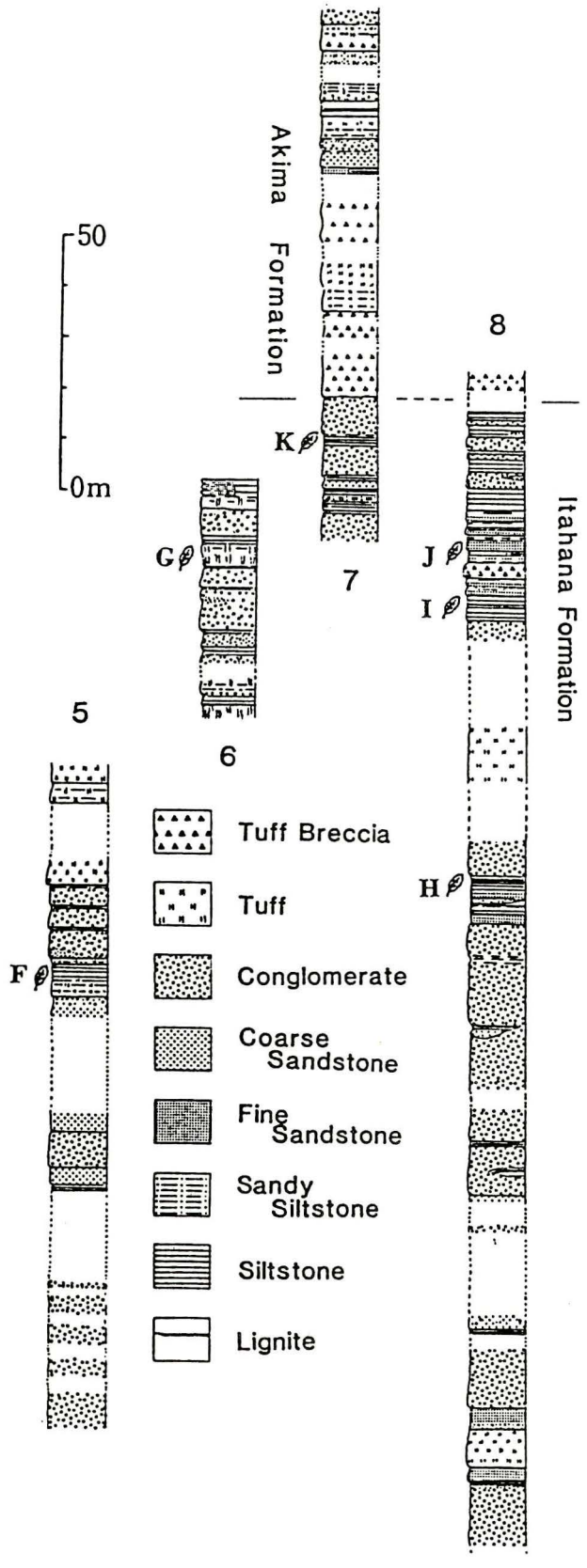


Fig. 5. Stratigraphic Relationships of Six Localities of the Upper Itahana Florule.
5: from Kurogo to Hebikui, An'naka City 6: around Tendai, An'naka City 7: from Kijigao to Kijigao Pass, An'naka City 8: from north of Jiseiji to Yoshigayatu Pass, An'naka City

Table 3. Numerical representation of the Itahana floras

Species	Loc.	A	B	C	Cb	D	E	F	Ga	Gb	H	Ia	Ib	Ic	J	K	sum
Salvinia sp. cf. *S. natans*		–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	3
Abies protofirma		2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Pinus miocenica		–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Pseudolarix japonica		–	–	–	–	–	–	3	–	–	–	–	–	–	2	–	5
Pseudotsuga tanaii		–	–	–	–	–	–	3	–	–	–	–	–	–	1	–	4
Tsuga miosieboldiana		–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
Metasequoia occidentalis		–	–	–	11	38	1	1	18	–	–	–	–	–	1	3	73
Taxodium dubium		–	–	–	–	–	–	–	2	–	2	–	–	–	–	–	4
Thujopsis miodolabrata		2	–	1	–	1	–	–	–	–	–	–	–	1	–	–	5
Magnolia sp.		–	1	–	–	1	–	–	–	–	–	–	–	–	1	–	3
Actinodaphne cf. *lancifolia*		4	1	1	–	–	–	–	–	–	–	–	–	–	–	–	6
Cinnamomum cf. *camphora*		–	–	1	–	10	–	–	1	–	–	–	–	–	–	–	12
Cinnamomum cf. *japonicum*		–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	2
Lindera cf. *erythrocarpa*		–	69	6	–	2	–	1	–	–	–	–	–	–	–	–	78
Lindera cf. *glauca*		–	21	–	–	11	–	–	–	–	–	–	–	–	–	–	32
Lindera cf. *miyataensis*		–	2	–	–	–	–	2	–	–	–	–	–	–	–	–	4
Parabenzoin sp.		–	–	–	–	5	–	–	–	1	–	–	–	–	–	–	6
Persea cf. *thunbergii*		–	–	–	–	1	2	–	–	–	–	–	–	–	–	–	3
Ceratophyllum miodemersum		–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	4
Cocculus sp.		–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	4
Liquidambar japonica		–	–	–	–	–	–	–	1	–	–	–	–	–	–	1	2
Liquidambar miosinica		1	–	1	–	–	5	–	3	–	–	–	8	–	–	–	18
Parrotia sp.		4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
Celtis hokiensis		–	–	–	–	–	–	–	–	1	–	–	–	2	4	–	7
Celtis sp.		–	–	–	1	–	1	1	–	–	–	–	–	–	–	–	3
Ulmus protojaponica		–	–	–	3	–	–	6	–	–	–	–	–	–	31	–	40
Ulmus sp.		–	–	–	14	–	–	–	–	–	–	–	–	–	–	–	14
Zelkova ungeri		1	–	–	7	1	2	15	–	2	–	–	–	6	6	–	40
Carya miocathayensis		–	–	–	1	–	–	–	–	1	–	–	–	–	63	–	65
Pterocarya asymmetrosa		–	1	–	4	–	–	1	–	–	–	–	–	–	1	–	7
Pterocarya protostenoptera		–	–	–	–	–	–	–	–	–	–	–	–	–	21	–	21
Fagus palaeojaponica		–	–	–	–	–	–	–	–	–	–	–	–	–	3	–	3
Fugus stuxbergii		5	–	–	–	–	–	6	–	–	–	–	–	15	14	–	40
Fagus sp.		2	–	–	–	–	–	–	–	–	–	–	–	–	1	–	3
Quercus miovariabilis		–	–	–	–	1	–	1	–	8	–	–	63	–	–	–	73
Quercus protoaliena		–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Quercus protosalicina		6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
Quercus protoserrata		–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Quercus aff. *glauca*		2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Alnus cf. *japonica*		–	–	–	–	–	5	–	–	–	104	–	–	–	1	22	132
Alnus sp.		1	–	–	–	–	23	1	–	–	–	–	–	–	–	–	25
Carpinus heigunensis		–	–	–	–	–	–	4	–	–	–	–	–	–	10	–	14
Carpinus miocenica		2	–	–	–	–	–	26	–	–	–	–	–	–	34	–	62
Carpinus cf. *japonica*		–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	2
Carpinus subcordata		–	–	–	–	–	–	1	–	–	–	–	–	8	–	–	9
Carpinus sp.		–	–	–	–	–	–	1	–	–	–	–	–	–	1	–	2
Corylus subsieboldiana		–	–	–	–	–	–	11	–	–	–	–	–	–	–	–	11
Ostrya sp.		–	–	–	–	–	–	6	–	–	1	–	–	–	1	–	8
Tilia sp.		–	–	–	2	–	–	1	–	–	–	–	–	–	–	–	3
"Ficus" tiliaefolia		–	1	13	3	6	1	–	68	–	16	17	–	–	–	148	273
Populus hokiensis		–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
Salix hokkaidoensis		–	–	–	–	–	–	–	–	1	2	–	–	–	–	–	3

Table 3. (*continued*)

Species	Loc.	A	B	C	Cb	D	E	F	Ga	Gb	H	Ia	Ib	Ic	J	K	sum
Salix k-suzukii		–	–	–	–	–	–	10	–	–	3	28	–	–	4	6	51
Salix misaotatewakii		–	–	–	–	–	–	–	31	–	–	2	–	–	–	4	37
Salix muraii		–	–	–	–	–	–	1	–	–	1	2	–	–	1	–	5
Salix parasachalinensis		–	–	–	3	–	–	2	–	–	1	58	–	–	7	5	76
Salix sp.		–	–	–	3	–	–	–	2	–	5	–	–	–	6	–	16
Salix cf. *integra*		–	–	–	8	–	–	–	31	–	–	–	–	–	–	–	39
Clethra? sp.		–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	2
Halesia sp.		–	–	–	–	–	–	–	–	–	–	–	–	–	35	–	35
Styrax cf. *japonica*		–	1	–	–	–	–	–	–	–	–	–	–	–	3	–	4
Pittosporum illicioides		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Deutzia sp.		–	–	–	–	–	–	1	–	3	–	–	–	–	–	–	4
Malus sp.		–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	2
Rosa usyuensis		–	–	–	–	–	–	–	–	–	18	–	–	–	–	–	18
Sorbus lesquereuxi		–	–	–	1	–	–	–	–	–	–	–	3	–	–	–	4
Spiraea protothunbergii		–	–	–	–	1	–	1	–	–	–	–	–	–	1	–	3
Caesalpinia hokiana		–	–	–	–	–	–	1	–	–	1	–	–	–	2	–	4
Cercis miochinensis		–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	2
Gleditsia miosinensis		–	–	–	–	–	–	2	–	–	–	–	–	–	1	–	3
Cladrastis aniensis		–	23	–	–	3	4	–	9	–	–	–	–	3	1	2	45
Cladrastis inouei		–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Lespedeza tatsumitogeana		–	–	–	–	–	–	–	2	–	–	–	–	1	–	–	3
Lespedeza sp.		–	–	–	1	–	–	–	4	–	–	–	–	1	2	1	9
Sophora hokiana		–	–	1	–	–	–	1	–	–	1	–	–	–	2	–	5
Wisteria fallax		–	2	–	–	4	–	5	–	–	–	–	–	–	–	1	12
Cornus cf. *miowalteri*		–	–	–	1	–	–	3	1	–	1	–	–	–	–	2	8
Ilex sp. cf. *I. serrata*		–	10	–	–	–	–	–	–	–	4	–	–	–	1	1	16
Berchemia miofloribunda		–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	2
Paliurus protonipponicus		–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	2
Parthenocissus? sp.		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Vitis naumannii		–	–	–	–	1	–	–	–	–	–	–	–	–	11	–	12
Sapindus? sp.		–	–	–	–	–	–	–	–	–	1	–	–	–	3	–	4
Acer nordenskioeldii		–	–	–	4	–	–	12	–	–	–	–	2	–	34	–	52
Acer protomatsumurae		–	–	–	–	–	2	1	–	–	–	–	–	–	–	–	3
Acer protomiyabei		–	–	–	–	–	1	1	–	–	–	–	9	–	3	–	14
Acer rotundatum		–	–	–	–	–	–	3	–	1	–	–	2	–	–	–	6
Acer tricuspidatum		–	–	–	–	2	–	–	1	–	–	–	–	–	–	–	3
Acer sp.		–	–	–	1	–	–	3	–	1	–	–	–	4	8	–	17
Euodia rutaecarpa		1	–	–	–	–	–	–	–	–	2	–	–	–	–	–	3
Fraxinus sanzugawaensis		–	–	–	–	–	–	–	–	–	7	–	–	–	–	–	7
Fraxinus sp.		–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	3
Ligustrum? sp.		–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	2
Syringa? sp.		1	–	–	–	–	–	1	–	–	3	–	–	–	–	–	5
Lonicera sp.		–	–	–	–	–	–	–	–	–	1	–	–	–	5	–	6
Viburnum? sp. cf. *V. opulus*		1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Caldesia sp.		–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
Potamogeton sp.		–	–	–	–	–	–	5	70	50	–	–	–	–	–	1	126
Carex spp.		–	–	–	–	6	10	22	6	–	–	–	3	–	3	–	50
Bambusites sp.		–	52	35	3	9	7	3	–	–	–	–	30	–	5	–	144
Gramineae gen. & sp. indet.		–	–	–	–	–	–	–	–	4	–	–	–	–	9	12	25
Phragmites? sp.		–	–	–	–	31	30	12	–	–	1	–	16	–	5	–	95
Carpolithes japonicus		–	–	–	–	–	–	–	–	–	–	–	–	–	32	–	32
		37	185	59	72	136	94	187	252	79	177	109	136	42	392	210	2167

bearing rocks are in middle part of the upper member of the Itahana Formation, and are stratigraphically situated about 200 m above the Tate tuff. Plant fossils are preserved in sandy siltstone between tuffaceous coarse-grained sandstone and the conglomerate, and are represented by a number of species and specimens. *Carpinus, Carex, Acer, Zelkova, Phragmites?, Corylus* and *Salix k-suzukii* are common.

Locality G: An earth-digging site at the east end of the road from Yoshigayatsu to Aimizuyatsu, Annaka City. The exposure with about 10 m thickness is composed of two cyclothems of conglomerate to fine-grained rock, and is in the middle-upper part of the upper member. Carbonized leaf fossils occur to gather in the siltsone, while sandy siltsone in the coarser-grained part also contains a small amount of fossils. But the species composition is quite different between the two lithology, except common occurrence of *Potamogeton.* Fossils in the siltstone are mostly "*Ficus*" and *Salix,* accompanied by abundant *Potamogeton* along some lamina. On the other hand, there are no particularly dominant species in the sandy siltstone except for aggregated *Potamogeton.*

Locality H: A small cliff at a stream at Tendai, Annaka City. The sediments of this locality are stratigraphically slightly above the upper tuff, which is contained in Locality G. Leaf fossils are preserved in a bent-down state within a fine-grained part of the tuff. *Alnus* occupies about 60% of the total specimens, followed by *Rosa* and "*Ficus*". No species of evergreen broad-leaved trees are found.

Locality I: A cliff west of a cement plant at Yoshigayatsu, Annaka City. This cliff is consisting of conglomerate, sandstone, siltstone, tuffaceous sandy siltstone and tuff breccia, and is of the upper member of the Itahana Formation. This outcrop is stratigraphically situated nearly 25 m above the sediments of Locality G. Plant fossils occur in siltstone, sandy siltstone and fine sandstone of lowermost outcrop. Siltstone yields *Salix* occupying about 85% of the total specimens, accompanied by only "*Ficus*". In the sandy siltstone *Quercus* occupies nearly half of the total, followed by *Bembusites, Phragmites?* and *Acer.* Sandstone abounds in *Fagus stuxbergii* which takes up 37%, accompanied by *Carpinus, Zelkova* and *Acer.* No species of evergreen broad-leaved trees are found.

Locality J: A cliff west of a cement plant at Yoshigayatsu, Annaka City. Above Loc. I are developed tuff breccia and several thin cyclothems. These beds are situated about 10 m above those of Loc. I. Bent-down leaf fossils occur in fine-grained sandstone showing disturbed lamina. Some fossils are partly well preserved because of iron oxide substitution. *Carya* is most predominant in number of specimens, followed by *Ulmus protojaponica, Carpinus miocenica, Halesia* sp., *Carpolithes japonicus,* and *Pterocarya protostenoptera.* No species of evergreen broad-leaved trees are found. Siltstone in the upper cyclothem yields poor fossils in three horizons, comprising only "*Ficus*" and Gramineae.

Locality K: A road cutting north of Kijigao, Shimo-akima, Annaka City. Siltsone of the outcrop represents the uppermost part of the upper member, and is covered by basal conglomerate of the Akima Formation. Plant fossils occur in siltstone facies which is correlated with the upper cyclothems of Locality J. Fossils are partly carbonized. Of 14 species identified, 3 occupy more than 90% of the total specimens: "*Ficus*" about 60%, *Alnus* 21% and *Salix misaotatewakii* 10%. No species of evergreen broad-leaved trees are found.

The plant fossil assemblages in the Itahana Formation are divided into two florules: the Lower Itahana florule covering Localities A-E from the lower member and a part of the basal part of the upper member of the Itahana Formation, and the Upper Itahana florule covering Localities F-K from middle to upper part of the upper member of the Itahana Formation.

The Lower Itahana Florule

Systematic Representation

The Lower Itahana florule is composed of 28 families, 45 genera and 60 species. There are 4 conifers, 3 monocotyledons, and the remainders are dicotyledons. The largest family is the

Table 4. Systematic List of the Families and Species

Pinaceae	*Abies protofirma* Tanai
	Pseudolarix japonica Tanai & Onoe
Taxodiaceae	*Metasequoia occidentalis* (Newb.) Chaney
Cupressaceae	*Thujopsis miodolabrata* Tanai & N. Suzuki
Magnoliaceae	*Magnolia* sp.
Lauraceae	*Actinodaphne* sp. cf. *A. lancifolia* Meisn.
	Cinnamomum sp. cf. *C. camphora* Sieb.
	Cinnamomum sp. cf. *C. japonicum* Sieb.
	Lindera sp. cf. *L. erythrocarpa* Makino
	Lindera sp. cf. *L. miyataensis* Huzioka & Uemura
	Lindera sp. cf. *L. glauca* Blume
	Parabenzoin sp.
	Persea sp. cf. *P. thunbergii* (Sieb. et Zucc.) Kosterm.
Hamamelidaceae	*Liquidambar miosinica* Hu & Chaney
	Parrotia sp.
Ulmaceae	*Celtis* sp.
	Ulmus protojaponica Tanai & Onoe
	Ulmus sp.
	Zolkova ungeri Kovats
Juglandaceae	*Carya miocathayensis* Hu & Chaney
	Pterocarya asymmetrosa Konno ex Tanai
Fagaceae	*Fagus stuxbergii* (Nathorst) Tanai
	Fagus sp.
	Quercus miovariabilis Hu & Chaney
	Quercus protosalicina K. Suzuki
	Quercus protoserrata Tanai & Onoe
	Quercus sp. cf. *Q. glauca* Thunb.
Betulaceae	*Alnus* sp. cf. *A. japonica* Steud.
	Alnus sp.
	Carpinus miocenica Tanai
Tiliaceae	*Tilia* sp.
Sterculiaceae	*"Ficus" tiliaefolia* Heer
Salicaceae	*Salix parasachalinensis* Tanai & N. Suzuki
	Salix sp.
	Salix sp. cf. *S. integra* Thunb.
Styracaceae	*Styrax* sp. cf. *S. japonica* Sieb. & Zucc.
Pittosporaceae	*Pittosporum* sp. cf. *P. illicioides* Makino
Rosaceae	*Sorbus lesquereuxi* Nathorst
	Spiraea protothunbergii Tanai & N. Suzuki
Caesalpiniaceae	*Cercis miochinensis* Hu & Chaney
Fabaceae	*Cladrastis aniensis* Huzioka
	Lespedeza sp.
	Sophora hokiana Ozaki
	Wisteria fallax (Nathorst) Tanai & Onoe
Cornaceae	*Cornus* sp. cf. *C. miowalteri* Hu & Chaney
Aquifoliaceae	*Ilex* sp. cf. *I. serrata* Thunb.
Rhamnaceae	*Paliurus protonipponicus* K. Suzuki
Vitaceae	*Parthenocissus*? sp.
	Vitis naumannii (Nathorst) Tanai
Aceraceae	*Acer nordenskioeldii* Nathorst
	Acer protomatsumurae Tanai
	Acer protomiyabei Endo
	Acer tricuspidatum Bronn.
	Acer sp.
Rutaceae	*Euodia* sp. cf. *E. rutaecarpa* Hock. & Thom.
Oleaceae	*Syringa*? sp.
Caprifoliaceae	*Viburnum* sp. cf. *V. opulus* Linn.
Cyperaceae	*Carex* spp.
Gramineae	*Bambusites* sp.
	Phragmites? sp.

Lauraceae with 5 genera and 8 species; next come the Fagaceae with 2 genera and 6 species, the Aceraceae with 1 genus and 5 species, the Fabaceae with 4 genera and 4 species, the Ulmacaceae with 3 genera and 4 species. The remaining families have 1 or 2 species; most of them are represented by only a single species.

The following genera are predominant in number of species; *Acer* with 6 species, *Quercus, Salix* and *Sorbus* with 4 species each, and *Carpinus* with 3 species. *Celtis, Ulmus, Fagus* and *Cladrastis* have 2 species each, and the remainder are represented by only a single species.

The Lower Itahana florule consists of both cool temperate and warm temperate or tropical families. The Pinaceae, Ulmaceae, Juglandaceae, Betulaceae, Salicaceae, Rosaceae, and Aceraceae are cool temperate families, while the Lauraceae, Hamamelidaceae, and Fabaceae are warm temperate or tropical families. The Fagaceae has 2 evergreen broad-leaved species. Four species of the Lauraceae and one species of Pittosporaceae are also evergreen broad-leaved species. The extant species equivalent to the evergreen broad-leaved fossils are the major constituents of the warm temperate and subtropical forests of East Asia. Thus, the lower Itahana plants are distributed in cool temperate to subtropical families.

Assumed Habits and Leaf Characters

The growth habit of a plant may be an important factor in determining the number of its foliar and fruiting units which are available for scattering and deposition at a sedimentary site. Preceding the consideration of numerical representation of the lower Itahana species, the author is listing their probable growth and abscission habits and leaf margin characters, judging from the living plants most similar to them and from the texture of the fossil leaves.

