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GEOLOGICAL SURVEY OF JAPAN

A MIO-PLIOCENE FLORA FROM THE NINGYO-TOGE AREA ON THE BORDER BETWEEN TOTTORI AND OKAYAMA PREFECTURES, JAPAN

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Katsu KANEKO, Director

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CONTENT

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Toshimasa TANAI* and Toru ONOE

Abstract

The plant-bearing formations of Neogene time are distributed around Ningyo-toge area, which is located in the boundary area between Tottori and Okayama prefectures. They have attracted attention because the uranium-bearing deposits, which are probably minable, are distributed in this area, and considered the floristic composition and paleoecologic conditions.

The fossil flora, which is now called the "Hoki flora", contains 67 species and 47 genera. Most of these plants are temperate elements, while some are warm or subtropical. The "Hoki flora" consists of three florules: the Mitoku, Onbara and Ningyo-toge. These three florules are comparatively similar in their floristic composition and components. The former two have several exotic genera such as *Taiwania*, *Carya*, *Liriodendron*, *Sassafras*, *Liquidambar*, etc., but the last contains few exotic genera. The three florules are described with respect to the relative abundance of materials, leaf characters and the relationships with the present flora, and the three florules are compared with each other. On the basis of these considerations, the Mitoku florule is late Miocene, the Onbara is Mio-Pliocene, and the Ningyo-toge is early Pliocene in age respectively. These three florules show a gradual change in their floristic compositions and components with the vicissitude of geological age; also their floristic changes correspond with the physical conditions during the respective ages.

I. Introduction

In the autumn of 1955, the Ningyo-toge uranium-bearing deposits were discovered by a carborne radiometric survey, and since then the distribution of these deposits and uranium-bearing minerals have been investigated by various methods. These uranium-bearing deposits are expected to be recognized as one of the promising minable uranium-bearing ores in Japan. Lately, the junior writer, ONOE, together with K. FUJIWARA and Y. SATO, surveyed the distribution of these deposits, and collected a good quantity of plant fossils from these deposits as already preliminarily reported. (FUJIWARA, SATO & ONOE, 1957) Most of these plant fossils are excellent in preservation, and they include much interesting material for paleobotanical research.

It is the purpose of this report to describe the characteristics of the floristic composition, to determine the geologic age of the fossil-bearing formation, and also to consider the paleoecologic or paleogeographic condition at that time.

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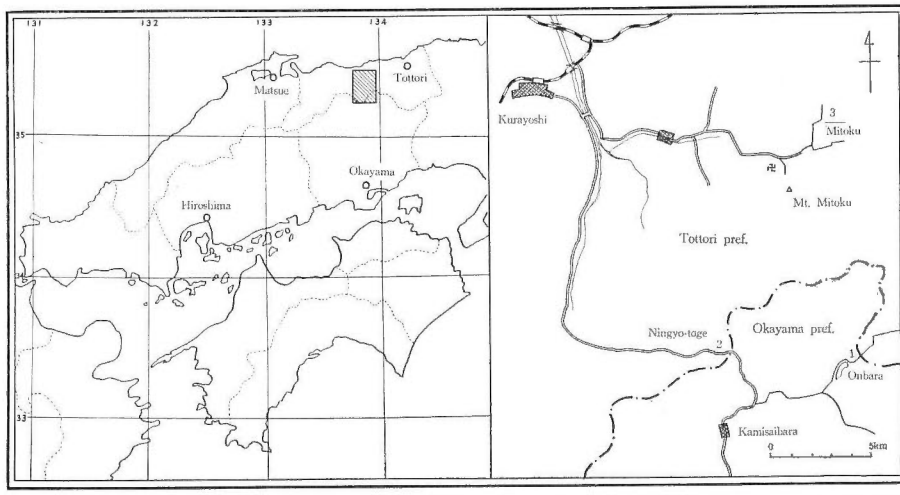
* Investigator, Geological Survey of Japan; and assistant professor of Hokkaido University

II. Physical Relationships

II. 1 Present Physical Conditions and Vegetation

The fossil localities are situated in the boundary area between Okayama and Tottori prefectures, and are at an altitude of 700 to 800 m in the backbone mountain area of the Chugoku district. The topography around the fossil localities is well dissected, and the major drainages develop toward the south or northwest forming the peneplained plateau. There are three fossil localities in this region as shown in Fig. 1 : Mitoku in Misasa-machi, Ningyo-toge also in Misasa-machi, Tottori prefecture and Onbara in Kamisaibara-mura, Okayama, prefecture.



1 Onbara 2 Ningyo-toge 3 Mitoku

Text-fig. 1 Maps showing the Fossil Localities

Exact climatic date are not available for the immediate fossil localities, but general climatic conditions are known from the nearby meteorological stations. In this region, summer temperatures average from 20° to 23°C in a month, and winter temperatures from 0° to 4°C. The monthly precipitation is about 170 mm in summer, and about 150 mm in winter. It is snowy in winter, but the snowfall does not exceed 2 m in a season. To the northwest, there are two meteorological stations along the Japan Sea, the Matsue and Yonago stations. According to K. WADACHI (1958), climatic data from these stations are as shown in Table 1.

The modern flora in the vicinity of the fossil localities is comparatively dominated by a Saseto-Fagetum crenatum association. Namely, north of Ningyo-toge the beech forest grows luxuriantly, and occupies the area at an altitude more than about 800 m above sea-level. In this area, *Fagus crenata* is most abundant, and associated mainly with *Quercus mongolica* var. *grosseserrata*, *Viburnum furcatum*, *Acer Mono*, *Carpinus cordata*, *Hamamelis japonica*, etc.. The beech forest grows, also luxuriantly, on Mitoku-yama as recently reported by Y. SASAKI (1958). According to him, a typical forest of *Sasa-Fagus crenata* thicket is distributed in the area at an altitude more than 700 m above sea-level. In this thicket, *Fagus crenata* is exclusively dominant, followed by *Viburnum furcatum*. Beside these trees, domi-

Table 1 Climatic Data for Yonago and Matsue (1940～1950)

Station	Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average
Yonago*	temp. (C)	3.5	3.1	6.2	11.2	16.0	20.6	25.2	25.2	21.5	15.4	10.9	6.1	13.8
	precip. (mm)	135	149	119	99	105	170	158	130	309	193	109	148	1824
Matsue*	temp. (C)	3.5	3.1	6.3	11.5	16.4	20.8	25.2	26.4	21.9	15.6	10.9	5.9	14.0
	precip. (mm)	157	157	130	98	121	185	154	162	337	193	118	162	1974

* The Yonago meteorological station is situated at an altitude of 7 m above sea-level, and the Matsue station is at an altitude of 17 m.

nant associated trees are *Quercus mongolica* var. *grosseserrata*, *Hamamelis japonica*, *Cornus kousa*, *Rhododendron lagopus*, *Lindera umbellata*, *Evodipanax innovans*, etc.. The shrub growth is composed almost entirely of *Sasa senanensis*, and also sometimes contains *Magnolia salicifolia*, *Daphiniphyllum macropodum* var. *borealis*, *Skimmia japonica* var. *repens*, *Pieris japonica*, *Ilex leucoclada*, etc.. The thicket at 600 to 700 m altitude, is a mixed forest, which is composed mainly of *Fagus crenata*, *Pinus parvifolia*, *Cryptomeria japonica*, *Chamaecyparis obtusa*, *Carpinus Tchonoskii*, *Stewartia pseudocamellia*, *Rhododendron Metternichii*, etc.. On the steep northern slope of Mitoku-yama at altitudes of 400 to 540 m, *Fagus crenata* decreases gradually, and *Cyclobalanopsis acuta*, *C. stenophylla*, *Abies firma*, *Camellia japonica*, *Thuja standishi*, etc., are mixed dominantly with beech.

II. 2 Geologic Occurrence of the Fossil Flora

The geology of the area including the fossil localities was investigated in great detail in part by Fujiwara and others of Geological Survey of Japan, and the sheet-map survey covering the whole area is in progress of completion by M. OSAWA. The following brief statement of the geologic relationships is a summary of these investigations.

"In this area, Neogene and Pleistocene sediments overlie unconformably the pre-Tertiary sediments and granitic rocks. These basement granitic rocks form the so-called 'Chugoku Plateau', which was considerably peneplained by erosion. Tertiary sediments seem to be of terrestrial origin; they are divided into four formations—namely the Mitoku, Onbara, Ningyo-toge and Takashimizu formations. Except for the last, these formations are isolated in their distribution; they rest directly on granitic rocks respectively. Accordingly, the stratigraphical relationships of these three formations cannot be ascertained by the surface survey. The Takashimizu formation usually covers these three formations, and especially it is observed to be conformable to the Ningyo-toge formation."

The fossil flora now under consideration is preserved in the following three formations: the Mitoku, Onbara and Ningyo-toge. The Mitoku formation is about 360 m in thickness. It consists mainly of andesitic or rhyolitic tuff breccia and tuff, and rarely intercalates thin layers of sandstone and siltstone. The tuffaceous siltstone of the upper part includes many well-preserved plant fossils. The Onbara formation is found mainly near Onbara, and unconformably covers granitic rocks. It is about 70 or 80 m in thickness, and consists of siltstone, sandstone and tuff, among which rocks siltstone and tuff contain many plant fossils. The Ningyo-toge formation is composed of siltstone, sandstone and conglomerate. The tuffaceous siltstone of the upper part has also many well-preserved plant fossils.

The writers call the vegetable associations which occur from these three formations, the Mitoku, Onbara and Ningyo-toge florules respectively; these three florules are, as a whole,

called the Hoki* flora.

III. Composition of the Flora

The "Hoki flora" is now known to include a total of 67 species, representing 47 genera and 29 families. Fifty-eight of the plants are dicotyledons, and the remaining 9 are conifers. Among these species, 37 are new or established as new combinations.

The following genera are dominant in number of species: *Acer* with 7 species, *Carpinus* with 5, *Quercus* with 4, *Betula* with 3, and *Alnus*, *Fagus*, *Celtis*, *Ulmus*, and *Cornus* with 2 each. The Betulaceae is the largest family in the flora, with 10 species; both the Fagaceae and Aceraceae have 7 species each; both the Pinaceae and Ulmaceae have 5 species each. Such characteristic features of floral composition are closely similar to those of Neogene floras in Japan. It is, however, a curious feature that the flora does not comprise such genera as *Metasequoia*, *Glyptostrobus* which are common in the usual Japanese Tertiary flora. These cosmopolitan genera do not occur at all in this flora, though coniferous trees are comparatively common. It is yet difficult to explain the ecologic or floristic conditions of this flora.

