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Miocene vegetational and climatic history of the eastern part of the Setouchi Geologic Province, Japan

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ABSTRACT

The floras of the Miocene Kani, Mizunami, Iwamura, Tomikusa and Shidara Group in the eastern part of the Setouchi region are analyzed for vegetational types. The vegetational histry of the area is summarized as follows.

	Lowlands	Mountains
14-16.5 Ma	Subtropical to warm-temperate, broad-leaved evergreen forest	Cool-temperate, broad-leaved deciduous forest
16.5-18 Ma	Warm-temperate, broad-leaved evergreen and deciduous forest	Warm-temperate, broad-leaved deciduous forest
18-20 Ma	Warm-temperate, broad-leaved deciduous forest	Cool-temperate, broad-leaved deciduous forest
20-22 Ma	Warm-temperate, broad-leaved deciduous forest	Cool-temperate, broad-leaved deciduous forest

The mean annual temperature of the area was 10°~13°C for 20-22 Ma, 10°~13°C for 18-20 Ma, 13°~16°C for 16.5-18 Ma and 15°~20°C for 14-16.5 Ma. The cold month mean for 14-16.5 Ma was 3°~10°C which is the highest of all, and for 18-20 Ma was −2°~1°C which is the lowest of all. The largest annual precipitation, 1,200~4,000mm is found for 14-16.5 Ma, and the smallest annual precipitation, 800~1,000mm for 18-20 Ma.

The close floristic resemblance between southwest Honshu and Korea of 20-22 Ma supports the idea that the two areas were geographically connected during this age. On the other hand for 14-16.5 Ma the remarkable floristic difference between them and increase of the winter precipitation in southwest Honshu suggest the separation of them by a sea in this age.

INTRODUCTION

The Miocene Kani, Mizunami and Iwamura Groups of the Tono district, Gifu Prefecture have been of interest to paleobotanists for these three decades owing to their prolific fossil plants. Tanai (1961) first described a flora consisting of 30 species from the Nakamura Formation of the Kani Group, the Toki Lignite-bearing Formation of the Mizunami Group and the Agi Formation of the Iwamura Group, and named it the Hiyoshi flora. He correlated it with the Aniai flora in the Aniai Formation, Akita Prefecture. Tokunaga and Onoe (1963) reported 25 species from the Nakamura and Toki Lignite-bearing Formations, and considered the flora represented by them to be an intermediate flora of the Aniai and Daijima type floras. Huzioka (1964) described 44 species from the above three formations, and correlated the flora with the Aniai

flora. Ozaki (1974) described 27 species from the Kujiri Facies of the Mizunami Group.

I have systematically studied Miocene floras of the eastern part of the Setouchi Geologic Province including the Tono district since 1971. Among results of this study there are description and climatic interpretation of fossil plants from the upper part of the Mizunami Group (Ina, 1974; 1981), and the Hiramaki Formation of the Kani Group (Ina, 1977; 1981), description of floras of the Hachiya Formation of the same group (Ina and others, 1983; 1985), the Tomikusa Group, Nagano Prefecture (Ina, 1988), the Iwamura Group (Ina, MS) and the Shidara Group (Shibata and Ina, 1983).

The previous works provide abundant floristic data enough for a restoration of the Early to Middle Miocene vegetation of the area. This paper analyzes these data for vegetational types, and estimates the paleoclimate of the eastern part of the Setouchi Geologic Province on the basis of modern correlatives of them and their constituent species.

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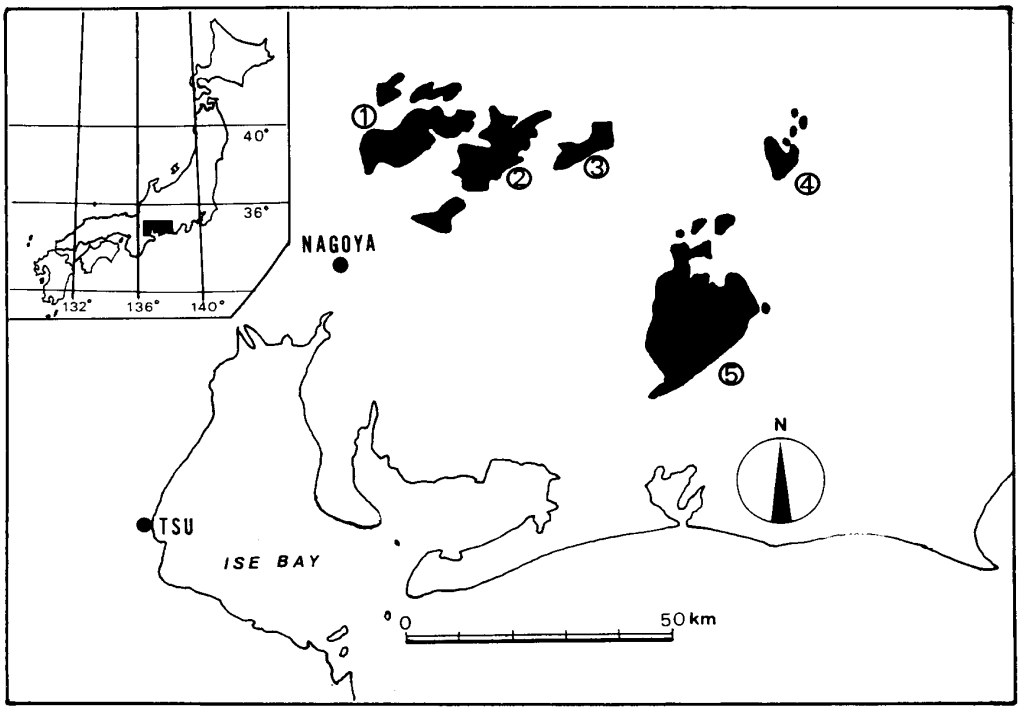

Fig. 1 Map showing location of plant-bearing formations of the First Setouchi Series in the eastern part of the Setouchi region. 1 : Kani Group 2 : Mizunami Group 3 : Iwamura Group 4 : Tomikusa Group 5 : Shidara Group.

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GEOLOGICAL SETTING

The five groups from which plant fossils were obtained, Kani, Mizunami, Iwamura,

Table 1 Stratigraphic classification of the groups from which plant fossils were obtained

Ma	Blow (1969)	Kani Group	flora	Mizunami Group	flora	Iwamura Group	flora	Tomikusa Group	flora	Shidara Group	flora
15	N.9			Oidawara Formation	f6					Nansetu Subgroup	f11
16	N.8			(Shukunohora Sandstone Facies)	f5						
						Toyama Formation	f8	Awano Formation			
				Akeyo Formation	f4			Arakida Formation	f10	Hokusetsu Subgroup	
17	N.7	Hiramaki Formation	f3	Hongo Formation		Agi Formation	f7	Oshimojo Formation Nukuta Formation	f9		
	N.6							Wachino Formation			
18											
19	N.5	Nakamura Formation	f2	Toki Lignite-bearing Formation	f2						
20											
21	N.4	Hachiya Formation	f1								
22											

f1: Hachiya flora, f2: Hiyoshi flora, f3: Hiramaki flora, f4: Inkyoyama and Akeyo floras, f5: Shukunohora flora, f6: Oidawara flora, f7: Agi flora, f8: Toyama flora, f9: Tajikara flora, f10: Tomikusa flora, f11: Shibaishitoge flora

Tomikusa and Shidara Groups occur scattered in small basins in the eastern part of the Setouchi Geologic Province (Fig. 1). The stratigraphic classification of these groups is shown in Table 1.

Plant-bearing horizones in each group and their sedimentary environment are as follows.

Kani Group

Plant fossils are abundant in all the three formations of this group, the Hachiya, Nakamura and Hiramaki Formations. The flora of the Hachiya Formation was named the Hachiya flora by Ina and others (1983), that of the Nakamura Formation was named the Hiyoshi flora by Tanai (1961), and that of the Hiramaki Formation was named the Hiramaki flora by Ina (1977). The Hachiya Formation consists of volcanic rocks and lacustrine sediments with plant fossils, and the others consist of lacustrine sediments.

Mizunami Group

Four floras, the Hiyoshi (Tanai, 1961; Huzioka, 1964), Inkyoyama (Ozaki, 1974), Akeyo (Ina, 1974) and Oidawara floras (Ina, 1974) have been described from this group. The first occurs in the Toki Lignite-bearing Formation, the third in the Akeyo Formation and the fourth in the Oidawara Formation. The second was named to the flora from the Kujiri Facies. In addition recently plants were found to occur in the Shukunohora Sandstone Facies of the Akeyo Formation (Ina, MS).

The Toki Lignite-bearing Formation consists of lacustrine sediments, the Akeyo Formation is a shallow sea sediment, and the Oidawara Formation is a deep sea sediment (Itoigawa, 1980).

Iwamura Group

Plants occur abundantly in the Agi Formation and the lower part of the Toyama Formation, the Kubohara Sandstone and the Maki Siltstone Members. Ina (Ms) named the flora of the former the Agi flora and that of the latter the Toyama flora. The Agi Formation consists largely of lacustrine sediments, but several members of brackish water and shallow sea sediments are intercalated in the middle part of it (Iwamura Research Group, 1989). The two members of the Toyama Formation are composed of shallow sea sediments (Itoigawa, 1955).

Tomikusa Group

Ina (1988) described the Tomikusa flora on the basis of fossil plants collected from the Nukuta, Oshimojo, Arakida and Awano Formations which represent stratigraphic units of the Tomikusa Group of the Tomikusa area, and the Tajikara flora on the basis of plants from the Tajikara Formation of the Yonekawa area. The Nukuta Formation is a lacustrine sediment, the other formations of the Tomikusa area are shallow sea sediments, and the Tajikara Formation consists largely of lacustrine sediments but the uppermost part of it consists of brackish water sediments (Ujihara and others, 1988).

Shidara Group

Shibata and Ina (1983) described the Shibaishitoge flora from the lower part of the Myojinyama Formation of the Nansetsu Subgroup, Shidara Group. This formation consists mainly of volcanic rocks with intercalations of tuff. The flora is based on plant fossils collected from tuffs in its lower part. The tuffs seem to have been deposited in a lake (Shibata and Ina, 1983).

AGE

Published radiometric dates from the Miocene from which plant fossils were obtained are limited. Torii (1982) gave a K-Ar age of 22.2 Ma for a welded tuff in the basal part of the Hachiya Formation, the Kani Group, and Nomura (1986) gave K-Ar dates of 20.6 Ma and 19.8 Ma for andesite lavas in the middle and upper parts of the formation, respectively. The age of the Hachiya Formation seems to be approximately 20-22 Ma from these dates. Kobayashi (1989) dated the Nakamura Formation of the Kani Group at 20.7 Ma and 21.3 Ma, the Hiramaki Formation of the group at 16.3 Ma and 17.5 Ma and the Toki Lignite-bearing Formation of the Mizunami Group at 18.3 Ma.

Many workers including Uemura (1961), Itoigawa (1974), Yoshida (1977), and Shibata and Itoigawa (1980) correlated the Nakamura Formation with the Toki Lignite-bearing Formation, and the Hiramaki Formation with the Hongo Formation of the Mizunami Group. Uemura (1961), Itoigawa (1974) and Yoshida (1977) correlated the Hongo Formation with the Agi Formation of the Iwamura Group. Itoigawa (1980) changed his opinion and correlated the Toki Lignite-bearing Formation to the Agi Formation thereafter. Iwamura Reseach Group (1989) made correlation between the Hongo and Agi Formations. The writer takes a stand of Iwamura Reseach Group. These dates and correlation indicate 18-20 Ma as an approximate time span for the Nakamura and Toki Lignite-bearing Formations, and 16.5-18 Ma for the Hiramaki, Hongo and Agi Formations.

The Shukunohora Sandstone Facies which constitutes the uppermost part of the Akeyo Formation, the Mizunami Group was assigned to the foraminiferal zone of N 8 (Ibaraki, 1981; Shibata and Ishigaki, 1981) which has been dated at Ca. 15.5-16.5 Ma (IGCP-114, National Working Group of Japan, 1981). The remaining part of the Akeyo Formation is roughly estimated at 16.5-18 Ma on the basis of the date of the top of the Hongo Formation and the date of the base of the N8 zone above mentioned. The Oidawara Formation of the Mizunami Group contains foraminiferas suggesting the N9 zone (Saito, 1963) and diatoms indicating the same zone (Koizumi, 1981). The Toyama Formation of the Iwamura Group was correlated with the Akeyo Formation excluding the Shukunohora Sandstone Facies (Shibata and Itoigawa, 1980).

Ujihara and others (1988) correlated the standard stratigraphic sequence of the Tomikusa Group ranging from the Oshimojo to the Awano Formation with the Toyama Formation, but they were not able to make clear the stratigraphic relationship between the standard sequence and the Tajikara Formation which occurs separated from it. The Tajikara Formation consists at least largely of lacustrine sediments and the Nukuta Formation of the standard unit consists of lacustrine sediments, both underlying marine sediments. From the resemblance in sedimentary environment and stratigraphical position the Tajikara Formation seems to be equivalent to the Nukuta Formation, and these formations are probably correlated with the Agi Formation.

Fission track dating (Suzuki, 1970) provided a date of 15.9 Ma for the Nansetsu Subgroup and K-Ar dating (Tsunekawa and others, 1983) gave a time span ranging from 14 Ma to 16 Ma for dikes of volcanic rocks in the subgroup. The age of the

Shibaishitoge flora is within this span.

As to age the plant-bearing formations of the eastern part of the Setouchi Geologic Province can be tentatively classified as follows.

20-22 Ma : the Hachiya Formation.
18-20 Ma : the Nakamura and Toki Lignite-bearing Formations.
16.5-18 Ma : The Hiramaki, Akeyo, Agi, Toyama, Tajikara, Oshimojo and Awano Formations.
14-16.5 Ma : The Shukunohora Sandstone Facies, the Oidawara Formation and the Nansetsu Subgroup.

FLORISTIC COMPOSITION

A checklist of plants by flora is shown in appendix I. The floral composition of each flora is summarized in the following lines.