The data in Table 5 show that 31 trees make up 58 percent of the total taxa, 17 small trees or shrubs perform 32 percent, and three vines and two herbs 6 and 4% respectively. Judging from these percentages, the Lower Ithana plants were predominantly arboreal. Of four conifers, *Metasequoia* and *Pseudolarix* were deciduous. Referring to the abscission habit of the broad-leaved members of the florule, two herbs and *Bambusites* are omitted from the consideration, but we shall include several angiosperms which have not been assigned specific status, and whose leaf characters indicate whether they were evergreen or deciduous. In this group of 47 angiosperms, the following 7 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 equivalents: *Actinodaphne* sp. cf. *A. lancifolia, Cinnamomum* sp. cf. *C. camphora, Cinnamomum* sp. cf. *C. japonicum, Persea* sp. cf. *P. thunbergii, Quercus* sp. cf. *Q. glauca, Quercus protosalicina, Pittosporum* sp. cf. *P. illicioides*

Numerical Representation

The following quantitative appraisal of the Lower Itahana florule is based on a count of 575 specimens from six localities. This count is not sufficiently large to preclude the possibility that the certain species, especially the evergreen broad-leaved ones, may have been more numerous in the lower Itahana forest than is suggested by these figures.

Of the 60 lower Itahana plants, 18 species are among the most numerous, making up more than one percent each, and they occupy about 83% of the total specimens. Three species of herbaceous plants, *Bambusites* sp., *Phragmites*? sp., and *Carex* sp. with fragile leaves are, predominant, representing 31.1% of the total specimens. They have exclusively lived in or near sites of deposition. It is noteworthy that *Metasequoia occidentalis* represented by leafy twigs shows a high score (8.7%). As concluded in the case of Paleogene Harutori flora by Tanai (1970), *Metasequoia occidentalis* appears to have been hydric in its requirements and to have been largely confined to the margin of sites of deposition.

Of the predominant 17 species *Cinnamomum* sp. cf. *C. camphora, Actinodaphne* sp. cf. *A. lancifolia* and *Quercus protosalicina* are warm temperate elements, and all of them are evergreen trees. It should be noted that broad-leaved evergreen trees may be at a disadvantage

Table 5. Assumed Habits and Leaf Characters of the Lower Itahana Plants

Species	Growth Habit	Leaf Characters
Abies protofirma	Tree	EC
Metasequoia occidentalis	Tree	DC
Pseudolarix japonica	DC	
Thujopsis miodolabrata	Tree	EC
Acer nordenskioeldii	Tree	Ds
Acer protomatsumurae	Tree	Ds
Acer protomiyabei	Tree	Ds
Acer tricuspidatum	Tree	Ds
Actinodaphne sp. cf. *A. lancifolia*	Tree	Ee
Alnus sp. cf. *A. japonica*	Tree	Ds
Carpinus miocenica	Tree	Ds
Carya miocathayensis	Tree	Ds
Celtis sp.	Tree	Ds
Cercis miochinensis	Tree	De
Cinnamomum sp. cf. *C. camphora*	Tree	Ee
Cladrastis aniensis	Tree	De
Cornus sp. cf. *C. miowalteri*	Tree	De
Fagus stuxbergii	Tree	Ds
Liquidambar miosinica	Tree	Ds
Magnolia sp.	Tree	De
Persea sp. cf. *P. thunbergii*	Tree	Ee
Pterocarya asymmetrosa	Tree	Ds
Quercus sp. cf. *Q. glauca*	Tree	Es
Quercus miovariabilis	Tree	Ds
Quercus protosalicina	Tree	Es
Quercus protoserrata	Tree	Ds
Sorbus lesquereuxi	Tree	Ds
Styrax sp. cf. *S. japonica*	Tree	Ds
Tilia sp.	Tree	Ds
Ulmus protojaponica	Tree	Ds
Zelkova ungeri	Tree	Ds
Cinnamomum sp. cf *C. japonicum*	ST or Shrub	Ee
Euodia sp. cf. *E. rutaecarpa*	ST or Shrub	De
Ilex sp. cf. *I. serrata*	ST or Shrub	Ds
Lespedeza sp.	ST or Shrub	De
Lindera sp. cf. *L. erythrocarpa*	ST or Shrub	De
Lindera sp. cf. *L. glauca*	ST or Shrub	De
Lindera sp. cf. *L. miyataensis*	ST or Shrub	De
Paliurus protonipponicus	ST or Shrub	Ds
Parabenzoin sp.	ST or Shrub	De
Parrotia sp.	ST or Shrub	Ds
Pittosporum sp. cf. *P. illicioides*	ST or Shrub	Ee
Salix sp. cf. *S. integra*	ST or Shrub	Ds
Salix parasachalinensis	ST or Shrub	Ds
Sophora hokiana	ST or Shrub	De
Spiraea protothunbergii	ST or Shrub	Ds
Syringa? sp.	ST or Shrub	De
Viburnum sp. cf. *V. opulus*	ST or Shrub	Ds
Parthenocissus? sp.	Vein	Ds
Vitis naumannii	Vein	Ds
Wisteria fallax	Vein	De
Carex spp.	Herb	
Phragmites? sp.	Herb	
"Ficus" tiliaefolia		De
Bambusites sp.		

ST : Small tree D : Deciduous E : Evergreen C : Conifer s : Serrate-margined broad-leaf e : Entire-margined broad-leaf

Table 6. Numerical Representation of the Lower Itahana Species

Species	Number of specimens	Percentage
Bambusites sp.	106	18.2
Lindera sp. cf. *L. erythrocarpa*	77	13.2
Phragmites? sp.	61	10.5
Metasequoia occidentalis	50	8.6
Lindera sp. cf. *L. glauca*	32	5.5
Cladrastis aniensis	30	5.1
"Ficus" tiliaefolia	24	4.1
Alnus sp.	24	4.1
Carex sp.	16	2.7
Ulmus sp.	14	2.4
Cinnamomum sp. cf. *C. camphora*	11	1.9
Zelkova ungeri	11	1.9
Ilex sp. cf. *I. serrata*	10	1.7
Salix sp. cf. *S. integra*	8	1.4
Liquidambar miosinica	7	1.2
Actinodaphne sp. cf. *A. lancifolia*	6	1.0
Quercus protosalicina	6	1.0
Wisteria fallax	6	1.0
Alnus sp. cf. *A. japonica*	5	0.9
Fagus stuxbergii (cupula)	5	0.9
Parabenzoin sp.	5	0.9
Pterocarya asymmetrosa	5	0.9
Acer nordenskioeldii	4	0.7
Parrotia sp.	4	0.7
Thujopsis miodolabrata	4	0.7
Persea sp. cf. *P. thunbergii*	3	0.5
Salix parasachalinensis	3	0.5
Salix sp.	3	0.5
Ulmus protojaponica	3	0.5
Abies protofirma	2	0.3
Acer protomatsumurae	2	0.3
Acer tricuspidatum	2	0.3
Carpinus miocenica	2	0.3
Celtis sp.	2	0.3
Fagus sp.	2	0.3
Lindera sp. cf. *L. miyataensis*	2	0.3
Magnolia sp.	2	0.3
Paliurus protonippoicus	2	0.3
Quercus sp. aff. *Q. glauca*	2	0.3
Tilia sp.	2	0.3
Acer protomiyabei	1	0.2
Acer sp.	1	0.2
Carya miocathayensis	1	0.2
Cinnamomum sp. cf. *C. japonicum*	1	0.2
Cornus sp. cf. *C. miowalteri*	1	0.2
Euodia sp. cf. *E. rutaecarpa*	1	0.2
Lespedeza sp.	1	0.2
Parthenocissus? sp.	1	0.2
Pittosporum sp. cf. *P. illicioides*	1	0.2
Quercus miovariabilis	1	0.2
Quercus protoserrata	1	0.2
Sophora hokiana	1	0.2
Sorbus lesquereuxi	1	0.2
Spiraea protothunbergii	1	0.2
Styrax protojaponica	1	0.2
Syringa? sp.	1	0.2
Viburnum? sp. cf. *V. opulus*	1	0.2
Vitis namannii	1	0.2
sum	583	100.1

so far as their record is concerned, since they shed their leaves in relatively small numbers, while deciduous leaves enter the fossil record in large quantities at the end of each growing season. The above-noted three evergreen trees show high scores in leaf record, and they grew on the flat-land or lower slopes adjacent to sites of deposition. The other evergreen trees such as *Persea* cf. *thunbergii, Quercus* aff. *glauca, Cinnamomum* cf. *japonicum* and *Pittosporum* sp. cf. *P. illicioides* are represented by small number of leaves and obtained from coarse-grained rocks; they seem to be transported from lower slope near the depositional sites. *Persea* cf. *thunbergii* is accompanied by relatively many leaves of *Cinnamomum* sp. cf. *C. camphora* in one locality, and *Persea* seems to have been one of mixed evergreen and deciduous forest member in flat-land or lower slopes near sites of deposition. *Fagus stuxbergii* is represented only by several cupules, together with fragmentary small twigs of *Thujopsis* and detached leaves of *Abies*. *Fagus* might be transported for some distance by streams into depositional sites, judging from coarse fossil-bearing rocks and habitat of the living equivalents. *Ulmus protojaponica* and *Ulmus* sp., *Zelkova ungeri, Pterocarya asymmetrosa, Acer nordenskioeldii,* and *Liquidambar miosinica* appear to have lived on valley and lower slopes slightly distant from the depositional sites, judging from their low representation in the fossil record and the habitat of their living related species. Their remains are also recorded by the coarse-grained rocks.

The proportion of the evergreen broad-leaved species to the total broad-leaved species is 7/47 that makes up 14.9 percent, and that of the entire-margined species is 17/47 and 36.2 percent.

Distribution of the Allied Living Species

As discussed in the section of the modern vegetation, the distribution of the living species most allied to the fossils is divided into 7 forest zones; Subtropical, Lower and Upper warm temperate, Lower and Upper cool temperate, Subalpine and Alpine forest zones.

Table 7 shows the most allied extant plants of the lower Itahana species and their modern distribution. The asterisk in column of distribution zone indicates the area where the species is predominantly distributed, and the plus sign indicates the area where the species is not always dominant. The total number of most allied living species in each zone of Table 7 (+ symbol stands for 0.5) and the percentages for the cumulative number of species in all zones are scored as follows:

Zone	1	2	3	4	5	6	7	Sum
No. of Species	5.0	20.5	34.0	30.5	21.0	1.0	0.0	112.0
Percentage	4.5	18.3	30.4	27.1	18.8	0.92	0.0	100.0

The values are highest in the upper warm temperate forest zone (zone 3), followed by the Lower cool temperate forest zone (zone 4). Judging from the distribution of the living species most allied to the lower Itahana species, the Lower Itahana florule was, on the whole, similar to the modern upper warm temperate zone forest.

Assumed Habitat

Table 8 shows the assumed habitat of the lower Itahana species, judging from the numerical representation of fossils and the habitat of their extant allied species listed in Table 7.

The Lower Itahana florule has only five aquatic or swamp plants. These four trees and a single herb of the swamp community were not confined to the lake shore, but also occupied stream sides in the region. Most of the lower Itahana species are included in two communities: riparian or valley forests and lower slope forest. The abundance of *Bambusites* (18.4%), *Lindera* cf. *erythrocarpa* (13.4%) and *Phragmites*? sp. (10.6%) indicates that some thick stands of these plants lined on the depositional sites and stream margins, along with *Matasequoia* (8.7%) and alders (5.1%). Many of riparian or valley species which mingled with members of lower

Table 7. Distribution of the most allied living species.

Fossil species	Most allied living species	1	2	3	4	5	6	7
Cinnamomum sp. cf. *C. camphora*	*C. camphora* Sieb.	*	*	−	−	−	−	−
Cinnamomum sp. cf. *C. japonicum*	*C. japonicum* Sieb.	*	*	*	−	−	−	−
Paliurus protonipponicus	*P. ramosissimus* (Lour.) Poir.	*	*	*	−	−	−	−
Persea sp. cf. *P. thunbergii*	*P. thunbergii* Sieb. et Zucc.	*	*	*	−	−	−	−
Styrax sp. cf. *S. japonica*	*S. japonica* Sieb. et Zucc.	*	*	*	*	−	−	−
Actinodaphne sp. cf. *A. lancifolia*	*A. lancifolia* Meisn.	−	*	*	−	−	−	−
Carya miocathayensis	*C. cathayensis* Sarg.	−	*	*	−	−	−	−
Euodia sp. cf. *E. rutaecarpa*	*E. rutaecarpa* (Jussieu) Bentham	−	*	*	−	−	−	−
Pseudolarix japonica	*P. kaempferi* Gord.	−	*	*	−	−	−	−
Quercus protosalicina	*Q. salicina* Blume	−	*	*	−	−	−	−
Quercus sp. cf. *Q. glauca*	*Q. glauca* Thunb.	−	*	*	−	−	−	−
Tilia sp.	*T. kiusiana* Makino et Shirasawa	−	*	*	−	−	−	−
Quercus miovariabilis	*Q. variabilis* Blume	−	*	*	+	−	−	−
Lindera sp. cf. *L. glauca*	*L. glauca* (Sieb. et Zucc.) Blume	−	*	*	*	−	−	−
Liquidambar miosinica	*L. formosana* Hance	−	*	*	*	−	−	−
Sophora hokiana	*Sophora* sp.	−	*	*	*	−	−	−
Cornus sp. cf. *C. miowalteri*	*C. walteri* Wanger	−	*	*	*	*	−	−
Lespedeza sp.	*Lespedeza* sp.	−	*	*	*	*	−	−
Parthenocissus? sp.	*Parthenocissus* sp.	−	*	*	*	*	−	−
Wisteria fallax	*W. floribunda* (Willd.) DC.	−	*	*	*	*	−	−
Zelkova ungeri	*Z. serrata* Makino	−	+	*	*	−	−	−
Pittosporum sp. cf. *P. illicioides*	*P. illicioides* Makino	−	−	*	−	−	−	−
Spiraea protothunbergii	*S. thunbergii* Sieb. ex Blume	−	−	*	−	−	−	−
Abies protofirma	*A. firma* Sieb. et Zucc.	−	−	*	*	−	−	−
Acer nordenskioeidii	*A. palmatum* Thunb.	−	−	*	*	−	−	−
Acer tricuspidatum	*A. pycnanthum* K. Koch	−	−	*	*	−	−	−
Ilex sp. cf. *I. serrata*	*I. serrata* Thunb.	−	−	*	*	−	−	−
Lindera sp. cf. *L. erythrocarpa*	*L. erythrocarpa* Makino	−	−	*	*	−	−	−
Metasequoia occidentalis	*M. glyptostroboides* Hu et Cheng	−	−	*	*	−	−	−
Quercus protoserrata	*Q. serrata* Murray	−	−	*	*	−	−	−
Cercis miochinensis	*C. chinensis* Bunge.	−	−	*	*	+	−	−
Alnus sp. cf. *A. japonica*	*A. japonica* Steud.	−	−	*	*	*	−	−
Lindera sp. cf. *L. miyataensis*	*L. umbellata* Thunb.	−	−	*	*	*	−	−
Salix sp. cf. *S. integra*	*S. integra* Thunb.	−	−	*	*	*	−	−
Carpinus miocenica	*C. laxiflora* Blume	−	−	+	*	+	−	−
Salix parasachalinensis	*S. sachalinensis* Fr. Schm.	−	−	+	*	*	−	−
Acer protomiyabei	*A. miyabei* Maxim.	−	−	−	+	*	−	−
Ulmus protojaponica	*U. davidiana* Planch. var. *japonica* (Rehd.) Nakai	−	−	−	+	*	−	−
Viburnum? sp. cf. *V. opulus*	*V. opulus* Linn.	−	−	−	+	*	−	−
Vitis naumannii	*V. coignetiae* Pulliat	−	−	−	+	*	−	−
Thujopsis miodolabrata	*T. dolabrata* Sieb. et Zucc.	−	−	−	+	*	*	−
Acer protomatsumurae	*A. palmatum* Thunb. var. *matsumurae* (Koidz.) Makino	−	−	−	*	*	−	−
Cladrastis aniensis	*C. platycarpa* (Maxim.) Makino	−	−	−	*	*	−	−
Fagus stuxbergii	*F. crenata* Blume	−	−	−	*	*	−	−
Pterocarya asymmetrosa	*P. rhoifolia* Sieb. et Zucc.	−	−	−	*	*	−	−
Schisandra cf. *florinii*	*S. chinensis* (Turcz.) Baill.	−	−	−	*	*	−	−
Sorbus lesquereuxi	*S. alnifolia* (Sieb. et Zucc.) K. Koch	−	−	−	*	*	−	−
Syringa sp.	*S. reticulata* (Blume) Hara	−	−	−	*	*	−	−

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

Table 8. Assumed Habitat of the Lower Itahana Plants

	1	2	3	4
Alnus cf. *japonica*	*	*		
Phragmites? sp.	*	*		
Salix parasachalinensis	*	*		
Salix cf. *integra*	*	*		
Ulmus protojaponica	*	*		
Acer tricuspidatum		*		
Bambusites sp.		*		
Carex sp.		*		
Cercis miochinensis		*		
"Ficus" tiliaefolia		*		
Lindera cf. *erythrocarpa*		*		
Metasequoia occidentalis		*		
Pterocarya asymmetrosa		*		
Acer nordenskioeldii		*	*	
Acer protomatsumurae		*	*	
Acer protomiyabei		*	*	
Carpinus miocenica		*	*	
Carya miocathayensis		*	*	
Celtis sp.		*	*	
Cladrastis aniensis		*	*	
Euodia cf. *rutaecarpa*		*	*	
Ilex cf. *serrata*		*	*	
Lespedeza sp.		*	*	
Liquidambar miosinica		*	*	
Spiraea protothunbergii		*	*	
Styrax cf. *japonica*		*	*	
Wisteria fallax		*	*	
Zelkova ungeri		*	*	
Actinodaphne cf. *lancifolia*			*	
Cinnamomum cf. *camphora*			*	
Cinnamomum cf. *japonicum*			*	
Lindera cf. *glauca*			*	
Magnolia sp.			*	
Paliurus protonipponicus			*	
Parabenzoin sp.			*	
Parrotia sp.			*	
Parthenocissus sp.			*	
Persea cf. *thunbergii*			*	
Pittosporum cf. *illicioides*			*	
Quercus protosalicina			*	
Quercus miovariabilis			*	
Quercus cf. *glauca*			*	
Sophora hokiana			*	
Syringa? sp.			*	
Cornus cf. *miowalteri*			*	*
Quercus protoserrata			*	*
Viburnum cf. *opulus*			*	*
Abies protofirma				*
Fagus stuxbergii				*
Pseudolarix japonica				*
Sorbus lesquereuxi				*
Thujopsis miodolabrata				*
Tilia sp.				*
Vitis naumannii				*

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

slope forests are broad-leaved species. Many deciduous trees such as *Cladrastis aniensis* (5.2%) *Zelkova ungeri* (1.9%), *Liquidambar* (1.2%), *Pterocarya asymmetrosa* (0.9%) inhabited together with maples and hornbeams along valley. Evergreen broad-leaved trees such as *Cinnamomum* cf. *camphora* (1.9%), *Actinodaphne* cf. *lancifolia* (1.0%), *Quercus protosalicina* (1.0%), *Persea* cf. *thunbergii* (0.5%) and the other small number of evergreen trees (*Quercus* cf. *glauca, Cinnamomum* cf. *japonica* and *Pittosporum* cf. *illicioides*) grew together with deciduous trees such as *Lindera* cf. *glauca* (5.6%), *Ilex* cf. *serrata* (1.7%), *Parabenzoin* sp. and the other deciduous broad-leaved species (*Magnolia, Paliurus, Syringa, Tilia, Cornus, Euodia,* and deciduous *Quercus*). Mountain slope forest was formed by deciduous broad-leaved trees and conifers such as *Fagus stuxbergii, Sorbus lesquereuxi, Tilia* sp., *Abies protofirma, Pseudolarix japonica, Thujopsis miodolabrata.*

The Upper Itahana Florule

Systematic Representation

The Upper Itahana florule is composed of 37 families, 63 genera and 82 species and 8 indeterminable species. There are 1 fern, 7 conifers, 5 monocotyledons, and the remainders are dicotyledons. The largest families are the Betulaceae with 4 genera and 7 species and the Salicaceae with 2 genera and 7 species; next come the Fabaceae with 4 genera and 6 species, the Aceraceae with 1 genus and 5 species, the Lauraceae with 3 genera and 5 species, the Pinaceae with 4 genera and 4 species, the Rosaceae with 4 genera and 4 species, the Fagaceae with 2 genera and 4 species, and the Ulmaceae, Caesalpiniaceae and Oleaceae with 3 genera and 3 species each. The remaining families have 1 or 2 species; most of them are represented by only one. The following genera are predominant in number of species; Salicaceae with 6 species, Aceraceae with 5 species, and *Carpinus* with 4 species. *Cinnamomum, Lindera,*