The "Hoki flora" consists of three florules as above-noted: the Onbara, Mitoku and Ningyo-toge. These three florules have many common species respectively, and especially the former two are common in the characteristic components, as is shown in Table 2.

III. 1 Mitoku Florule

The Mitoku florule comprises 39 species, representing 28 genera and 20 families. Thirty-seven of the plants are dicotyledons, while the remaining two are conifers. The following genera are dominant in number of species; *Acer* with 6 species, *Quercus* with 3, and *Betula*, *Carpinus*, *Ulmus*, and *Cornus* with 2 each. Each of remaining genera is represented by a single species.

The relative abundance of the species in the Mitoku florule, as estimated from 204 determinable specimens, is shown in Table 3. *Fagus palaeocrenata*** and *Zelkova Ungeri* are the most abundant species, followed by *Acer palaeodiabolicum* and *Wistaria fallax*. Together they make up 71% of the flora, being represented by 145 specimens. None of the remaining species is common, most being represented by not more than 4 or 5 specimens. However, *Wistaria* occurs as leaflets and *Acer palaeodiabolicum* is represented by leaves and samaras. Accordingly, the actual abundance of these plants in this florule may be less than the number indicated by countings.

This florule consists mainly of the deciduous broad-leaved trees such as *Juglans*, *Betula*, *Carpinus*, *Fagus*, *Quercus*, *Zelkova*, *Ulmus*, *Acer*, *Tilia* and *Cornus*. These genera are commonly living at present not only in Japan, but also they are widely distributed in the temperate region of East Asia. It is, however, characteristic for the floristic composition of this florule to include such several genera as *Taiwania*, *Carya*, *Liriodendron*, *Sassafras* and *Liquidambar*, which are now extinct in the present flora of Japan. Most of these extinct genera are now limited in their distribution in the world, and grow only in China or North America.

The genus *Taiwania* is now found only in Formosa and Southwest China, and present-

* Most of the fossil localities are included in the Hoki province, which is a name of one of the old administrative divisions in Japan.

** The bud-scales of beech commonly occur in this florule, and they are 12 specimens in number. But the scales are excluded from this counting.

Table 3 Relative Abundance of Species in the Mitoku Florule

Fossil species	No. specimens	percentage
Fagus palaeocrenata	51	25.0
Zelkova Ungeri	51	25.0
Acer palaeodiabolicum	30	14.7
Wistaria fallax	13	6.3
Rhododendron protodilatatum	5	2.4
Quercus protoserrata	4	2.0
Ulmus protojaponica	4	2.0
Tilia miohenryana	3	1.5
Acer Nordenskiöldi	2	0.9
Acer palaeorufinerve	2	0.9
Acer subpictum	2	0.9
Carpinus nipponica	2	0.9
Carya miocathayensis	2	0.9
Cornus subkousa	2	0.9
Liquidambar mioformosana	2	0.9
Magnolia elliptica	2	0.9
Quercus miocrispula	2	0.9
Sassafras subtriloba	2	0.9
Sorbus nipponica	2	0.9
Taiwania japonica	2	0.9
Acer submayrii	1	9.3
Acer cfr. *pseudocarpinifolium*	1	
Betula protoermani	1	
Betula protoglobispica	1	
Carpinus subyedoensis	1	
Castanea miocrenata	1	
Celtis Nordenskioldii	1	
Clethra sp.	1	
Cornus megaphylla	1	
Ficus sp.	1	
Juglans sp.	1	
Juniperus honshuensis	1	
Liriodendron honsyuensis	1	
Populus aizuana	1	
Pterocarya nipponica	1	
Quercus protodentata	1	
Schizophragma mitokuensis	1	
Stewartia submonadelpha	1	
Ulmus protolaciniata	1	
(Total)	204	99.0%

Table 4 Relative Abundance of Species in the Onbara Florule

Fossil species	No. specimens	percentage
Fagus palaeocrenata	117	46.4
Quercus protodentata	19	7.5
Quercus miocrispula	18	7.1
Castanea miocrenata	11	4.4
Carpinus nipponica	10	4.0
Zelkova Ungeri	9	3.5
Acer palaeodiabolicum	7	2.8
Betula onbaraensis	5	2.0
Carpinus subyedoensis	4	1.6
Quercus protoserrata	4	1.6
Sassafras subtriloba	4	1.6
Wistaria fallax	4	1.6
Alnus protohirsuta	3	1.2
Populus aizuana	3	1.2
Abies sp.	2	0.8
Acer subpictum	2	0.8
Alnus miojaponica	2	0.8
Buxus protojaponica	2	0.8
Carpinus miocenica	2	0.8
Carpinus subcarpinoides	2	0.8
Larix onbaraensis	2	0.8
Pinus palaeopentaphylla	2	0.8
Thuja nipponica	2	0.8
Betula protoermanii	2	0.8
Betula protoglobispica	1	
Carpinus subcordata	1	
Cunninghamia protokonishii	1	
Euonymus palaeosieboldianus	1	
Fagus palaeojaponica	1	
Hamamelis sp.	1	
Ilex sp.	1	5.5
Juglans sp.	1	
Lonicera protojaponica	1	
Paliurus nipponica	1	
Pseudolarix japonica	1	
Quercus sp.	1	
Tripetaleia pseudopaniculata	1	
Ulmus protolaciniata	1	
(Total)	252	100.0%

ly one species only, *Taiwania cryptomeroides*, is living. *Liquidambar* flourished from Eocene to Pliocene time in Japan, but it is extinct now in the Japanese Islands. Fossil leaves of this genus in this florule are closely similar to the Formosan living species, *L. formosana*. *Sassafras* and *Liriodendron* are confined now to Southwest China and southeastern North America in their distribution, and only two living species of each genus are known respectively. *S. subtriloba* of this florule is closely similar to these Chinese and American living species. *Liriodendron honsyuensis* is also close to the American living species, *L. tulipifera*. Many characteristic genera are common at present between Chinese and North American floras as already described by many botanists, so that it is very interesting from the viewpoint of phytogeography that some of these genera are commonly found in the Tertiary flora of Japan.

III. 2 Onbara Florule

The Onbara florule comprises 36 species, representing 26 genera and 18 families. These plants comprise 7 conifers and 32 dicotyledons. The following genera are dominant in number of species, *Carpinus* with 5 species, *Quercus* with 4, *Betula* with 3, and *Alnus*, *Fagus*, and *Acer* with 2 each. All the remaining genera are represented by a single species.

The relative abundance of the species in the Onbara florule, as estimated out of 252 determinable specimens, is shown in Table 4. *Fagus palaeocrenata** is the most abundant species, followed by *Quercus protodentata*, *Q. miocrispula* and *Castanea miocrenata*. These species belonging to the Fagaceae make up about 65% of the flora, represented by approximately 165 specimens. The next 4 species, *Carpinus nipponica*, *Zelkova Ungeri*, *Acer palaeodiabolicum* and *Betula onbaraensis*, include another nearly 12% of the total number of specimens. None of the remaining species is common, most being represented by not more than 4 specimens. *Carpinus* and *Acer* are represented by leaves and fruits, therefore the actual abundance of these plants in this florule was probably less than the number indicated by counting.

The Onbara florule is closely similar to the above-described Mitoku florule in the floristic composition, and consists mainly of the deciduous broad-leaved trees growing in temperate zone of Eastern Asia. The plants belonging to Betulaceae, Fagaceae, Ulmaceae and Aceraceae, occupied nearly 85% of the total specimens. Living species close to these plants are common in existing floras of Japan and China. Beside these, some Chinese-American elements such as *Carpinus nipponica*, *Sassafras subtriloba* and *Populus aizuana*, are also included in this florule similar to the case of the Mitoku florule. However, it is characteristic for the Onbara florule to contain 4 genera of Pinaceae, which are not comprised at all in the Mitoku florule. Among the Onbara coniferous trees, *Abies*, *Larix* and *Pinus* are commonly distributed now in Eastern Asia, but *Pseudolarix* exists only in Central and Southeast China. The Onbara species of golden larch is closely similar to the Chinese living species, *Pseudolarix Kaempferi*.

Even though general resemblance is recognized in the floristic components between the Onbara and Mitoku florules, coniferous trees in the latter are less than in the former. Such difference may probably be due to environmental factors at the time when they flourished.

III. 3 Ningyo-toge Florule

The Ningyo-toge florule is represented by 25 species, 18 genera and 18 families. These plants consist of 2 conifers and 23 dicotyledons. The largest family is the Fagaceae with 6 species representing 3 genera of *Fagus*, *Quercus* and *Castanea*; the next are the Betulaceae and Ulmaceae with 3 genera each. The following genera are the most numerous in number of

* Fifty-two bud-scales of beech are enumerated from this florule, but they are excluded from counting.

Table 5 Relative Abundance of Species in the Ningyo-toge Florule

Fossil species	No. specimens	percentage
Fagus palaeocrenata	172	71.0
Zelkova Ungeri	14	5.7
Carpinus nipponica	11	4.5
Thuja nipponica	8	3.3
Pterocarya nipponica	7	3.0
Castanea miocrenata	3	1.2
Fagus palaeojaponica	3	1.2
Celtis Nordenskioldii	2	0.8
Pinus palaeopentaphylla	2	0.8
Quercus protodentata	2	0.8
Quercus protoserrata	2	0.8
Styrax protoobassia	2	0.8
Acer protosieboldianum	2	0.8
Acer subpictum	1	5.0
Carpinus miocenica	1	
Carpinus subcarpinoides	1	
Celtis Nathorstii	1	
Cornus subkousa	1	
Fraxinus honshuensis	1	
Juglans sp.	1	
Picea Kaneharai	1	
Prunus protossiori	1	
Quercus miocrispula	1	
Symplocos sp.	1	
Wistaria fallax	1	
(Total)	242	99.7%

species ; *Carpinus* and *Quercus* with 3 species, *Fagus*, *Celtis* and *Acer* with 2 each. All the remaining genera are represented by a single species.

The relative abundance of the species in the Ningyo-toge florule, as estimated from 242 determinable specimens, is shown in Table 5. *Fagus palaeocrenata** is the most abundant species, and sufficiently common to account for 71% of the flora. The next 4 species : *Zelkova Ungeri*, *Carpinus nipponica*, *Thuja nipponica*, *Pterocarya nipponica*, constitute nearly 16% of the specimens. None of the remaining species is common, most being represented by not more than 3 specimens. Among the abundant species, *Carpinus nipponica* occurs as involucres, and *Pterocarya nipponica* as leaflets. Accordingly, the actual abundance of these trees was probably less than the number indicated by the counts.