1. Kani Group

Hachiya flora

Reference : Ina and others (1985).
Occurrence : The Hachiya Formation.
Composition : 29 families, 41 genera, 64 species and *Banisteriaecarpum giganteum.*
Ferns; two species, evergreen conifers; two species, deciduous conifer; one species, broad-leaved evergreen trees; two species, broad-leaved deciduous trees; 54 species and aquatic herbs; three species.
Percentage of species that have entire margined leaves in broad-leaved trees: 20%.
Percentage of evergreen species in broad-leaved trees: 4%.
Families dominant in number of species: Betulaceae, Ulmaceae, Aceraceae, Juglandaceae, Fagaceae and Tiliaceae.
Dominant species: *Alnus penepalensis, Alangium aequalifolium, Hemitrapa borealis, Ulmus appendiculata, Metasequoia occidentalis, Ulmus pseudolongifolia, Zelkova ungeri* and *Acer ezoanum.*
Remarks : Deciduous broad-leaved trees are dominant. Species which form fringing and ravine forests and aquatic plants are included.

Hiyoshi flora

Reference : Tanai (1961), Huzioka (1964) and Ina and others (1985).
Occurrence : The Nakamura Formation of the Kani Group and Toki Lignite-bearing Formation of the Mizunami Group.
Composition : 22 families, 41 genera, 61 species and *Banisteriaecarpum giganteum.*
Ferns; three species (including one aquatic herb), evergreen conifers; seven species, deciduous conifers; three species, broad-leaved deciduous trees; 43 species and aquatic herbs; five species.
Percentage of species that have entire margined leaves in broad-leaved trees: 13%.
All of the broad-leaved trees deciduous.
Families dominant in number of species: Betulaceae, Pinaceae, Aceraceae, Juglandaceae and Ulmaceae.

Dominant species: *Metasequoia occidentalis, Carpinus subyedoensis, Fagus antipofi, Ulmus minoensis, Acer ezoanum, Alangium aequalifolium, Populus balsamoides, Salix varians* and *Ulmus takayasui.*

Remarks : Broad-leaved deciduous trees are dominamt. Species which form fringing and ravine forests and aquatic plants are included.

Hiramaki flora

Reference : Ina (1981).

Occurrence : The Hiramaki Formation.

Composition : 43 families, 67 genera, 100 species and *Carpolithes japonica.*

Ferns; three species (including one aquatic herb), evergreen conifers; five species, deciduous conifer; one species, broad-leaved evergreen trees; six species, broad-leaved deciduous trees; 77 species, herbs; six species and aquatic herbs; two species.

Percentage of species that have entire margined leaves in broad-leaved trees: 27%.

Percentage of evergreen species in broad-leaved trees: 7%.

Families dominant in number of species: Betulaceae, Ulmaceae, Aceraceae, Juglandaceae, Hamamelidaceae, Rosaceae and Leguminosae.

Dominant species: *Ulmus carpinoides, Liquidambar miosinica, Parrotia fagifolia, Pterocarya asymmetrosa, Pterocarya protostenoptera, Alnus kefersteinii, Betula uzenensis, Carpinus miofangiana, Ostrya shiragiana, Quercus miovariabilis, Ulmus longifolia, Zelkova ungeri* and *Smilax trinervis.*

Remarks : Broad-leaved deciduous trees are dominant. It is a mixed flora of broad-leaved evergreen and deciduous trees. Species which form fringing and ravine forests, secondary forests, and aquatic plants are included.

2. Mizunami Group

Akeyo flora

Reference : Ina (1974).

Occurrence : The Togari, Yamanouchi and Hazama Members of the Akeyo Formation.

Composition : 26 families, 43 genera and 62 species.

Evergreen conifers; three species, deciduous conifer; one species, broad-leaved evergreen trees; nine species, broad-leaved deciduous trees; 48 species and herb; one species.

Percentage of species that have entire margined leaves in broad-leaved trees: 25%.

Percentage of evergreen species in broad-leaved trees: 16%.

Families dominant in number of species: Betulaceae, Fagaceae, Juglandaceae and Lauraceae.

Dominant species: *Quercus* sp., *Quercus nathorsti, Quercus miovariabilis* and *Pinus miocenica.*

Remarks : It is a mixed flora of broad-leaved evergreen and deciduous trees,

with admixture of conifers.

Inkyoyama flora

Reference : Ozaki (1974).
Occurrence : The Kujiri Facies of the Akeyo Formation.
Composition : 15 families, 22 genera and 27 species.
Evergreen conifers; six species, deciduous conifer; one species, broad-leaved evergreen trees; four species, broad-leaved deciduous trees; 14 species and herbs; two species.
Percentage of species that have entire margined leaves in broad-leaved trees: 33%.
Percentage of evergreen species in broad-leaved trees: 22%..
Families dominant in number of species: Pinaceae, Fagaceae, Lauraceae and Aceraceae.
Dominant species: *Calocedrus notoensis, Pseudotsuga huziokana* and *Quercus protosalicina.*
Remarks : It is a mixed flora of broad-leaved evergreen and deciduous trees, with admixture of conifers.

Shukunohora flora

Reference : Ina (MS).
Occurrence : The Shukunohora Sandstone Facies of the Akeyo Formation.
Composition : 20 families, 23 genera and 32 species.
Evergreen conifers; two species, deciduous conifer; one species, broad-leaved evergreen trees; 15 species and broad-leaved deciduous trees; 14 species.
Percentage of species that have entire margined leaves in broad-leaved trees: 59%.
Percentage of evergreen species in broad-leaved trees: 52%.
Families dominant in number of species: Lauraceae and Fagaceae.
Dominant species: *Machilus ugoana, Machilus nathorsti* and *Camellia protojaponica.*
Remarks : Broad-leaved evergreen trees are dominant.

Oidawara flora

Reference : Ina (1974).
Occurrence : The Oidawara Formation.
Composition : 7 families, 13 genera and 18 species.
Evergreen conifers; three species, deciduous conifer; one species, broad-leaved evergreen trees; 11 species and broad-leaved deciduous trees; three species.
Percentage of species that have entire margined leaves in broad-leaved trees: 50%.
Percentage of evergreen species in broad-leaved trees: 79%.
Families dominant in number of species: Fagaceae.
Dominant species: *Fagus palaeocrenata* and *Quercus protosalicina.*
Remarks : Broad-leaved evergreen trees are dominant.

3. Iwamura Group

Agi flora

Reference : Ina (MS).

Occurrence : The Agi Formation.

Composition : 22 families, 49 genera, 61 species and *Banisteriaecarpum giganteum*.
Fern; one species, evergreen conifers; four species, deciduous conifers; two species, broad-leaved evergreen trees; seven species, broad-leaved deciduous trees; 46 species and herb; one species.
Percentage of species that have entire margined leaves in broad-leaved trees: 30%.
Percentage of evergreen species in broad-leaved trees: 13%.
Families dominant in number of species: Betulaceae, Ulmaceae, Lauraceae, Leguminosae, Hamamelidaceae and Pinaceae.
Dominant species: *Ulmus carpinoides, Quercus miovariabilis, Zelkova ungeri, Alangium aequalifolium* and *Acer ezoanum*.

Remarks : Broad-leaved deciduous trees are dominant. Species which form fringing and ravine forests and secondary forests are included.

Toyama flora

Reference : Ina (MS).

Occurrence : The Kubohara Sandstone Member, Maki Siltstone Member of the Toyama Formation.

Composition : 27 families, 52 genera and 62 species.
Evergreen conifers; seven species, deciduous conifer; one species, broad-leaved evergreen trees; 10 species, broad-leaved deciduous trees; 43 species and herb; one species.
Percentage of species that have entire margined leaves in broad-leaved trees: 40%.
Percentage of evergreen species in broad-leaved trees: 19%.
Families dominant in number of species: Betulaceae, Fagaceae, Lauraceae, Pinaceae and Leguminosae.
Dominant species: *Quercus miovariabilis, Comptonia naumanni, Quecus* sp., *Liquidambar miosinica* and *Keteleeria ezoana*.

Remarks : It is a mixed flora of broad-leaved evergreen and deciduous trees, with admixture of conifers. Species which constitute secondary forests are included.

4. Tomikusa Group

Tajikara flora

Reference : Ina (1988).

Occurrence : The Tajiakra Formation.

Composition : 18 families, 26 genera and 29 species.
Ferns; two species, deciduous conifer; one species, broad-leaved evergreen trees; two species and broad-leaved deciduous trees; 24 species.
Percentage of species that have entire margined leaves in broad-leaved trees: 35%.
Percentage of evergreen species in broad-leaved trees: 8%.

Families dominant in number of species: Leguminosae, Betulaceae and Ulmaceae.
Dominant species: *Metasequoia occidentalis, Carpinus miofangiana* and *Parrotia fagifolia.*

Remarks : Broad-leaved deciduous trees are dominant. Species which form fringing and ravine forests, and secondary forests are included.

Tomikusa Flora

Reference : Ina (1988).
Occurrence : The Nukuta, Oshimojo, Arakida and Awano Formations.
Composition : 22 families, 47 genera and 62 species.
Evergreen conifers; eight species, deciduous conifer; one species, broad-leaved evergreen trees; 12 species and broad-leaved deciduous trees; 41 species.
Percentage of species that have entire margined leaves in broad-leaved trees: 36%.
Percentage of evergreen species in broad-leaved trees: 23%.
Families dominant in number of species: Fagaceae, Leguminosae, Betulaceae, Lauraceae, Pinaceae and Aceraceae.
Dominant species: *Pterocarya asymmetrosa, Quercus miovariabilis, Rosa usyuensis, Zelkova ungeri, Ulmus carpinodides, Calocedrus notoensis, Keteleeria ezoana* and *Comptonia naumanni.*
Remarks : It is a mixed flora of broad-leaved evergreen and deciduous trees, with admixture of conifers.

5. Shidara Group

Shibaishitoge flora

Reference : Shibata and Ina (1983).
Occurrence : The Nansetsu Subgroup.
Composition : 27 families, 42 genera and 58 species.
Fern; one species, broad-leaved evergreen trees; eight species, broad-leaved deciduous trees; 45 species, herbs; three species and aquatic herb; one species.
Percentage of the species that have entire margined leaves in broad-leaved trees: 47.2%.
Percentage of evergreen species in broad-leaved trees: 15%.
Families dominant in number of species: Betulaceae, Leguminosae, Juglandaceae, Ulmaceae, Magnoliaceae, Lauraceae and Aceraceae.
Dominant species: *Alnus subfirma, Betula protoermanni, Carpinus subcordata* and *Ulmus protojaponica.*
Remarks : It is a mixed flora of broad-leaved evergreen and deciduous trees. Species which form fringing and ravine forests, and secondary forests, and aquatic plants are included.

VEGETATIONAL HISTORY

As a general rule, fossil floras consist of plant remains transported from various kinds of vegetation in back lands. For example, all the Miocene floras from the eastern part of the Setouchi Geologic Province were deposited in the sea and in lowlands, and contain both warm- and cool-temperate plants. The former were derived from lowlands around their depositional sites and the latter from mountainous back lands.

20-22 Ma

The Hachiya flora includes elements of four kinds of vegetation. *Nelumbo endoana, Hemitrapa borealis* and *Hemitrapa hokkaidoensis* represent an aquiherbosa in lakes and ponds. *Salix miosinica, Pterocarya asymmetrosa, Alnus arasensis, Alnus miojaponica, Ulmus appendiculata* and *Ulmus harutoriensis* are commonly found along rivers. This indicates the existence of a fringing forest and a ravine forest including these trees. A warm-temperate, broad-leaved deciduous forest including such trees as *Carya miocathaensis, Platycarya miocenica, Hydrangea lanceolimba, Rhus miosuccedanea, Hovenia miodulsis, Viburnum miocenicum* grew in lowlands around the lake in which the flora was deposited. It seems to have been associated with such warm-temperate, broad-leaved evergreen trees as *Machilus ugoana* and *Elaeocarpus notoensis*, and such warm-temperate conifers as *Metasequoia occidentalis, Sequoia langsdorfii*. On the other hand, a cool-temperate, broad-leaved deciduous forest including *Betula uzenensis, Carpinus stenophylla, Carpinus subcordata, Corylus subsieboldiana, Fagus antipofi, Hydrangea* sp., *Rhus protoambigua, Acer ezoanum, Acer tottoriense, Tilia hommashinichii, Tilia sekiensis, Tilia* sp. and *Styrax miyataensis* seems to have existed on mountains and mountain slopes.

18-20 Ma

A vegetational analysis of the Hiyoshi flora suggests the following kinds of vegetation.

An aquiherbosa including *Salvinia pseudoformosa, Nelumbo endoana, Nuphar* sp., *Nymphar ebae, Hemitrapa borealis* and *Hemitrapa hokkaidoensis* existed in lakes and ponds. A fringing forest and a ravine forest with *Glyptostrobus europaeus, Salix varians, Pterocarya asymmetrosa, Alnus penepalensis, Ulmus minoensis* and *Ulmus takayasui* appeared along rivers and valleys. A warm-temperate, broad-leaved deciduous forest similar to that of the preceding age was distributed around lakes and ponds in lowlands, and a cool-temperate, broad-leaved deciduous forest resembling that of the preceding age grew on mountains and mountain slopes. Such subalpine conifers as *Picea kanoi* grew on higher mountains.