Table 9. Systematic List of the Families and Species

Salviniaceae	*Salvinia* sp. cf. *S. natans* Allioni
Pinaceae	*Pinus miocenica* Tanai
	Pseudolarix japonica Tanai & Onoe
	Pseudotsuga tanaii Huzioka
	Tsuga miosieboldiana Ozaki
Taxodiaceae	*Metasequoia occidentalis* (Newb.) Chaney
	Taxodium dubium (Sternb.) Heer
Cupressaceae	*Thujopsis miodolabrata* Tanai & N. Suzuki
Magnoliaceae	*Magnolia* sp.
Lauraceae	*Actinodaphne* sp. cf. *A. lancifolia* Meisn.
	Cinnamomum sp. cf. *C. camphora* Sieb.
	Cinnamomum sp. cf. *C. japonicum* Sieb.
	Lindera sp. cf. *L. erythrocarpa* Makino
	Lindera sp. cf. *L. miyataensis* Huzioka & Uemura
	Parabenzoin sp.
Ceratophyllaceae	*Ceratophyllum miodemersum* Hu & Chaney
Menispermaceae	*Cocculus*? sp.
Hamamelidaceae	*Liquidambar japonica* K. Suzuki
	Liquidambar miosinica Hu & Chaney
Ulmaceae	*Celtis hokiensis* Ozaki
	Celtis sp.
	Ulmus protojaponica Tanai & Onoe
	Zelkova ungeri Kovats
Juglandaceae	*Carya miocathayensis* Hu & Chaney
	Pterocarya asymmetrosa Konno ex Tanai
	Pterocarya protostenoptera Tanai
Fagaceae	*Fagus palaeojaponica* Tanai & Onoe
	Fagus stuxbergii (Nathorst) Tanai
	Fagus sp.
	Quercus miovariabilis Hu & Chaney
	Quercus protoaliena Ozaki
Betulaceae	*Alnus* sp. cf. *A. japonica* Steud.
	Alnus sp.
	Carpinus heigunensis Huzioka
	Carpinus miocenica Tanai
	Carpinus sp. cf. *C. japonica* Maxim.
	Carpinus subcordata Nathorst
	Carpinus sp.
	Corylus subsieboldiana K. Suzuki
	Ostrya sp.
Tiliaceae	*Tilia* sp.
Sterculiaceae	"*Ficus*" *tiliaefolia* Heer
Salicaceae	*Populus hokiensis* Ozaki
	Salix hokkaidoensis Tanai & N. Suzuki
	Salix k-suzukii Tanai
	Salix misaotatewakii Tanai & N. Suzuki
	Salix muraii Huzioka & Uemura
	Salix parasachalinensis Tanai & N. Suzuki
	Salix sp. cf. *S. integra* Thunb.
	Salix sp.
Clethraceae	*Clethra*? sp.
Styracaceae	*Halesia* sp.
	Styrax sp. cf. *S. japonica* Sieb. & Zucc.
Saxifragaceae	*Deutzia* sp.
Rosaceae	*Malus* sp.
	Rosa usyuensis Tanai
	Sorbus lesquereuxi Nathorst
	Spiraea protothunbergii Tanai & N. Suzuki
Caesalpiniaceae	*Caesalpinia hokiana* Ozaki
	Cercis miochinensis Hu & Cheney
	Gleditsia miosinensis Hu & Chaney

Fabaceae	*Cladrastis aniensis* Huzioka
	Cladrastis inouei (Huzioka) Ozaki
	Lespedeza tatsumitogeana Ozaki
	Lespedeza sp.
	Sophora hokiana Ozaki
	Wisteria fallax (Nathorst) Tanai & Onoe
Cornaceae	*Cornus* sp. cf. *C. miowalteri* Hu & Chaney
Aquifoliaceae	*Ilex* sp. cf. *I. serrata* Thunb.
Rhamnaceae	*Berchemia miofloribunda* Hu & Chaney
Vitaceae	*Vitis naumannii* (Nathorst) Tanai
Sapindaceae	*Sapindus*? sp.
Aceraceae	*Acer nordenskioeldii* Nathorst
	Acer protomatsumurae Tanai
	Acer protomiyabei Endo
	Acer rotundatum Huzioka
	Acer tricuspidatum Bronn.
	Acer sp.
Rutaceae	*Euodia* sp. cf. *E. rutaecarpa* Hock. & Thom.
Oleaceae	*Fraxinus* sp. cf. *F. sanzugawaensis* Huzioka & Uemura
	Ligustrum sp.
Caprifoliaceae	*Lonicera* sp.
Alismataceae	*Caldesia* sp.
Potamogetonaceae	*Potamogeton* sp.
Cyperaceae	*Carex* spp.
Gramineae	*Bambusites* sp.
	Gramineae gen. & sp. indet.
	Phragmites? sp.
Incertae sedis	*Carpolithes japonicus* (Morita) Ishida

Liquidambar, Pterocarya, Fagus, Quercus and *Cladrastis* have 2 species each, and the remainder are represented by one species.

The Pinaceae, Ulmaceae, Juglandaceae, Betulaceae, Tiliaceae, Salicaceae, Rosaceae, and Aceraceae are temperate families, and Lauraceae, Hamamelidaceae and Fabaceae are warm temperate to tropical ones. The Fagaceae has no evergreen species. Although fossils are found only from the lower horizon of the upper member of the Itahana Formation, Lauraceae has 2 evergreen species of *Cinnamomum,* whose allied living species grow well in warm temperate forests of Japan. All the species of Caesalpiniaceae and Fabaceae from the Upper Itahana florule extend northward to the cool temperate region. There are 3 evergreen broad-leaved species which amount to 4.6% of the total broad-leaved species. The entire-margined broad-leaved species are 21, which correspond to 32.3% of the total broad-leaved species.

Thus, the Upper Itahana florule consists of many cool temperate families and some warm temperate or tropical families, although the latter group is restricted to the lower part of the upper member of the Itahana Formation.

Assumed Habits and Leaf Characters

The probable habit of the members of the Upper Itahana florule, judging from their most allied living species, is indicated in Table 10, with 46 trees (62%), 18 small trees and shrubs (24%), 5 vines (7%), and 6 herbs (8%). The Upper Itahana florule was predominantly arboreal, although containing much herbaceous plants than the Lower Itahana florule.

Of seven conifers, *Metasequoia occidentalis, Pseudolarix japonica,* and *Taxodium dubium* were deciduous. Referring to the abscission habit of the broad-leaved members of the florule, the six herbs, *Bambusites* and *Carpolithes* are omitted from consideration, but we shall include several angiosperms which have not been assigned specific status, and whose leaf characters indicate whether they were evergreen or deciduous. In this group of 64 angiosperms, the

Table 10. Assumed Habit and Leaf Characters of the Upper Itahana Plants

Species	Growth Habit	Leaf Characters
Metasequoia occidentalis	Tree	DC
Pinus miocenica	Tree	EC
Pseudolarix japonica	Tree	DC
Pseudotsuga tanaii	Tree	EC
Taxodium dubium	Tree	DC
Thujopsis miodolabrata	Tree	EC
Tsuga miosieboldiana	Tree	EC
Acer nordenskioeldii	Tree	Ds
Acer protomatsumurae	Tree	Ds
Acer protomiyabei	Tree	Ds
Acer rotundatum	Tree	Ds
Acer tricuspidatum	Tree	Ds
Alnus sp. cf. *A. japonica*	Tree	Ds
Carpinus sp. cf. *C. japonica*	Tree	Ds
Carpinus heigunensis	Tree	Ds
Carpinus miocenica	Tree	Ds
Carpinus subcordata	Tree	Ds
Carya miocathayensis	Tree	Ds
Celtis hokiensis	Tree	Ds
Cercis miochinensis	Tree	De
Cinnamomum sp. cf. *C. camphora*	Tree	Ee
Cladrastis aniensis	Tree	De
Cladrastis inouei	Tree	De
Cornus sp. cf. *C. miowalteri*	Tree	De
Fagus palaeojaponica	Tree	Ds
Fagus stuxbergii	Tree	Ds
Fraxinus cf. *sanzugawaensis*	Tree	Ds
Gleditsia miosinensis	Tree	De
Halesia sp.	Tree	Ds
Liquidambar japonica	Tree	Ds
Liquidambar miosinica	Tree	Ds
Malus sp.	Tree	Ds
Ostrya sp.	Tree	Ds
Populus hokiensis	Tree	Ds
Pterocarya asymmetrosa	Tree	Ds
Pterocarya protostenoptera	Tree	Ds
Quercus miovariabilis	Tree	Ds
Quercus protoaliena	Tree	Ds
Salix k-suzukii	Tree	Ds
Salix muraii	Tree	Ds
Sapindus? sp.	Tree	De
Sorbus lesquereuxi	Tree	Ds
Styrax sp. cf. *S. japonica*	Tree	Ds
Tilia sp.	Tree	Ds
Ulmus protojaponica	Tree	Ds
Zelkova ungeri	Tree	Ds
Caesalpinia hokiana	ST or Shrub	De
Cinnamomum sp. cf. *C. japonicum*	ST or Shrub	Ee
Clethra? sp.	ST or Shrub	Ds
Corylus subsieboldiana	ST or Shrub	Ds
Deutzia sp.	ST or Shrub	Ds
Euodia sp. cf. *E. rutaecarpa*	ST or Shrub	De
Ilex sp. cf. *I. serrata*	ST or Shrub	De
Lespedeza sp.	ST or Shrub	De
Lespedeza tatsumitogeana	ST or Shrub	De
Ligustrum? sp.	ST or Shrub	Ee
Lonicera sp.	ST or Shrub	De
Parabenzoin sp.	ST or Shrub	De
Salix sp. cf. *S. integra*	ST or Shrub	Ds
Salix hokkaidoensis	ST or Shrub	Ds
Salix misaotatewakii	ST or Shrub	Ds
Sophora hokiana	ST or Shrub	De
Spiraea protothunbergii	ST or Shrub	Ds
Syringa? sp.	ST or Shrub	De
Berchemia miofloribunda	Vine	De
Cocculus? sp.	Vine	De
Rosa usyuensis	Vine	Ds
Vitis naumannii	Vine	Ds
Wisteria fallax	Vine	De
Caldesia sp.	Terr. Herb	
Carex spp.	Terr. Herb	
Phragmites? sp.	Terr. Herb	
Ceratophyllum miodemersum	Aqua. Herb	
Potamogeton sp.	Aqua. Herb	
Salvinia sp. cf. *S. natans*	Aqua. Herb	
"Ficus" tiliaefolia		De
Bambusites sp.		
Carpolithes japonicus		

ST : Small Tree Terr. : Terrestrial Aqua. : Aquatic D : Deciduous E : Evergreen C : Conifer
s : Serrate-margined broad-leaf e : Entire-margined broad-leaf

following 3 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 equivalents: *Cinnamomum* sp. cf. *C. camphora, Cinnamomum* sp. cf. *C. japonicum and Ligustrum*? sp.

Numerical Representation

The following quantitative appraisal of the Upper Itahana florule is based on a count of 1586 specimens from six localities. Of the 90 upper Itahana species, "*Ficus*" and *Alnus* occupy nearly one-fourths of the total specimens. "*Ficus*" is represented by large leaves which seem unsuited to survive transport for a long distances. *Alnus* cf. *japonica* appears to have been an abundant member in or around the depositional sites. Fragile leaves of *Potamogeton* represent high percentage in occurrence. Four species of *Salix* (*S. parasachalinensis, S. k-suzukii, S. misaotatewakii* and *Salix* sp. cf. *S. integra*), *Bambusites, Carex, Phragmites, Metasequoia* and *Rosa* are represented rather by many specimens of more than 1 percent, and they have been also members around the depositional sites. It is supported by the fact that all the plants are obtained from fine siltstones. Twelve plants of *Quercus miovariabilis, Carya miocathayensis, Carpinus miocenica, Acer nordenskioeldii, Bambusites* sp., *Ulmus protojaponica, Halesia* sp., *Fagus stuxbergii, Carpolithes japonicus, Zelkova ungeri* and *Pterocarya protostenoptera* show comparatively high scores with five to one percent, and almost all of these plants are obtained

Table 11. Numerical Representation of the Upper Itahana Species

Species	Number of specimens	Percentage
"Ficus" tiliaefolia	249	15.7
Alnus sp. cf. *A. japonica*	127	8.0
Potamogeton sp.	126	7.9
Salix parasachalinensis	73	4.6
Quercus miovariabilis	72	4.5
Carya miocathayensis	64	4.0
Carpinus miocenica	60	3.8
Salix k-suzukii	51	3.2
Acer nordenskioeldii	48	3.0
Bambusites sp.	38	2.4
Salix misaotatewakii	37	2.3
Ulmus protojaponica	37	2.3
Halesia sp.	35	2.2
Fagus stuxbergii	35	2.2
Carex spp.	34	2.1
Phragmites? sp.	34	2.1
Carpolites japonicus	32	2.0
Salix sp. cf. *S. integra*	31	2.0
Zelkova ungeri	29	1.8
Metasequoia occidentalis	23	1.5
Pterocarya protostenoptera	21	1.3
Rosa usyuensis	18	1.1
Acer sp.	16	1.0
Cladrastis aniensis	15	0.9
Carpinus heigunensis	14	0.9
Acer protomiyabei	13	0.8
Corylus subsieboldiana	11	0.7
Liquidambar miosinica	11	0.7
Vitis naumannii	11	0.7
Carpinus subcordata	9	0.6
Lespedeza sp.	8	0.5
Ostrya sp.	8	0.5
Celtis hokiensis	7	0.4
Cornus sp. cf. *C. miowalteri*	7	0.4
Fraxinus sp. cf. *F. sanzugawaensis*	7	0.4
Acer rotundatum	6	0.4
Ilex sp. cf. *I. serrata*	6	0.4
Lonicera sp.	6	0.4
Wisteria fallax	6	0.4
Pseudolarix japonica	5	0.3
Salix muraii	5	0.3
Caesalpinia hokiana	4	0.3
Ceratophyllum miodemersum	4	0.3
Cocculus? sp.	4	0.3
Deutzia sp.	4	0.3
Pseudotsuga tanaii	4	0.3
Sapindus? sp.	4	0.3
Sophora hokiana	4	0.3
Syringa? sp.	4	0.3
Taxodium dubium	4	0.3
Fagus palaeojaponica	3	0.2
Fraxinus sp.	3	0.2
Gleditsia miosinensis	3	0.2
Lespedeza tatsumitogeana	3	0.2
Salix hokkaidoensis	3	0.2
Salvinia sp. cf. *S. natans*	3	0.2
Sorbus lesquereuxi	3	0.2
Berchemia miofloribunda	2	0.1
Liquidambar japonica	2	0.1
Carpinus sp. cf. *C. japonica*	2	0.1
Carpinus sp.	2	0.1
Cercis miochinensis	2	0.1
Clethra? sp.	2	0.1
Euodia sp. cf. *E. rutaecarpa*	2	0.1
Ligustrum? sp.	2	0.1
Malus sp.	2	0.1
Pterocarya asymmetrosa	2	0.1
Spiraea protothunbergii	2	0.1
Styrax sp. cf. *S. japonica*	2	0.1
Acer protomatsumurae	1	0.1
Acer tricuspidatum	1	0.1
Actinodaphne sp. cf. *A. lancifolia*	1	0.1
Alnus sp.	1	0.1
Caldesia sp.	1	0.1
Cinnamomum sp. cf. *C. camphora*	1	0.1
Cinnamomum sp. cf. *C. japonicum*	1	0.1
Celtis sp.	1	0.1
Cladrastis inouei	1	0.1
Fagus sp.	1	0.1
Parabenzoin sp.	1	0.1
Pinus miocenica	1	0.1
Populus hokiensis	1	0.1
Quercus protoaliena	1	0.1
Thujopsis miodolabrata	1	0.1
Tilia sp.	1	0.1
Tsuga miosieboldiana	1	0.1
sum	1586	97.7

from fine- to medium-grained sandstones in a bent-down condition. As judged from the states of preservation of fossils and from the habitat of their living equivalent species, they have been transported over a distance.

Figure 10 shows that there is no marked warm temperate element among the predominant species. Two species of *Cinnamomum,* although being the warm temperate elements, are represented by only one specimen respectively, and were obtained only from the lower part of the upper member of the Itahana Formation.

The ratio of the evergreen broad-leaved species to the total broad-leaved species is 2/65 that makes up 3.1 perecent, and that of the entire-margined species is 21/65 and 32.3 percent.

Distribution of the Allied Living Species

Table 12 shows the most allied living species of the Upper Itahana species, and their zonal distributions in the modern forests. About a half of the predominant species with more than 0.5% are members of the cool temperate forest. The remaining species have a range from warm temperate to cool temperate forests, but no species is restricted only to the warm forest

Table 12. Distribution of the Allied Living Species

Fossil species	Most allied living species	1	2	3	4	5	6	7
Cinnamomum sp. cf. *C. camphora*	*C. camphora* Sieb.	*	*	−	−	−	−	−
Caesalpinia hokiana	*C. japonica* Sieb. et Zucc.	*	*	*	−	−	−	−
Cinnamomum sp. cf. *C. japonicum*	*C. japonicum* Sieb.	*	*	*	−	−	−	−
Styrax sp. cf. *S. japonica*	*S. japonica* Sieb. et Zucc.	*	*	*	*	−	−	−
Carya miocathayensis	*C. cathayesis* Sarg.	−	*	*	−	−	−	−
Euodia sp. cf. *E. rutaecarpa*	*E. rutaecarpa* (Jussieu) Bentham	−	*	*	−	−	−	−
Ligustrum? sp.	*Ligustrum* sp.	−	*	*	−	−	−	−
Liquidambar japonica	*L. styraciflua* Linn.	−	*	*	−	−	−	−
Pinus miocenica	*P. thunbergii* Pari.	−	*	*	−	−	−	−
Pseudolarix japonica	*P. kaempferi* Gord.	−	*	*	−	−	−	−
Taxodium dubium	*T. distichum* Rich.	−	*	*	−	−	−	−
Tilia sp.	*T. kiusiana* Makino et Shirasawa	−	*	*	−	−	−	−
Lespedeza tatsumitogeana	*L. cuneata* G. Don	−	*	*	+	−	−	−
Quercus miovariabilis	*Q. variabilis* Blume	−	*	*	+	−	−	−
Liquidambar miosinica	*L. formosana* Hance	−	*	*	*	−	−	−
Quercus protoaliena	*Q. aliena* Blume	−	*	*	*	−	−	−
Sophora hokiana	*Sophora* sp.	−	*	*	*	−	−	−
Ceratophyllum miodemersum	*C. demersum* Linn.	−	*	*	*	*	−	−
Cornus sp. cf. *C. miowalteri*	*C. walteri* Wanger	−	*	*	*	*	−	−
Lespedeza sp.	*Lespedeza* sp.	−	*	*	*	*	−	−
Pterocarya protostenoptera	*P. stenoptera* DC.	−	*	*	*	*	−	−
Rosa usyuensis	*Rosa* sp.	−	*	*	*	*	−	−
Salix hokkaidoensis	*S. koriyanagi* Kimura	−	*	*	*	*	−	−
Salvinia sp. cf. *S. natans*	*S. natans* All.	−	*	*	*	*	−	−
Wisteria fallax	*W. floribunda* (Willd.) DC.	−	*	*	*	*	−	−
Zelkova ungeri	*Z. serrata* Makino	−	+	*	*	−	−	−
Spiraea protothunbergii	*S. thunbergii* Sieb. ex Blume	−	−	*	−	−	−	−
Acer nordenskioeldii	*A. palmatum* Thunb.	−	−	*	*	−	−	−
Acer tricuspidatum	*A. pycnanthum* K. Koch	−	−	*	*	−	−	−
Berchemia miofloribunda	*B. racemosa* Sieb. et Zucc.	−	−	*	*	−	−	−
Carpinus heigunensis	*C. tschonoskii* Maxim.	−	−	*	*	−	−	−
Fagus palaeojaponica	*F. japonica* Maxim.	−	−	*	*	−	−	−
Gleditsia miosinensis	*G. japonica* Miq.	−	−	*	*	−	−	−
Ilex sp. cf. *I. serrata*	*I. serrata* Thunb.	−	−	*	*	−	−	−
Metasequoia occidentalis	*M. glyptostroboides* Hu et Cheng	−	−	*	*	−	−	−
Pseudotsuga tanaii	*P. japonica* (Shirasawa) Beissn.	−	−	*	*	−	−	−
Tsuga miosieboldiana	*T. sieboldii* Carr.	−	−	*	*	−	−	−
Cercis miochinensis	*C. chinensis* Bunge.	−	−	*	*	+	−	−
Salix k-suzukii	*S. jessoensis* Seemen	−	−	*	*	+	−	−
Acer rotundatum	*A. mono* Maxim.	−	−	*	*	*	−	−
Alnus sp. cf. *A. japonica*	*A. japonica* Steud.	−	−	*	*	*	−	−
Carpinus sp. cf. *C. japonica*	*C. japonica* Blume	−	−	*	*	*	−	−
Cladrastis inouei	*C. sikokiana* (Makino) Makino	−	−	*	*	*	−	−
Populus hokiensis	*P. sieboldii* Miq.	−	−	*	*	*	−	−
Salix misaotatewakii	*S. gracilistyla* Miq.	−	−	*	*	*	−	−
Salix sp. cf. *S. integra*	*S. integra* Thunb.	−	−	*	*	*	−	−
Carpinus miocenica	*C. laxiflora* Blume	−	−	+	*	+	−	−
Ostrya sp.	*O. japonica* Sarg.	−	−	+	*	*	−	−
Salix parasachalinensis	*S. sachalinensis* Fr. Schm.	−	−	+	*	*	−	−
Acer protomatsumurae	*A. palmatum* Thunb. var. *matsumurae* (Koidz.) Makino	−	−	−	*	*	−	−
Carpinus subcordata	*C. cordata* Blume	−	−	−	*	*	−	−
Celtis hokiensis	*C. jessoensis* Koidz.	−	−	−	*	*	−	−
Cladrastis aniensis	*C. platycarpa* (Maxim.) Makino	−	−	−	*	*	−	−
Corylus subsieboldiana	*C. sieboldiana* Blume	−	−	−	*	*	−	−
Fagus stuxbergii	*F. crenata* Blume	−	−	−	*	*	−	−
Fraxinus sp. cf. *F. sanzugawaensis*	*F. sieboldiana* Blume	−	−	−	*	*	−	−
Malus sp.	*Malus* sp.	−	−	−	*	*	−	−
Pterocarya asymmetrosa	*P. rhoifolia* Sieb. et Zucc.	−	−	−	*	*	−	−
Sorbus lesquereuxi	*S. alnifolia* (S. et Z.) K. koch	−	−	−	*	*	−	−
Syringa? sp.	*S. reticulata* (Blume) Hara)	−	−	−	*	*	−	−
Acer protomiyabei	*A. miyabei* Maxim.	−	−	−	+	*	−	−
Ulmus protojaponica	*U. davidiana* Planch. var. *japonica* (Rehd.) Nakai	−	−	−	+	*	−	−
Vitis naumannii	*V. coignetiae* Pulliat	−	−	−	+	*	−	−
Thujopsis miodolabrata	*T. dolabrata* Sieb. et Zucc.	−	−	−	+	*	*	−
Salix muraii	*S. rorida* Lackschewitz	−	−	−	−	*	*	−

1) Subtropical forest zone 2) Lower warm terperate 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

region.