The Ningyo-toge florule consists of deciduous broad-leaved trees and some conifers, such as *Pterocarya*, *Carpinus*, *Castanea*, *Fagus*, *Quercus*, *Zelkova*, *Acer*, *Styrax*, *Pinus* and *Thuja*, etc.. Nearly all of them are represented by closely related living species, which are widely

* Sixty-eight bud-scales of beech are found from this florule, but they are excluded from the counting.

distributed now in Japan. Comparing this to the Mitoku and Onbara florules, the occurrence of beech is very considerable in this florule, and also conifers were increased more or less in number of specimen over the former two florules. There are nearly none of the so-called Chinese-American elements such as *Carya*, *Sassafras*, *Liriodendron*, *Liquidambar*, etc., which are found in the Mitoku or Onbara florule. This is a striking contrast in floristic composition to the other two florules. Such difference of floristic composition was, of course, due to ecological or climatic change, but it may rather signify the difference of geologic age more than the environmental factors.

IV. Paleoecological Condition of the Flora

In forming some conclusion with regard to the ecological condition indicated by the fossil flora, there are several useful sources of evidence as follows:

1) A comparison with the habit and habitat of similar living species. Where the modern relationships are known definitely, this method is probably useful for the most accurate information.

2) The mode of occurrence of the fossil, and nature or texture of fossil plants.

3) The analysis of leaf characters. The method of analyzing leaf characters is frequently useful for determination of their relation to the environment.

IV. 1 Modern Relationships of the Fossil Flora

Among 47 genera of this flora, most of them are now found in the present flora of Eastern Asia, excluding already extinct six genera in Japan proper. Largely equivalent plants to the Hoki species grow now in Japan, China and its adjacent regions. These plants consist mostly of temperate elements with some exception. In order to reconstruct the environments during that time, it is necessary first to determine the relationships of the fossil flora to living vegetation. Table 6 gives a list of the fossil species comparing with the most similar living species and their distribution in Eastern Asia.

The nearest equivalent living species are distributed most dominantly in Japan proper, and next in China and Korea. The equivalent species in Japan proper are generally common from central to southern Japan. The Hoki flora comprises three florules, among which the Onbara and Mitoku florules are nearly similar in the distribution of their living equivalents. The Ningyo-toge florule consists mostly of northern Japan elements, and on the contrary, only slightly of Chinese-American elements, as compared to the older two florules. Such tendency shall be more clearly observed, if the widely-distributed plants such as *Pterocarya*, *Quercus*, *Zelkova*, *Fagus*, etc., are exclusively considered.

The Mitoku and Onbara florules are most similar to the present flora of central to southern Japan, while the Ningyo-toge florule is close to the living flora grown from central to northern Japan. As is shown in Tables 3, 4 and 5, the three florules comprise many specimens of *Fagus palaeocrenata*, which is particularly abundant in the Onbara and Ningyo-toge florules: for instance, they make up 71% of the total specimens in the Ningyo-toge, 46.4% in the Onbara, and 25% in the Mitoku. Accordingly, these florules seem to correspond to the so-called beech forest in the present Japanese forest. *Fagus palaeocrenata* is closely similar to the living *F. crenata*, which is one of the trees being most sensitive to climate. The Japanese beech, *F. crenata*, is one of the representatives from southwestern Hokkaido to Kyushu, but it varies in vertical distribution due to the climatic environments. The examples of typical vegetation are seen in the Chichibu district, Mt. Fuji, Mt. Hakkoda in Honshu and Kuro-

matsunai Depression in Hokkaido as its northern limit.

On Mt. Fuji, the Japanese beech grows luxuriantly from 1,000 to 1,600 m above sea level by forming a pure stand, and sometimes it is associated with the deciduous trees such as *Fagus japonica*, *Quercus mongolica* var. *grosseserrata*, *Zelkova serrata*, *Cladrastis platycarpa*, *Acer Mono*, etc.. At the same time, on Mt. Hakkoda in northern Honshu, the Japanese beech is exclusively dominant at an altitude of 300 to 900 m above sea level by forming a pure stand ; it is associated frequently with *Acanthopanax sciadophylloides*, *Quercus mongolica* var. *grosseserrata*, *Acer Mono*, *Viburnum furcatum*, *Acer japonicum*, *Pterocarya rhoifolia*, etc.. The beech forest in central Honshu is frequently associated with many broad-leaved trees, but in northeastern Honshu, the broad-leaved trees except beech are scarce in number. The conifer forest at higher altitudes than the beech forest has a luxuriant growth of *Abies Veitchii*, *Picea jessoensis* var. *hondoensis*, *Tsuga diversifolia*, etc. in central Honshu. In the conifer forest of northern Honshu, *Abies Mariesii* only is dominant, while *Tsuga diversifolia* merely grows among the above-noted trees.

The Kuromatsunai Depression, situated in the central part of southwestern Hokkaido, is known as the demacation line in the plant distribution of Hokkaido. It is remarkable that the Japanese beech is not found to the north of this depression. On the hilly area around Kuromatsunai at an altitude of about 200 m in maximum, the Japanese beech grows luxuriantly forming almost a pure stand ; it is accompanied with *Quercus mongolica* var. *grosseserrata*, *Acer Mono*, *Kalopanax pictus*, *Carpinus cordata*, *Acer japonicum*, *Betula Ermanni*, *Tilia japonica*, *Sorbus alnifolia*, *Ulmus laciniata*, etc.

Except conifers, the living trees equivalent to the Hoki species are mostly species associated with the present beech forest in Japan. Considering from the relative abundance of fossil leaves, the Hoki flora seemed to be a beech forest, which was accompanied with the direct progenitors of *Carpinus laxiflora*, *Castanea crenata*, *Quercus mongolica* var. *grosseserrata*, *Zelkova serrata*, *Acer diabolicum*, etc.. The Mitoku and Onbara florules have several warm-temperate trees such as *Liquidambar*, *Cunninghamia*, *Taiwania*, etc., and so both of the florules may probably have been a beech forest in warmer region. As the Ningyo-toge florule is considerably abundant in *Fagus* as is shown in Table 5, it seems to have been nearly a pure beech forest. Considering from the distribution of the modern equivalents, the Ningyo-toge florule is closely similar to the present beech forest from northern to central Honshu of Japan.

IV. 2 Habitat Relationships of the Fossil Flora

The modern relationships of 67 fossil species in the Hoki flora are sufficiently clear to permit a determination of their habits and habitats.

Considering from the habits of modern equivalents, among 67 fossil species, 50 were trees, 13 species are shrubs or small trees, and the remaining 4 are vines. The ratio of each habit in the three florules is shown in Table 7.

There is more chance for the leaves of a tree to enter the fossil record than there is for the leaves of a shrub or small tree, since the trees are higher, bear more leaves, and reach farther up into the path of the wind. However, considering such conditions, the ratio of trees to shrubs in these florules is still rather higher in comparison with that found in other Neogene floras of Japan.

In order to facilitate considerations on the probable ecologic conditions under which those plants lived, the living species nearest equivalent to the fossil plants are grouped according to their habitats—three types of uplands, mixed-slope and stream-side or riparian as shown

Table 7 Habit Ratio of the Hoki Flora

Florule / Habits	Mitoku florule		Onbara florule		Ningyo-toge florule	
	No. species	percentage	No. species	percentage	No. species	percentage
Trees	30	76.9	28	73.7	21	84.0
Shrubs or Small tree	8	20.5	7	18.4	3	12.0
Vine	1	2.6	3	7.9	1	4.0
Total	39	100%	38	100%	25	100%

Table 8 Habitat of the Hoki Species as Judged from Similar Living Species

1) Stream-side or riparian
Juniperus honshuensis
Populus aizuana
Juglans sp.
Alnus miojaponica
Ulmus protojaponica
Liriodendron honsyuensis
Liquidambar mioformosana
Paliurus nipponicus

2) Mixed-slope to riparian
Pterocarya nipponica
Alnus protohirsuta
Carpinus subyedoensis
Carpinus subcordata
Quercus protoserrata
Zelkova Ungeri
Magnolia elliptica
Euonymus palaeosieboldianus
Cornus megaphylla
Cornus subkousa
Lonicera protojaponica
Wistaria fallax

3) Mixed-slope
Abies sp.
Larix onbaraensis
Carya miocathayensis
Betula protoglobispica
Betula onbaraensis
Carpinus nipponica
Carpinus miocenica
Carpinus subcarpinoides
Castanea miocrenata
Fagus palaeojaponica
Quercus miocrispula
Quercus protodentata
Quercus sp.
Celtis Nathorstii
Celtis Nordenskioldii
Ulmus protolaciniata
Ficus sp.
Sassafras subtriloba
Hamamelis sp.
Sorbus nipponica
Prunus protossiori
Buxus protojaponica
Ilex sp.
Acer Nordenskiöldi
Acer palaeodiabolicum
Acer palaeorufinerve
Acer protosieboldianum
Acer submayrii
Acer subpictum
Acer cfr. *pseudocarpinifolium*
Tilia miohenryana
Stewartia submonadelpha
Clethra sp.
Rhododendron protodilatatum
Tripetaleia pseudopaniculata
Symplocos sp.
Styrax protoobassia
Fraxinus honshuensis

4) Mixed-slope to uplands
Betula protoermanni
Fagus palaeocrenata

5) Uplands
Picea Kaneharai
Pseudolarix japonica
Pinus palaeopentaphylla
Taiwania japonica
Cunninghamia protokonishii
Thuja nipponica

in Table 8.

On the basis of the data shown in Table 8, the habitat relationships of each florule are shown as follows: (In the following table, the figures in the parentheses show the percentages of each total number.)

Table 9 Habitat Ratio of the Hoki Flora

Florule \ Habitat		Uplands	Mixed-slope to uplands	Mixed-slope	Mixed-slope to riparian	Riparian	Totals
Mitoku	No. species	1 (2.6%)	2 (5.1%)	22 (56.4%)	9 (23.0%)	5 (12.8%)	39
	No. specimens	2 (1.0%)	52 (25.5%)	65 (31.9%)	76 (37.2%)	9 (4.4%)	204
Onbara	No. species	4 (10.5%)	2 (5.3%)	20 (52.6%)	8 (21.2%)	4 (10.5%)	38
	No. specimens	6 (2.4%)	118 (46.8%)	93 (36.9%)	27 (10.7%)	8 (3.2%)	252
Ningyo-toge	No. species	3 (12.0%)	1 (4.0%)	14 (56.0%)	6 (24.0%)	1 (4.0%)	25
	No. specimens	11 (4.6%)	172 (71.1%)	32 (13.2%)	26 (10.7%)	1 (0.4%)	242

The Mitoku florule is composed mainly of "mixed-slope" or "mixed-slope to riparian" elements in number of species and specimens, and also abundantly contains "upland to mixed-slope" elements in number of species. Accordingly, this florule seems to represent a mixed-slope to riparian forest. In this florule, riparian elements are contained more abundantly than in the other two florules.