16.5-18 Ma

Salvinia pseudoformosa and *Lemna* sp. in floras of lacustrine sediments suggest the existence of an aquiherbosa including these species in lakes and ponds. *Salix miosinica, Salix* sp., *Pterocarya asymmetrosa, Pterocarya protostenoptera, Alnus arasensis, Ulmus carpinoides* and *Ulmus shiragica* in them suggest that of a fringing forest and ravine forest including these species along rivers and valleys. Among the other species in them are such warm-temperate, broad-leaved deciduous trees as *Hamamelis* cfr. *miomolis, Liquidambar miosinica, Liquidambar protopalmata, Parrotia fagifolia, Rosa*

sp., *Sorbus* cfr. *nipponica, Mallotus populifolia, Mallotus* sp., *Acer prototrifidium, Sapindus tanaii* and *Styrax* sp., and such warm-temperate, broad-leaved evergreen trees as *Quercus protosalicina, Quercus* sp., *Ficus* sp., *Actinodaphne nipponica, Actinodaphne oishii, Cinnamomum oguniense, Machilus ugoana, Buxus protojaponica, Maesa* sp., *Symplocos* sp. and *Osmanthus* sp., and such warm-temperate conifers as *Keteleeria ezoana, Cunninghamia protokonishii, Metasequoia occidentalis* and *Calocedrus notoensis.* The first group is found in the warm-temperate, broad-leaved deciduous forest on mountains and mountain slopes and also in the warm-temerate, broad-leaved evergreen and deciduous forest in lowlands around lakes. The second and the third groups are found only in the latter forest. Such cool-temperate, broad-leaved deciduous trees as *Alnus kefersteinii, Betula protoermanni, Betula uzenensis, Carpinus stenophylla, Carpinus subcordata, Corylus miosieboldiana, Celtis* sp., *Ilex* sp., *Acer subnikoense* and *Cornus subkousa* seem to have constituted a cool-temperate, broad-leaved deciduous forest in higher mountains. Warm-temperate, broad-leaved deciduous trees as *Comptonia naumanni, Pterocarya ezoana, Alnus* sp., *Quercus protoaliena, Celtis* sp., *Ulmus longifolia, Sassafras subtriloba, Corylopsis kobensis, Liquidambar miosinica, Parrotia fagifolia, Indigofera* sp., *Mallotus populifolia, Mallotus protojaponica, Rhus miosuccedanea, Acer nordenskiöldi, Acer prototrifidium, Sapindus tanaii, Vitis* sp., *Firmiana* sp. and *Ehretia* sp., warm-temperate, broad-leaved evergreen trees as *Castanopsis miocuspidata, Castanopsis* sp., *Quercus nathorsti, Quercus praegilva, Quercus protosalicina, Quercus* sp., *Ficus* sp., *Actinodaphne nipponica, Cinnamomum lanceolatum, Cinnamomum miocenum, Cinnamomum oguniense, Machilus ugoana, Neolitsea* sp., *Pittosporum* sp., *Euonymus* sp., *Perrotetia notoensis, Buxus protojaponica, Ilex heeri, Meliosma* sp., *Camellia protojaponica, Camellia* sp. and *Lonicera* sp. and warm-temperate conifers as *Keteleeria ezoana, Metasequoia occidentalis, Cunninghamia protokonishii* and *Calocedrus notoensis* are abundant in floras of marine sediments. They seem to represent a warm-temperate, broad-leaved evergreen and deciduous forest in lowlands along the coast.

Floras of marine sediments contain much more broad-leaved evergreen trees and conifers than those of lacustrine sediments. This may be possibly due to (1) difference in their depositional time, (2) difference altitude of their depositional sites and (3) sorting during transpotation of leaves. The altitude of the depositional site of lacustrine sediments, however, seems to have been nearly equal to that of marine sediments in the Mizunami basin, which is indicated by the fact that the lacustrine sediments are conformably overlain by the marine sediments, and the difference in the distance of transportation between lacustrine and marine sediments, seems to have been not great, as the latter have been deposited in shallow waters in bays. (2) and (3) thus seem to be the least possible, and (1) seems the most probable.

14-16.5 Ma

The Shibaishitoge flora of lacustrine sediments remarkably differs in composition from the Shukunohora and Oidawara floras of marine sediments.

Lemna sp. in the Shibaishitoge flora is a constituent of an aquiherbosa in lakes and ponds of this age, and *Pterocarya asymmetrosa, Alnus miojaponica,* and *Ulmus protojaponica* in the flora are constituents of a fringing forest and a ravine forest. It includes such warm-temperate, broad-leaved deciduous trees as *Sassafras subtriloba,*

Entada sp., *Rhus nathorsti, Sapindus tanaii, Elaeagnus* sp. and *Styrax* sp., such warm-teperate, broad-leaved evergreen trees as *Quercus protoacuta, Quercus protosalicina, Ficus* sp., *Actinodaphne oishii, Buxus protojaponica* and *Ternstroemia maekawai*, and in addition such cool-temperate, broad-leaved deciduous trees as *Betula protoermanni, Betula uzenensis* and *Carpinus subcordata.* The first and the second groups seem to have formed a warm-temperate, broad-leaved evergreen and deciduous forest dominated by broad-leaved deciduous trees around the site of deposition, while the third group seems to represent a cool-temperate, broad-leaved deciduous forest on mountains and mountain slopes.

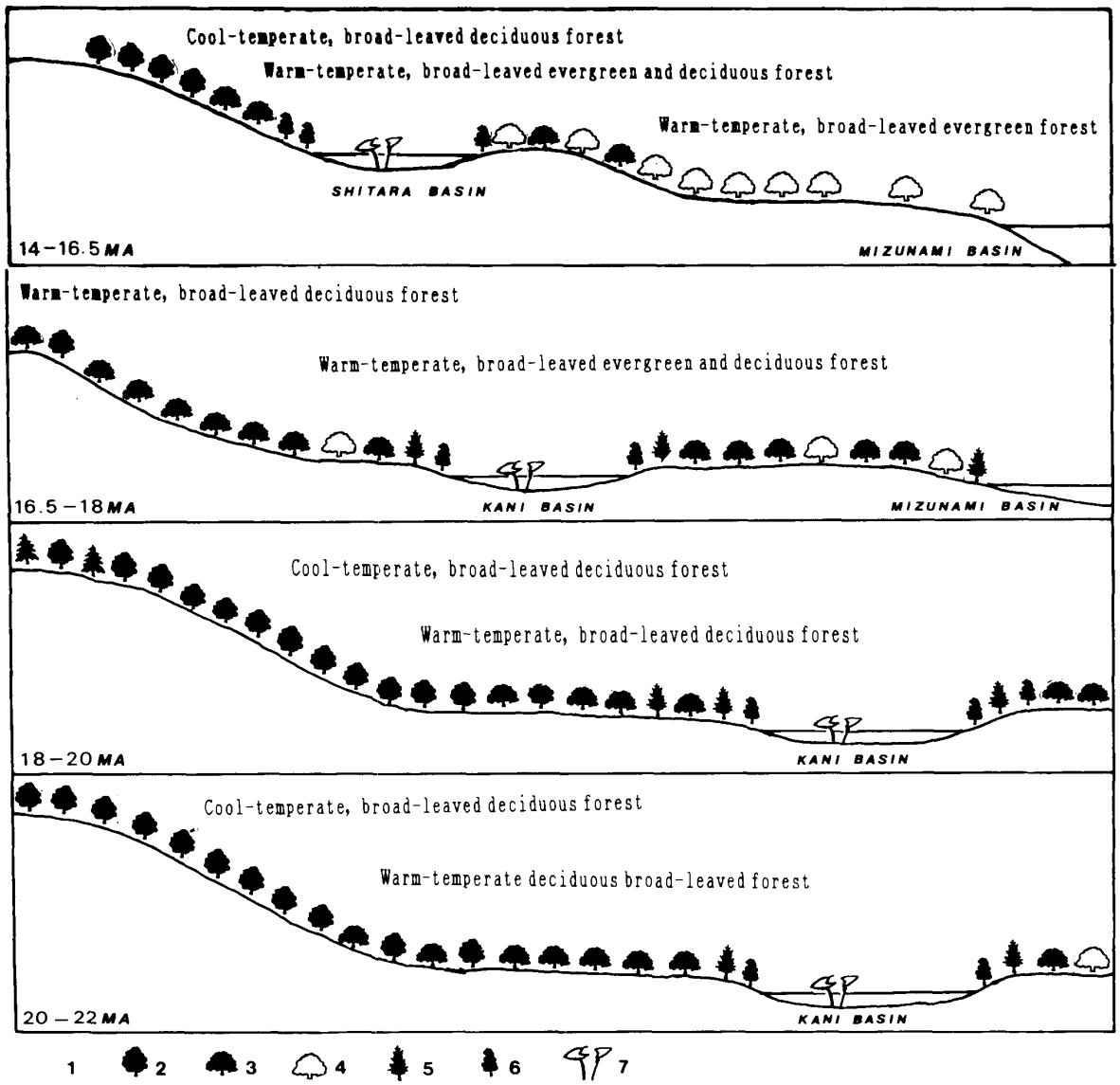


Fig. 2 Miocene vegetation in the eastern part of the Seotuchi Geologic Province.
1 : subalpine conifers 2 : cool-temperate, broad-leaved deciduous trees 3 : warm-temperate, broad-leaved deciduous trees 4 : warm-temperate, broad-leaved evergreen trees 5 : warm-temperate conifers 6 : species constituting fringing and ravine forests 7 : aquatic plants.

To the contrary broad-leaved evergreen trees are predominant in the Shukunohora and Oidawara floras. A subtropical~warm-temperate, broad-leaved evergreen forest with *Myrica* sp., *Castanopsis miocuspidata, Passania mioedulis, Quercus nathorsti, Quercus praegilva, Quercus protoacuta, Quercus protosalicina, Quercus* sp., *Ficus* sp., *Actinodaphne nipponica, Cinnamomum miocenum, Machilus nathorsti, Machilus ugoana, Neolitsea* sp., *Loropetalum* sp., *Buxus protojaponica, Ilex ohashii, Meliosma* sp. and *Camellia protojaponica* seems to have grown in lowlands along the coast. The occurence in the Oidawara Formation of cupula of *Fagus antipofi* and *Fagus palaeo-crenata* suggests the existence of a cool-temperate, broad-leaved deciduous forest in higher mountains. The predominance of broad-leaved deciduous trees in the Shibaishitoge flora seems to be due to the greater altitude of the lake in which enclosing sediments of the flora were deposited.

A schematic diagram of vegetation for each age of the eastern part of the Setouchi Geologic Province is given in Fig. 2.

CLIMATIC HISTORY

The paleoclimate of the eastern part of the Setouchi Geologic Province is inferred from comparing the Miocene forest types of lowlands of this area to the modern correlatives in east Asia and China. It is also deduced from the vertical distribution of the modern equivalents to those commonly found in the Tokai district of Japan (Table 2), and the geographic distribution of modern equivalents in Japan (Appendix II).

20-22 Ma

The Mixed Mesophitic forest of east Asia, the modern correlative of the warm-temperate, broad-leaved deciduous forest indicated by the Hachiya flora is distributed in areas which have the mean annual temperature of 10°~13°C, the cold month mean of −2°~1°C and the warm month mean of higher than 20°C (Wolfe, 1979).

The temperate, broad-leaved deciduous forest including subtropical deciduous trees, another modern correlative of China, grows in areas which have the mean annual temperature of 12°~14°C, the cold month mean of −4°~0°C , the warm month mean of 27°~28°C and the annual precipitation of 800~1,000mm.

For the altitude of 800m in the Tokai district the mean annual temperature is 9°C, the cold month mean of −2°C and the warm month mean of 21°C. With respect to species which constituted forest in lowlands, most of their modern equivalents seem to grow in areas lower than 800m in altitude.

Climatic conditions of lowlands in this age are estimated from these data as follows: the mean annual temperature is within the range of 10°~13°C, the cold month mean within the range of −2°~1°C, the warm month mean within the range of 21°~28°C and the annual precipitation within the range of 800~1,000mm.

The warm-temperate broad-leaved forest was associated with a small number of broad-leaved evergreen trees. This suggests that the temperature and the precipitation for the forest are probably placed near the upper limits of the above ranges.

Plant fossils were collected from various horizones in the Hachiya Formation. There is little floral difference between these horizons. This indicates that there was

no remarkable climatic change during this age.

18-20 Ma

The vegetational similarity between this and preceding ages indicates the climatic similarity between them . The warm-temperate, broad-leaved deciduous forest of this age, however, was not associated with broad-leaved evergreen trees. The absence of such trees seems to suggest that the temperature and the precipitation of this age were slightly lower than those of 20-22 Ma. The Hiyoshi flora of the Kani basin hardly differs from that of the Mizunami basin, indicating no climatic difference between the two basins.

16.5-18 Ma

The Notophyllous Broad-leaved Evergreen forest in east Asia, the modern correlative of the warm-temperate, broad-leaved evergreen and deciduous forest indicated by the Hiramaki, Inkyoyama, Akeyo, Agi, Toyama, Tajikara and Tomikusa floras is distributed in areas which have the mean annual temperature of 13°~20°C, the cold month mean of higher than 1°C and the warm month mean of higher than 20°C (Wolfe, 1979).

The subtropical, broad-leaved deciduous forest including broad-leaved evergreen trees, another modern correlative of China grows in areas which have the mean annual temperature of 14°~16°C, the cold month mean of 0°~3°C, the warm month mean of 27°~29°C and the annual precipitation of 800~1,200mm.

The Tokai district has the mean annual temperature of 13°C, the cold month mean of 2°C and the warm month mean of 25°C at the altitude of 300m. With respect to species which constituted forest in lowlands, most of their modern equivalents seem to grow in areas lower than 300m in altitude.

Climatic conditions of lowlands in this age are estimated from these data as follows: the mean annual temperature is within the range of 13°~16°C, the cold month mean within the range of 1°~3°C, the warm month mean within the range of 25°~29°C and the annual precipitation within the range of 800~1,200mm.

The floras of marine sediments contain much more broad-leaved evergreen trees and conifers than those of lacustrine sediments. This suggests that the annual precipitation for the former was larger than that for the latter.

14-16.5 Ma

A warm-temperate, broad-leaved evergreen forest indicated by the Shukunohora and Oidawara floras is correlated with the Notophyllous Broad-leaved Evergreen forest in east Asia.

The subtropical, broad-leaved evergreen forest, another modern correlative of China grows in areas which have the mean annual temperature of 16°~19°C, the cold month mean of 3°~10°C, the warm month mean of 24°~30°C and the annual precipitation of 1,200~4,000mm.

The Tokai district has the mean annual temperature of 15°C, the cold month mean of 5°C and the warm month mean of 27°C at the altitude of 0m . With respect to species which constituted forest in lowlands, most of their modern equivalents seem to grow in areas of 0m in altitude.

Climatic conditions of lowlands in this age are estimated from these data as follows: the mean annual temperature is within the range of 15°~20°C, the cold month

mean within the range of 3°～10°C, the warm month mean within the range of 24°～30° C and the annual precipitation within the range of 1,200～4,000mm.

The pollens of mangroves were described from the Shukunohora Sandstone Member (Konomatsu, 1989). It suggests that the temperature and precipitation for the forest are probably placed near the upper limits of the above range in the age when the Shukunohora Sandstone Member accumulated.

A warm-temperate, broad-leaved evergreen and deciduous forest indicated by Shibaishitoge flora is correlated with the Notophyllous Broad-leaved Evergreen forest in east Asia and the subtropical, broad-leaved deciduous forest including broad-leaved evergreen trees, another modern correlative of China.

With respect to species which constituted forest in the site of a lake, most of their modern equivalents seem to grow in areas lower than 300m in altitude. Climatic conditions for the site are estimated as follows: the mean annual temperature is within the range of 13°～16°C, the cold month mean within the range of 2°～3°C and the warm month mean within the range of 25°～29°C.