Tho total number of species in each zone and the percentages for the cumulative number of species in all zones are shown as follows:

Zone	1	2	3	4	5	6	7	Sum
No. of Species	4.0	25.5	46.5	49.0	34.5	2.0	0.0	161.5
Percentage	2.5	15.8	28.8	30.3	21.4	1.2	0.0	100.0

The number of species is the highest in the lower cool temperate forest zone (zone 4) as 49.0, which corresponds to 30.3% of the total. Next come the upper warm temperate forest zone (zone 3) as 46.5 species and 28.8%, then the upper cool temperate forest zone (zone 5). Considering from the distribution of the living species most closely allied to fossil species, the Upper Itahana florule is closely related to the lower cool temperate zone forests, such as the lower part of the *Fagus crenata* forest or the transitional zone forest between the warm and cool temperate zones.

Assumed Habitat

In the back swamp along the braided rivers during the Upper Itahana age *Potamogeton, Caldesia, Ceratophyllum* and *Salvinia* formed a part of the aquatic community in the Itahana area, where *Potamogeton* may have been one of the predominant water plant. *Taxodium, Alnus, Metasequoia, Phragmites, Salix* and *Ulmus* are riparian in habitat. *"Ficus" tiliaefolia* is also considered to be a stream-side plant, because it is accompanied almost always by many specimens of *Alnus* cf. *japonica* and/or *Salix* lived in the swamp or on river banks. The relative abundance of *"Ficus"* (15.7%), *Alnus* cf. *japonica* (8.0%) and *Salix parasachalinensis* (7.9%) indicates that rather a dense stand of these plants lined the depositional sites or stream margins, along with the other willows (*Salix k-suzukii,* 3.2%; *S. misaotatewakii,* 2.3%; *S.* cf. *integra,* 2.0%), *Bambusites* (2.4%), and *Phragmites* (2.1%). Most of these swamp or riparian trees were also members in the valley forest, which is composed of all the deciduous hardwoods. *Carya miocathayensis* (4.0%), *Carpinus miocenica* (3.8%), *Acer nordenskioeldii* (3.0%) and *Zelkova ungeri* (1.8%) were common members in the valley forest.

The lower slope forest during the Upper Itahana time was composed of all the deciduous hardwoods, except in early stage, when some evergreen trees such as *Cinnamomum* were included. This forest is common in member with valley forest. *Quercus miovariabilis, Halesia* sp., *Cladrastis* and *Liquidambar* together with maples and hornbeams were predominant or common members in the lower slope forest, while *Pinus miocenica* may be a minor element.

The montane slope forest was composed mainly of *Fagus stuxbergii* with some other deciduous broad-leaved species such as *Ostrya* sp., *Magnolia* sp., *Quercus protoserrata* and *Sorbus lesquereuxi*, and conifers such as *Pseudolarix, Pseudotsuga, Tsuga* and *Thujopsis*.

Summary

The plant-bearing Itahana Formation is subdivided into the lower and the upper members by the tuff and lignite beds which are developed in the middle horizon considering the lithological sequence and fossil occurrence, the Itahana Formation was deposited near coastal plain; sites of deposition gradually shifted from shallow marine to brackish or nonmarine conditions. The Lower Itahana florule is composed of 60 species (28 families and 45 genera), and is characterized by well-developed riparian taxa on the coastal plain and slopes. The coastal plain and hilly or lower slope area were covered by evergreen-mixed deciduous forest containing a number of living analogues in the warm-temperate forest. Montane conifers and a beech were the main members of the mountain slope forest. The climate indicated by the Lower Itahana florule was rather warm-temperate, representing coastal climatic conditions during the middle-Late Miocene of Central Honshu.

The upper Itahana Formation composed mainly of cyclic sediments of conglomerate,

Table 13. Assumed Habitat of the Upper Itahana Plants

Species	1	2	3	4
Caldesia sp.	*			
Ceratophyllum miodemersum	*			
Potamogeton sp.	*			
Salvinia cf. *natans*	*			
Taxodium dubium	*			
Alnus cf. *japonica*	*	*		
Carex sp.	*	*		
Metasequoia occidentais	*	*		
Phragmites? sp	*	*		
Salix hokkaidoensis	*	*		
Salix k-suzukii	*	*		
Salix misaotatewakii	*	*		
Salix muraii	*	*		
Salix parasachalinensis	*	*		
Salix cf. *integra*	*	*		
Ulmus protojaponica	*	*		
Acer tricuspidatum		*		
Bambusites sp.		*		
Lindera cf. *erythrocarpa*		*		
Populus hokiensis		*		
Pterocarya asymmetrosa		*		
Pterocarya protostenoptera		*		
Sapindus? sp.		*		
Wisteria fallax		*		
Zelkova ungeri		*		
"Ficus" tiliaefolia		*		
Acer nordenskioeldii		*	*	
Acer protomatsumurae		*	*	
Acer protomiyabei		*	*	
Acer rotundatum		*	*	
Caesalpinia hokiana		*	*	
Cladrastis aniensis		*	*	
Carpinus heigunensis		*	*	
Carpinus miocenica		*	*	
Carya miocathayensis		*	*	
Cercis miochinensis		*	*	
Cornus cf. *miowalteri*		*	*	
Corylus subsieboldiana		*	*	
Cocculus? sp.		*	*	
Deutzia sp.		*	*	
Fraxinus sanzugawaensis		*	*	
Fraxinus sp.		*	*	

Spesies	1	2	3	4
Lindera miyataensis		*	*	
Liquidambar japonica		*	*	
Liquidambar miosinica		*	*	
Lonicera sp.		*	*	
Malus sp.		*	*	
Rosa usyuensis		*	*	
Spiraea protothunbergii		*	*	
Styrax protojaponica		*	*	
Syringa? sp.		*	*	
Tilia sp.		*	*	
Carpinus cf. *japonica*		*	*	*
Carpinus subcordata		*	*	*
Cinnamomum cf. *camphora*			*	
Cinnamomum cf. *japonicum*			*	
Celtis hokiensis			*	
Cladrastis inouei			*	
Clethra? sp.			*	
Euodia cf. *rutaecarpa*			*	
Fagus palaeojaponica			*	
Halesia sp.			*	
Ilex cf. *serrata*			*	
Ligustrum? sp.			*	
Parabenzoin sp.			*	
Pinus miocenica			*	
Quercus miovariabilis			*	
Quercus protoaliena			*	
Sophora hokiana			*	
Berchemia miofloribunda			*	*
Gleditsia miosinensis			*	*
Lespedeza tatsumitogeana			*	*
Lespedeza sp.			*	*
Magnolia sp.			*	*
Ostrya sp.			*	*
Quercus protoserrata			*	*
Vitis naumannii			*	*
Fagus stuxbergii				*
Pseudolarix japonica				*
Pseudotsuga tanaii				*
Sorbus lesquereuxi				*
Tsuga miosieboldiana				*
Thujopsis miodolabrata				*

1 : Aquatic or marsh 2 : Riparian or valley 3 : Lower slope 4 : Upper Slope

sandstone and siltsone, and is of terrestrial origin except the basal part. The Upper Itahana florule consists of 90 species distributed in 37 families and 63 genera. All dicot trees are deciduous except for two evergreen species from the lower horizon. The florule consists largely of two communities: wet plain to mesic valley and slope ones. Some aquatic plants as *Potamogeton* grew in a back swamp, and such water-loving plants as alder, wilows and bamboos fringed the rivers on the lowland. The deciduous broad-leaved slope forest composed predominantly of deciduous oaks, *Carya,* hornbeams and maples was accompanied with some conifers, and beech stands were dominated in the upper slopes.

The Yagii Flora

Late Neogene plant fossils in the Hiki area south of Kumagaya City have been reported by some authors. Many stump and some leaf fossils from the Yagii Formation were first reported by Kawamoto Fossil Forest Research Group (1983). Homma (1987) reported 30 species with only illustrations from four localities in the Yagii Formation exposed along the Arakawa River. Based on my collection from the Yagii Formation along the Arakawa River, I could find 60 species, which are enough to discuss the floristic composition of the assemblage.

Geologic Occurrence

The Neogene sediments in the Hiki Hills have been disputed in their stratigraphy and division by various authors, as shown in Table 14. It is probably due to the fact that the Neogene are poorly exposed in this area. However, all the authors except Kobayashi (1935) concluded that the plant-bearing Yagii Formation of terrestrial origin occupies the uppermost of the Neogene, which are of marine origin. The Yagii Formation is correlated with the Itahana Formation of the Takasaki area by many authors. Regarding geologic age, however, the opinions are divided into two ; some peoples assign the Yagii Formation to the Middle Miocene (Watanabe, 1954 ; Matsumaru and Hayashi, 1980), while the others insist to be of Late Miocene time (Fukuta and Ishiwada, 1964 ; Takei and Koike, 1981). Hatai and Masuda (1962) pointed out the molluscan fossils from the underlying Tsuchishio Formation are commonly found in the Late Miocene of central Japan. The basal thick pumiceous tuff bed of the Yagii Formation was correlated with the middle tuff in the Itahana Formation by Homma (1987). He also suggested that the plant assemblage of the Yagii Formation determined by K. Suzuki shows a close resemblance to the Late Miocene Fujitoge flora of Fukushima Prefecture. The Yagii Formation is probably correlated with the Upper Itahana Formation, because they have common features in similar lithology and in lacking marine molluscan fossils.

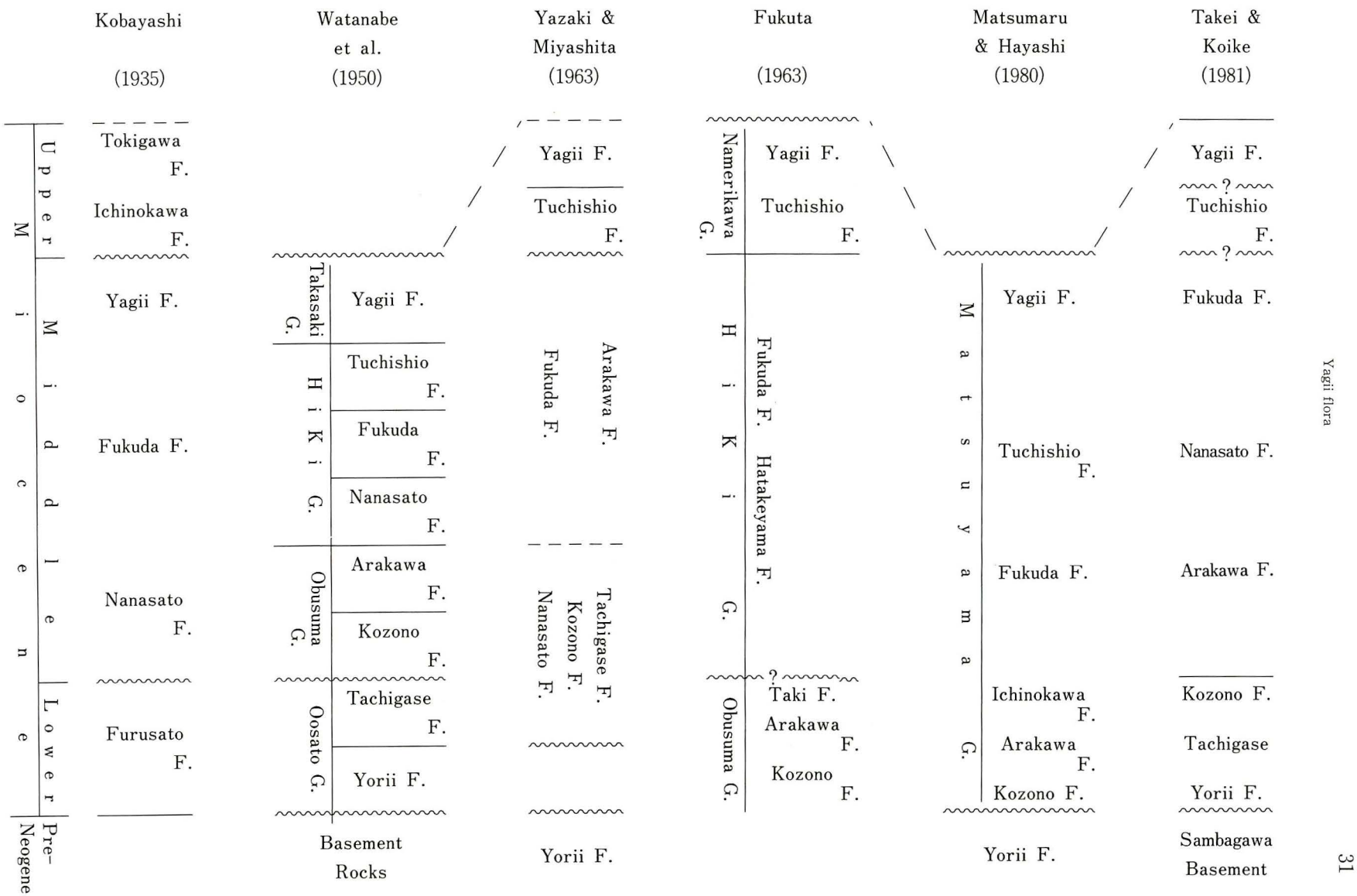
The Yagii Formation consists of conglomerate, sandstone, siltstone, and tuff, interbedding lignite. The formation shows a remarkable lateral change in lithology. Consecutive exposures of the formation are observed in the river bed of the Arakawa River, except a part of the conglomerate horizon. Leaf fossils are preserved in the fine-grained rocks of more than eight horizons as shown in Fig. 6, two of which yield especially numerous fossils. The fossils obtained are given in Table 15. The lithology of each locality is as follows: Locality A-fine sandstone ; Locality B-siltstone ; Locality F1-siltstone ; Locality F2-fine sandstone ; Locality K -fine siltstone ; Locality L-siltstone ; Locality M-coarse siltstone to fine sandstone ; Locality N -fine siltstone ; Locality P-fine siltstone.

Systematic Representation

The Yagii flora contains 60 species in 28 families and 45 genera as listed in Table 16. These plants comprise two conifers, four monocotyledons and the remainders are dicotyledons. The largest family is the Lauraceae represented by 5 genera and 7 species. Next come the Salicaceae with 2 genera and 6 species and the Aceraceae with 1 genus and 6 species, the Fagaceae with 2 genera and 5 species, and the Fabaceae and Betulaceae both with 4 genera and 4 species. The Hamamelidaceae, Juglandaceae, Ulmaceae, Styracaceae and Rosaceae have 2 species each, and the other have a single species.

The Betulaceae, Salicaceae, Ulmaceae, Juglandaceae Styracaceae, Rosaceae and Aceraceae are cool temperate families, whereas the Lauraceae, Fabaceae and Hamamelidaceae are warm temperate to tropical plant families. The Fagaceae has two and the Lauraceae has four evergreen species ; living species allied to these evergreen species are the main components of the warm temperate forests of Japan. Thus, the Yagii flora is composed of cool temperate families with some warmer temperate to subtropical families. Except for *Parrotia* and two uncertain genera, all the genera are now living in East Asia. All genera are known in the

Table 14. Correlation of the Neogene sequences by various authors in Hiki Hills, south of Kumagaya City, Saitama Prefecture, Central Japan.



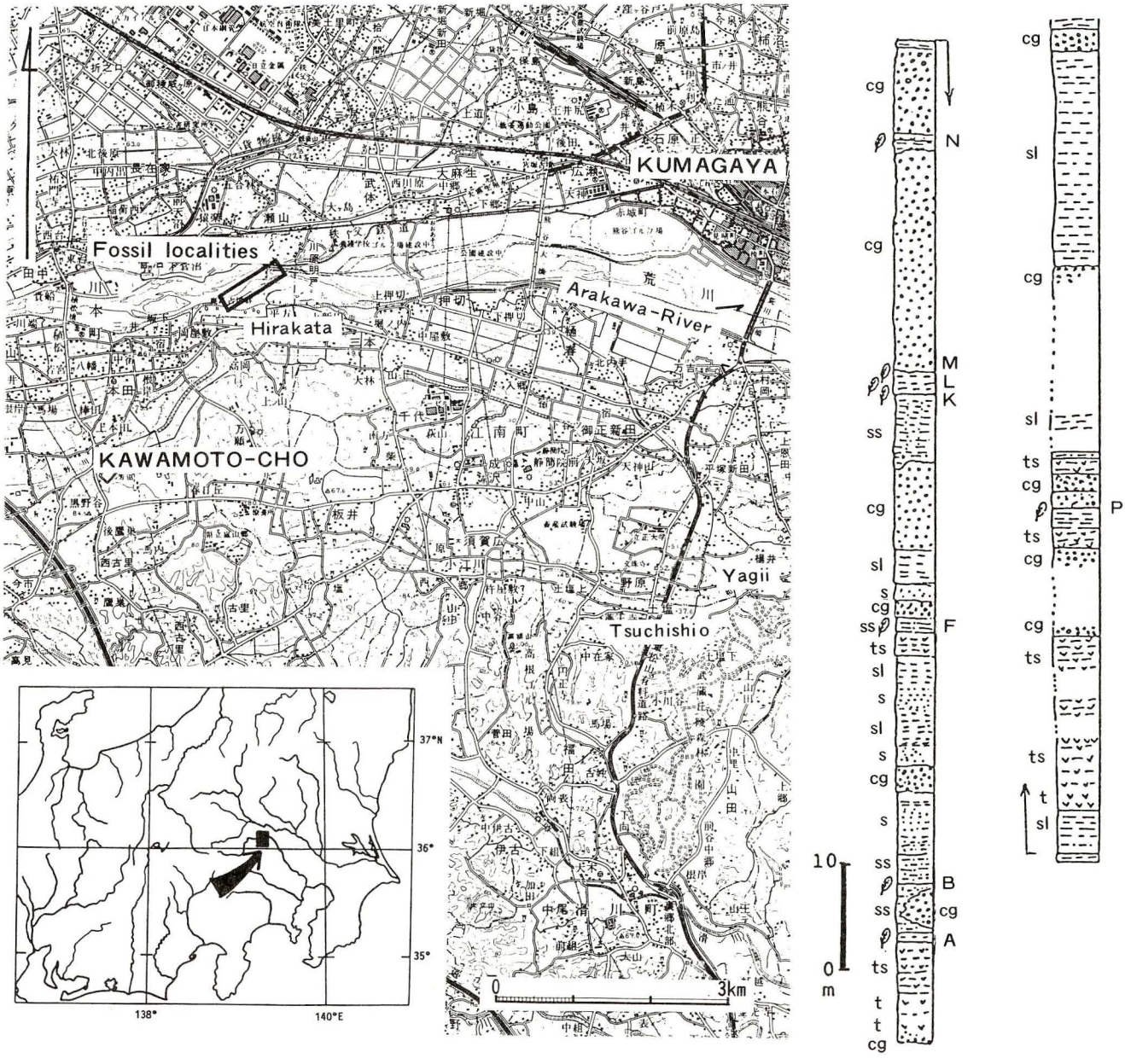


Fig. 6. Localities of the Yagii flora and the columner section showing lithology and horizons of plant megafossils along Arakawa River.
t: Tuff cg: Conglomerate sl: Siltstone ts: Tuffaceous siltsone s: Sandstone ss: Sandy siltstone A-P: Plant fossil horizones