The Onbara florule is most abundant in "mixed-slope" elements in respect to number of species, but in number of specimens "mixed-slope to upland" elements are most abundant. As regards number of species, the percentage of each habitat association scarcely differ between the Mitoku and Onbara florules, while it is very different as regards the number of specimens. Namely, the percentage of mixed-slope or upland specimens in the Onbara is considerably higher than that of the Mitoku. Accordingly, the Onbara florule probably represents a forest of higher altitude than the Mitoku florule. The two florules contain, however, 4 or 5 riparian species such as *Juniperus honshuensis*, *Populus aizuana*, *Ulmus protojaponica*, etc., whose modern equivalents grow now in the lowland or sea-side area. So, though both florules consisted mainly of montane elements, their plant remains seem to have been brought out and deposited near the sea in that time.

The Ningyo-toge florule consists mostly of "mixed-slope" plants, which supply about 71 % of the total specimens. The riparian plants are scarce in this florule, and on the contrary, the upland plants are comparatively more in number of specimens than in the above-named two florules. Accordingly, this florule represents a forest which grew from mixed-slope to uplands in that time, which was probably at higher altitude than the forest represented by the Mitoku and Onbara florules.

IV. 3 Climatic Indications of Leaf Characters

The method of analyzing leaf characters according to size, nervation, margin, etc., in their relation to environments, was developed by BAILEY and SINNOT (1916), and CHANEY and his students (CHANEY & SANBORN, 1933; POTBURRY, 1935; DORF, 1938; MACGINITIE, 1937, 1941) availed this method for the climatic analysis of fossil flora. Briefly stated, some of original conclusions of BAILEY and SINNOT may be summarized as follows:

Table 10 Analysis of Broad Leaf Characters

	Non-entire	Entire	Simple	Compound	Pinnate	Palmate	over 10 cm in diam.	under 10cm in diam.
Ningyo-toge florule	86%	14%	82%	19%	92%	8%	37%	63%
Onbara florule	81%	19%	94%	6%	90%	10%	34%	66%
Mitoku florule	73%	27%	86%	14%	73%	27%	30%	70%

(1) The characters of large size, entire margin, pinnate venation, and compound organization occur most frequently in the tropics and decrease proportionately in the temperate zones.

(2) Palmate leaves are more primitive than pinnate. The relation between leaf margin and climate appears to be the most direct, and thus the percentage of dicotyledons with entire leaves may be a reliable indication of the climatic environments.

The analysis of the four leaf characters for the three florules is shown in Table 10. The figures are precentages of the total number of broad-leaved tree species which fall into each division. From the Mitoku and to the Ningyo-toge florules, the percentage of species having entire-margined or pinnate-nerved leaves increases gradually, though these are not so considerable difference among their florules.

The nature of leaf margin in dicotyledonous trees seems generally to depend on climatic factors. ENDO, S. (1931, 1935) divided the Japanese forest region into three zones, and computed percentages of entire and non-entire-leaved trees which were growing in each forest zone. His computation on the frigid, temperate and warm-temperate forest zones of Japan*, is shown as follows :

Leaf serration / Climatic forest zone of Japan	Entire	Non-entire
Warm-temperate	56%	44%
Temperate	19%	81%
Frigid	8%	92%

The percentage figures shown in Table 10, are generally similar to those of the temperate forest zone in present Japan, and especially the percentage figures of the Onbara florule are quite similar to those of the temperate forest. Though no remarkable differences are observed among their florules, the percentage of trees with entire-margined or pinnate-nerved leaves increases gradually, from the Mitoku and Onbara to the Ningyo-toge florules. Thus, on the basis of leaf characters, the climate indicated by the florules seems to have changed becoming gradually lower in temperature from the Mitoku to the Ningyo-toge time.

IV. 4 Climatic Environments Indicated by the Flora

On presuming the climatic environments of the fossil flora, the general nature of the

* This zoning of Japanese forest was actually done by HONDA, S. (1911). The warm-temperate zone occupies central and southern Honshu, northern Kyushu, and northern Shikoku. The temperate zone is from southern Hokkaido to northern Honshu, and the frigid zone included northern Hokkaido and southern Saghalien.

climate in the several areas occupied by the living equivalents must be considered. Although the present climatic environments are not always available for the condition of past time just as they are, they must afford an approximation of past climate.

In the foregoing discussion of modern relationships of the fossil flora, the Hoki flora is stated to be similar to the present beech forest of Japan. Especially, the Ningyo-toge florule shows close similarity to the beech forest which is distributed from northern Honshu to southwestern Hokkaido. In the regions occupied by beech forests in northern Japan, summer average temperatures in a month seem to range from 14° to 20°C, while winter temperatures vary from −4° to 0°C, depending upon altitude and latitude. The monthly precipitation averages from 100 to 200 mm in summer season, and from 50 to 200 mm in winter. Considering from the habitat, the Ningyo-toge florule was a montane forest and seems to have grown under cold-temperate climatic conditions which probably showed values similar to the above-noted present temperature and precipitation. Thus, the Ningyo-toge florule was grown under somewhat lower climatic conditions than the present temperature around the fossil localities.

The Onbara florule is similar to the temperate forest in central or southwestern Honshu, which is more or less lower in altitude than the pure beech forest in those districts. In such region, the average monthly temperatures range from 18° to 24°C in summer season, and from −2° to 2°C in winter. The mean precipitation varies from 150 to 300 mm in the summer months, and from 50 to 150 mm in the winter. The Onbara florule is considered to represent a mixed-slope forest, and the climatic conditions during that time may have been close to the above-described climate. As the florule has, however, some warm elements such as *Cunninghamia*, the climate during Onbara time seems to have been more mild than the above-described. The Mitoku florule contains several warm or subtropical elements such as *Liquidambar*, *Taiwania*, etc., and also has more riparian elements than the Onbara florule. Accordingly, the climate during that time had probably somewhat higher temperature than during Onbara time, and was slightly controlled by the influence of the sea.

V. Correlation and Geologic Age

The stratigraphic distribution of most species in the "Hoki flora" is confined to Japanese Tertiary sediments, and especially in the Neogene floristic composition of Japan, the broad-leaved trees of this flora include a large number of Betulaceae, Fagaceae, Ulmaceae and Aceraceae. These broad-leaved species are considerably modernized, and their living equivalents are mostly distributed in Japan proper except some plants.

As already described, the Hoki flora contains some exotic genera such as *Pseudolarix*, *Cunninghamia*, *Taiwania*, *Carya*, *Liquidambar*, *Sassafras* and *Liriodendron*, which are not living now in the Japanese Islands. These genera are living now in China or North America. The exotic elements are most abundant in the Mitoku florule, and scarce in the Ningyo-toge florule. Considering from the living equivalents of the fossil species, the exotic trees are 10 species in the Mitoku florule, 5 in the Onbara, and only 2 in the Ningyo-toge. This fact seems to suggest the difference of geological age.

The Plants such as Betulaceae, Ulmaceae, Fagaceae and Aceraceae appeared since Paleogene time in Japanese Cenozoic flora, but they flourished luxuriantly since Middle Miocene time. As already described by the senior writer (TANAI, 1955), the Aniai-type flora which is of middle Miocene age, is composed mainly of the above-mentioned temperate families. However, most of the modern equivalents of their middle Miocene species are scarcely living in Japan proper, but rather grow in China. On the other hand, the modern equivalents of the Hoki species are now mostly distributed in Japan proper rather than in China.

These exotic genera such as *Carya*, *Liquidambar*, *Sassafras* and *Liriodendron*, are known from Paleogene to Pleistocene time in North America and Europe. Whereas, in Japan such genera as *Liquidambar*, *Sassafras* and *Carya* are known from Eocene to Pliocene time, and *Cunninghamia* and *Liriodendron* have appeared since middle Miocene time. Chinese endemic conifers such as *Pseudolarix* and *Taiwania* have been known in the Pliocene sediments of Japan.

As already described, the present three fossil florules are composed mainly of cool-temperate elements, and resemble comparatively the so-called "Aniai-type flora" in their floristic compositions. However, in view of their components, the florules are distinctly younger in age than the Aniai-type flora*. At the same time, they do contain several warm-temperate or subtropical genera such as *Liquidambar*, *Cunninghamia*, etc., which are some of the characteristic elements in the so-called "Daishima-type flora*" which is middle Miocene in age. The three florules are distinctly different from the Daishima-type flora in their floristic composition and components, and are younger than the latter.

There are, as far as known at present, several fossil floras from Japan which exhibit some significant similarities to the Hoki flora; these are the Nenoshiroishi, Gosho, Fuji-toge, Okitama and Omi floras. Table 11 summarizes the floral relations of the Hoki flora with several other Neogene floras of Japan. The Mitoku and Onbara florules are closely related to the Nenoshiroishi, Gosho and Omi floras in their floristic components, and especially have most abundant common species with the lower Nenoshiroishi flora. The latter three floras are now considered to be late Miocene in age. Both the florules have some common species with the Shichiku flora of the Aniai-type and the Kamigo flora of the Daishima-type, which are both certainly middle Miocene in age. However, such plants as *Carpinus subcordata*, *Zelkova Ungeri*, *Acer subpictum*, *A. palaeodiabolicum*, ranged from early Miocene to Pleistocene, and so they are of little value in establishing stratigraphic or floristic relationships. Excluding these species from consideration, the two florules are only slightly similar to middle Miocene flora.

On the other hand, the Ningyo-toge florule does not include exotic genera at all, and is more or less similar to the Akashi and Oya floras which are considered to be late Pliocene in age. As shown in Table 11, this florule is also related to such late Miocene flora as the Nenoshiroishi, Gosho and Omi in general floristic composition and components, though the fossil species, being common with late Miocene flora, decrease somewhat in number as compared with the above-described two florules. Recently, SOMA, T. (1957) studied on autunite which was found from the Ningyo-toge formation; he estimated the absolute years of its minerals at about 36,000 years by the uranium-radium method. That is to say, considering this estimation, the Ningyo-toge's autunite is Pleistocene in age. However, floristic facts available for age-determination do not show the florule to be Pleistocene in age at all as already stated. For instance, the beech leaves with serrate margin such as *Fagus palaeocrenata*, have not been known from the Pleistocene sediments in Japan.