CLIMATIC COMPARISON WITH KOREA AND ADJACENT REGIONS OF JAPAN

The Early to Middle Miocene climate of the eastern part of the Setouchi Geologic Province is compared with that of Korea and the adjacent regions of southwest Honshu inferred from correlative floras from them.

18-22 Ma

The Soyamatoge flora (Fuji and Yoshida, 1984) of Ishikawa Prefecture, the Itoo flora (Azuma and Furuichi, 1976) of Fukui Prefecture, the Changgi flora (Huzioka, 1972) of Kyongsang-bukdo and Yongdong flora (Huzioka, 1972) of Hamg'yeong-bukdo, Korea are nearly synchronous with the Hachiya and Hiyoshi flora. Many species of these floras are common to one another, suggesting that southwest Honshu was connected to the Asiatic Continent. Warm-temperate, broad-leaved deciduous trees contained in the Hachiya and Hiyoshi floras and broad-leaved evergreen trees found in the former, however, are not included in the other floras; A cool-temperate, broad-leaved deciduous forest seems to have prevailed in lowlands of the Hokuriku district and Korea, and the temperature and precipitation of these areas seem to have been lower than those of eastern part of the Setouchi region. This difference was probably caused by the differnce in distance from the sea; the latter was nearer to the sea than the former.

16.5-18 Ma

The following floras are chronologically placed in this age; the Kuragatake flora (Matsuo and Omura, 1965), the Ukawa flora (Fuji and Haba, 1983) and the Noroshi flora (Ishida, 1970) of Ishikawa Prefecture, the Yosa flora (Onoe, 1978) and the Toyooka flora (Tanai, 1961) of Kyoto Prefecture, the Koura flora (Tai, 1952; Takahashi, 1959) and the Fukui flora (Imamura, 1957; Takahashi, 1959) of Shimane Prefecture, and the Shiomachi flora (Takahashi, 1958) of Okayama and Hiroshima Prefectures in southwest Honshu, and the Tongcheon flora (Huzioka, 1972) of Kangweondo and the Kungshim flora (Huzioka, 1972) of Hamg'yeong-bukdo in Korea.

Among those floras the Kuragatake, Ukawa, Noroshi, Koura, Fukui and Shiomachi

Table 2-1 Mean annual temperature of the eastern part of the Setouchi Geologic Province in the Miocene.

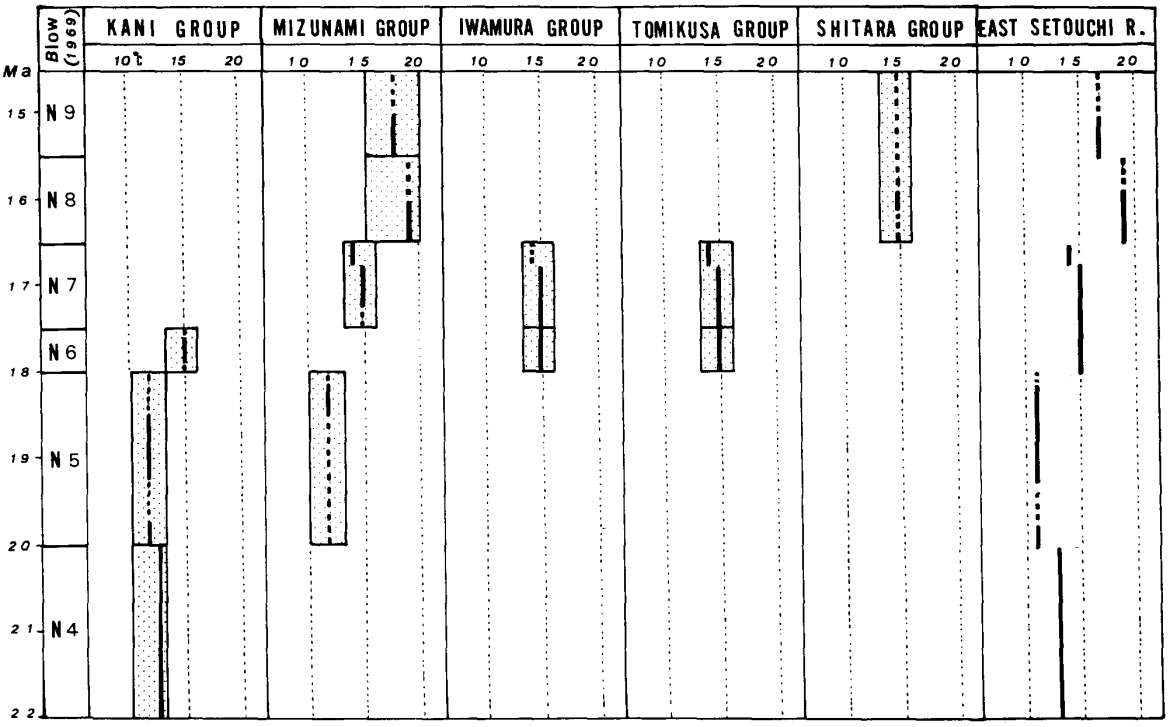


Table 2-2 Cold month mean of the eastern part of the Setouchi Geologic Province in the Miocene.

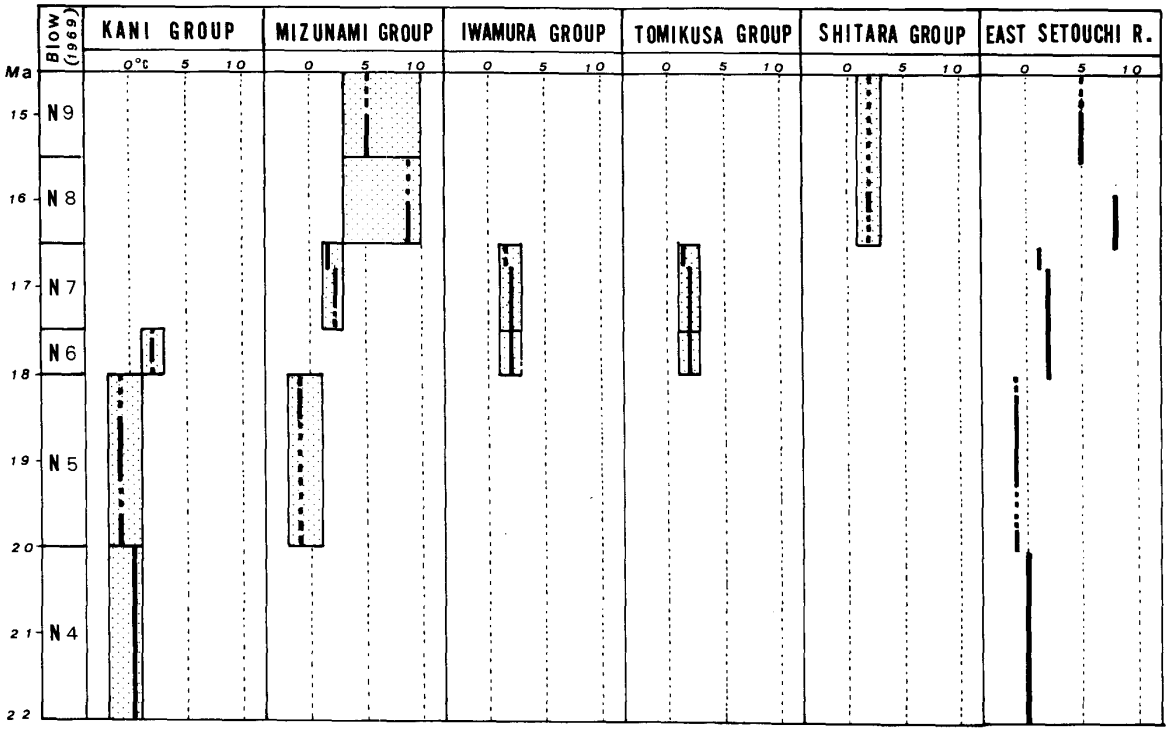


Table 2-3 Warm month mean of the eastern part of the Setouchi Geologic Province in the Miocene.

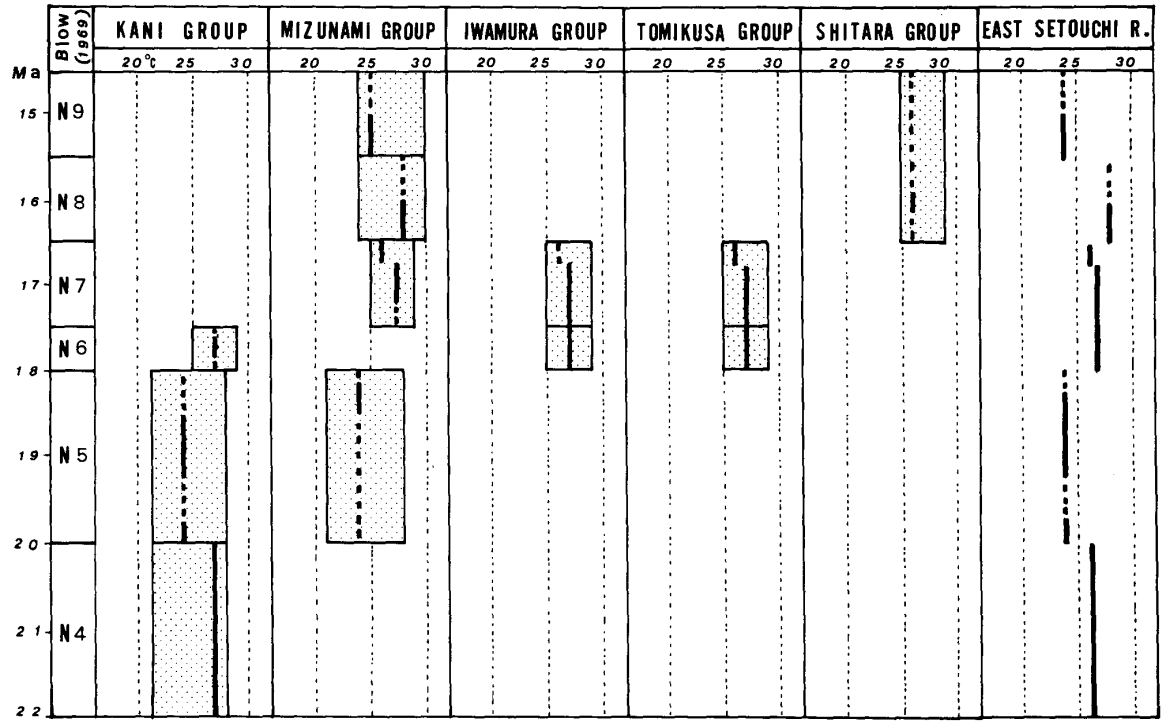
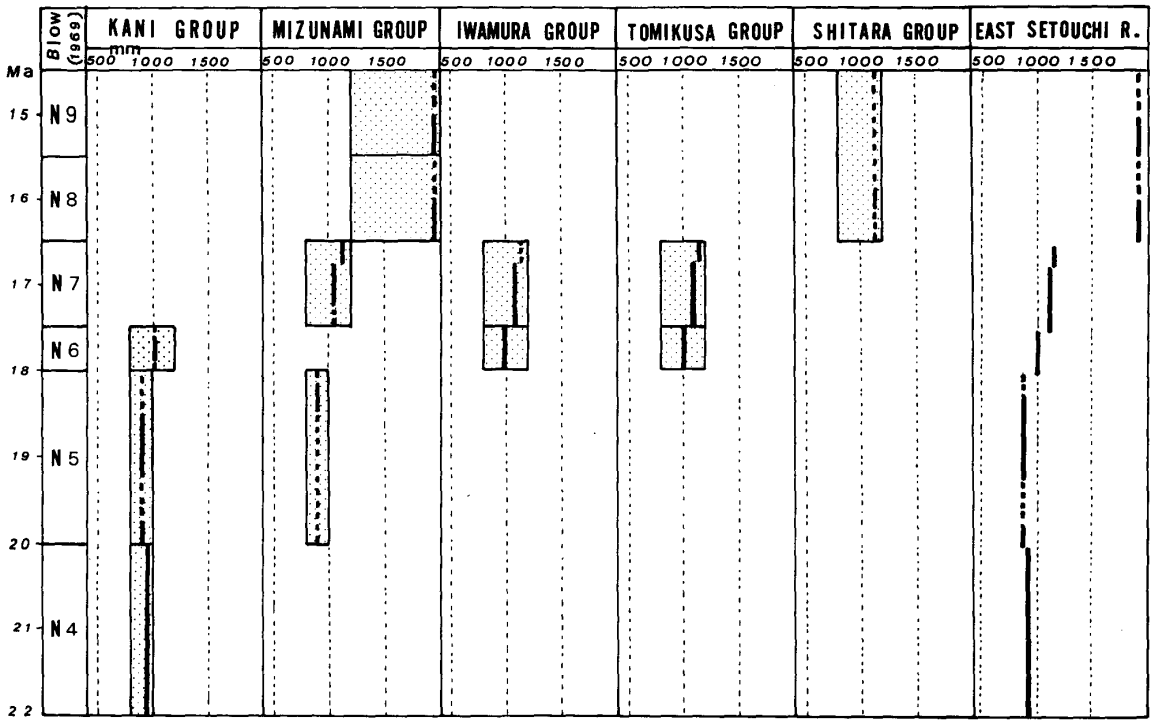


Table 2-4 Annual precipitation of the eastern part of the Setouchi Geologic Province in the Miocene.



floras are mixture of broad-leaved evergreen and deciduous trees. The Yosa and Toyooka floras abundantly include deciduous trees whose modern equivalents grow in the cool-temperate zone to the warm-temperate zone. Such trees are predominant in the Tongcheon and Kungshim floras, and evergreen trees are absent in them.

From these floras it is inferred that warm-temperate, broad-leaved evergreen and deciduous forests widely prevailed in lowlands of southwest Honshu, but warm-temperate, broad-leaved deciduous forests were distributed in those of Korea and a part of southwest Honshu. The mean annual temperature of Korea seems to have been 2° C lower than that of the eastern part of the Setouchi Geologic Province, the cold month mean of the former seems to have been 3°～4°C lower than that of the latter, and the annual precipitation of the former seems to have been smaller than that of the latter.

In this age warm-temperate, broad-leaved evergreen forests were not established in southwest Honshu, but warm-temperate, broad-leaved evergreen and deciduous forests were established. It seems to have been due to a very small winter precipitation owing to the absence of a sea between southwest Honshu and Korea.