Table 15. Numerical Representation of the Yagii Species

Spesies Locality:	A	B	F1	F2	K	L	M	N	P	sum
Metasequoia occidentalis	215	71	61	27	26	6	6	–	70	482
Pinus cf. *trifolia*	–	–	–	–	–	–	–	3	–	3
Magnolia sp.	1	–	–	–	–	–	–	–	–	1
Actinodaphne sp. cf. *A. lancifolia*	–	–	2	3	–	–	–	2	–	7
Cinnamomum sp. cf. *C. camphora*	–	1	–	–	–	–	–	–	–	1
Cinnamomum sp. cf. *C. japonicum*	5	–	–	2	–	–	–	–	–	7
Lindera sp. cf. *L. miyataensis*	–	–	–	4	–	–	–	–	–	4
Parabenzoin sp. cf. *P. trilobum*	–	–	–	1	–	–	–	–	–	1
Persea sp. cf. *P. thunbergii*	–	–	4	1	–	–	–	–	–	5
Persea? sp.	–	–	1	4	1	–	–	1	–	7
Cocculus? sp.	–	–	–	1	–	–	–	–	–	1
Meliosma sp. cf. *M. oldhami*	2	–	–	–	–	–	–	–	–	2
Cercidiphyllum crenatum	–	–	–	2	–	–	–	–	–	2
Liquidambar miosinica	–	–	–	15	–	–	–	1	–	16
Parrotia sp.	–	–	–	4	–	–	–	–	–	4
Ulmus protojaponica	–	–	–	2	–	–	–	–	–	2
Ulmus sp.	–	–	–	2	–	–	–	–	–	2
Zelkova ungeri	–	–	1	20	–	–	–	–	–	21
Platycarya miocenica	–	–	–	–	–	–	–	–	1	1
Pterocarya asymmetrosa	–	–	–	1	–	–	–	–	–	1
Castanea miocrenata	–	–	–	1	–	–	–	–	–	1
Quercus miovariabilis	1	–	–	–	–	–	–	–	–	1
Quercus protoaliena	–	–	–	1	–	–	–	–	–	1
Quercus protoacuta	–	–	–	–	–	–	1	–	–	1
Quercus protosalicina	–	–	–	–	–	–	–	1	–	1
Quercus sp.	3	–	–	3	–	–	–	–	–	6
Alnus sp. cf. *A. japonica*	1	–	46	8	–	–	–	–	–	55
Alnus sp.	1	–	–	–	–	1	–	–	–	2
Carpinus heigunensis	–	–	2	2	–	–	–	–	–	4
Corylus subsieboldiana	–	–	–	1	–	–	–	–	–	1
Ostrya sp. cf. *O. japonica*	–	–	–	1	–	–	–	–	–	1
Ostrya sp.	–	–	–	1	–	–	–	–	–	1
Rumex? sp.	1	–	–	–	–	–	–	–	–	1
Tilia miohenryana	27	–	2	8	–	–	–	–	–	37
Tilia sp.	12	–	–	5	–	–	–	–	–	17
"Ficus" tiliaefolia	–	–	20	–	–	7	–	–	–	27
Populus hokiensis	–	–	–	6	–	–	–	–	–	6
Populus kobayashii	–	–	–	13	–	–	–	–	–	13
Salix k-suzukii	–	–	–	1	–	–	–	–	–	1
Salix misaotatewakii	8	3	22	–	6	–	9	–	–	48
Salix parasachalinensis	3	–	–	–	–	–	7	–	1	11
Salix sp. cf. *S. integra*	6	3	22	–	–	–	–	–	–	31
Halesia sp.	–	1	–	–	–	–	–	–	–	1
Styrax sp. cf. *S. japonica*	–	4	–	–	–	–	–	–	–	4
Sorbus palaeojaponica	–	–	–	1	–	–	–	–	–	1
Sorbus lesquereuxi	–	–	–	2	–	–	–	–	–	2
Cladrastis aniensis	23	–	2	–	–	–	1	–	–	26
Cladrastis? sp.	4	–	–	–	–	–	–	–	–	4
Lespedeza sp.	3	–	–	3	–	–	–	–	–	6
Sophora miojaponica	–	–	4	6	–	–	–	–	–	10
Wisteria fallax	3	57	–	5	1	2	1	–	–	69
Buxus protojaponica	–	–	–	67	–	–	–	–	–	67
Paliurus protonipponicus	1	–	–	–	–	–	–	–	–	1
Vitis naumannii	–	–	–	1	–	–	–	–	–	1
Sapindus tanaii	1	–	–	34	–	–	–	–	–	35
Acer nordenskioeldii	1	–	–	1	–	–	–	–	–	2
Acer protomatsumurae	–	–	–	1	–	–	–	–	–	1
Acer protomiyabei	–	–	–	1	1	–	–	–	–	2
Acer prototrifidium	–	–	–	1	–	–	–	1	–	2
Acer rotundatum	–	–	–	10	–	–	–	–	–	10
Acer tricuspidatum	2	–	2	1	–	–	–	–	–	5
Fraxinus sp. af. *F. k-yamadae*	1	–	–	–	–	–	–	–	–	1
Potamogeton sp.	4	–	–	–	–	–	–	–	–	4
Bambusites sp.	37	10	17	7	4	–	–	5	–	80
Phragmites? sp.	–	–	–	–	–	–	–	1	70	71
Smilax aff. *hokkaidoensis*	1	–	–	1	–	–	–	–	–	2
Carpolithes japonicus	–	–	–	1	–	–	–	–	–	1
	367	150	208	283	39	16	25	15	142	1245

Table 16. Systematic List of Families and Species

Pinaceae	*Pinus* sp. cf. *P. trifolia* Miki
Taxodiaceae	*Metasequoia occidentalis* (Newb.) Chaney
Magnoliaceae	*Magnolia* 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
	Parabenzoin sp. cf. *P. trilobum* (Sieb. & Zucc.) Nakai
	Persea sp. cf. *P. thunbergii* Kosterm.
	Persea? sp.
Menispermaceae	*Cocculus*? sp.
Sabiaceae	*Meliosma* sp. cf. *M. oldhamii* Maxim.
Cercidiphyllaceae	*Cercidiphyllum crenatum* (Unger) Brown
Hamamelidaceae	*Liquidambar miosinica* Hu & Chaney
	Parrotia sp.
Ulmaceae	*Ulmus protojaponica* Tanai & Onoe
	Ulmus sp.
	Zelkova ungeri Kovats
Juglandaceae	*Platycarya miocenica* Hu & Chaney
	Pterocarya asymmetrosa Konno ex Tanai
Fagaceae	*Castanea miocrenata* Tanai & Onoe
	Quercus miovariabilis Hu & Chaney
	Quercus protoacuta K. Suzuki
	Quercus protoaliena Ozaki
	Quercus protosalicina K. Suzuki
	Quercus sp.
Betulaceae	*Alnus* sp. cf. *A. japonica* Steud.
	Alnus sp.
	Carpinus heigunensis Huzioka
	Corylus subsieboldiana K. Suzuki
	Ostrya sp. cf. *O. japonica* Sarg.
	Ostrya sp.
Polygonaceae	*Rumex*? sp.
Tiliaceae	*Tilia miohenryana* Hu & Chaney
	Tilia sp.
Sterculiaceae	*"Ficus" tiliaefolia* Heer
Slicaceae	*Populus hokiensis* Ozaki
	Populus kobayashii K. Suzuki
	Salix k-suzukii Tanai
	Salix misaotatewakii Tanai & N. Suzuki
	Salix parasachalinensis Tanai & N. Suzuki
	Salix sp. cf. *S. integra* Thunb.
Styracaceae	*Halesia* sp.
	Styrax sp. cf. *S. japonica* Sieb. & Zucc.
Rosaceae	*Sorbus lesquereuxi* Nathorst
	Sorbus palaeojaponica Murai
Fabaceae	*Cladrastis aniensis* Huzioka
	Cladrastis? sp.
	Lespedeza sp.
	Sophora miojaponica Hu & Chaney
	Wisteria fallax (Nathorst) Tanai & Onoe
Buxaceae	*Buxus protojaponica* Tanai & Onoe
Rhamnaceae	*Paliurus protonipponicus* K. Suzuki
Vitaceae	*Vitis naumannii* (Nathorst) Tanai
Sapindaceae	*Sapindus tanaii*
Aceraceae	*Acer nordenskioeldii* Nathorst
	Acer protomatsumurae Tanai
	Acer protomiyabei Endo
	Acer prototrifidium Tanai
	Acer rotundatum Huzioka
	Acer tricuspidatum Bronn.
Oleaceae	*Fraxinus* sp. aff. *F. k-yamadae* Tanai & N. Suzuki
Potamogetonaceae	*Potamogeton* sp.
Poaceae	*Bambusites* sp.
	Phragmites? sp
Smilacaceae	*Smilax* aff. *hokkaidoensis* Tanai
Incertae sedis	*Carpolithes japonicus* (Morita) Ishida

modern forests of Japan, except *Metasequoia, Liquidambar,* and *Halesia*, which are found in the forests of southern or central China and Taiwan.

Assumed Habits and Leaf Characters

The habit of a plant is of importance in determining the number of its foliar and fruiting units which may be available for scattering and deposition in the sedimentary record. As a preliminary to considering the numerical representation of the Yagii species, in the Table 17 are listing their probable habits and leaf characters, as judged from their fossil leaf texture and the most similar living equivalents. 41 trees make up 70.7 percent, 10 shrubs or small trees make up 17.2 percent, 4 vines comprise 6.9 percent, and herbs 5.2 percent. Judging from these percentage, trees were predominant in the Yagii vegetation.

Table 17. Assumed Habit and Leaf Characters of the Yagii Plants

Species	Growth Habit	Leaf Characters
Metasequoia occidentalis	Tree	DC
Pinus cf. *trifolia*	Tree	EC
Acer nordenskioeldii	Tree	Ds
Acer protomatsumurae	Tree	Ds
Acer protomiyabei	Tree	Ds
Acer prototrifidium	Tree	Ds
Acer rotundatum	Tree	Ds
Acer tricuspidatum	Tree	Ds
Actinodaphne sp. cf. *A. lancifolia*	Tree	Ee
Alnus sp. cf. *A. japonica*	Tree	Ds
Carpinus heigunensis	Tree	Ds
Castanea miocrenata	Tree	Ds
Cercidiphyllum crenatum	Tree	Ds
Cinnamomum sp. cf. *C. camphora*	Tree	Ee
Cinnamomum sp. cf. *C. japonicum*	Tree	Ee
Cladrastis? sp.	Tree	De
Cladrastis aniensis	Tree	De
Fraxinus sp. aff. *F. k-yamadae*		
Halesia sp.	Tree	Ds
Liquidambar miosinica	Tree	Ds
Magnolia sp.	Tree	De
Meliosma sp. *M. oldhamii*	Tree	Ds
Ostrya sp. cf. *O. japonica*	Tree	Ds
Persea sp. cf. *P. thunbergii*	Tree	Ee
Persea? sp.	Tree	De
Platycarya miocenica	Tree	Ds
Populus hokiensis	Tree	Ds
Populus kobayashii	Tree	Ds
Pterocarya asymmetrosa	Tree	Ds
Quercus miovariabilis	Tree	Ds
Quercus protoacuta	Tree	Ee
Quercus protoaliena	Tree	Ds
Quercus protosalicina	Tree	Es
Salix k-suzukii	Tree	Ds
Sapindus tanaii	Tree	De
Sophora miojaponica	Tree	De
Sorbus lesquereuxi	Tree	Ds
Sorbus palaeojaponica	Tree	Ds
Styrax sp. cf. *S. japonica*	Tree	Ds
Tilia miohenryana	Tree	Ds
Ulmus protojaponica	Tree	Ds
Zelkova ungeri	Tree	Ds
Buxus protojaponica	ST or Shrub	Ee
Corylus subsieboldiana	ST or Shrub	Ds
Lespedeza sp.	ST or Shrub	De
Lindera cf. *miyataensis*	ST or Shrub	De
Paliurus protonipponicus	ST or Shrub	Ds
Parabenzoin sp. cf. *P. trilobum*	ST or Shrub	De
Parrotia sp.	ST or Shrub	Ds
Salix sp. cf. *S. integra*	ST or Shrub	Ds
Salix misaotatewakii	ST or Shrub	Ds
Salix parasachalinensis	ST or Shrub	Ds
Cocculus sp.	Vine	De
Smilax aff. *hokkaidoensis*	Vine	Ee
Vitis naumannii	Vine	Ds
Wisteria fallax	Vine	De
Phragmites? sp.	Terr. Herb	
Rumex? sp.	Terr. Herb	
Potamogeton sp.	Aqua. Herb	
Bambusites sp.		

ST : Small Tree Terr. : Terrestrial Aqua. : Aquatic D : Deciduous E : Evergreen s : Serrate-margined broad-leaf
e : Entire-margined broad-leaf

Numerical Representation

As already shown in Table 15, the Yagii plants were obtained from 9 localities on a river floor along the Arakawa River. *Metasequoia occidentalis* is recorded from 8 localities, *Wisteria fallax* and *Bambusites* are from 6 and *Salix misaotatewakii* is from 5 localities. All these species are predominant plants in the Yagii flora.

Table 18 shows the total numerical representation of the Yagii plants which count 1245 specimens. Of the Yagii plants the total specimens of the top ten species account for 79 percent of the whole and sixteen species making up more than one percent each combine to constitute 88 percent of the total. All of these dominant plants, excluding only one species, *Buxus,* are deciduous. It is noteworthy that the Yagii flora is dominated by *Metasequoia occidentalis* which is represented by fragile leafy twigs and occupies nearly 40 percent of all specimens. Accordingly, this species has been dominant member nearby the depositional sites.

Table 18. Numerical Representation of the Yagii Species

Species	Number of specimens	Percentage
Metasequoia occidentalis	482	38.7
Bambusites sp.	80	6.4
Phragmites? sp.	71	5.7
Wisteria fallax	69	5.5
Buxus protojaponica	67	5.4
Alnus sp. cf. *A. japonica*	55	4.4
Salix misaotatewakii	48	3.8
Tilia miohenryana	37	3.0
Sapindus tanaii	35	2.8
Salix sp. cf. *S. integra*	31	2.5
"Ficus" tiliaefolia	27	2.2
Cladrastis aniensis	26	2.1
Zelkova ungeri	21	1.7
Tilia sp.	17	1.4
Liquidambar miosinica	16	1.3
Populus kobayashii	13	1.0
Salix parasachalinensis	11	0.8
Acer rotundatum	10	0.8
Sophora miojaponica	10	0.8
Actinodaphne sp. cf. *A. lancifolia*	7	0.6
Cinnamomum sp. cf. *C. japomicum*	7	0.6
Persea? sp.	7	0.6
Lespedeza sp.	6	0.5
Populus hokiensis	6	0.5
Quercus sp.	6	0.5
Pinus sp. cf. *P. trifolia*	5	0.4
Acer tricuspidatum	5	0.4
Persea sp. cf. *P. thunbergii*	5	0.4
Carpinus heigunensis	4	0.3
Cladrastis? sp.	4	0.3
Lindera sp. cf. *L. miyataensis*	4	0.3
Parrotia sp.	4	0.3
Potamogeton sp.	4	0.3
Styrax sp. cf. *S. japonca*	4	0.3
Acer nordenskioeldii	2	0.2
Acer protomiyabei	2	0.2
Acer prototrifidium	2	0.2
Alnus sp.	2	0.2
Cercidiphyllum crenatum	2	0.2
Meliosma sp. cf. *M. oldhamii*	2	0.2
Smilax aff. *hokkaidoensis*	2	0.2
Sorbus lesquereuxi	2	0.2
Ulmus protojaponica	2	0.2
Ulmus sp.	2	0.2
Acer protomatsumurae	1	0.1
Carpolites japonicus	1	0.1
Castanea miocrenata	1	0.1
Cinnamomum sp. cf. *C. camphora*	1	0.1
Cocculus? sp.	1	0.1
Corylus subsieboldiana	1	0.1
Fraxinus sp. aff. *F. k-yamadae*	1	0.1
Halesia sp.	1	0.1
Magnolia sp.	1	0.1
Ostrya sp. cf. *O. japonica*	1	0.1
Ostrya sp.	1	0.1
Paliurus protonipponicus	1	0.1
Parabenzoin sp. cf. *P. trilobum*	1	0.1
Platycarya miocenica	1	0.1
Pterocarya asymmetrosa	1	0.1
Quercus miovariabilis	1	0.1
Quercus protoacuta	1	0.1
Quercus protoaliena	1	0.1
Quercus protosalicina	1	0.1
Rumex? sp.	1	0.1
Salix k-suzuki	1	0.1
Sorbus palaeojaponica	1	0.1
Vitis naumannii	1	0.1
sum	1247	100.9

The second and the third species, *Bambusites* and *Phragmites,* are herbaceous large leaves which would seem unsuited to survive transport for a long distances, then they were also dominant members of the forest around the depositional sites. The other plants till the eighteenth except the fifth species, *Buxus,* were all deciduous plants and they must have been common members of the Yagii forest.

As judged from the living equivalent species and by the consideration on the Oligocene floras by Tanai (1970), it was suggested that *Metasequoia occidentalis* was hydric in its requirements and was confined mainly to sites of deposition much like those of the modern *Taxodium* and *Glyptostrobus*. *Bambusites, Phragmites, Alnus* and *Salix* are hydric in its requirements, judging from the living equivalents. It is considered that *"Ficus" tiliaefolia* was also probably water-loving plant. This interpretation agrees with the fact that *"Ficus" tiliaefolia* is associated almost always with the species of *Salix* and *Alnus*. *Wisteria* and *Zelkova* are also found in the modern stream-side forests. Most living species of *Buxus* is also a stream-side tree in China. Thus, the predominant taxa of the Yagii flora seem to be almost marsh or riparian species, and the depositional sites of the flora were probably in marsh or riparian condition. It is noteworthy that *Persea, Cinnamomum,* and *Actinodaphne* of the evergreen broad-leaved species are high-ranked in relative abundance. Then these trees were probably common members in the Yagii forest, considering from that they may be at a disadvantage for shedding leaves.

The ratio of the evergreen broad-leaved species to the total broad-leaved species is 8/60 that makes up 13.3 percent, and that of the entire-margined species is 20/60 and 33.3 percent.

Distribution of the Allied Living Species

Table 19 shows the most allied living species of the Yagii species and their regional distribution in the modern forests. The asterisk indicates the principal area of distribution and the plus sign shows the secondary area of the distribution. The following table indicates total number of the most allied living species in each zone indicated in the preceding table and percentages for the cumulative number of species in all zones.

Zone	1	2	3	4	5	6	7	Sum
No. of Species	5.0	17.5	32.0	35.0	26.5	0.0	0.0	116.0
Percentage	4.3	15.1	27.6	30.2	22.8	0.0	0.0	100.0

The closely allied species concentrate largely in the lower cool temperata forest zone (zone 4), and also in the upper warm temperate forest zone (zone 3). Thus, the distributional consideration of the living species indicates that the Yagii flora bears a marked similarity to the lower part of the modern cool temperate zone forests and also to the modern upper warm temperate zone forests.

Assumed Habitat

Table 20 indicates the assumed habitat of the Yagii species, considering from the numerical representation of the fossil species and the habitat of the most allied living species.

The ten aquatic or swamp members of the Yagii flora, notably *Metasequoia, Phragmites, Alnus* sp. cf. *A. japonica, Salix misaotatewakii* and *Salix* sp. cf. *S. integra* show high representation in the fossil record with a total of about 55 percent; these plants formed thickets near lake shore together with the other swamp species. Trees and shrubs of this community were not confined to the lake shore, excepting one water plant, *Potamogeton,* but also occupied stream banks in the region. Most of the Yagii species are included in the categories which consist of two communities; riparian or valley forests and lower slope forest. Many Yagii species mingled with members of valley-slope forests which occupied the watered flood-plain and valley flats or cliffs flanking the stream. Some of predominant species such as *Bambusites* sp., *Wisteria fallax, Tilia miohenryana, Buxus protojaponica, "Ficus" tiliaefolia, Cladrastis aniensis, Zelkova ungeri, Liquidambar miosinica* and *Populus kobayashi* probably found their most luxuriant growth in this community along with some willows, maples and hornbeams. The hilly and lower slope forests are largely represented by mixed broad-leaved forest, which contains deciduous hardwoods, vines, and some evergreen trees such as *Actinodaphne* cf. *lancifolia, Cinnamomum* cf. *camphora, Quercus protoacuta, Q. protosalicina* and *Persea* cf. *thunbergii*. Several shrubs and vines may have formed the understory of the above trees; they are *Wisteria fallax, Cinnamomum* cf. *japonica, Cocculus*? sp., *Lespedeza* sp., *Paliurus protonipponicus, Corylus subsieboldiana, Smilax* aff. *hokkaidoensis* and *Vitis naumannii.* No megafossil records of montane or higher slope forest are found in the Yagii flora. Accordingly, it is supposed that the Yagii flora represents mainly forests which lived from the lake borders to lower slopes.

The Yagii flora is composed principally of the species of riparian or valley forests and of lower slope forest. The high ranking species in number of specimens are almost all riparian species. The species belonging to the riparian forest count nearly a half of the total. The mountain slope species mainly belonging to Betulaceae, Salicaceae and Aceraceae are generally members of the cool temperate zone forest. Their specimens are obtained mainly from Localities A and F2 where the plant-bearing rock is sandstone. Most of these specimens were probably transported from the neighboring mountain slopes or valleys nearby sites of deposition.