Thus, from the foregoing discussion, the Mitoku and Onbara florules are considered to be late Miocene in age. As already described, in spite of general resemblance batween the respective floristic compositions, the Onbara florule has slightly less number of exotic genera than the latter. Then, the Onbara florule may probably be a transitional flora in Mio-Pliocene time, whereas the Ningyo-toge florule is Pliocene in age, and probably dates from the earlier half of that age.

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* Though the floras of both type are of middle Miocene age, the Aniai-type flora is more or less generally found in lower horizon than the Daishima-type as already described by the senior writer. (TANAI, 1955)

VI. Conclusion

The "Hoki flora" comprising 67 species is described from Neogene sediments in the boundary area between Tottori and Okayama prefectures. These plant-bearing deposits, which are probably of terrestrial origin, are underlain directly by pre-Tertiary rocks; the deposits are from late Miocene to Pliocene in age. That is to say, in this district, the sediments from late Miocene to Pliocene are distributed on pre-Tertiary rocks, lacking lower Neogene sediments. It has recently been accepted that a crustal movement in late Miocene time prevailed in most parts of Japan. For instance, many geological evidences of such movement* are frequently observed in Neogene sections of northeastern Honshu and Hokkaido. Regional emergence or submergence took place renewedly in various areas of Japan. In consequence, the depositional basins since early Neogene time were sometimes caused to differentiate gradually since late Miocene age, or in this stage new depositional basins were borne. Thus, this area containing the Hoki flora, belongs probably to the latter case.

The Mitoku florule which is contained in the lowermost formation in this area, has several riparian elements, and especially some sea-side trees such as juniper. This fact may suggest that a transgressive sea-invasion commenced in this area in late Miocene time.

The Hoki flora consists of three florules, the Mitoku, Onbara and Ningyo-toge. They show a gradual change in their floristic compositions and components with the lapse of geological time, and also their floristic changes corresponded with physical conditions during those times. Considering from their floristic composition, the temperature in this area gradually lowered from late Miocene to early Pliocene time. Such tendency of climatic change at that age is also observed in other districts of Japan.

It is characteristic that this flora lacks several coniferous trees such as *Metasequoia*, *Glyptostrobus*, *Taxodium*, which are usually contained in Japanese Tertiary floras. Why the above-stated widely-distributed trees are not found in this flora, must be investigated carefully in future.

VII. Systematic Descriptions

PHYLUM SPERMATOPHYTA
CLASS GYMNOSPERMAE
Family Pinaceae

Abies sp.
(Plate I, Figure 2)

Description: Cone-scale large, half-circular in shape, 3.2 cm wide (estimated) and 2.5 cm high; stalk 0.5 cm long; base of scale subcordate, with appendage-like flange on the lower-side; margin finely irregular-serrulate; bract broken, reversely trigonal.

Remarks: This material is a incomplete cone-scale, a half portion which is missing. Considering from the restored figure, it seems a comparatively large scale. It is closely similar to the scales with attached bracts produced by the living *Abies firma* S. et Z. in shapes and dimension, though its bract was broken. The fossil cone-scales, seeds and leaves of this living fir were described from the upper Pliocene sediments near Akashi city, Japan by MIKI (1937, Fig. 1-K). *Abies firma* is now distributed in Honshu, Shikoku and Kyushu.

Occurrence: Onbara formation

* Such crustal movements were discussed by the senior writer in other paper. (TANAI, 1959)

Collection : GSJ. Holotype No. 4059

Larix onbaraensis sp. nov.
(Plate I, Figures 6, 7)

Description : Fruits prolonged-triangular in shape, 12 mm long and 4 mm wide ; wing ovate, gradually narrowed and rounded at the apex ; the inner margin nearly straight, outer margin convex, widest about one-third distance from apex to seeds ; seeds triangular, 3 mm long and 2 mm wide.

Remarks : Several small fruits of Pinaceae are now assigned to the genus *Larix* with some hesitation. They resemble more or less some fruits of *Tsuga* in general outline, but the latters are usually shorter in their wings than the former.

The present materials are close to the fruits of the modern *Larix Kaempferi* SARG., which is now restricted to central and northeastern Honshu, at the altitude of 1,000 to 2,500 m above sea level. The fossil cones, seeds, branches and leaves of this living species were described from the Pliocene and Pleistocene sediments in Honshu, Japan (MIKI, 1938, 1941, etc.).

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4060 ; Paratype No. 4061

Picea Kaneharai sp. nov.
(Plate I, Figure 9)

Description : Seeds triangularly oval in shape, acute at base, 5 mm long and 3 mm wide ; wing narrowly ovate, widest just beyond the middle part, rounded at the end, 1.5 cm long and 6.4 mm in the widest part.

Remarks : It is doubtful whether specific difference can be usually established only by seeds of conifers, but the present large seeds are similar to those of the modern *Picea polita* CARR. in their shape and dimension. The fossil cones and leaves of this living species were described from the upper Pliocene sediments near Akashi city, Hyogo prefecture, Japan (MIKI, 1937 : Fig. 1 H, H'). Among the fossil seeds of the spruce, *Picea magna* MACGINIT. has large seeds (MACGINITIE, 1953 ; AXELROD, 1956), which is known from many of the middle and late Miocene floras of western North America.

This resembling species, *Picea polita* CARR., is now living in central Honshu, Shikoku and Kyushu of Japan at the altitude of about 1,000 m above sea level.

The new species is named in honour of Dr. K. KANEHARA, who rendered the encouragement of this study of the writers.

Occurrence : Ningyo-toge formation

Collection : GSJ. Holotype No. 4062

Pseudolarix japonica sp. nov.
(Plate I, Figure 5)

Description : Cone-scale ovately spate-like in shape, small in size, 3.2 cm long and 1.8 cm wide in maximum, cordate at base and roundly obtuse at apex ; texture thick, woody ; stalk stout, thick, short, 2 to 3 mm long ; bract small, 5 mm long and 1 mm wide, lanceolate in shape, decurrent below.

Remarks : The present species is based on only one well-preserved cone-scale.

The present material is more or less close to the cone-scale of *Abies* or *Keteleeria*, but

differs distinctly from them by its shape and small lanceolate bract. The above-stated characters are quitely identical to those of living *Pseudolarix*.

The fossils *Pseudolarix* are recorded from the Pliocene sediments in Europe (FLORSCHÜTS, 1925) and Japan (MIKI, 1941 ; 1953), or the Oligocene sediments in North America (BROWN, 1940). Among the fossils of *Pseudolarix* the present species is closely similar to *P. Kaempferi* GORD. described by MIKI from the Pliocene sediments of central Honshu, Japan.

The living *Pseudolarix Kaempferi* is confined now to central China, about 1,000 m above sea level.

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4063

Pinus palaeopentaphylla sp. nov.
(Plate I, Figures 8, 10, 12)

Description : Leaves linear, 5 cm long and 1 mm wide, five in a fascicle, slightly curved, acutely pointed at apex ; 2 grooves on lowerside, separated by a ridge ; sheath slender, 2 mm long.

Seed obovate, 6.5 mm long and 4 mm wide, bluntly pointed at the base ; the wing slender ovate-elliptical in shape, widest just behind the point of attachment to the seed, about 1.7 mm long and 5 mm in the widest part.

Remarks : The present species is based on several needles and seeds of pine, and no cones which can be related to this leaf species have yet been found.

The living five-leaved pines are known in several species or varieties, and the present well-preserved materials are closely similar to modern *Pinus pentaphylla* MAYR. which is now living in Hokkaido and Honshu, Japan. Though the living species is deciduous in the sheath, the slender sheath is preserved in this fossil materials. Such five-leaved pine has not yet been known from the Tertiary sediments of Japan, and this is the first occurrence. MIKI (1941, 1956) described five-needles fossils of pine, *Pinus koraiensis* S. et Z., from the Pleistocene deposits in various localities of Honshu. His figured leaves are fragmental, and so not comparable to the present materials. But the living *P. koraiensis* is longer in leaf than this new species.

In North America, the five-needles pine fossils are known as following species : *Pinus florissanti* LESQ. and *P. Wheeleri* COCKEREL from Oligocene to Pliocene floras (MACGINITIE, 1953 ; AXELROD, 1956 etc.), but they are two times longer in leaf than the present new species.

Occurrence : Ningyo-toge and Onbara formations

Collection : GSJ. Holotype No. 4064 ; Paratype No. 4065 ; No. 4066

Family Taxodiaceae

Cunninghamia protokonishii sp. nov.
(Plate I, Figure 1)

1941. *Cunninghamia Konishii*, MIKI : Jap. Jour. Botany, Vol. 11, p. 257, figs. 7A, B
1955. *Cunninghamia Konishii*, TANAI : Geol. Surv. Jap. Rep., No. 163, pl. 1, fig. 6

Description : The present material is a fragmental foliaged shoot.

Leaves lanceolate or linear, and occasionally falcate in shape, 1.5 to 2.0 cm long and 2 to 3 mm wide ; apex acute ; margin coarsely fine-serrate. The leaves arranged spirally, jointing

decurrently on the stem ; stem thick, slightly curved, about 4 mm in width.

Remarks : Though the present material is so fragmental, it is fairly indentical to the genus *Cunninghamia* by the spiral arrangements and serrate margin of leaves. Two species of this genus exist now in East Asia : *Cunninghamia Konishii* HAYATA in Formosa, *C. lanceolata* HOOK and *C. Konishii* HAY. in central and southern China. This fossil material is very close to *C. Konishii* in the foliar characters, and also identical to the fossil foliaged shoot of this species from the Miocene deposits of the Nishitagawa coal field, Japan.

The fossil foliaged shoots and cones of the living *C. Konishii* were found from the lower Pliocene deposits in central Japan by MIKI (1941), and also the silicified woods of this genus were described from the Miocene deposits in the inner zone of northeastern Japan by WATARI (1952). Accordingly, this extinct genus seems to be grown luxuriantly in Japan during Neogene time.