14-16.5 Ma

The Notonakajima flora (Matsuo, 1963) of Ishikawa Prefecture, the Takakubo flora (Takahashi, 1959; Hojo, 1973) of Shimane Prefecture and the Yeonil flora (Huzioka, 1972) of Kyongsang-bukdo and the Hamjindong flora (Huzioka, 1972) of Hamg'yeong-bukdo, Korea are assigned to this age.

Broad-leaved evergreen trees are predominant in the Notonakajima and Takakubo floras as in the Shukunohora and Oidawara floras. The Yeonil flora is a mixture of broad-leaved evergreen and deciduous trees. The Hamjindong flora is dominated by broad-leaved deciduous trees of which modern equivalents grow in the warm-temperate zone to the cool-temperae zone. The floras of southwest Honshu indicate that warm-temperate to subtropical, broad-leaved evergreen forests grew in lowlands of southwest Honshu, and that the vegetation changed into a warm-temperate, broad-leaved evergreen and deciduous forest and then into a cool-temperate, broad-leaved deciduous forest with increase in altitude. Warm-temperate, broad-leaved evergreen and deciduous forests seem to have grown in south Korea, and warm-temperate, broad-leaved deciduous forests seem to have flourished in north Korea.

The mean annual temperature, the cold month mean and the annual precipitation of the eastern part of the Setouchi Geologic Province compared with those of southwest Honshu were probably as follows; 2°～3°C lower than the mean annual temperature of southwest Honshu, 3°～4°C lower than the cold month mean of it and 400～600mm smaller than the annual precipitation of it, and those of north Korea were probably as follows; 4°～5°C lower than the mean annual temperature of southwest Honshu, 7°～10°C lower than the cold month mean of it and 400～1,000mm smaller than the annual precipitation of it.

A vegetational and climatic interpretation of these floras suggests that the warm-temperate, broad-leaved evergreen forests appeared in southwest Honshu according to the increase of the winter precipitation in it as a result of the the establishment of a sea between it and Korea.

A vegetational map is given for each age in Fig. 3.

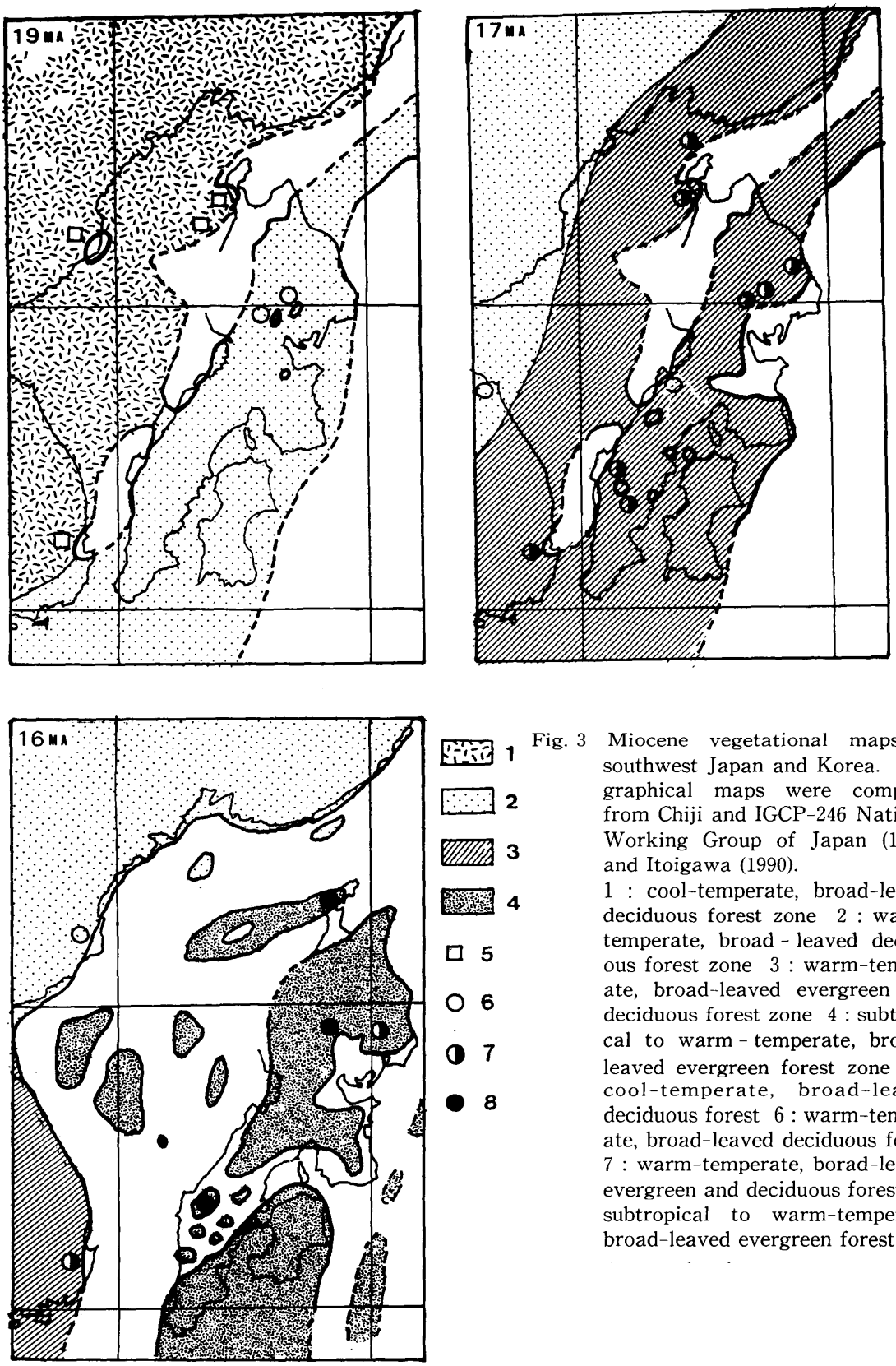


Fig. 3 Miocene vegetational maps of southwest Japan and Korea. Geographical maps were compiled from Chiji and IGCP-246 National Working Group of Japan (1989), and Itoigawa (1990).
1 : cool-temperate, broad-leaved deciduous forest zone 2 : warm-temperate, broad-leaved deciduous forest zone 3 : warm-temperate, broad-leaved evergreen and deciduous forest zone 4 : subtropical to warm-temperate, broad-leaved evergreen forest zone 5 : cool-temperate, broad-leaved deciduous forest 6 : warm-temperate, broad-leaved deciduous forest 7 : warm-temperate, borad-leaved evergreen and deciduous forest 8 : subtropical to warm-temperate, broad-leaved evergreen forest.

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Appendix I Checklist of constituent species of the Miocene floras from the eastern part of the Setouchi Geologic Province

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Equisetum sp.		+	+					+		+		
Osmunda japonica Thunberg fossilis Oishi and Huzioka		+										
Osmunda tsunemoriensis Matsuo												+
Ctenis sp.	+											
Cyclosorus sp.	+											
Dryopteris sp.			+							+		
Salvinia pseudoformosa Oishi and Huzioka		+	+									
Cephalotaxus sp.	+											
Abies sp.		+										
Keteleeria ezoana Tanai		+	+	+	+			+	+		+	
Picea kanoi Huzioka		+										
Picea magna Macginitie		+										
Picea miocenica Tanai		+										
Pinus miocenica Tanai			+	+	+	+	+		+		+	
Pinus oishii Ishida											+	
Pseudolarix japonica Tanai and Onoe		+						+				
Pseudotsuga ezoana Tanai								+	+	+	+	
Pseudotsuga huziokana Ozaki					+							
Tsuga miocenica Tanai		+						+				
Tsuga miosieboldiana Ozaki			+		+				+		+	
Sciadopitys sp.			+				+					
Cunninghamia protokonishii Tanai and Onoe				+	+		+	+	+		+	
Glyptostrobus europaeus (Brongniart) Heer		+				+						
Metasequoia occidentalis (Newberry) Chaney	+	+	+	+	+	+	+	+	+	+	+	
Sequoia langsdorfii (Brongniart) Heer	+											
Cfr. *Sequoiadendron primarium* Miki									+		+	
Calocedrus notoensis (Matsuo) Ishida			+		+				+		+	
Juniperus sp.		+										
Populus balsamoides Goeppert	+	+	+					+				
Populus kobayashii Suzuki												+
Populus tuberculata Ishida											+	
Populus sp. A			+									
Populus sp. B				+								
Salix k-suzukii Tanai				+					+			
Salix miosinica Hu and Chaney	+			+						+	+	
Salix varians Goeppert		+										
Salix sp.			+									
Comptonia naumanni (Nathorst) Huzioka				+		+	+		+		+	
Myrica sp.							+					
Carya miocathaensis Hu and Chaney	+	+						+				
Juglans japonica Tanai		+									+	
Juglans miocathaensis Hu and Chaney	+											
Juglans miochinensis (Tanai and Onoe) Suzuki												+
Juglans shanwangensis Hu and Chaney			+					+	+			
Juglans sp.				+								

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Platycarya miocenica Hu and Chaney	+	+										
Pterocarya asymmetrosa Konno	+	+	+	+				+	+	+	+	+
Pterocarya ezoana Tanai and N. Suzuki			+	+								+
Pterocarya cfr. *nipponica* Tanai and Onoe				+								
Pterocarya protostenoptera Tanai			+									
Pterocaya sp.			+									
Alnus arasensis Huzioka	+		+	+				+		+		
Alnus kefersteinii (Goeppert) Unger	+	+	+						+			
Alnus miojaponica Tanai	+										+	+
Alnus penepalensis Hu and Chaney	+	+										
Alnus protomaximowiczii Tanai		+		+								
Alnus sakaii Huzioka		+										
Alnus subfirma Tanai and N. Suzuki			+	+								+
Alnus usyuensis Huzioka		+						+	+			
Alnus sp. A				+								
Alnus sp. B												+
Alnus sp. C									+			
Betula mioluminifera Hu and Chaney	+	+		+				+	+		+	
Betula nathorsti Suzuki		+		+								+
Betula onbaraensis Tanai	+											
Betula protoermanni Endo			+	+								+
Betula uzenensis Tanai	+		+									+
Betula sp.												+
Carpinus ishikiensis Tanai and Onoe		+										
Carpinus kodairae-bracteata Huzioka		+										
Carpinus cfr. *megabracteata* Hu and Chaney			+									
Carpinus miocenica Tanai		+										
Carpinus miofangiana Hu and Chaney			+	+				+	+	+		
Carpinus mioturczaninovii Hu and Chaney			+					+				
Carpinus shimizui Tanai		+		+								
Carpinus s-satoi Tanai and Onoe		+										
Carpinus stenopylla Nathorst	+	+	+					+	+		+	
Carpinus subcordata Nathorst	+	+	+	+				+	+		+	+
Carpinus subyedoensis Konno	+	+	+	+	+	+		+	+	+		+
Carpinus sp. A	+											
Carpinus sp. B			+									
Carpinus sp. C					+							
Corylus macquarrii (Forbes) Heer	+											
Corylus subsieboldiana Suzuki	+		+					+			+	
Ostrya shiragiana Huzioka	+	+	+	+					+	+	+	+
Castanea kubinyi Kovats	+											
Castanea miomollissima Hu and Chaney	+	+	+	+				+	+		+	
Castanopsis miocuspidata Matsuo				+			+		+		+	
Castanopsis sp.				+								
Fagus antipofi Heer	+	+					+	+			+	

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Fagus palaeocrenata Okutsu							+					
Passania mioedulis Kobatake						+			+			
Quercus miovariabilis Hu and Chaney			+	+	+			+	+	+	+	
Quercus nathorsti Kryshtofovich				+		+	+		+		+	
Quercus praegilva Kryshtofovich							+					
Quercus protoacuta Suzuki							+					+
Quercus protoaliena Ozaki											+	
Quercus protosalicina Suzuki			+		+		+					+
Quercus protoserrata Tanai and Onoe									+			
Quercus sinomiocenicum Hu and Chaney				+								
Quercus sp. A				+	+	+	+	+	+		+	
Quercus sp. B							+					
Quercus sp. C			+			+						
Quercus sp. D						+						
Quercus sp. E											+	
Aphananthe sp.								+				
Celtis miobungeana Hu and Chaney						+						
Celtis sp. A			+									
Celtis sp. B			+									
Celtis sp. C			+									
Celtis sp. D				+								
Ulmus appendiculata Heer	+							+				
Ulmus carpinoides Goeppert			+							+	+	
Ulmus harutoriensis Oishi and Huzioka	+											
Ulmus lognifolia Unger			+					+	+	+	+	
Ulmus minoensis Huzioka		+										
Ulmus miopumila Hu and Chaney	+		+	+	+			+	+			+
Ulmus protojaponica Tanai and Onoe												+
Ulmus pseudolongifolia Oishi and Huzioka	+	+										
Ulmus shiragica Huzioka			+									
Ulmus takayasui Huzioka		+										
Ulmus sp.			+									
Zelkova ungeri (Ettings.) Kovats	+	+	+	+	+	+		+	+	+	+	+
Eucommia nipponica Ozaki					+							
Morus sp.				+								
Ficus sp. A			+			+						
Ficus sp. B				+								
Ficus sp. C												+
Ficus sp. D												+
Fagopyrum sp.			+									
Polygonum sp.			+									
Magnolia elliptica Tanai and Onoe											+	+
Magnolia miocenica Hu and Chaney	+	+	+	+	+	+		+	+	+	+	+
Magnolia sp. A	+											
Magnolia sp. B			+	+								