Summary

The Yagii flora of 66 species in 28 families and 44 genera occurs in mudstones and fine

Table 19. Distribution of the Allied Living Species

Fossil species	Most allied living species	1	2	3	4	5	6	7
Cinnamomum sp. cf. *C. camphora*	*C. camphora* Sieb.	*	*	−	−	−	−	−
Cinnamomum sp. cf. *C. japonicum*	*C. japonicum* Sieb.	*	*	*	−	−	−	−
Paliurus protonipponicus	*P. ramosissimus* (Lour.) Poir.	*	*	*	−	−	−	−
Persea sp. cf. *P. thunbergii*	*P. thunbergii* Sieb. et Zucc.	*	*	*	−	−	−	−
Styrax sp. cf. *S. japonica*	*S. japonica* Sieb. et Zucc.	*	*	*	*	−	−	−
Meliosma sp. cf. *M. oldhami*	*M. oldhami* Maxim.	−	*	−	−	−	−	−
Acer prototrifidium	*A. buergerianum* Miq.	−	*	*	−	−	−	−
Actinodaphne sp. cf. *A. lancifolia*	*A. lancifolia* (Blume) Nakai	−	*	*	−	−	−	−
Quercus protosalicina	*Q. salicine* Blume	−	*	*	−	−	−	−
Tilia sp.	*T. kiusiana* Makino. et Shirasawa	−	*	*	−	−	−	−
Quercus miovariabilis	*Q. variabilis* Blume	−	*	*	+	−	−	−
Liquidambar miosinica	*L. formosana* Hance	−	*	*	*	−	−	−
Platycarya miocenica	*P. strobilacea* Sieb. et Zucc.	−	*	*	*	−	−	−
Quercus protoacuta	*Q. acuta* Oerst.	−	*	*	*	−	−	−
Quercus protoaliena	*Q. aliena* Blume	−	*	*	*	−	−	−
Lespedeza sp.	*Ligustrum.* sp.	−	*	*	*	*	−	−
Wisteria fallax	*W. floribunda* (Willd.) DC.	−	*	*	*	*	−	−
Zelkova ungeri	*Z. serrata* Makino	−	+	*	*	−	−	−
Buxus protojaponica	*B. microphylla* Sieb. et Zucc. var. *japonica* Rehd. et Wils.	−	−	*	−	−	−	−
Acer nordenskioeldii	*A. palmatum* Thunb.	−	−	*	*	−	−	−
Acer tricuspidatum	*A. pycnanthum* K. Koch	−	−	*	*	−	−	−
Carpinus heigunensis	*C. tschonoskii* Maxim.	−	−	*	*	−	−	−
Metasequoia occidentalis	*M. glyptostroboides* Hu et Cheng	−	−	*	*	−	−	−
Parabenzoin sp. cf. *P. trilobum*	*P. trilobum* (Sieb. et Zucc.) Nakai	−	−	*	*	−	−	−
Salix k-suzukii	*S. jessoensis* Seemen	−	−	*	*	+	−	−
Acer rotundatum	*A. mono* Maxim.	−	−	*	*	*	−	−
Alnus sp. cf. *A. japonica*	*A. japonica* Steud.	−	−	*	*	*	−	−
Castanea miocrenata	*C. crenata* Sieb. et Zucc.	−	−	*	*	*	−	−
Lindera sp. cf. *L. miyataensis*	*L. umbellata* Thunb.	−	−	*	*	*	−	−
Populus hokiensis	*P. sieboldii* Miq.	−	−	*	*	*	−	−
Salix misaotatewakii	*S. gracilistyla* Miq.	−	−	*	*	*	−	−
Salix sp. cf. *S. integra*	*S. integra* Thunb.	−	−	*	*	*	−	−
Ostrya sp. cf. *O. japonica*	*O. japonica* Sarg.	−	−	+	*	*	−	−
Ostrya sp.	*O. japonica* Sarg.	−	−	+	*	*	−	−
Salix parasachalinensis	*S. sachalinensis* Fr. Schm.	−	−	+	*	*	−	−
Smilax aff. *hokkaidoensis*	*S. trinerbula* Miq.	−	−	+	*	*	−	−
Acer protomatsumurae	*A. palmatum* Thunb. var. *matsumurae* (Koidz.) Makino	−	−	−	*	*	−	−
Cercidiphyllum crenatum	*C. japonicum* Sieb. et Zucc.	−	−	−	*	*	−	−
Cladrastis aniensis	*C. platycarpa* (Maxim.) Makino	−	−	−	*	*	−	−
Corylus subsieboldiana	*C. sieboldiana* Blume	−	−	−	*	*	−	−
Pterocarya asymmetrosa	*P. rhoifolia* Sieb. et Zucc.	−	−	−	*	*	−	−
Sophora miojaponica	*S. japonica* Linn.	−	−	−	*	*	−	−
Sorbus lesquereuxi	*S. alnifolia* (S. et Z.) K. Koch	−	−	−	*	*	−	−
Sorbus palaeojaponica	*S. japonica* (Decne.) Hedlund	−	−	−	*	*	−	−
Acer protomiyabei	*A. miyabei* Maxim.	−	−	−	+	*	−	−
Ulmus protojaponica	*U. davidiana* Planch. var. *japonica* (Rehd.) Nakai	−	−	−	+	*	−	−
Vitis naumannii	*V. coignetiae* Pulliat	−	−	−	+	*	−	−
Fraxinus sp. aff. *F. k-yamadae*	*F. mandshurica* Rupr. var. *japonica* Maxim.	−	−	−	−	*	−	−
Tilia miohenryana	*T. maximowicziana* Shirasawa	−	−	−	−	*	−	−

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

Table 20. Assumed Habitat of the Yagii Plants

Species	1	2	3	4
Potamogeton sp.	*			
Alnus cf. *japonica*	*	*		
Metasequoia occidentalis	*	*		
Phragmites? sp.	*	*		
Rumex? sp.	*	*		
Salix k-suzukii	*	*		
Salix misaotatewakii	*	*		
Salix parasachalinensis	*	*		
Salix cf. *integra*	*	*		
Ulmus protojaponica	*	*		
Acer tricuspidatum		*		
Bambusites sp.		*		
Buxus protojaponica		*		
Cercidiphyllum crenatum		*		
"Ficus" tiliaefolia		*		
Fraxinus aff. *k-yamadae*		*		
Pterocarya asymmetrosa		*		
Sapindus tanaii		*		
Zelkova ungeri		*		
Acer nordenskioeldii		*	*	
Acer prototrifidium		*	*	
Acer rotundatum		*	*	
Carpinus heigunensis		*	*	
Cladrastis aniensis		*	*	
Liquidambar miosinica		*	*	
Meliosma cf. *oldhami*		*	*	
Populus hokiensis		*	*	
Populus kobayashii		*	*	
Styrax protojaponica		*	*	
Tilia miohenryana		*	*	
Tilia sp.		*	*	
Vitis naumannii		*	*	
Wisteria fallax		*	*	
Acer protomiyabei			*	
Actinodaphne cf. *lancifolia*			*	
Castanea miocrenata			*	
Cinnamomum cf. *camphora*			*	
Cinnamomum cf. *japonica*			*	
Cocculus? sp.			*	
Corylus subsieboldiana			*	
Halesia sp.			*	
Lespedeza sp.			*	
Lindera cf. *miyataensis*			*	
Magnolia sp.			*	
Ostrya cf. *japonica*			*	
Paliurus protonipponicus			*	
Parabenzoin cf. *trilobum*			*	
Parrotia sp.			*	
Persea cf. *thunbergii*			*	
Pinus sp.			*	
Platycarya miocenica			*	
Quercus miovariabilis			*	
Quercus protoacuta			*	
Quercus protoaliena			*	
Quercus protosalicina			*	
Smilax aff. *hokkaidoensis*			*	
Sophora miojaponica			*	
Sorbus lesquereuxi			*	
Sorbus palaeojaponica			*	

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

sandstones of the Yagii Formation which well crops out on the bed of Ara River in Hirakata area south of Kumagaya City in Saitama Prefecture. The Yagii Formation is composed of cyclic sediments of conglomerate, sandstone and siltsone with intercalations of thin lignite and tuff beds, but is complex with a wide variety of lithology laterally. It is considered that the depositional sites were coastal plain covered by a braided river near the southern hills, judging from the markedly variable lithology and from the conglomerates which contain rock fragments of the underlaying Middle Miocene Fukuda Formation. The mountain slope was far from the depositional sites, judging from the scarcity of the montane plants.

The Yagii flora is characterized by the rich deciduous broad-leaved species, but includes some evergreen broad-leaved trees such as *Actinodaphne, Cinnamomum, Persea* and *Quercus*. The floristic composition shows an affinity with warm-temperate deciduous broad-leaved forests in southern Northeast Honshu of Japan. The coastal plain was covered by water-loving plants along the river. The evergreen trees formed forest or thicket together with deciduous trees on mesic sites and hills of the lowland. The lower slopes near the depositional sites were covered by mainly deciduous broad-leaved forest lacking the beech. The climate indicated by the Yagii flora was slightly cool temperate, representing coastal climatic conditions in the late Middle stage of the Late Miocene of Central Honshu.

The Kabutoiwa Flora

It has been known since the end of last century that plant fossils occur from the lacustrine deposits distributed south of Mt. Kabutoiwa (altitude 1366 m) in the border area of Nagano and Gunma Prefectures in central Japan. Plant fossils were first reported by Yagi (1921), and he listed 33 species as one of the Pleistocene flora in 1931. This plant-bearing area is on the mountainous region at an altitude of 1000 to 1200 m, and the paleobotanical and geological investigation had been remained to be untouched until the 1960's. The geology of the area was reported by Motojuku Green Tuff Research Group (1968, 1970), and the geologic map of the Motojuku Formation was published by Geological Survey of Japan (1969). Suzuki et al. (1970)

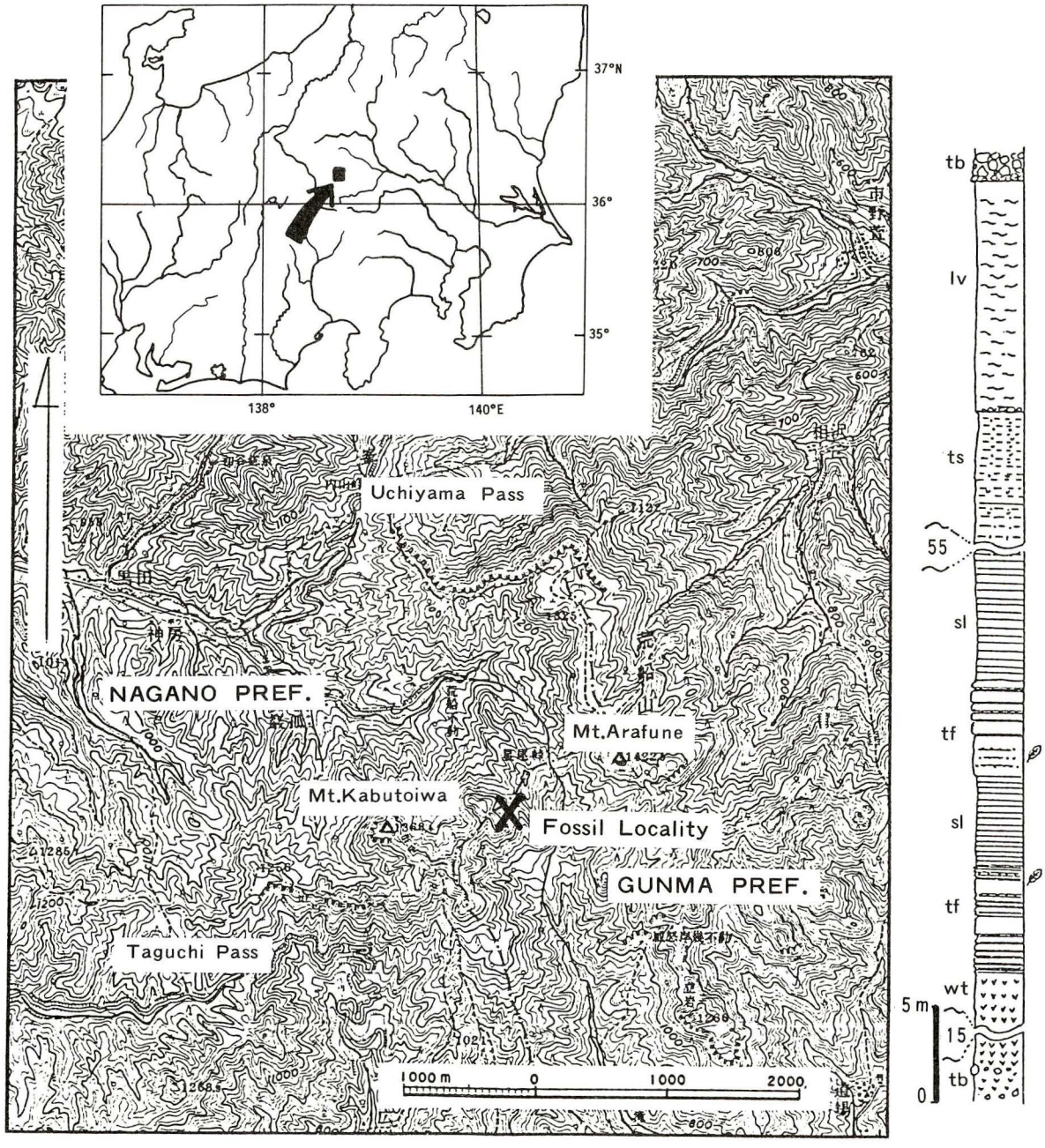


Fig. 7. Locality of the Kabutoiwa flora in the border of Gunma and Nagano Prefectures, and the columner section in the fossil locality.
tb: tuff breccia wt: welded tuff tf: tuffite sl: siltstone ts: tuffeceous siltstone
lv: andesite lava

reported 41 species with the description of 4 species from the Upper Motojuku Formation (syn. Kabutoiwa Formation). Judging from floristic composition and components, they assigned this flora to Late Miocene age. The Kabutoiwa plant-bearing deposits yield a number of well-preserved plants, sometimes associated with insect and frog fossils. The Kabutoiwa flora must play an important role to discuss Late Tertiary forest history in northwestern Kwanto district, but it has not been still fully described, and even in taxonomy of the component species. Only several species were described in this flora by K. Suzuki (1967), K. Suzuki et al. (1970) and Ozaki (1984, 1987).

I started to investigate the Kabutoiwa flora with collection of several times since 1983, and described some interesting genera which are now extinct from Japan (Ozaki, 1984, 1987). Through the investigation during these several years, I could identify 110 plants which are enough to discuss Late Tertiary forest in this region. The Kabutoiwa flora contains many exotic genera, and is one ef the representative floras of Japan during the Tertiary.

Geologic Occurrence

Volcanic and pyroclastic rocks mainly of Pliocene and Pleistocene age are known along the northwestern margin of the Kwanto Plain. The rocks of the southern outcrops west of Shimonita-machi were called Kabutoiwa Formation by Watanabe (1954), and were correlated with a upper sequence of the Motojuku Formation by Motojuku Collabolative Research Group (1968). The stratigraphic investigations have been reported by many workers have been reported (Fujimoto and Kobayashi, 1938; Iijima et al., 1958; Motojuku Green-tuff Research Group, 1968, 1970; Geol. Surv. of Japan, 1969; Akima Collaborative Research Group et al., 1976; Nomura et al., 1981; Nomura and Kosaka, 1987).

According mainly to Motojuku Green-Tuff Research Group (1968, 1970), the Motojuku Formation is distributed in a roughly circular area with about 10 km across, covering the Pre-Tertiary rocks and the Early to Middle Miocene formations by distinct unconformity. The Motojuku Formation is composed mainly of tuff and volcanic breccia, associated with andesite lavas and welded tuffs; it interbeds tuffacecous silststone and tuffite of lacustrine origin in the middle and upper horizons. Plant fossils were obtained mainly from the lacustrine sediments around the Mt. Arafuneyama, which were called the "Kabutoiwa Formation" by many workers or the Upper Lacustrine beds by Motojuku Research Group (1968). The "Kabutoiwa" Formation is about 80 m thick, and contains abundant plant fossils in the basal part of 15 m thickness as shown in Fig. 7. Plant fossils are more well-preserved in the finely laminated tuffites than in the siltstones.

The radiometric age of the Upper Motojuku Formation (="Kabutoiwa" Formation) were reported by many authors (Iijima, 1962; Kawachi and Kawachi, 1963; Matsubayashi, 1975); all the K-Ar age values are from 3.12 to 3.35 Ma. These dating were done for the Shiga welded tuff bed which is interbedded in the upper part of the Motojuku Formation. I obtained the K-Ar age of 3.7 ± 0.8 Ma for the tuff breccia below the Kabutoiwa plant-bearing beds (mesured by Teledyne Isotopes Co.). Nomura and Kosaka (1987) ad Nomura and Ebihara (1988) recently reported K-Ar dating for the volcanic rocks of the basal part of the Motojuku Formation: 3.64 ± 0.12, 5.58 ± 0.74 and 5.36 ± 0.93 Ma. These radiometric dating may indicate that the plant-bearing "Kabutoiwa" Formation is Pliocene in age.

Systematic Representation

The Kabutoiwa flora is composed of 45 families, 76 genera and 111 species. There are 1 fern, 5 conifers, 2 monocotyledons, and the remainders are dicotyledons. The largest family is the Betulaceae with 5 genera and 13 species; next come the Aceraceae with 1 genus and 7 species, the Rosaceae and Fagaceae with 3 genera and 6 species each, and the Fabaceae and Caprifoliaceae with 4 genera and 5 species each. The Pinaceae is composed of 4 genera and 4 species, and the Lauraceae, Ulmaceae, Juglandaceae, Salicaceae, and Vitaceae are with 3

Table 21. Systematic List of Families and Species

Osmundaceae	*Osmunda* sp. cf. *O. japonica* Linn.
Pinaceae	*Picea* sp.
	Pinus miocenica Tanai
	Pseudotsuga tanaii Huzioka
	Tsuga miosieboldiana Ozaki
Taxodiaceae	*Taiwania japonica* Tanai & Onoe
Magnoliaceae	*Liriodendron honsyuensis* Endo
	Magnolia sp. cf. *M. obovata* Thunb.
Lauraceae	*Lindera paraobtusiloba* Hu & Chaney
	Neolitsea sp.
	Persea? sp.
Ceratophyllaceae	*Ceratophyllum miodemersum* Hu & Chaney
Coriariaceae	*Coriaria* sp. cf. *C. japonica* A. Gray
Sabiaceae	*Meliosma* sp. cf. *M. myriantha* Sieb. & Zucc.
	Meliosma sp. cf. *M. tenuis* Maxim.
Tetracentraceae	*Tetracentron masuzâwaense* (Murai) Ozaki n. comb.
Eupteleaceae	*Euptelea* sp. cf. *E. polyandra* Sieb. & Zucc.
Hamamelidaceae	*Fortunearia kabutoiwana* Ozaki
	Liquidambar miosinica Hu & Chaney
Ulmaceae	*Celtis nathorstii* Tanai & Onoe
	Ulmus protojaponica Tanai & Onoe
	Zelkova ungeri Kovats
Moraceae	*Ficus* sp.
Juglandaceae	*Cyclocarya ezoana* (Tanai & N. Suzuki) Wolfe & Tanai
	Juglans japonica Tanai
	Pterocarya asymmetrosa Konno ex Tanai
Fagaceae	*Castanea miocrenata* Tanai & Onoe
	Fagus palaeojaponica Tanai & Onoe
	Fagus stuxbergii (Nathorst) Tanai
	Quercus miocrispula Huzioka
	Quercus protosalicina K. Suzuki
	Quercus protoserrata Tanai & Onoe
Betulaceae	*Alnus protohirsuta* Endo
	Alnus protmaximowiczii Tanai
	Alnus sp. cf. *A. firma* Sieb. & Zucc.
	Betula miomaximowicziana Endo ex Tanai
	Betula sp. cf. *B. grossa* Sieb. & Zucc.
	Betula sp. cf. *B. schmidtii* Regel.
	Betula sp.
	Carpinus miocenica Tanai
	Carpinus sp. cf. *C. nipponica* Endo
	Carpinus subcordata Nathorst
	Carpinus sp.
	Corylus subsieboldiana K. Suzuki
	Corylus sp. cf. *C. heterophylla* Fisch.
	Ostrya aizuana K. Suzuki
	Ostrya sp. cf. *O. japonica* Sarg.
Tiliaceae	*Tilia kabutoiwaensis* Suzuki, Ogawa & Ibe
	Tilia protojaponica Endo
	Tilia sp.
Salicaceae	*Populus hokiensis* Ozaki
	Populus sanzugawaensis Huzioka & Uemura
	Salix akitaensis Huzioka & Uemura
Clethraceae	*Clethra maximoviczii* Nathorst
Ericaceae	*Rhododendron hokiense* Ozaki
	Rhododendron protodilatatum Tanai & Onoe
Styracaceae	*Styrax protoobassia* Tanai & Onoe
Saxifragaceae	*Deutzia* sp. cf. *D. crenata* Sieb. & Zucc.
	Deutzia sp.
	Hydrangea sp.

	Hydrangea sp. cf. *H. petiolaris* Sieb. & Zucc.
	Schizophragma sp.
Rosaceae	*Prunus protossiori* Tanai & Onoe
	Prunus sp.
	Prunus sp. cf. *P. apetala* Fr. & Sav.
	Pyrus hokiensis Ozaki
	Sorbus lesquereuxi Nathorst
	Sorbus palaeojaponica Murai
	Sorbus uzenensis Huzioka
Caesalpiniaceae	*Gleditsia miosinensis* Hu & Chaney
Fabaceae	*Cladrastis aniensis* Huzioka
	Cladrastis inouei (Huzioka) Ozaki
	Pueraria miothunbergiana Hu & Chaney
	Sophora miojaponica Hu & Chaney
	Wisteria fallax (Nathorst) Tanai & Onoe
Haloragaceae	*Myriophyllum* sp.
Nyssaceae	*Davidia kabutoiwana* Ozaki
Cornaceae	*Cornus megaphylla* Hu & Chaney
	Cornus sp. cf. *C. miowalteri* Hu & Chaney
Celastraceae	*Tripterygium* sp. cf. *T. regelii* Sprange & Takeda
Rhamnaceae	*Berchemia miofloribunda* Hu & Chaney
Vitaceae	aff. *Tetrastigma* sp.
	Parthenocissus? sp.
	Vitis naumannii (Nathorst) Tanai
Staphyleaceae	*Euscaphis* sp. cf. *E. japonica* Kanitz.
	Staphylea sp. cf. *S. bumalda* DC.
Sapindaceae	*Koelreuteria miointegrifoliola* Hu & Chaney
	Koelreuteria? sp.
Hippocastanaceae	*Aesculus majus* (Nathorst) Tanai
Aceraceae	*Acer huziokae* Tanai
	Acer nordenskioeldii Nathorst
	Acer palaeorufinerve Tanai & Onoe
	Acer protomatsumurae Tanai
	Acer rotundatum Huzioka
	Acer sp. cf. *A. crataegifolium* Sieb. & Zucc.
	Acer subnikoense Tanai & Ozaki
Anacardiaceae	*Rhus miojavanica* Suzuki
	Rhus miosuccedanea Hu & Chaney
Simaroubaceae	*Ailanthus yezoense* Oishi & Huzioka
Meliaceae	*Cedrela*? sp.
Rutaceae	*Euodia* sp. cf. *E. rutaecarpa* Hock. & Thom.
Boraginaceae	*Ehretia* sp.
Oleaceae	*Fraxinus* sp. cf. *F. miyataensis* Huzioka & Uemura
Bignoniaceae	*Catalpa szei* Hu & Chaney
Caprifoliaceae	*Heptacodium hokianum* Ozaki
	Lonicera sp.
	Viburnum sp. cf. *V. otukae* Tanai
	Viburnum sp. cf. *V. uttoensis* Huzioka
	Weigela sanzugawaensis Huzioka & Uemura
Potamogetonaceae	*Potamogeton* sp.
Poaceae	*Bambusites* sp.

species each. The remaining families have less than 2 species each; most of them are represented by a single one. *Acer* is composed of 7 species, and *Quercus, Alnus, Betula, Carpinus* and *Sorbus* have 3 species each, *Meliosma, Fagus, Corylus, Ostrya, Tilia, Populus, Rhododendron, Prunus, Cladrastis, Cornus, Rhus* and *Viburnum* have 2 species each, and the remainder are represented by a single species.