Occurrence : Onbara formation
Collection : GSJ. Holotype No. 4067

Taiwania japonica sp. nov.
(Plate I, Figure 4)

1954. *Taiwania cryptomeroides*, MIKI : Proc. Japan Acad., Vol. 30, No. 10, p. 976, figs. A~D

Description : Leafy twigs stout, largest specimen measuring up to 10 cm long and 7 mm wide ; twigs covered with spirally arranged leaves ; comparatively stout, awl-like in shape, bluntly pointed at the apex, gradually thicker toward the base, slightly curved inwards, 3 to 5 mm long and about 2 mm wide at the base.

Remarks : This new species is represented by a well-preserved impression of branched leafy twig. The present material is closely similar to the modern *Taiwania cryptomeroides* HAYATA, which grows now in Formosa, southwest China and Burma. The fossil leafy twigs and cones of this living species were described from the Pliocene sediments in various localities of Japan (MIKI, 1954), and their leafy twigs are quite identical to the present specimen. Though there are found no cones of this genus in the writers' collection, the present new species includes probably MIKI's Pliocene materials. The present material is somewhat similar to some leafy twigs of the living *Cryptomeria japonica* D. DON, but is distinct from the latter species by broad dentate leaf and expansion of attachment of the leaves.

The genus *Taiwania* is now confined only to eastern Asia in its distribution, and there is only one existing species in the world. This fossil species is probably one of the direct progenitors of the living species.

Occurrence : Mitoku formation
Collection : GSJ. Holotype No. 4068

Family Cupressaceae

Thuja nipponica sp. nov.
(Plate I, Figures 11 a, b)

1936. *Thujopsis dolabrata*, MIKI : Chikyu, Vol. 26, No. 3, fig. 1 D
1937. *Thuja japonica*, MIKI : Jap. Jour. Botany, Vol. 8, p. 308, fig. 1 D
1954. *Thuja Standshii*, TAKAHASHI : Mem. Fac. Sci. Kyushu Univ., Ser. D, Vol. 5, No.

1, taf. 1, fig. 3

Description : Leafy twig stout, largest specimen measuring up to 2.5 cm long and 1.5 mm wide; twigs covered with spirally arranged, ralatively short, lapidoid leaf; leaves slender, 1.5 to 2 mm long and 1 mm wide, closely attached to twig with bluntly pointed tip, the leaves on the upper and lower sites rhombic in shape, the lateral leaves curved inwards.

Remarks : This new species is represented by several impressions of small terminal branchlets. The present materials are occurred in the Ningyo-toge and Onbara formations, and abundantly in the former.

The present materials are closely similar to the modern *Thuja Standishii* CARR. (Synonym : *T. japonica* MAX.), which is now restricted from northeastern to central Honshu, Japan. The fossil leafy twigs of this living species were described from the upper Pliocene sediments of Japan from MIKI and TAKAHASHI, and they are identified to this new species in general character. This new species is closely similar to *T. protojaponica* MIKI from the various Pliocene floras in Honshu, Japan (MIKI, 1941, 1956), but the latter species is more slender or constricted tenuous in leaves than the former. It is somewhat close to *T. dimorpha* (OLIVER) CHANEY et AXELROD (AXELROD, 1956 : Pl. 4, fig. 24 ; Pl. 12, figs. 1～4, etc.) from Mio-Pliocene floras in west-central Nevada, North America.

This new species, along with the above-described several conifers, was probably restricted chiefly to slopes above the lowland basins of deposition at that time.

Occurrence : Ningyo-toge and Onbara formations

Collection : GSJ. Holotype No. 4069 ; Paratypes Nos. 4070, 4071

Juniperus honshuensis sp. nov.
(Plate I, Figure 3)

Description : Terminal part of leafy twig slender, gently curved, about 2.4 cm long and 1.0 mm wide ; twig covered with spirally-arranged and lapidoid leaves ; leaves slender, awl-like in shape, bluntly pointed in apex, closely attached to twig and arranged in 4 rows, 1.0 to 1.5 mm in length.

Remarks : This new species is represented by a well-preserved impression of small terminal twig. The present material is closely similar to the old branches of the living *Juniperus chinensis* LINNE (Synonym : *Sabina chinensis* (L.) ANTOINE), or *J. Sargentii* (HENRY) TAKEDA (Synonym : *S. Sargentii* HENRY), especially almost identical to the former species. These two living species have twigs with spiny leaves in the young trees, but the twigs of old trees are generally covered with lapidoid leaves.

The fossil *Juniperus* has been scarcely described from Japanese Cenozoic flora, and some leafy twigs of *J. chinensis* L. were reported only their occurrence from Pleistocene floras by MIKI (1950, 1953). But the fossil junipers were commonly described from Tertiary floras of Europe and North America, and in North America known from Palaeocene to Pliocene floras. The present species is closely similar to *J. alvordensis* AXELROD (AXELROD, 1944 : Pl. 43, figs. 1, 2, 5) in general outline, and scarcely distinguishable each other.

The living *J. chinensis* is widely distributed in Japan, China and Mongolia, and especially in Japan grows now in the coastal areas in Honshu, Shikoku and Kyushu.

Occurrence : Mitoku formation

Collection : GSJ. Holotype No. 4072

CLASS ANGIOSPERMAE

Family Salicaceae

Populus aizuana HUZIOKA et SUZUKI
(Plate I, Figure 13)

1954. *Populus aizuana*, HUZIOKA et SUZUKI: Trans. Proc. Palaeont. Soc. Japan, N.S., No. 14, p. 137, pl. 16, figs. 1~4

Remarks: They are identical to this species from the upper Miocene Shiotsubo flora in Hukushima prefecture, though the present materials are fragmental. Comparing to the crenato-dentate margin of the original specimens, the present specimens are wavy-undulate in the margin, but their venation fairly agrees with that of the original specimens.

This species does not resemble Japanese living *Populus*, and rather close to some leaves of American *Populus*. Namely, it is somewhat similar to *P. alba* LINNE or *P. Fremonti* WATS. in the venation and marginal characters.

Occurrence: Onbara and Mitoku formations

Collection: GSJ. Plesiotype No. 4074; No. 4075

Family Juglandaceae

Juglans sp.
(Plate II, Figure 3)

Description: Leaflets somewhat asymmetrical, oblong to elliptical in shape, length unknown, but probably about 10 to 12 cm long (in restored specimens) and 3.2 to 4 cm wide; base missing, apex abruptly pointed and acute; midrib stout and straight; secondary nerves rather slender, about 20 alternate pairs, diverging from the midrib at the angles of about 60 degrees, curving upwards, forked or branched near the margin, then forming loops; tertiaries branched from the secondaries forming a fine loops or entering to marginal teeth; tertiaries in the inter-secondary spaces irregularly percurrent; nervilles thin but distinct, finely reticulate; margin serrulate or argute-serrulate; texture thin, membranaceous.

Remarks: The present specimens are fairly identical to some leaves of Juglandaceae by the above-described characters, especially by venation and margin, though they are fragmental. They resemble most closely the modern *Juglans ailanthifolia* CARR. (Synonym: *J. Sieboldiana* MAXIM.) in general outline, which is widely distributed from Hokkaido to Kyushu in Japan.

These specimens are almost identical to fossil leaves of *Juglans Sieboldiana* MAX. described from Pliocene Mogi flora near Nagasaki (NATHORST, 1883: Pl. 1, figs. 13~17), and the both are probably same species. The fossil leaves or nuts of this living species are known from Pliocene and Pleistocene floras of Japan.

Occurrence: Ningyo-toge, Onbara and Mitoku formations

Collection: GSJ. Holotype No. 4076; No. 4077

Pterocarya nipponica sp. nov.
(Plate II, Figures 2, 4, 5)

1955. *Pterocarya rhoifolia*, OKUTSU: Sci. Rep. Tohoku Univ., 2nd Ser., Vol. 26, p. 82, pl. 1, figs. 6a, 6b

Description: Leaflets subsessile, medium in size, oblong-obovate or lanceolate in shape, the terminal with a relatively symmetrical, bluntly to narrowly cuneate base, and the lateral slight-

ly falcate, with an asymmetrically rounded base ; apex acute or slightly acuminate ; length 5.0 to 9.0 cm, width 1.7 to 3.5 cm ; midrib stout, gently curving on the lateral leaflets, or nearly straight on the terminals ; secondary nerves 15 to 20 pairs, thin but distinct opposite to subalternate, leaving the midrib at the angles of 50 to 70 degrees, somewhat more spreading near the base, curving upwards, camptodrome, but the arches not reaching marginal border, and forming loops with small branches ; tertiaries thin, indistinct, irregularly percurrent ; margin finely serrulate with acute teeth, except on the basal part ; texture thin, membranaceous.

Remarks : These characteristic leaves seem to be allied to the modern *Pterocarya rhoifolia* S. et Z., which is now distributed from southern Hokkaido to Kyushu in Japan. The fossil leaves of this living species were described from the upper Miocene sediments near Sendai, Japan by OKUTSU (1955), and they are almost identical to the present new species. The present materials are close to *P. asymetrosa* KONNO in general outline, which is one of the common species in Japanese Miocene floras (KONNO, 1931 : Pl. 16, figs. 5, 6, 7 ; TANAI, 1952 : Pl. 5, fig. 1, etc.). The lateral leaves of *P. asymetrosa* are generally ovate in shape, but the both species are frequently indistinguishable respectively.

The leaflets of this species closely resemble some leaflets of *Platycarya miocenica* HU et CHANEY from Shantung Miocene flora of China (HU et CHANEY, 1940 : Pl. 4, figs. 6, 7 ; Pl. 5, figs. 1, 3, 4), but differs somewhat in the marginal serration and secondary venation. Namely, the secondary nerves of the latter species form usually loops more closely to the marginal teeth than those of the former. But it is frequently difficult to distinguish the leaflets of Juglandaceae respectively by their foliar characters, and the above both species may represent the same species. *Pterocarya denticulate* (WEBER) HEER from Miocene flora of Europe (HEER, 1855 : Pl. 131, figs. 5~7, etc.) are also closely similar to the present specimens, and frequently not distinguishable respectively.

Occurrence : Ningyo-toge and Mitoku formations

Collection : GSJ. Holotype No. 4078 ; Paratypes Nos. 4079, 4080 ; No. 4081

Carya miocathayensis HU et CHANEY
(Plate II, Figure 6)

1940. *Carya miocathayensis*, HU et CHANEY : Pub. Carnegie Inst. Wash., No. 507, p. 26, pl. 6, fig. 1 ; pl. 7, figs. 5~7

1955. *Carya miocathayensis*, TANAI : op. cit. pl. 3, fig. 6

Remarks : The present fragmental leaves are identical to this species from Miocene Shantung flora of China by their venation and marginal characters. This species is closely similar to the above-described *Juglans* sp. in general outline, but the former is more in secondary number, and closely and sharply serrulate in margin than the latter.