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Magnolia sp. C			+									
Magnolia sp. D				+								+
Tetracentron sp.				+								
Eupterea sp.												+
Cercidiphyllum crenatum (Unger) Brown		+										
Nelumbo endoana Oishi and Huzioka	+	+										
Nuphar sp.		+										
Nymphar ebae Ozaki		+										
Cocculus sp.			+									
Actinodaphne nipponica Tanai			+			+	+	+				
Actinodaphne oishii Huzioka								+				+
Cinnamomum lanceolatum (Unger) Heer					+				+		+	
Cinnamomum miocenum Morita						+	+		+		+	
Cinnamomum oguniense Morita								+	+		+	
Lindera gaudini (Nathorst) Tanai								+				
Lindera miyataensis Huzioka and Uemura			+						+			+
Lindera paraobtusiloba Hu and Chaney											+	
Lindera sp.											+	
Machilus nathorsti Huzioka						+						
Machilus ugoana Huzioka	+			+		+		+	+			
Neolitsea sp.				+		+						
Parabenzoin protopraecox (Endo) Tanai		+		+		+		+	+		+	
Parabenzoin sp.			+									
Sassafras subtriloba (Konno) Tanai and Onoe		+		+								+
Deutzia sp.						+						
Hydrangea lanceolimba Hu and Chaney	+											
Hydrangea sp. A	+											
Hydrangea sp. B												+
Pittosporum sp.				+								
Corylopsis kobensis Kobatake									+			
Hamamelis cfr. *miomolis* Hu and Chaney			+									
Hamamelis sp.								+				
Liquidambar miosinica Hu and Chaney			+	+				+	+	+		
Liquidambar protopalmata (K. Suzuki) Uemura			+					+				
Loropetalum sp.							+					
Parrotia fagifolia (Goeppert) Heer			+	+				+	+	+	+	
Sycopsis chaneyi Ishida								+				
Prunus ishidai Tanai and N. Suzuki			+									
Prunus protossiori Tanai and Onoe												+
Prunus sp.			+							+		
Rosa usyuensis Tanai		+	+	+				+	+		+	+
Rosa sp.			+									
Sorbus cfr. *nipponica* Tanai and Onoe			+									
Sorbus sp. A	+											
Sorbus sp. B								+				

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Spiraea sp.		+										
Cassia notoensis Ishida								+				
Cassia sp.			+									
Cercis miochinensis Huzioka			+									
Cladrastis aniensis Huzioka	+		+	+		+		+	+	+	+	+
Desmodium tatsumitogeanum Ozaki												+
Desmodium sp.												+
Entada sp.												+
Gleditschia miosinensis Hu and Chaney			+					+			+	+
Indigofera sp.											+	
Kummerovia sp.									+			
Milletia notoensis Ishida					+			+		+		
Mucuna sp.				+								
Peuraria tanaii Ozaki				+	+							
Podogonium knorrii A. Brawn					+						+	
Robinia nipponica Tanai								+	+	+	+	+
Sophora miojaponica Hu and Chaney						+				+	+	+
Wistaria fallax (Nathorst) Tanai and Onoe	+		+					+	+	+	+	+
Phellodendron mioamurense Tanai and N. Suzuki												+
Ailanthus cfr. *yezoensis* Oishi and Huzioka			+									
Mallotus populifolia Hu and Chaney			+			+			+			
Mallotus protojaponica Ozaki					+							
Mallotus sp.			+									
Buxus protojaponica Tanai and Onoe					+	+		+				+
Rhus miosuccedanea Hu and Chaney	+							+	+		+	
Rhus nathorsti Tanai												+
Rhus protoambigua Suzuki	+					+			+			
Rhus sp. A			+									
Rhus sp. B												+
Ilex heeri Nathorst											+	
Ilex ohashii Huzioka						+	+					
Ilex sp. A			+									
Ilex sp. B										+		
Euonymus protobungeana Hu and Chaney		+										
Euonymus sp.											+	
Perrotetia notoensis Ishida									+		+	
Acer chiharae Huzioka and Nishida											+	
Acer ezoanum Oishi and Huzioka	+	+	+					+	+		+	
Acer nordenskiöldi Nathorst	+		+	+	+			+		+		+
Acer palaeorufinerve Tanai and Onoe	+											+
Acer protojaponicum Tanai and Onoe		+										
Acer protonegundo Tanai			+									
Acer prototrifidium Tanai			+								+	
Acer pseudocarpinifolium Endo				+								
Acer rotundatum Huzioka	+	+	+		+			+	+		+	

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Acer submayrii Tanai and Onoe												+
Acer subnikoense Tanai and Ozaki			+									
Acer tokiensis Ozaki					+							
Acer tottoriense Tanai and Ozaki	+											
Acer tricuspidatum Bronn		+										
Acer yamanae Tanai and Ozaki		+	+							+	+	
Acer sp.			+									
Aesculus majus (Nathorst) Tanai				+								
Sapindus tanaii Onoe			+						+		+	+
Meliosma shanwangensis Hu and Chaney			+									
Meliosma sp.				+		+						
Berchemia floribunda Brongniart			+	+								
Hovenia miodulcis Hu and Chaney	+											
Ampelopsis sp.									+			
Vitis naumanni (Nathorst) Tanai				+				+				
Vitis sp. A	+	+	+						+			
Vitis sp. B				+		+						
Elaeocarpus notoensis Ishida	+											
Tilia hommashinichii Huzioka and Nishida	+											
Tilia sekiensis Huzioka and Nishida	+											
Tilia subnobilis Huzioka											+	
Tilia sp.	+											
Firmiana sp.				+					+			
Camellia protojaponica Huzioka						+			+			
Camellia sp.											+	
Stewartia submonadelpha Tania and Onoe								+	+			
Ternstroemia maekawai Matsuo											+	+
Viola sp.			+									
Elaeagnus sp.												+
Alangium aequalifolium (Goeppert) Krysht. and Borsuk	+	+	+					+	+			
Hemitrapa borealis (Heer) Miki	+	+										
Hemitrapa hokkaidoensis (Okutsu) Miki	+	+										
Acanthopanax sp.	+											
Aralia hokiana Ozaki												+
Cornus megaphylla Hu and Chaney	+		+									+
Cornus minoensis Huzioka		+	+			+						
Cornus subkousa Tanai and Onoe			+	+						+		
Clethra maximowiczii Nathorst	+											+
Clethra sp.				+						+		
Maesa sp.			+									
Diospyros miokaki Hu and Chaney	+		+			+			+			
Symplocos sp.			+									
Styrax miyataensis Huzioka and Uemura	+											
Styrax protoobassia Tanai and Onoe										+		
Styrax sp. A			+									

Species	floras											
	1	2	3	4	5	6	7	8	9	10	11	12
Styrax sp. B												+
Fraxinus honshuensis Tanai and Onoe			+									
Syringa notoensis Ishida												+
Ligustrum sp.			+									+
Osmanthus sp.										+		
Ehretia sp.				+				+	+			
Clerodendron sp.									+			
Viburnum miocenicum Tanai and N. Suzuki	+											
Viburnum uzenensis Huzioka												+
Lonicera sp.									+			
Gramineae								+				
Cfr. *Phragmites* sp.					+							
Sasa sp.			+									
Carex sp.			+		+							
Lemna sp.			+									+
Smilax trinervis Morita			+					+			+	
Carpolithes japonica (Morita) Ishida			+									
Banisteriaecarpum giganteum (Goeppert) Krausel	+	+						+				
Total	65	62	101	62	27	32	18	61	62	29	62	58

1 : Hachiya flora, 2 : Hiyoshi flora, 3 : Hiramaki flora, 4 : Akeyo flora, 5 : Inkyoyama flora, 6 : Shukunohora flora, 7 : Oidawara flora, 8 : Agi flora, 9 : Toyama flora, 10 : Tajikara flora, 11 : Tomikusa flora, 12 : Shibaishitoge flora

Appendix II Climatic occurence of species representing modern equivalents of Miocene species from the eastern part of the Setouchi Geologic Province

Species	Living equivalents	SA	CT	WT	ST
Equisetum sp.	*E. hiemale*	+	+		
Osmunda japonica fossilis	*O. japonica*	+	+	+	+
Osmunda tsunemoriensis	*O. japonica*	+	+	+	+
Ctenis sp.	*C. subglandulosa*			+	+
Cyclosorus sp.	*C. parasiticus*			+	+
Dryopteris sp.	*D. erythrosora*			+	+
Salvinia pseudoformosa	*S. formosa*				+
Cephalotaxus sp.	*C. harringtonia*			+	
Abies sp.	*A. firma*		+	+	
Keteleeria ezoana	*K. davidiana*			+	+
Picea kanoi	*P. jezoensis hondoensis*	+			
Picea magna	*P. polita*		+	+	
Picea miocenica	*P. polita*		+	+	
Pinus miocenica	*P. densiflora*		+	+	
Pinus oishii	*P. pentaphylla*	+	+		
Pseudolarix japonica	*P. amabilis*		+	+	
Pseudotsuga ezoana	*P. japonica*		+	+	
Pseudotsuga huziokana	*P. japonica*		+	+	
Tsuga miocenica	*T. longibracteata*		+	+	
Tsuga miosieboldiana	*T. sieboldii*		+	+	
Sciadopitys sp.	*S. verticilata*		+	+	
Cunninghamia protokonishii	*C. konishii*			+	
Glyptostrobus europaeus	*G. lineatus*			+	+
Metasequoia occidentalis	*M. glyptostroboides*			+	
Sequoia langsdorfii	*S. sempervirens*			+	
Cfr. *Sequoiadendron primarium*	*S. giganteum*		+	+	
Calocedrus notoensis	*C. macrolepis*			+	+
Juniperus sp.	*J. sargentii*	+	+		
Populus balsamoides	*P. balsamifera*		+		
Populus kobayashii	*P. sieboldii*		+		
Populus tuberculata	*P. simonii*		+		
Populus sp. A	*P. sieboldii*		+		
Populus sp. *B*	*P. sieboldii*		+		
Salix k-suzukii	*S. jezoensis*	+	+		
Salix miosinica	*S. wilsoniis*		+	+	
Salix varians	*S. sacharinensis*	+	+		
Salix sp.	*S. sacharinensis*	+	+		
Comptonia naumanni	*C. peregrina*			+	
Myrica sp.	*M. rubura*			+	
Carya miocathaensis	*C. cathaensis*			+	
Juglans japonica	*J. ailanthifolia*		+	+	
Juglans miocathaensis	*J. cathaensis*		+	+	
Juglans miochinesis	*J. ailanthifolia*		+	+	
Juglans shanwangensis	*J. regia*		+	+	
Juglans sp.	*J. ailantifolia*		+	+	

Species	Living equivalents	SA	CT	WT	ST
Platycarya miocenica	*P. stroboilacea*			+	
Pterocarya asymmetrosa	*P. rhoifolia*		+		
Pterocarya ezoana	*P. paliurus*			+	
Pterocarya cfr. *nipponica*	*P. rhoifolia*		+		
Pterocarya protostenoptera	*P. stenoptera*		+	+	
Pterocaya sp.	*P. rhoifolia*		+		
Alnus arasensis	*A. japonica*	+	+	+	+
Alnus kefersteinii	*A. sitchensis*		+		
Alnus miojaponica	*A. japonica*	+	+	+	+
Alnus penepalensis	*A. nepalensis*		+	+	
Alnus protomaximowiczii	*A. maximowiczii*	+	+		
Alnus sakaii	*A. hirsuta*	+	+	+	
Alnus subfirma	*A. firma*		+	+	
Alnus usyuensis	*A. sitchensis*		+		
Alnus sp. A	*A. trabeculosa*			+	
Alnus sp. B	*A. pendula*		+	+	
Alnus sp. C	*A. sieboldiana*			+	
Betula mioluminifera	*B. luminifera*		+	+	
Betula nathorsti	*B. grossa*		+	+	
Betula onbaraensis	*B. grossa*		+	+	
Betula protoermanni	*B. ermanii*	+	+		
Betula uzenensis	*B. schmidtii*		+		
Betula sp.	----------				
Carpinus ishikiensis	----------				
Carpinus kodairae-bracteata	*C. laxiflora*		+	+	
Carpinus cfr. *megabracteata*	*C. kweichowensis*			+	
Carpinus miocenica	*C. laxiflora*		+	+	
Carpinus miofangiana	*C. fangiana*		+	+	
Carpinus mioturczaninovii	*C. turczaninovii*		+	+	
Carpinus shimizui	----------				
Carpinus s-satoi	*C. turczaninovii*		+	+	
Carpinus stenopylla	*C. japonica*		+		
Carpinus subcordata	*C. cordata*		+		
Carpinus subyedoensis	*C. tschonoskii*		+	+	
Carpinus sp. A	*C. cordata*		+		
Carpinus sp. B	----------				
Carpinus sp. C	*C. kweitingensis*		+	+	
Corylus macquarrii	*C. heteropylla*		+		
Corylus subsieboldiana	*C. sieboldiana*		+		
Ostrya shiragiana	*O. japonica*		+	+	
Castanea kubinyi	*C. crenata*		+	+	
Castanea miomollissima	*C. mollissima*		+		
Castanopsis miocuspidata	*C. cuspidata*			+	+
Castanopsis sp.	*C. cuspidata*			+	+
Fagus antipofi	*F. grandifolia*		+		

Species	Living equivalents	SA	CT	WT	ST
Fagus palaeocrenata	*F. crenata*		+		
Passania mioedulis	*P. edulis*			+	+
Quercus miovariabilis	*Q. variabilis*		+	+	
Quercus nathorsti	*Q. glauca*			+	
Quercus praegilva	*Q. gilva*			+	
Quercus protoacuta	*Q. acuta*			+	
Quercus protoaliena	*Q. aliena*		+	+	
Quercus protosalicina	*Q. salicina*			+	
Quercus protoserrata	*Q. serrata*		+	+	
Quercus sinomiocenicum	*Q. acutissima*		+	+	
Quercus sp. A	*Q. hondai*				+
Quercus sp. B	*Q. salicina*			+	
Quercus sp. C	*Q. sessilifolia*			+	
Quercus sp. D	*Q. phillyraeoides*			+	
Quercus sp. E	*Q. morii*			+	
Aphananthe sp.	*A. aspera*		+	+	
Celtis miobungeana	*C. bungeana*		+	+	
Celtis sp. A	*C. jessoensis*		+		
Celtis sp. B	*C. jessoensis*		+		
Celtis sp. C	*C. jessoensis*		+		
Celtis sp. D	*C. sinensis*			+	
Ulmus appendiculata	*U. davidiana*		+		
Ulmus carpinoides	*U. davidiana*		+		
Ulmus harutoriensis	*U. davidiana*		+		
Ulmus longifolia	*U. lanceaefolia*			+	
Ulmus minoensis	*U. davidiana*		+		
Ulmus miopumila	*U. pumila*		+	+	
Ulmus protojaponica	*U. davidiana*		+		
Ulmus pseudolongifolia	*U. lanceaefolia*			+	
Ulmus shiragica	*U. davidiana*		+		
Ulmus takayasui	*U. davidiana*		+		
Ulmus sp.	*U. davidiana*		+		
Zelkova ungeri	*Z. serrata*		+	+	
Eucommia nipponica	*E. ulmoides*		+	+	
Morus sp.	*M. bombycis*	+	+	+	
Ficus sp. A	*F. thunbergii*			+	+
Ficus sp. B	*F. nipponica*			+	+
Ficus sp. C	*F. erecta*			+	
Ficus sp. D	*F. pumila*			+	+
Fagopyrum sp.	*F. esculentum*		+	+	
Polygonum sp.	*P. cuspidatum*		+	+	+
Magnolia elliptica	*M. obovata*		+	+	
Magnolia miocenica	*M. kobus*	+	+	+	
Magnolia sp. A	*M. obovata*		+	+	
Magnolia sp. B	*M. liliflora*		+	+	