Among the families predominant in the number of species, the Betulaceae, Aceraceae, Rosaceae, Caprifoliaceae, Pinaceae, Ulmaceae Juglandaceae and Salicaceae are typically cool

temperate families. On the other hand, Fabaceae, Lauraceae and Vitaceae generally range from warm temperate to tropical regions in their modern distribution. However, the Fabaceae and Vitaceae extend their distribution to the cool temperate region. Thus, the Kabutoiwa flora is composed mainly of cool temperate families with some warm temperate ones.

Assumed Habits and Leaf Characters

The probable growth and abscission habits of the Kabutoiwa flora are indicated in Table 22. These estimations are based upon the habits of the equivalent living species and the texture of the fossil leaves. The data in Table 22 show that 72 trees make up 68.6 per cent, 20 small trees or shrubs comprise 19.0 per cent, 9 vines make up 8.6 per cent and 4 herbs 3.8 per cent. Judging from these percentage, trees were predominant in the Kabutoiwa vegetation.

Five species of conifers are assumably evergreen trees. Referring to the abscission habit of the broad-leaved members of the flora, the herbs and bamboo are omitted from consideration, but we shall include several angiosperms which have not been assigned specific status, and whose leaf characters indicate whether they were evergreen or deciduous. In this group of the 96 dicotyledonous species, only two species *Neolitsea* sp. and *Quercus protosalicina* 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 equivalents.

Numerical Representation

The quantitative appraisal of the Kabutoiwa flora is based on a count of 661 specimens collected, as shown in Table 23. This count is not sufficiently large to preclude the possibility that certain species, especially the rare ones, may have been more numerous in the Kabutoiwa forest than is suggested by these figures. They represent, however, the totals for each of several collections and with respect to the dominant species their proportional representations have not greatly changed during several leaf counts in the field. Of the 111 Kabutoiwa plants, 26 species make up more than one per cent each and occupy 71 per cent of the total. The predominant 12 species with more than 2 per cent score occupy about a half of the total specimens, and *Acer rotundatum* is most predominant with 12.7 per cent of the total. It is characteristic of the Kabutoiwa flora that there is no single species especially abundant in number of specimens and there were many plants which could enter the depositional sites. Such fossil occurrence may indicate that swamp flat area around the depositional sites was small and that slope and valley forests were close to the depositional sites. It is supported by the fact that the typical swamp members such as a reed, willows and alders are absent or represented by a few specimens in the flora. Among the predominant species, some leaves of *Fagus stuxbergii* are fragmentary, and it may have lived in rather upper slopes near the depositional sites. Some of specimens of *Zelkova ungeri* are represented by twigs with leaves, and this plant was a dominant member near the depositional sites along with *Acer rotundatum* and *Cladrastis aniensis*. It is suggested that the fifth and tenth species, *Sorbus lesquereuxi* and *Betula* sp. cf. *B. grossa,* were common member on sunny slope near the depositional sites, judging from the scoring of leaves and from the ecology of living equivalents. The nineth and eleventh species, *Acer subnikoense* and aff. *Tetrastigma* sp. represented with trifoliated leaves which would seem unsuited to survive transport for long distance, were probably common member near the depositional sites. *Myriophyllum* flourished on the shallow lake bottom together with *Ceratophyllum* and *Potamogeton*. The following species, *Acer palaeorufinerve, Hydrangea* sp. cf. *H. petiolaris, Liriodendron honsyuensis, Schizophragma* sp., *Euptelea* sp. cf. *E. polyandra, Tripterygium* sp. cf. *T. regelii, Vitis naumannii, Catalpa szei* and *Magnolia* sp. cf. *M. obovata,* are represented by large leaves which would seem unsuited to survive transport for a long distances; they were probably common members of the Kabutoiwa forest. Evergreen broad-leaves species is a minor element in this flora; the two species are both represented by

Table 22. Assumed Habits and Leaf Characters

Species	Growth Habit	Leaf Characters
Picea sp.	Tree	EC
Pinus miocenica	Tree	EC
Pseudotsuga tanaii	Tree	EC
Taiwania japonica	Tree	EC
Tsuga miosieboldiana	Tree	EC
Acer huziokae	Tree	Ds
Acer nordenskioeldii	Tree	Ds
Acer palaeorufinerve	Tree	Ds
Acer protomatsumurae	Tree	Ds
Acer rotundatum	Tree	Ds
Acer subnikoense	Tree	Ds
Acer sp. cf. *A. crataegifolium*	Tree	Ds
Aesculus majus	Tree	Ds
Ailanthus yezoense	Tree	De
Alnus protohirsuta	Tree	Ds
Alnus protomaximowiczii	Tree	Ds
Alnus sp. cf. *A. firma*	Tree	Ds
Betula sp. cf. *B. grossa*	Tree	Ds
Betula sp. cf. *B. schmidtii*	Tree	Ds
Betula miomaximowicziana	Tree	Ds
Carpinus miocenica	Tree	Ds
Carpinus sp. cf. *C. nipponica*	Tree	Ds
Carpinus subcordata	Tree	Ds
Castanea miocrenata	Tree	Ds
Catalpa szei	Tree	De
Celtis nathorstii	Tree	Ds
Cladrastis aniensis	Tree	De
Cladrastis inouei	Tree	De
Cornus megaphylla	Tree	De
Cornus sp. cf. *C. miowalteri*	Tree	De
Cyclocarya ezoana	Tree	Ds
Davidia kabutoiwana	Tree	Ds
Ehretia sp.	Tree	Ds
Euptelea sp. cf. *E. polyandra*	Tree	Ds
Euscaphis sp. cf. *E. japonica*	Tree	Ds
Fagus palaeojaponica	Tree	Ds
Fagus stuxbergii	Tree	Ds
Fortunearia kabutoiwana	Tree	Ds
Fraxinus cf. miyataensis	Tree	Ds
Gleditsia miosinensis	Tree	Ds
Juglans japonica	Tree	Ds
Koelreuteria miointegrifoliola	Tree	Ds
Liquidambar miosinica	Tree	Ds
Liriodendron honsyuensis	Tree	De
Magnolia sp. cf. *M. obovata*	Tree	De
Meliosma sp. cf. *M. myriantha*	Tree	Ds
Neolitsea sp.	Tree	Ee
Ostrya sp. cf. *O. japonica*	Tree	Ds
Ostrya aizuana	Tree	Ds
Persea? sp.	Tree	De
Populus hokiensis	Tree	Ds
Populus sanzugawaensis	Tree	Ds
Prunus sp. cf. *P. apetala*	Tree	Ds
Prunus protossiori	Tree	Ds
Pterocarya asymmetrosa	Tree	Ds
Pyrus hokiensis	Tree	Ds
Quercus miocrispula	Tree	Ds
Quercus protosalicina	Tree	Es
Quercus protoserrata	Tree	Ds
Rhus miojavanica	Tree	De
Rhus miosuccedanea	Tree	De
Sophora miojaponica	Tree	De
Sorbus lesquereuxi	Tree	Ds
Sorbus palaeojaponica	Tree	Ds
Staphylea sp. cf. *S. bumalda*	Tree	Ds
Styrax protoobassia	Tree	Ds
Tetracentron masuzawaense	Tree	Ds
Tilia kabutoiwaensis	Tree	Ds
Tilia protojaponica	Tree	Ds
Ulmus protojaponica	Tree	Ds
Zelkova ungeri	Tree	Ds
Clethra maximoviczii	ST or Shrub	Ds
Coriaria sp. cf. *C. japonica*	ST or Shrub	De
Corylus sp. cf. *C. heterophylla*	ST or Shrub	Ds
Corylus subsieboldiana	ST or Shrub	Ds
Deutzia sp. cf. *D. crenata*	ST or Shrub	Ds
Deutzia sp.	ST or Shrub	Ds
Euodia sp. cf. *E. rutaecarpa*	ST or Shrub	De
Heptacodium hokianum	ST or Shrub	De
Hydrangea sp.	ST or Shrub	Ds
Lindera paraobtusiloba	ST or Shrub	De
Lonicera sp.	ST or Shrub	De
Meliosma sp. cf. *M. tenuis*	ST or Shrub	Ds
Rhododendron hokiense	ST or Shrub	De
Rhododendron protodilatatum	ST or Shrub	De
Salix akitaensis	ST or Shrub	Ds
Sorbus uzenensis	ST or Shrub	Ds
Viburnum sp. cf. *V. otukae*	ST or Shrub	Ds
Viburnum sp. cf. *V. uttoensis*	ST or Shrub	Ds
Weigela sanzugawaensis	ST or Shrub	Ds
Berchemia miofloribunda	Vine	De
Ficus sp.	Vine	De
Hydrangea cf. *petiolaris*	Vine	Ds
Parthenocissus? sp.	Vine	Ds
Pueraria miothunbergiana	Vine	De
Schizophragma sp.	Vine	Ds
Tripterigium cf. *regelii*	Vine	Ds
Vitis naumannii	Vine	Ds
Wisteria fallax	Vine	De
Osmunda sp. cf. *O. japonica*	Terr. Herb	
Ceratophyllum miodemersum	Aqua. Herb	
Myriophyllum sp.	Aqua. Herb	
Potamogeton sp.	Aqua. Herb	

ST : Small Tree Terr. : Terrestrial Aqua. : Aquatic D : Deciduous E : Evergreen C : Conifer s : Serrate-margined broad-leaf
e : Entire-margined broad-leaf

only a single leaf.

The ratio of the evergreen broad-leaved species to the total broad-leaved species is 2/94 that makes up 2.1 percent, and that of the entire-margined species is 24/94 and 25.5 percent,

Table 23. Numerical Representation of the Kabutoiwa Species

Species	Number of specimens	Percentage
Acer rotundatum	84	12.7
Cladrastis aniensis	53	8.0
Fagus stuxbergii	30	4.5
Zelkova ungeri	29	4.4
Sorbus lesquereuxi	25	3.8
Acer palaeorufinerve	21	3.2
Alnus protomaximowiczii	20	3.0
Myriophyllum sp.	18	2.7
Acer subnikoense	17	2.6
Betula sp. cf. *B. grossa*	16	2.4
Tetracentron masuzawaense	16	2.4
aff. *Tetrastigma* sp.	13	2.0
Lindera paraobtusiloba	12	1.8
Populus hokiensis	12	1.8
Carpinus subcordata	11	1.7
Hydrangea sp. cf. *H. petiolaris*	10	1.5
Prunus protossiori	10	1.5
Clethra maximoviczii	9	1.4
Liriodendron honsyuensis	9	1.4
Acer protomatsumurae	8	1.2
Carpinus sp.	8	1.2
Cornus sp. cf. *C. miowalteri*	8	1.2
Fraxinus sp. cf. *F. miyataensis*	8	1.2
Tilia protojaponica	8	1.2
Ulmus protojaponica	8	1.2
Carpinus miocenica	7	1.1
Fagus palaeojaponica	6	0.9
Quercus protoserrata	6	0.9
Acer nordenskioeldii	5	0.8
Aesculus majus	5	0.8
Alnus sp. cf. *A. firma*	5	0.8
Cladrastis inouei	5	0.8
Ostrya aizuana	5	0.8
Schizophragma sp.	5	0.8
Taiwania japonica	5	0.8
Acer huziokae	4	0.6
Cedrela? sp.	4	0.6
Cyclocarya ezoana	4	0.6
Euptelea sp. cf. *E. polyandra*	4	0.6
Koelreuteria? sp	4	0.6
Prunus sp. cf. *P. apetala*	4	0.6
Pterocarya asymmetrosa	4	0.6
Betula sp.	3	0.5
Ceratophyllum miodemersum	3	0.5
Fortunearia kabutoiwana	3	0.5
Osmunda sp. cf. *O. japonica*	3	0.5
Pinus miocenica	3	0.5
Pseudotsuga tanaii	3	0.5
Quercus miocrispula	3	0.5
Sophora miojaponica	3	0.5
Tilia sp.	3	0.5
Tripterygium sp. cf. *T. regelii*	3	0.5
Viburnum sp. cf. *V. uttoensis*	3	0.5
Vitis naumannii	3	0.5
Ailanthus yezoense	2	0.3
Betula sp. cf. *B. schmidtii*	2	0.3
Carpinus sp. cf. *C. nipponica*	2	0.3
Castanea miocrenata	2	0.3
Catalpa szei	2	0.3
Coriaria sp. cf. *C. japonica*	2	0.3
Corylus sp. cf. *C. heterophylla*	2	0.3
Deutzia sp. cf. *D. crenata*	2	0.3
Euscaphis sp. cf. *E. japonica*	2	0.3
Koelreuteria miointegrifoliola	2	0.3
Liquidambar miosinica	2	0.3
Ostrya sp. cf. *O. japonica*	2	0.3
Parthenocissus? sp.	2	0.3
Persea? sp.	2	0.3
Potamogeton sp.	2	0.3
Pyrus hokiensis	2	0.3
Rhododendron hokiense	2	0.3
Rhododendron protodilatatum	2	0.3
Sorbus palaeojaponica	2	0.3
Staphylea sp. cf. *S. bumalda*	2	0.3
Tilia kabutoiwaensis	2	0.3
Viburnum sp. cf. *V. otukae*	2	0.3
Weigela sanzugawaensis	2	0.3
Acer sp. cf. *A. crataegifolium*	1	0.2
Alnus protohirsuta	1	0.2
Bambusites sp.	1	0.2
Berchemia miofloribunda	1	0.2
Betula miomaximowicziana	1	0.2
Celtis nathorstii	1	0.2
Cornus megaphylla	1	0.2
Corylus subsieboldiana	1	0.2
Davidia kabutoiwana	1	0.2
Deutzia sp.	1	0.2
Ehretia sp.	1	0.2
Euodia sp. cf. *E. rutaecarpa*	1	0.2
Ficus sp.	1	0.2
Gleditsia miosinensis	1	0.2
Heptacodium hokianum	1	0.2
Hydrangea sp.	1	0.2
Juglans japonica	1	0.2
Lonicera sp.	1	0.2
Magnolia sp. cf. *M. obovata*	1	0.2
Meliosma sp. cf. *M. myriantha*	1	0.2
Meliosma sp. cf. *M. tenuis*	1	0.2
Neolitsea sp.	1	0.2
Picea sp.	1	0.2
Populus sanzugawaensis	1	0.2
Prunus sp.	1	0.2
Pueraria miothunbergiana	1	0.2
Quercus protosalicina	1	0.2
Rhus miojavanica	1	0.2
Rhus miosuccedanea	1	0.2
Salix akitaensis	1	0.2
Sorbus uzenensis	1	0.2
Styrax protoobassia	1	0.2
Tsuga miosieboldiana	1	0.2
Wisteria fallax	1	0.2
	661	102.4

Distribution of the Allied Living Species

Table 24 shows the most allied living species of the Kabutoiwa species and the altitudinal distribution in the modern forests.

The following table indicates the total number of the most allied living species in each

forest zone of the Table 24 (+symbol stands for 0.5) and the percentages for the cumulative number of species in all zones.

Zone	1	2	3	4	5	6	7	Sum
No. of Species	6.0	35.5	64.5	78.5	60.5	5.5	0.0	250.5
Percentage	2.4	14.2	25.7	31.3	24.2	2.2	0.0	100.0

The number of the species is highest in the lower cool temperate forest zone (zone 4) as 78.5, which corresponds to 31.3 per cent of the total. Next come in the upper warm temperate forest zone (zone 3) as 64.5 species, then the upper cool temperate forest zone (zone 5) as 60.5 species. When we count only on the predominant fossil species in the number of specimens, their most allied living species are distributed mostly in the lower and upper cool temperate zone forests and subordinately in the upper warm temperate zone forest.

The distribution of the living species most allied to the Kabutoiwa fossil species indicates that the Kabutoiwa flora bears a close resemblance to the lower cool temperate zone forest.

Assumed Habitat

Table 25 represents the assumed habitat of the Kabutoiwa species. The Kabutoiwa flora has three water plants among which *Myriophyllum* sp. may be predominant of all. The lake-border flat forest was probably small in the area and was composed of deciduous hardwood trees such as *Fraxinus* cf. *miyataensis* and *Ulmus protojaponica,* and *Osmunda* making up the understory. The trees and herbs of this community were not confined to the lakeshore, excepting swamp plants, but also occupied stream sides in the region. Most of them mingled with members of valley forest. Most of the Kabutoiwa species are included in the category which consists of two communities : valley forest and slope forest. These valley and slope forests are composed mostly of deciduous hardwoods and some conifers, and have only two evergreen broad-leaved trees. Judging from the living equivalents and composition of the community, the riparian or valley members of the Kabutoiwa flora seem largely to form the valley forest. The valley forest of 43 species was made up of very mesic to mean hydric plants which were confined mainly to well drained, moist, valley sites. Some of predominant species of the flora, such as *Acer rotundatum, Cladrastis aniensis, Zelkova ungeri, Acer palaeorufinerve, Acer subnikoense, Populus hokiensis, Carpinus subcordata, Acer protomatsumurae, Cornus* cf. *miowalteri, Fraxinus* cf. *miyataensis, Tilia protojaponica, Ulmus protojaponica* and *Carpinus miocenica,* probably found their most luxuriant growth in the valley forest. Several shrubs and vines may have formed the understory of the above trees, such as *Hydrangea, Schizophragma, Viburnum, Wisteria, Lonicera, Meliosma, Bambusites* and *Deutzia.* Many of the members of the valley forest mingled in the lower slope forest. Some predominant species of this forest, such as *Sorbus lesquereuxi, Cladrastis aniensis, Tetracentron masuzawaensis, Lindera paraobtusiloba, Prunus protossiori, Quercus protoserrata* and *Fagus palaeojaponica* along with maples (*Acer rotundatum, A. palaeorufinerve,* and *A. subnikoense*), probably found their luxuriant growth in the lower slope forest. Some conifers such as *Taiwania, Pseudotsuga, Tsuga* and *Pinus* seem to have mingled in the lower slope forest. Mountain slope forest was dominated in *Fagus stuxbergii*, and *Alnus protomaximowiczii, Betula* cf. *grossa* were common members of the mountain slope forest.