This species is comparatively common in Miocene floras of Japan, especially abundant in middle Miocene floras.

Occurrence : Mitoku formation

Collection : GSJ. No. 4082

Family Betulaceae

Alnus protohirsuta ENDO
(Plate II, Figure 1 ; Plate III, Figure 5)

1940. *Alnus hirsuta*, OKUTSU : Saito Ho-on kai Mus. Res. Bull., No. 19, p. 157, pl. 9, figs. 3, 4

1954. *Alnus tinctoria*, HUZIOKA et SUZUKI : op. cit. p.139
1955. *Alnus protohirsuta*, ENDO : Icones of Fossil Plants from Japanese Islands, pl. 27, fig. 5

Description : Leaves medium in size, 5.0 to 8.0 cm long and 5.0 to 7.0 cm wide, ovate-orbiculate or broadly ovate in shape ; apex acute ; base truncate to broadly rounded, margin coarsely and subduplicately denticulate, with numerous pinnately acute lobes ; midnerve stout below, nearly straight, becoming thin distantly ; secondaries of about 6 subopposite pairs stout, straight, regularly spaced and nearly parallel, diverging from the midnerve at the angles of 30 to 60 degrees, running into the largest teeth ; tertiaries thin, percurrent, perpendicular to the secondaries ; nervilles thin, indistinct, forming a fine polygonal mesh ; petiole missing ; texture subcoriaceous.

Remarks : The present species was only figured by a leaf-impression from the upper Miocene sediments near Sendai, Japan by ENDO (1955), but its description is not yet given. The present specimens are quite similar to his original figure in general characters, and also fairly similar to the fossil leaves of recent *Alnus hirsuta* TURCZ. described from the upper Miocene sediments near Sendai by OKUTSU (1940). The fossil species is somewhat close to *Alnus tenuifolia* NUTTALL, which grows now in the Pacific slope of North America.

The existing *Alnus hirsuta* grows now in Kurile Islands, Hokkaido, Honshu, Shikoku, and Kyushu, Japan and also is known from Korea, Manchuria, eastern Siberia and Kamchatka. It is grown luxuriantly at about 900 to 1,400 m above sea level in central Honshu, Japan.

Occurrence : Onbara and Mitoku formations

Collection : GSJ. Plesiotype No. 4083 ; Nos. 4084, 4085

Alnus miojaponica TANAI
(Plate II, Figure 7)

1954. *Alnus japonica*, HUZIOKA et SUZUKI : op. cit. p. 138
1955. *Alnus miojaponica*, TANAI : op. cit. pl. 6, fig. 8

Description : Leaves elliptical in outline, 6 cm long (estimated) and 3.2 cm wide ; apex missing, probably abruptly acuminate ; base cuneate or slightly rounded ; midrib stout, nearly straight ; secondaries 8 to 9 pairs, opposite to subalternate, leaving the midrib at the angles of 40 to 45 degrees, gently curved up near the marginal border, craspedodrome, running into large marginal teeth ; tertiary nerves thin, indistinct, coarsely percurrent ; nervilles indistinct, forming a fine-polygonal mesh ; margin double-serrate, with acutely tipped teeth ; petiole stout, about 4 mm long ; texture firm, membranaceous.

Remarks : The present materials are rare in the writers' collection, and quite indentical to *Alnus miojaponica* TANAI figured from the middle Miocene sediments of the Nishitagawa coal field by the senior writer.

The present species is closely similar to the modern *Alnus japonica* S. et Z., which is widely distributed over Japan and extending also to China and Korea. Among the fossil leaves of *Alnus*, the present species is very close to, or almost unseperable from *Alnus relatus* (KNOWLTON) BROWN (BROWN, 1937 : Pl. 49, figs. 1~6), which is one of the narrow leaves of Miocene alder in North America. This species somewhat resembles *A. prenepalensis* HU et CHANEY from Miocene flora of Shantung province, China (HU et CHANEY 1940 : Pl. 10, figs. 1, 4, 6), but differs distinctly by the shape and marginal serration.

Occurrence : Onbara formation

Collection : GSJ. Paratype No. 4086

Betula protoermanni ENDO
(Plate III, Figure 4)

1940. *Betula Ermanni*, OKUTSU : op. cit. p. 158, pl. 11, figs. 1, 2
1954. Cfr. *Betula Ermanni*, HUZIOKA et SUZUKI : op. cit. p. 139
1955. *Betula protoermanni*, ENDO : op. cit. pl. 26, fig. 4

Description : Leaves medium in size, 5.5 to 7.0 cm long and 5.0 cm wide, ovate orbicular or orbicular-deltoid in shape ; base inequilateral, broadly rounded, truncate or slightly cordate ; apex acute ; midrib slightly curved, stout below, becoming thin distantly ; secondary nerves stout, 10 to 13 pairs, subopposite, straight or slightly curved, leaving the midrib at the angles of about 50 degrees on the basal part, and about 30 degrees on the middle part, entering into the largest teeth, craspedodrome ; tertiaries thin, percurrent, at the margin branching from the secondaries to enter the smaller teeth ; nervilles indistinct, finely areolate ; margin duplicately serrulate, with acute teeth, particularly acuminate teeth at termination of each secondaries ; petiole thick, 1.0 to 1.5 cm long ; texture thin, membranaceous.

Remarks : The present species was only figured by a leaf-impression from the late Miocene sediments near Sendai, Japan by ENDO (1955), but description is not yet given. The present specimens are quite identical to his original figure in general characters, and also to the fossil leaves of the livings *Betula Erammni* CHAM. described from the late Miocene flora near Sendai by OKUTSU (1940). It is also closely similar to the living *B. papyrifera* MARSH., which is widely distributed in the northern part of North America.

The present materials are closely similar to the modern *B. Ermanni* CHAM. var. *communis* KOIDZ., which now exists in Hokkaido, northern and central Honshu, and also extending to Korea, Manchuria, eastern Siberia, Amur, Kamchatka, Saghalien, etc.. In Hokkaido, it is one of the most common deciduous trees in the mountain region of various altitudes.

Occurrence : Onbara and Mitoku formations

Collection : GSJ. Plesiotype No. 4087 ; No. 4088

Betula protoglobispica sp. nov.
(Plate III, Figures 1, 2)

1940. *Betula globispica*, OKUTSU : op. cit. p. 159, pl. 10, figs. 1, 2

Description : Leaves medium in size, ovate to ovate-rhomboid in shape, 7.0 to 7.5 cm long (estimated) and 4.5 to 5.0 cm wide ; base acute or broadly cuneate ; apex acutely pointed ; midrib stout and thick, straight to the tip ; secondary nerves stout, nearly straight, 8 to 10 pairs, subopposite to opposite, diverging from the midrib at the angles of about 40 degrees on middle portion, curving up near the margin, then entering into the largest teeth ; tertiaries thin, percurrent, at the margin branching from the secondaries to enter the smaller teeth ; nervilles indistinct, forming a fine areolation ; margin subduplicately denticulate or serrulate with long linear tip ; petiole stout and thick, about 1.7 cm in length ; texture firm, membranaceous.

Remarks : The present materials are closely similar to the living *Betula globispica* SHIRAI, which grows now in central Honshu, Japan. They are fairly identical to the leaves described as *B. globispica* from the upper Miocene sediments near Sendai (OKUTSU, 1940). This new species is close to the above-described species, *B. protoermanni* ENDO, in general characters, but it differs from the latter by the cuneate base.

The present species is somewhat close to the modern *B. nigra* L. in general shape, which is now distributed southwestern part of North America.

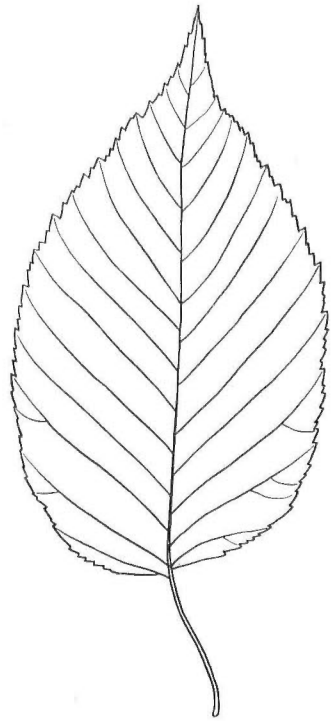
Occurrence : Onbara and Mitoku formations

Collection : GSJ. Holotype No. 4089 ; Paratype No. 4090

Betula onbaraensis sp. nov.
(Plate IV, Figures 1, 2)

Description : Leaves comparatively large in size, obovate in shape, 10 to 11 cm long (estimated) and about 6 cm wide ; base truncate, asymmetrical ; apex acuminate ; midrib stout, nearly straight ; secondary nerves stout, nearly straight, about 13 pairs, subopposite to alternate, leaving the midrib at the angles of 35 to 40 degrees on middle portion, near the margin curving upwards, entering into the larger teeth, craspedodrome ; tertiaries branched from the secondaries, entering into smaller teeth ; tertiaries in the inter-secondary spaces irregularly percurrent ; nervilles indistinct, finely reticulate ; margin doubly serrulate, with acute teeth ; petiole thick, stout, 3 cm long and 1 mm wide ; texture firm, membranaceous.

Remarks : This new species is based on some fragmental leaves, and their specimens are so well-preserved that restored figure is shown in Fig. 2. The present materials are closely



Text-fig. 2 A Restoration of *Betula onbaraensis* TANAI et ONOE (×2/3)

similar to *Betula grossa* S. et Z. or *B. grossa* S. et Z. var. *ulmifolia* MAKINO in the general characters, and especially close to the latter species. These related species are distributed now in montane area of Honshu, Shikoku and Kyushu, Japan.

This species are closely similar to some leaves of *Alnus Kefersteinii* (GOEPPERT) UNGER in general outline, which is widely ranged from Eocene to Miocene age in Europe and North

America. Though the latter species, *Alnus Kefersteinii*, is somewhat various in foliar characters, it is generally less in secondary number and more acute in marginal teeth than this new species. However, many fossil leaves as such type have been frequently confused whether they belong to *Alnus* or to *Betula* in the world. Accordingly, the writers refered the present materials to the genus *Betula* this time, but it is somewhat doubtful in identification.