Species	Living equivalents	SA	CT	WT	ST
Magnolia sp. C	*M. salicifolia*		+	+	
Magnolia sp. D	*M. sieboldii*		+		
Tetracentron sp.	*T. sinense*		+		
Eupterea sp.	*E. polyandra*		+	+	
Cercidiphyllum crenatum	*C. japonicum*		+	+	
Nelumbo endoana	*N. nucifera*			+	
Nuphar sp.	*N. japonica*		+	+	
Nymphar ebae	----------				
Cocculus sp.	*C. trilobus*		+	+	+
Actinodaphne nipponica	*A. longifolia*			+	+
Actinodaphne oishii	*A. lancifolia*			+	+
Cinnamomum lanceolatum	*C. japonicum*			+	+
Cinnamomum miocenum	*C. camphora*			+	+
Cinnamomum oguniense	*C. camphora*			+	+
Lindera gaudini	*L. glauca*			+	
Lindera miyataensis	*L. umbellata*		+	+	
Lindera paraobtusiloba	*L. obtusiloba*		+	+	
Lindera sp.	*L. umbellata*		+	+	
Machilus nathorsti	*M. thunbergii*			+	
Machilus ugoana	*M. japonica*			+	+
Neolitsea sp.	*N. sericea*			+	+
Parabenzoin protopraecox	*P. praecox*		+	+	
Parabenzoin sp.	*P. trilobum*			+	
Sassafras subtriloba	*S. tsumu*			+	
Deutzia sp.	----------				
Hydrangea lanceolimba	*H. umbellata*			+	
Hydrangea sp. A	*H. paniculata*		+		
Hydrangea sp. B	*H. macrophylla*			+	
Pittosporum sp.	*P. tobira*			+	+
Corylopsis kobensis	*C. spicata*			+	
Hamamelis cfr. *miomolis*	*H. molis*			+	
Hamamelis sp.	*H. japonica*		+	+	
Liquidambar miosinica	*L. formosana*			+	+
Liquidambar protopalmata	*L. styraciflua*			+	
Loropetalum sp.	*L. chinense*			+	
Parrotia fagifolia	*P. percia*			+	
Sycopsis chaneyi	*S. formosana*		+	+	
Prunus ishidai	*P. apetala*		+	+	
Prunus protossiori	*P. jamasakurai*		+	+	
Prunus sp.	*P. jamasakurai*		+	+	
Rosa usyuensis	*R. multiflora*		+	+	
Rosa sp.	*R. wichuraiana*			+	+
Sorbus cfr. *nipponica*	*S. rufo-ferrugundiana*			+	
Sorbus sp. A	*S. japonica*		+	+	
Sorbus sp. B	*S. gracilis*		+		

Species	Living equivalents	SA	CT	WT	ST
Spiraea sp.	*S. saliciflora*	+	+		
Cassia notoensis	*C. siamera*			+	+
Cassia sp.	*C. tora*			+	
Cercis miochinensis	*C. chinensis*		+	+	
Cladrastis aniensis	*C. platycarpa*		+	+	
Desmodium tatsumitogeanum	*D. oldhamii*		+	+	
Desmodium sp.	*D. oldhamii*		+	+	
Entada sp.	*E. phaseoloides*			+	
Gleditschia miosinensis	*G. japonica*		+	+	
Indigofera sp.	*I. decora*			+	
Kummerovia sp.	*K. stipulacea*		+	+	
Milletia notoensis	*M. japonica*			+	
Mucuna sp.	*M. ferruginea*			+	+
Peuraria tanaii	*P. lobata*		+	+	
Podogonium knorrii	----------				
Robinia nipponica	*R. pseudo-acacia*		+	+	
Sophora miojaponica	*S. japonica*		+	+	
Wistaria fallax	*W. floribunda*		+	+	
Phellodendron mioamurense	*P. amurense*		+		
Ailanthus cfr. *yezoensis*	*A. altissima*		+	+	
Mallotus populifolia	*M. apelta*			+	
Mallotus protojaponica	*M. japonicus*			+	
Mallotus sp.	*M. japonicus*			+	
Buxus protojaponica	*B. japonica*			+	
Rhus miosuccedanea	*R. succedanea*			+	
Rhus nathorsti	*R. sylvestris*			+	
Rhus protoambigua	*R. ambigua*		+		
Rhus sp. A	*R. tricocarpa*		+	+	
Rhus sp. B	*R. verniciflua*		+	+	
Ilex heeri	*I. pedunclosa*			+	
Ilex ohashii	*I. rotunda*			+	+
Ilex sp. A	*I. geniculata*		+		
Ilex sp. B	*I. rotunda*			+	+
Euonymus protobungeana	*E. bungeana*		+	+	
Euonymus sp.	*E. japonicus*			+	
Perrotetia notoensis	*P. arisanensis*			+	
Acer chiharae	*A. mono*		+	+	
Acer ezoanum	*A. saccharinum*		+		
Acer nordenskiöldi	*A. palmatum*			+	
Acer palaeorufinerve	*A. rufinerve*		+	+	
Acer protojaponicum	*A. japonicum*		+		
Acer protonegundo	*A. negundo*		+	+	
Acer prototrifidium	*A. trifidium*			+	
Acer pseudocarpinifolium	*A. carpinifolium*		+		
Acer rotundatum	*A. mono*	+	+	+	

Species	Living equivalents	SA	CT	WT	ST
Acer submayrii	*A. rufinerve*		+	+	
Acer subnikoense	*A. nikoense*		+		
Acer tokiensis	*A. miyabei*	+	+		
Acer tottoriense	*A. argutum*		+		
Acer tricuspidatum	*A. pycanthum*		+	+	
Acer yamanae	*A. saccharinum*		+		
Acer sp.	*A. buergerianum*			+	
Aesculus majus	*A. turbinata*		+		
Sapindus tanaii	*S. mukurossi*			+	+
Meliosma shanwangensis	*M. myriantha*			+	
Meliosma sp.	*M. rigida*			+	+
Berchemia floribunda	*B. racemosa*		+	+	
Hovenia miodulcis	*H. dulcis*			+	
Ampelopsis sp.	*A. brevipedunculata*		+	+	
Vitis naumanni	*V. coignetiae*	+	+		
Vitis sp. A	*V. coignetiae*	+	+		
Vitis sp. B	*V. flexuosa*			+	
Elaeocarpus notoensis	*E. japonicus*			+	+
Tilia hommashinichii	*T. maximowicziana*		+		
Tilia sekiensis	*T. japonica*		+		
Tilia subnobilis	*T. nobilis*		+		
Tilia sp.	*T. maximowiczii*		+		
Firmiana sp.	*F. platanifolia*			+	
Camellia protojaponica	*C. japonica*			+	
Camellia sp.	*C. sasanqua*			+	
Stewartia submonadelpha	*S. monadelpha*		+		
Ternstroemia maekawai	*T. japonica*			+	+
Viola sp.	*V. ovato-oblonga*			+	
Elaeagnus sp.	*E. pungens*			+	
Alangium aequalifolium	*A. chinensis*		+	+	
Hemitrapa borealis	----------				
Hemitrapa hokkaidoensis	----------				
Acanthopanax sp.	*A. sciadophylloides*		+	+	
Aralia hokiana	*A. cordata*		+	+	
Cornus megaphylla	*C. bracypoda*		+	+	
Cornus minoensis	*C. controversa*		+	+	
Cornus subkousa	*C. kousa*		+		
Clethra maximowiczii	*C. barbinervis*		+	+	
Clethra sp.	*C. barbinervis*		+	+	
Maesa sp.	*M. japonica*			+	
Diospyros miokaki	*D. kaki*		+	+	
Symplocos sp.	*S. lancifolia*			+	
Styrax miyataensis	*S. obassia*		+		
Sryrax protoobassia	*S. obassia*		+		
Styrax sp. A	*S. subniveus*			+	

Species	Living equivalents	SA	CT	WT	ST
Styrax sp. B	*S. shiraiana*			+	
Fraxinus honshuensis	*F. eanuginosa*		+	+	
Syringa notoensis	*S. reticulata*		+		
Ligustrum sp.	*L. obtusifolium*		+	+	
Osmanthus sp.	*O. heterophyllus*			+	
Ehretia sp.	*E. dicksonii*			+	+
Clerodendron sp.	*C. trichotomum*		+	+	+
Viburnum miocenicum	*V. theiferum*			+	
Viburnum uzenensis	*V. plicatum tomentosum*		+		
Lonicera sp.	*L. japonica*		+	+	+
Gramineae	----------				
Cfr. *Phragmites* sp.	----------				
Sasa sp.	----------				
Carex sp.	----------				
Lemna sp.	*L. paucicostata*		+	+	
Smilax trinervis	*S. china*		+	+	
Carpolithes japonica	----------				
Banisteriaecarpum giganteum	----------				

SA : subalpine zone, CT : cool-temperate zone, WT : warm-temperate zone, ST : subtropical zone.

Plate I Warm-temperate conifers

Figs. 1, 2 *Metasequoia occidentalis* (Newberry) Chaney (Tomikusa Group)
Figs. 3, 4, 5 *Pinus miocenica* Tanai (Oidawara Formation)
Fig. 6 *Cunninghamia protokonishii* Tanai and Onoe (Akeyo Formation)
Figs. 7, 9 *Keteleeria ezoana* Tanai (Akeyo Formation)
Fig. 8 *Pseudotsuga ezoana* Tanai (Tomikusa Group)
Fig. 10 *Tsuga miosieboldiana* Ozaki (Hiramaki Formation)
Figs. 11, 12, 13 *Calocedrus notoensis* (Matsuo) Ishida (Tomikusa Group)
(All figures in natural size)

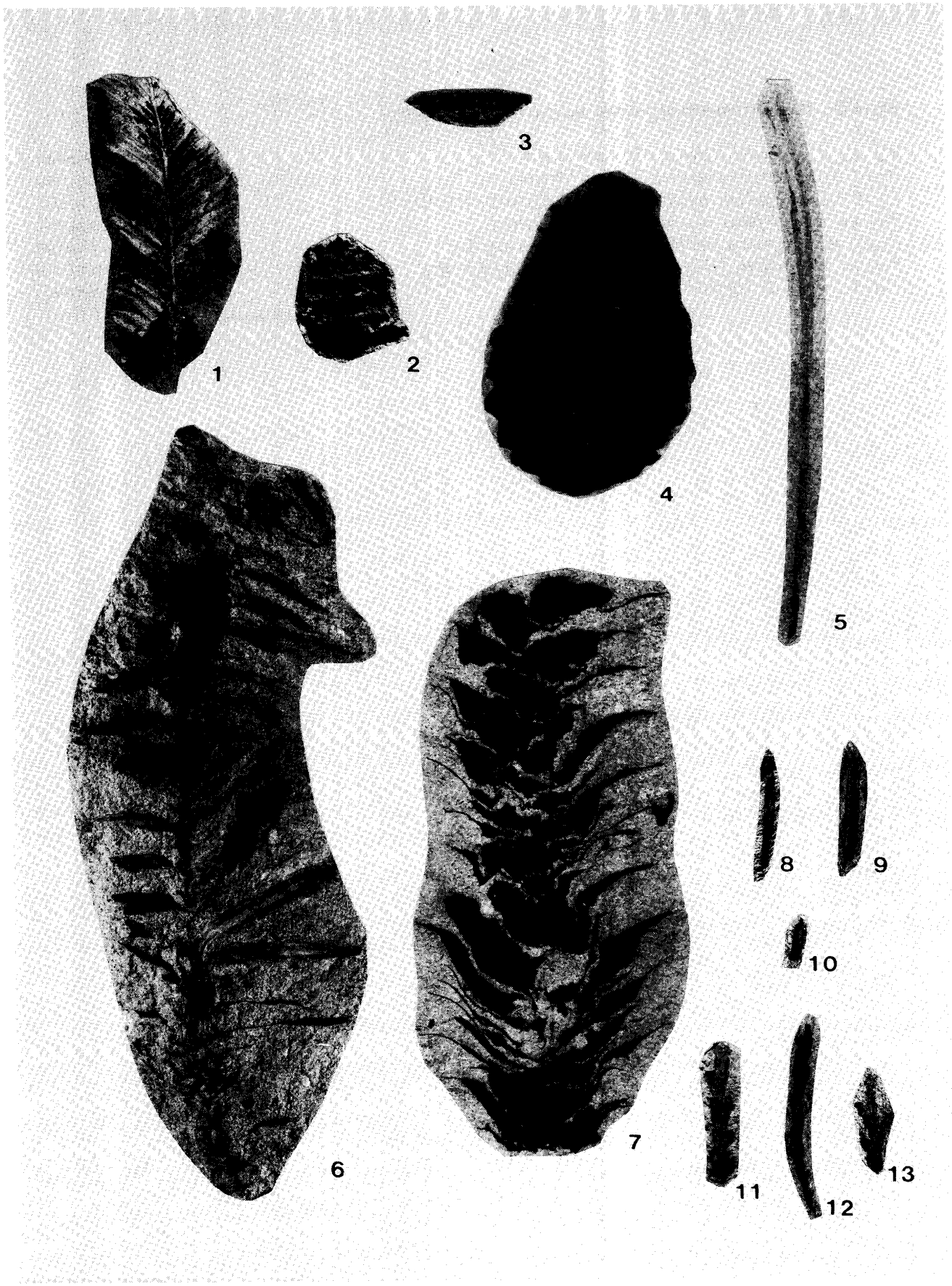
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Plate II Warm-temperate, broad-leaved deciduous trees