Summary

The Kabutoiwa flora of 111 species in 45 families and 75 genera including many exotic genera and many species heretofore unknown for the Tertiary floras of East Asia is preserved mainly in tuffite and fine tuffaceous rocks of the upper Motojuku (Kabutoiwa) Formation distributed in the border of Gunma and Nagano Prefectures. The formation is composed largely of various pyroclastic rocks of resultants of effusive volcanism which has been prevailed from the latest Miocene in this area. The Kabutoiwa basin was entirely of lacus-

Table 24. Distribution of the most allied living species

Fossil species	Most allied living species	1	2	3	4	5	6	7
Ehretia sp.	*Ehretia* sp.	*	*	*	—	—	—	—
Euscaphis sp. cf. *E. japonica*	*E. japonica* Kanitz.	*	*	*	—	—	—	—
Ficus sp.	*F. pumila* Linn.	*	*	*	—	—	—	—
Neolitsea sp.	*N. sericea* (Blume) Koidz.	*	*	*	—	—	—	—
Rhus miosuccedanea	*R. succedanea* Linn.	*	*	*	—	—	—	—
Myriophyllum sp.	*M. spicatum* Linn.	*	*	*	*	*	*	—
Euodia sp. cf. *E. rutaecarpa*	*E. rutaecarpa* (Jussieu) Bentham	—	*	*	—	—	—	—
Heptacodium hokianum	*H. jasminoides* Airy-Ahaw	—	*	*	—	—	—	—
Hydrangea sp.	*H. macrophylla* Seringe	—	*	*	—	—	—	—
Koelreuteria miointegrifoliola	*K. integrifoliola* Merr.	—	*	*	—	—	—	—
Liquidambar miosinica	*L. formosana* Hance	—	*	*	—	—	—	—
Pinus miocenica	*P. thunbergii* Parl.	—	*	*	—	—	—	—
Quercus protosalicina	*Q. salicine* Blume	—	*	*	—	—	—	—
Taiwania japonica	*T. cryptomerioides* Hayata	—	*	*	—	—	—	—
Tilia sp.	*T. kiusiana* Makino et Shirasawa	—	*	*	—	—	—	—
Cyclocarya ezoana	*C. paliurus* (Batal.) Iljinskaja	—	*	*	*	—	—	—
Davidia kabutoiwana	*D. involuculata* Baillon	—	*	*	*	—	—	—
Deutzia sp. cf. *D. crenata*	*D. crenata* Sieb. et Zucc.	—	*	*	*	—	—	—
Fortunearia kabutoiwana	*F. sinensis* Rehd. et Wils.	—	*	*	*	—	—	—
Liriodendron honsyuensis	*L. chinense* (Hemsl.) Sarg.	—	*	*	*	—	—	—
Rhus miojavanica	*R. javanica* Linn.	—	*	*	*	—	—	—
Tetracentron masuzawaense	*T. sinense* Oliv.	—	*	*	*	—	—	—
Ailanthus yezoense	*A. altissima* Swingle	—	*	*	*	*	—	—
Catalpa szei	*C. ovata* Don	—	*	*	*	*	—	—
Cedrela? sp.	*C. sinensis* Juss.	—	*	*	*	*	—	—
Celtis nathorstii	*C. sinensis* Pers. var. *japonica* Nakai	—	*	*	*	*	—	—
Ceratophyllum miodemersum	*C. demersum* Linn.	—	*	*	*	*	—	—
Cornus megaphylla	*C. controversa* Hemsl.	—	*	*	*	*	—	—
Cornus miowalteri	*C. walteri* Wanger	—	*	*	*	*	—	—
Osmunda sp. cf. *O. japonica*	*O. japonica* Thunb.	—	*	*	*	*	—	—
Parthenocissus? sp.	*Parthenocissus* sp.	—	*	*	*	*	—	—
Pueraria miothunbergiana	*P. lobata* (Willd.) Ohwi	—	*	*	*	*	—	—
Rhododendron hokiense	*R. kaempferi* Planch.	—	*	*	*	*	—	—
Wisteria fallax	*W. floribunda* (Willd.) DC.	—	*	*	*	*	—	—
Carpinus sp. cf. *C. nipponica*	*C. betulus* Linn.	—	*	*	*	*	*	—
Zelkova ungeri	*Z. serrata* Makino	—	+	*	*	—	—	—
Acer nordenskioeldii	*A. palmatum* Thunb.	—	—	*	*	—	—	—
Acer sp. cf. *A. crataegifolium.*	*A. crataegifolium* Sieb. et Zucc.	—	—	*	*	—	—	—
Berchemia miofloribunda	*B. racemosa* Sieb. et Zucc.	—	—	*	*	—	—	—
Euptelea sp. cf. *E. polyandra*	*E. polyandra* Sieb. et Zucc.	—	—	*	*	—	—	—
Fagus palaeojaponica	*F. japonica* Maxim.	—	—	*	*	—	—	—
Gleditsia miosinensis	*G. japonica* Miq.	—	—	*	*	—	—	—
Juglans japonica	*J. ailanthifolia* Carr.	—	—	*	*	—	—	—
Lindera paraobtusiloba	*L. obtusiloba* Blume	—	—	*	*	—	—	—
Meliosma sp. cf. *M. myriantha*	*M. myriantha* Sieb. et Zucc.	—	—	*	*	—	—	—
Meliosma sp. cf. *M. tenuis*	*M. tenuis* Maxim.	—	—	*	*	—	—	—
Pseudotsuga tanaii	*P. japonica* Shirasawa	—	—	*	*	—	—	—
Pyrus hokiensis	*P. callyana* Decne.	—	—	*	*	—	—	—
Quercus protoserrata	*Q. serrata* Murray	—	—	*	*	—	—	—
Tsuga miosieboldiana	*T. sieboldii Carr.*	—	—	*	*	—	—	—
Vibrnum sp. cf. *V. otukae*	*V. erosum* Thunb.	—	—	*	*	—	—	—
Acer huziokae	*A. mono* Maxim.	—	—	*	*	*	—	—
Acer rotundatum	*A. mono* Maxim.	—	—	*	*	*	—	—
Alnus sp. cf. *A. firma*	*A. firma* Sieb. et Zucc.	—	—	*	*	*	—	—
Castanea miocrenata	*C. crenata* Sieb. et Zucc.	—	—	*	*	*	—	—
Cladrastis inouei	*C. sikokiana* (Makino) Makino	—	—	*	*	*	—	—
Clethra maximoviczii	*C. barbinervis* Sieb. et Zucc.	—	—	*	*	*	—	—
Coriaria sp. cf. *C. japonica*	*C. japonica* A. Gray	—	—	*	*	*	—	—
Magnolia sp. cf. *M. obovata*	*M. obovata* Thunb.	—	—	*	*	*	—	—

Populus hokiensis	*P. sieboldii* Miq.	−	−	*	*	*	−	−
Prunus protossiori	*P. jamasakura* Sieb. ex Koidz.	−	−	*	*	*	−	−
Staphylea sp. cf. *S. bumalda*	*S. bumalda* DC.	−	−	*	*	*	−	−
Alnus protohirsuta	*A. hirsuta* Turcz.	−	−	+	*	*	−	−
Ostrya aizuana	*O. japonica* Sarg.	−	−	+	*	*	−	−
Ostrya sp. cf. *O. japonica*	*O. japonica* Sarg.	−	−	+	*	*	−	−
Salix akitaensis	*S. sachalinensis* Fr. Schm.	−	−	+	*	*	−	−
Carpinus miocenica	*C. laxiflora* Blume	−	−	+	*	+	−	−
Acer subnikoense	*A. nikoense* Maxim.	−	−	−	*	−	−	−
Rhododendron protodilatatum	*R. dilatatum* Miq.	−	−	−	*	−	−	−
Acer palaeorufinerve	*A. rufinerve* Sieb. et Zucc.	−	−	−	*	*	−	−
Acer protomatsumurae	*A. palmatum* Thunb. var. *matsumurae* (Koidz.) Makino	−	−	−	*	*	−	−
Betula miomaximowicziana	*B. maximowicziana* Regel	−	−	−	*	*	−	−
Betula sp. cf. *B. grossa*	*B. grossa* Sieb. et Zucc.	−	−	−	*	*	−	−
Betula sp. cf. *B. schmidtii*	*B. schmidtii* Regel.	−	−	−	*	*	−	−
Betula sp.	*Betula* sp.	−	−	−	*	*	−	−
Carpinus subcordata	*C. cordata* Blume	−	−	−	*	*	−	−
Cladrastis aniensis	*C. platycarpa* (Maxim.) Makino	−	−	−	*	*	−	−
Corylus subsieboldiana	*C. sieboldiana* Blume	−	−	−	*	*	−	−
Corylus sp. cf. *C. heterophylla*	*C. heterophylla* Fischer	−	−	−	*	*	−	−
Fagus stuxbergii	*F. crenata* Blume	−	−	−	*	*	−	−
Fraxinus sp. cf. *F. miyataensis*	*F. japonica* Blume	−	−	−	*	*	−	−
Hydrangea sp. cf. *H. petiolaris*	*H. petiolaris* Sieb. et Zucc.	−	−	−	*	*	−	−
Prunus sp. cf. *P. apetala*	*P. apetala* Fr. et Sav.	−	−	−	*	*	−	−
Pterocarya asymmetrosa	*P. rholfolia* Sieb. et Zucc.	−	−	−	*	*	−	−
Schizophragma sp.	*S. hydrangeoides* Sieb. et Zucc.	−	−	−	*	*	−	−
Sophora miojaponica	*S. japonica* Linn.	−	−	−	*	*	−	−
Sorbus lesquereuxi	*S. alnifolia* (Sieb. et Zucc.) K. Koch	−	−	−	*	*	−	−
Sorbus palaeojaponica	*S. japonica* (Decne.) Hedlund	−	−	−	*	*	−	−
Styrax protoobassia	*S. obassia* Sieb. et Zucc.	−	−	−	*	*	−	−
Viburnum sp. cf. *V. uttoensis*	*V. wrightii* Miq.	−	−	−	*	*	−	−
Weigela sanzugawaensis	*W. sanguinea* (Nakai) Nakai	−	−	−	*	*	−	−
Aesculus majus	*A. turbinata* Blume	−	−	−	+	*	−	−
Ulmus protojaponica	*U. davidiana* Planch. var. *japonica* (Rehd.) Nakai	−	−	−	+	*	−	−
Vitis naumannii	*V. coignetiae* Pulliat	−	−	−	+	*	−	−
Quercus miocrispula	*Q. mongolica* Fisch. var. *grosseserrata* Rehd. et Wils.	−	−	−	−	*	−	−
Tilia kabutoiwaensis	*T. maximowicziana* Shirasawa	−	−	−	−	*	−	−
Tilia protojaponica	*T. japonica* Simonkai	−	−	−	−	*	−	−
Tripterygium sp. cf. *T. regelii*	*T. regelii* Sprange et Takeda	−	−	−	−	*	+	−
Populus sanzugawaensis	*P. maximowiczii* A. Henry	−	−	−	−	*	*	−
Sorbus uzenensis	*S. commixta* Hedlund	−	−	−	−	*	*	*
Alnus protomaximowiczii	*A. maximowiczii* Call.	−	−	−	−	−	*	*

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

trine origin, surrounded by mountain slopes with many valleys. The level of depositional basin and relief of hinterland were lower than that of nowadays (1100-1200 m) and are estimated between 300 m and 400 m above the sea.

The Kabutoiwa flora is composed of typical cool-temperate elements; the majority is deciduous dicotyledons in which many exotic ones are contained. Most of the Kabutoiwa components have generally modern aspects, and have affinities to the plants growing in the cool-temperate deciduous broad-leaved forests in central to northern Japan. The Kabutoiwa flora is characterized by abundant plants of the valley and slope forests with some aquatic and mountain slope plants. The climate in a inland mountain region indicated by the Kabutoiwa flora was cool-temperate, although it may be warmer than in the Latest Miocene of Central Honshu.

Table 25. Assumed Habitat of the Kabutoiwa Species.

species	1	2	3	4
Ceratophyllum miodemersum	*			
Myriophyllum sp.	*			
Potamogeton sp.	*			
Osmunda cf. *japonica*	*	*		
Fraxinus cf. *miyataensis*	*	*		
Populus sanzugawaensis	*	*		
Salix akitaensis	*	*		
Ulmus protojaponica	*	*		
Acer huziokae		*		
Acer protomatsumurae		*		
Aesculus majus		*		
Alnus protohirsuta		*		
Bambusites sp.		*		
Cornus cf. *miowalteri*		*		
Cyclocarya ezoana		*		
Euptelea cf. *polyandra*		*		
Euscaphis cf. *japonica*		*		
Hydrangea sp.		*		
Juglans japonica		*		
Pterocarya asymmetrosa		*		
Wisteria fallax		*		
Zelkova ungeri		*		
Acer nordenskioeldii		*	*	
Acer palaeorufinerve		*	*	
Acer rotundatum		*	*	
Acer subnikoense		*	*	
Ailanthus yezoense		*	*	
Alnus cf. *firma*		*	*	
Carpinus miocenica		*	*	
Carpinus subcordata		*	*	
Celtis nathorstii		*	*	
Cladrastis aniensis		*	*	
Deutzia cf. *crenata*		*	*	
Gleditsia miosinensis		*	*	
Hydrangea cf. *petiolaris*		*	*	
Lonicera sp.		*	*	
Meliosma cf. *myriantha*		*	*	
Populus hokiensis		*	*	
Pueraria miothunbergiana		*	*	
Pyrus hokiensis		*	*	
Rhus miojavanica		*	*	
Schizophragma sp.		*	*	
Staphylea cf. *bumalda*		*	*	
Sorbus lesquereuxi		*	*	
Tilia protojaponica		*	*	
Rhus miosuccedanea		*	*	*
Acer cf. *crataegifolium*			*	
Castanea miocrenata			*	
Catalpa szei			*	

Species	1	2	3	4
Cladrastis inouei			*	
Clethra maximoviczii			*	
Coriaria cf. *japonica*			*	
Cornus megaphylla			*	
Corylus subsieboldiana			*	
Corylus cf. *heterophylla*			*	
Davidia kabutoiwana			*	
Ehretia sp.			*	
Euodia cf. *rutaecarpa*			*	
Fagus palaeojaponica			*	
Ficus sp.			*	
Fortunearia kabutoiwana			*	
Heptacodium hokianum			*	
Koelreuteria miointegrifoliola			*	
Lindera paraobtusiloba			*	
Liquidambar miosinica			*	
Liriodendron honsyuensis			*	
Magnolia cf. *obovata*			*	
Neolitsea sp.			*	
Ostrya aizuana			*	
Picea sp.			*	
Pinus miocenica			*	
Prunus protossiori			*	
Prunus cf. *apetala*			*	
Quercus protosalicina			*	
Quercus protserrata			*	
Rhododendron hokiense			*	
Rhododendron protodilatatum			*	
Sophora miojaponica			*	
Taiwania japonica			*	
Tetracentron masuzawaense			*	
Tilia kabutoiwaensis			*	
Tsuga miosieboldiana			*	
Viburnum cf. *otukae*			*	
Weigela sanzugawaensis			*	
Alnus protomaximowiczii			*	*
Betula miomaximowicziana			*	*
Betula cf. *grossa*			*	*
Betula cf. *schmidtii*			*	*
Fagus stuxbergii			*	*
Meliosma cf. *tenuis*			*	*
Ostrya cf. *japonica*			*	*
Pseudotsuga tanaii			*	*
Quercus miocrispula			*	*
Sorbus palaeojaponica			*	*
Sorbus uzenensis			*	*
Styrax protoobassia			*	*
Viburnum cf. *uttoensis*			*	*

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

The Akima Flora

The Akima Formation consisting chiefly of volcanic flow deposits and pyroclastics locally yields some plant fossils. It is distributed on the west of Takasaki City of Gunma Prefecture. The relationship between the Akima and underlying Itahana Formations is considered to be a parallel unconformity by Akima Collaborative Research Group (1971). Fossil diatoms indicating stagnant fresh water condition were reported from the formation (Nakajima et al., 1976).

The megaplant fossils were obtained from the lower horizon of the Akima Formation in the Kijigao and Yoshigaya Passes west of Takasaki City. The two localities are regarded as of the same stratigraphic horizon, judging from the lithology. Almost all the fossils were obtained from the former locality, as listed below.

Liquidambar miosinica Hu et Chaney (1)
Fagus stuxbergii (Nathorst) Tanai (283)
Quercus miovariabilis Hu et Chaney (2)
Stewartia submonadelpha Tanai (1)
Cladrastis aniensis Huzioka (2)
Trapa sp. cf. *T. angusticerata* Miki (11)
Trapa sp. cf. *T. macropoda* Miki (12)
Trapa sp. cf. *T. mamminifera* Miki (12)
Cornus sp. cf. *C. miowalteri* Hu et Chaney (4)
Potamogeton sp. (50)

(The numerals in parentheses are the number of specimens obtained)

All the specimens are represented by leaves or leaflets except for *Trapa*. The Akima flora, although less in composition, is dominated by *Fagus stuxbergii* with some deciduous broad-leaved species. *Trapa* spp. and *Potamogeton* indicate the aquatic community in shallow bottom, considering from the living equivalents. The Akima flora occurs in a fine-grained tuffaceous siltstone intercalated in the thick volcanic flow deposits. It seems to represent one of the cool temperate deciduous forest around a dammed lake.

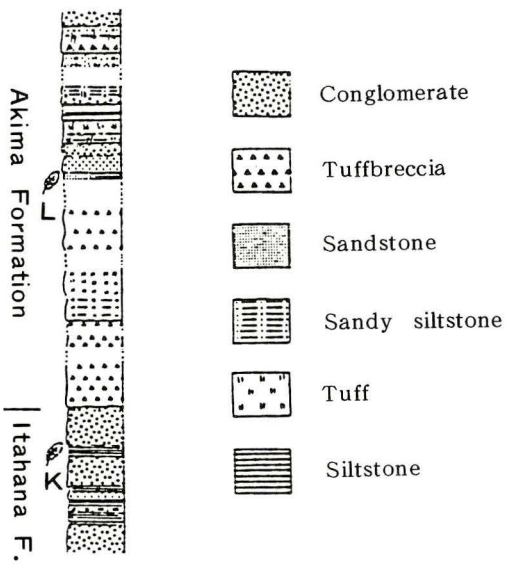


Fig. 8. Columnmer section in the Locality L of the Akima flora.

The Daido flora

Around Sarugakyo and its southern area west of Numata City in the central Gunma Prefecture are distributed the Miocene and Pliocene rocks. Some stratigraphic studies on these Neogene sediments are shown in Table 26. Plant bearing Daido Formation generally rests conformably upon the Kassezawa or Akasaka Formations and unconformably underlies the Kirigakubo welded tuff Formation. The Daido Formation is composed mainly of cyclic

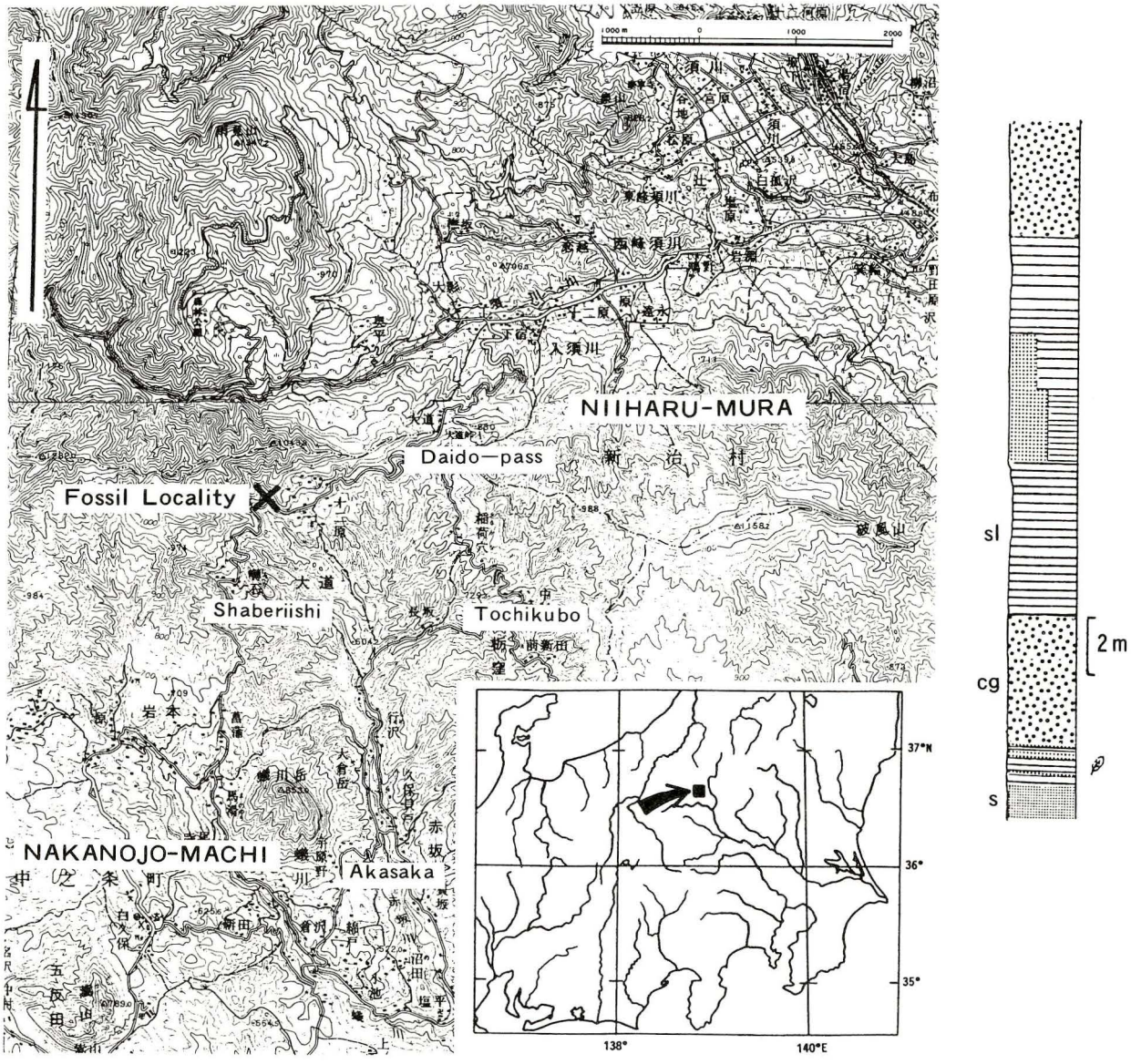


Fig. 9. Locality of the Daido flora in Gunma Prefecture, and the columner section in the fossil locality. s: Sandstone cg: Conglomerate sl: Siltstone

Table 26. Correlation of Neogene sequences in northern Gunma Prefecture, Central Japan

Western Area	Eastern Area	
Joetsu Nanbu Research Group (1976, 81)	Arai・Kizaki (1958)	
Kirigakubo F.		Plio.
Daidou F.		Late Miocene
Akasaka F. / Kassezawa F. / Tochikubo F.		
Hara F.	Hara F.	Middle Miocene
Akaya F.	Akaya F.	
	Gokan F.	Early Miocene -Oligocene
	Up. Namezawa F.	
	Low Namezawa F.	
	Yubara F.	
	Awazawa F.	
	Ookura F.	
	Basement Rocks	

sediments of conglomerate, sandstone and siltstone; it is correlative with the Late Miocene Itahana Formation by the lithology. Plant fossils are obtained from siltstones facing the road near the Daido pass situated between Nakanojo-machi and Niihari-mura. The plant-bearing rocks are stratigraphically upper part of the Daido Formation, and are composed of alternation of sandy siltstone and siltstone, intercalated within conglomerate.

The following species were identified (The numerals in the parentheses are the number of specimens obtained):

Metasequoia occidentalis (8),
Thuja sp. (1),
Alnus sp. cf. *A. hirsuta* Turcz. (32),
Alnus sp. cf. *A. japonica* Steud. (2),
Carpinus heigunensis Huzioka (2),
Fagus stuxbergii (Nathorst) Tanai (23),
Fagus sp. cf. *F. stuxbergii* (Nathorst) Tanai (15),
Quercus miovariabilis Hu and Chaney (2),
Cladrastis aniensis? Huzioka (1),
Vitis sp. (1).

Fagus stuxbergii and its related species take up nearly a half of the total specimens. Most of the Daido species are considered to show habitat of valley to mountain slope, and their most allied living species are common in the cool temperate region, although the specimens are small in number and sporadic in occurrence. The floristic composition suggests that the Daido flora was derived from the forest somewhat similar to the existing *Fagus* forest, which is now distributed in the valley to slope area of the cool temperate zone.