Fig. 1 *Carya miocathaensis* Hu and Chaney (Hachiya Formation)
Fig. 2 *Platycarya miocenica* Hu and Chaney (Hachiya Formation)
Fig. 3 *Liquidambar miosinica* Hu and Chaney (×1/2) (Hiramaki Formation)
Fig. 4 *Liquidambar miosinica* Hu and Chaney (Hiramaki Formation)
Figs. 5, 6 *Comptonia naumanni* (Nathorst) Huzioka (Tomikusa Group)
Fig. 7 *Liquidambar protopalmata* (K. Suzuki) Uemura (Hiramaki Formation)
Fig. 8 *Parrotia fagifolia* (Goeppert) Heer (Hiramaki Formation)

(All figures in natural size, except fig. 3)


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Plate III Cool-temperature, broad-leaved deciduous trees, the species consistuting fringing and ravine forests, and aquatic species

Fig. 1 *Populus balsamoides* Goeppert (Hiramaki Formation)
Fig. 2 *Betula protoermanni* Endo (Nansetsu Subgroup)
Fig. 3 *Betula uzenensis* Tanai (Hiramaki Formation)
Fig. 4 *Alnus arasensis* Huzioka (Akeyo Formation)
Fig. 5 *Carex* sp. (Hiramaki Formation)
Fig. 6 *Salix k-suzukii* Tanai (Akeyo Formation)
Fig. 7 *Hemitrapa borealis* (Heer) Miki (Hachiya Formation)

(All figures in natural size)

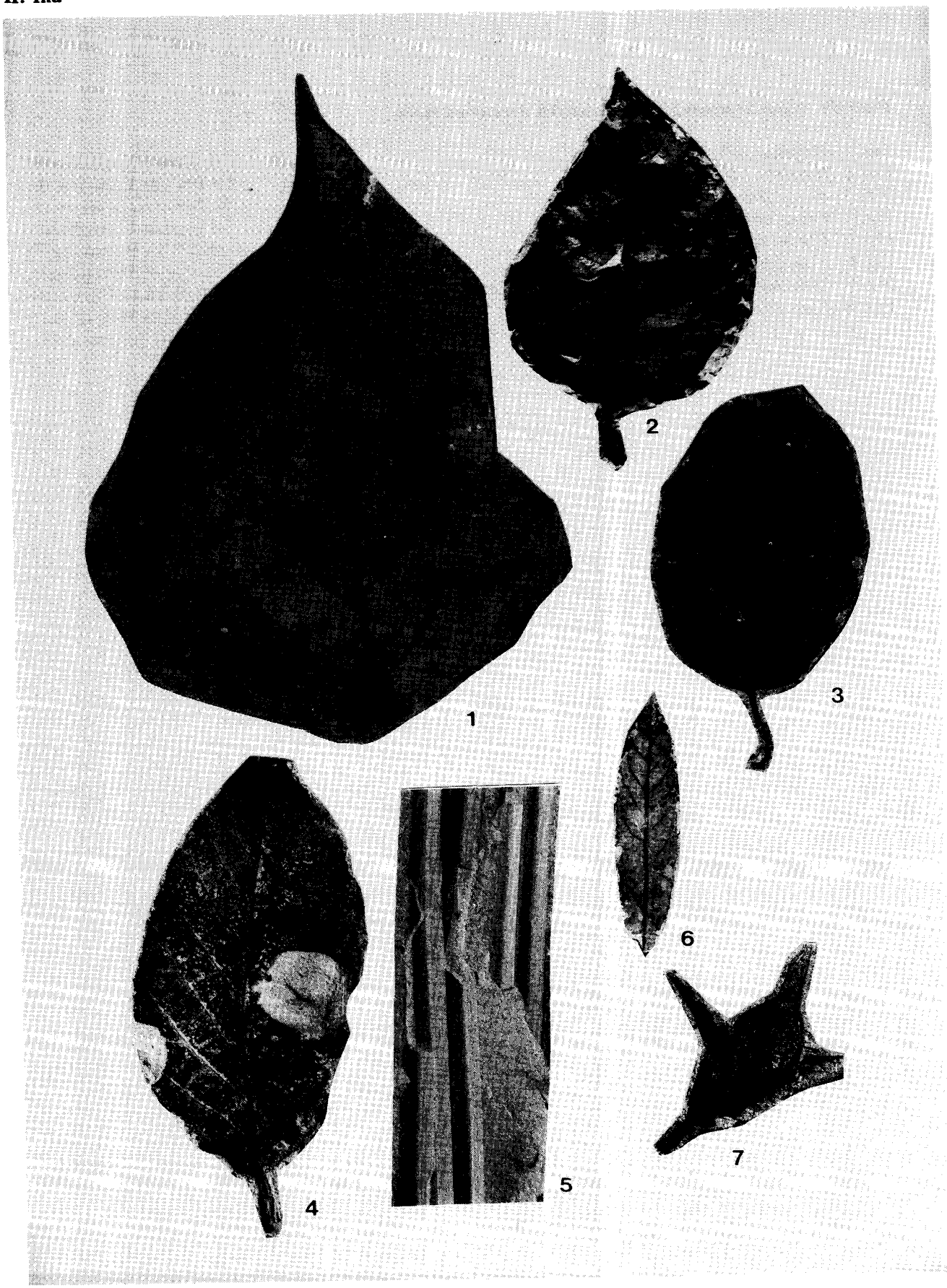
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Plate IV Cool-temperate, broad-leaved deciduous trees

Fig. 1 *Carpinus subcordata* Nathorst (Hachiya Formation)
Fig. 2 *Carpinus stenopylla* Nathorst (Hiramaki Formation)
Fig. 3 *Fagus palaeocrenata* Okutsu (Oidawara Formation)
Fig. 4 *Fagus antipofi* Heer (Hachiya Formation)
Fig. 5 *Ulmus appendiculata* Heer (Hachiya Formation)
Fig. 6 *Tilia* sp. (Hachiya Formation)
Fig. 7 *Tilia hommashinichii* Huzioka and Nishida (Hachiya Formation)
Fig. 8 *Rhus* sp. (Hiramaki Formation)

(All figures in natural size)

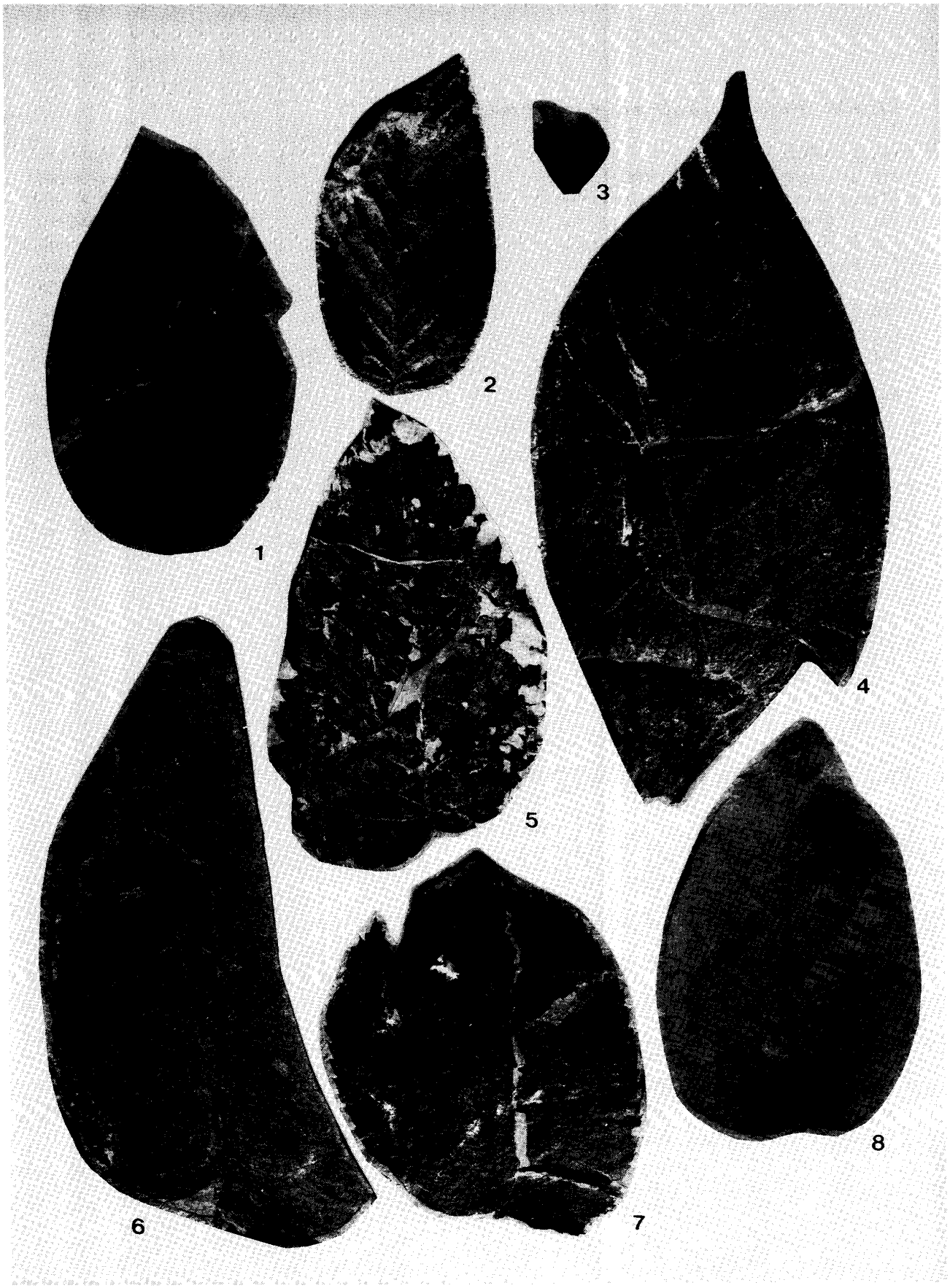
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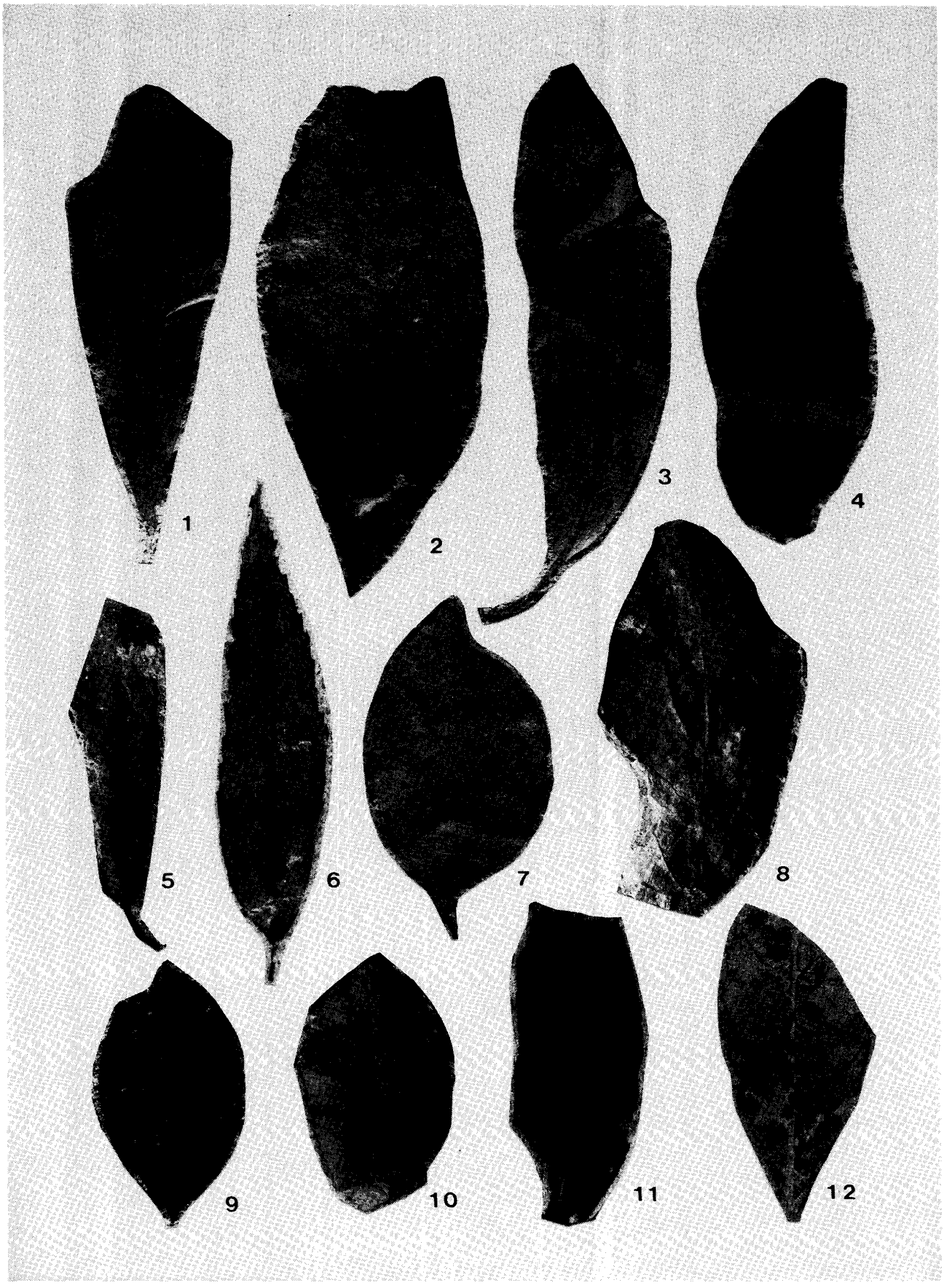
Plate V Warm-temperate, broad-leaved evergreen tress

Fig. 1 *Myrica* sp. (Oidawara Formation)
Fig. 2 *Quercus nathorsti* Kryshtofovich (Oidawara Formation)
Fig. 3 *Quercus praegilva* Kryshtofovich (Oidawara Formation)
Fig. 4 *Quercus protosalicina* Suzuki (Oidawara Formation)
Fig. 5 *Actinodaphne nipponica* Tanai (Agi Formation)
Fig. 6 *Quercus* sp. A (Akeyo Formation)
Fig. 7 *Ilex ohashii* Huzioka (Oidawara Formation)
Fig. 8 *Cinnamomum oguniense* Morita (Tomikusa Group)
Fig. 9 *Cinnamomum miocenum* Morita (Tomikusa Group)
Fig. 10 *Quercus* sp. D (Shukunohora Sandstone Facies)
Fig. 11 *Machilus ugoana* Huzioka (Akeyo Formation)
Fig. 12 *Quercus* sp. B (Oidawara Formation)

(All figures in natural size)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