Occurrence : Onbara formation

Collection : GSJ. Holotypes Nos. 4091, 4092 ; No. 4093

Carpinus nipponica ENDO
(Plate IV, Figures 5, 8)

1950. *Carpinus nipponica*, ENDO : Short Papers I.G.P.S., p. 53, pl. 6, fig. 8

1955. *Carpinus nipponica*, ENDO : op. cit. pl. 34, fig. 5 ; pl. 35, figs. 1, 7, 9, 11

Remarks : The present involucres have a short lobe between the main and lateral large lobes, and is slightly shorter in length than the type specimen. But the present materials with a fairly well-preservation is quite similar in other characters to the involucres and nutlets of this species described from the upper Miocene sediments near Sendai by ENDO (1950).

ENDO compared this species to the recent *Carpinus betulus* L. living now in Europe and eastern Asia, but this species is rather closely similar to *C. londoniana* WINKI. or *C. lanceolata* HANDEL-M., which are living in southern China, especially close to the latter species. BERGER, W. (1953) grouped many involucres of modern *Carpinus* in the world and stated also their relationships with fossil species. According to his grouping, the present species belongs to the form-group of "*Carpinus caroliniana*".

Occurrence : Ningyo-toge, Onbara and Mitoku formations

Collection : GSJ. Plesiotype No. 4095 ; No. 4096

Carpinus miocenica TANAI
(Plate III, Figure 3 ; Plate IV, Figure 4)

1955. *Carpinus laxiflora*, OKUTSU : op. cit. p. 86, pl. 1, fig. 8

1955. *Carpinus miocenica*, TANAI : op. cit. pl. 5, figs. 1, 2

Description : Leaves medium in size, oblong-elliptic or ovate-oblong in shape, 6.5 to 7.5 cm long and 2.4 to 2.8 cm wide ; apex acuminate ; base slightly asymmetrical, rounded ; midrib rather slender, straight to the top of the leaf ; 10 to 13 pairs of secondary nerves regularly parallel, leaving the midrib at the angles of 30 to 40 degrees, almost straight to the tip of the marginal dents, craspedodrome, branching off some tertiary laterals to the marginal teeth ; tertiaries obscure, percurrent ; margin unequally dupplicate-serrulate, with acute teeth ; petiole stout, about 0.7 to 1.0 cm long ; texture thin, membranaceous.

Involucre with short stalk, three-lobed at the base, prolongly deltoid and inequilateral in shape ; base broadly rounded ; apex acutely pointed ; middle lobe lanceolate, 3 or 4 time as long as the lateral ones, 1.5 cm long and 0.4 cm wide ; other lobe small, diverging at 40 to 50 degrees from the main lobe ; palmately three-veined, primaries on each lobe nearly straight, distinct, running into the tip ; two intermediate primaries radiating from the base on one side, straight to the margin ; a few secondaries branching off from the primaries, indistinct ; tertiaries thin, indistinct, forming a irregular mesh ; margin with a few dentations on one side, and on the other side entire or with a few serration, except the basal small lobe ; stalk short, thick, 1 mm long ; nutlet poorly preserved, apparently globular, 1 mm in diameter.

Remarks : The present materials, leaves and involucres, are almost identical to this

species, which is described from the middle Miocene sediments in the Nishitagawa coal field, Japan. They are closely similar to the modern *Carpinus laxiflora* BLUME, which is widely distributed now in Hokkaido, Honshu, Shikoku and Kyushu. They resemble also *C. londoniana* WINKI., *C. lanceolata* HANDLEL-MAZZ. and *C. viminea* WALL. which are existing now southern China or India, especially related to the latest species.

Carpinus honshuensis ENDO described from Pliocene flora of Fukushima prefecture (ENDO, 1950 : Pl. 6, fig. 6), is closely similar to the involucres of this species in general characters, and may be probably same species. *C. Kodairae-bracteata* HUZIOKA from Miocene flora of Korea, and above-described *C. nipponica* ENDO, are somewhat close to this species, but they are different by the shape and venation of lobes.

Occurrence : Onbara and Mitoku formations

Collection : GSJ. Plesiotype No. 4097 ; No. 4098

Carpinus subcordata NATHORST
(Plate IV, Figure 11)

1883. *Carpinus subcordata*, NATHORST : Kgl. Svensk, Vet.-Akad. Handl., Bd. 20, No. 2, p. 39, pl. 2, figs. 13～18, 20
1931. *Carpinus cordata*, KONNO : Geology of Central Shinano (in HONMA), pl. 1, fig. 7 ; pl. 2, fig. 4 ; pl. 8, figs. 9, 10
1931. *Carpinus subcordata*, KONNO : op. cit. pl. 1, figs. 2～6, 10, 12
1939. *Carpinus cordata*, ENDO : Jub. Pub. Comm. Prof. H. YABE's. 60th Birth., Vol. 1, p. 339, pl. 23, fig. 5
1940. *Carpinus miocordata*, HU et CHANEY : op. cit. p. 31, pl. 12, figs. 1, 2, 11
1950. *Carpinus cordata*, ENDO : op. cit. p. 51, pl. 6, fig. 1
1954. *Carpinus miocordata*, HUZIOKA : Trans. Proc. Palaeont. Soc. Japan, N.S., No. 13, p. 120, pl. 13, figs. 5, 6
1954. *Carpinus erosa*, HUZIOKA et SUZUKI : op. cit. p. 139
1955. *Carpinus miocordata*, ENDO : op. cit. pl. 34, fig. 1
1955. *Carpinus protocordata*, ENDO : op. cit. pl. 35, fig. 15
1958. *Carpinus miocordata*, TANAI et ONOE : Bull. Geol. Surv. Japan, Vol. 10, No. 4, pl. 3, fig. 3 ; pl. 4, fig. 16

Description : Leaves elongate-ovate to ovate in shape, variable in size, 3 to 11 cm long and 1.8 to 5.0 cm wide ; apex elongately acuminate ; base rounded, shallowly cordate, sometimes slightly inequilateral ; midrib stout, straight or slightly curved ; secondaries 14 to 20 pairs, opposite or subopposite, leaving the midrib at the angles of 40 to 50 degrees, or as low as 30 degrees near the apex, extending straight to the margin, where they curve up slightly into the teeth, occasionally forking well within the margin, closely parallel except at the base, where they are more spreading ; tertiaries thin, irregularly percurrent, indistinct on smaller leaves, near the margin branching from secondaries to the smaller teeth and to the notches between them ; from the lowermost secondaries, the tertiaries diverging acutely and abaxially, ending in the basal teeth ; nervilles forming fine areolation ; margin closely and duplicately serrate, the teeth in which the secondaries end being largest, with 2 to 5 smaller teeth ; petiole stout, straight, 1 to 2 cm long ; texture from thin to slightly firm, membranaceous.

Involucres ovate to ovately elliptical in shape, 1.8 to 2.5 cm long and 1.2 to 1.4 cm wide, asymmetrically rounded or broadly cuneate at the base, acute at the apex ; primary nerves 3 or 4 in number, prominent, craspedodrome ; a few secondary branches from the main nerves curved distantly, ending in the smaller teeth, tertiary nerves diverge at right angles from the main

nerves, forming a transverse network ; margin irregularly serrulate, with a few dentation.

Remarks : The present materials, though fragmental, are closely similar to the leaves and involucres of the modern *Carpinus cordata* BLUME, which is widely distributed in eastern Asia.

The fossil leaves and involucres resembling closely this living species have been already described from the Neogene and Pleistocene sediments over Japan, and given various names. At first, NATHORST (1883) gave the name of *Carpinus subcordata* NATHORST to such fossil leaves from the Pliocene Mogi Plant beds near Nagasaki. HU et CHANEY (1940) described *Carpinus miocordata* HU et CHANEY on the basis of leaves and involucres from the Miocene sediments in the Shantung province, China, and distinguished from *C. subcordata* by leaves with compound-serrate margin. However, the morphological resemblance between these two species is fairly obvious, and both species are rather not distinguishable. Accordingly, the writers consider that the latter species must be included into the former species within the limits of their variation range. The fossil involucres of *Carpinus cordata* BL. was described from the Miocene sediments in Korea by ENDO (1939, 1950, 1955), and also they are probably included into *C. subcordata* in a wide sense.

Occurrence : Onbara formation

Collection : GSJ. No. 4099

Carpinus subcarpinoides sp. nov.
(Plate IV, Figure 9)

1941. *Carpinus carpinoides*, MIKI : op. cit. p. 267, figs. 10 C, F
1954. *Carpinus carpinoides*, TAKAHASHI : op. cit. p. 55, taf. 3, figs. 1~10 ; taf. 3, figs. 1~5
1955. *Carpinus carpinoides*, OKUTSU : op. cit. p. 85, pl. 1, fig. 7

Description : Leaves rather small in size, lanceolate to ovate-lanceolate in shape, 6.6 to 9.0 cm long and 2.8 to 4.0 cm wide ; apex acuminate ; base slightly cordate, asymmetrical ; midrib stout, below thin distantly, nearly straight ; secondary nerves stout, about 16 subalternate pairs, regularly spaced, diverging from the midrib at the angles of about 40 degrees in the middle portion, then almost straight or gently curved upwards, entering into large teeth, craspedodrome ; near the margin a few tertiaries branched from each secondary, entering into smaller teeth ; tertiaries in inter-secondary spaces thin, percurrent ; nervilles indistinct, forming a fine areolation ; margin duplicately serrate ; petiole stout, 1 cm long.

Remarks : The present materials are comparatively well in preservation, and closely similar to the modern *Carpinus carpinoides* MAKINO (Synonym : *C. japonica* BLUME) by general characters. The fossil leaves of this living species described from the various Pliocene or Miocene flora of Japan, are quite identical to this new species. In the writers' collection, there are no fossil involucre which is referable to *C. carpinoides*. However, some fossil involucres described as *C. japonica* from Pliocene flora of Gihu prefecture (MIKI, 1941 : Fig. 10 F) and the Miocene flora of northern Korea (ENDO, 1939 : Pl. 23, figs. 3, 4), are closely similar to those of this living species, and probably included into this new species. Recently, ENDO described some involucres of *C. protojaponica* from Miocene floras in the various localities of Japan and Korea (ENDO, 1950 : Pl. 6, fig. 2 ; 1955 : Pl. 34, fig. 2 ; Pl. 35, figs. 2, 12, 13, 16), but they are somewhat different from those of the living *C. japonica* on their shapes and nervations. Accordingly, the writers think that *C. protojaponica* is probably different from this new species.

The present species closely resembles *C. miocenica* TANAI in general outline, but differs

distinctly in secondary number and marginal character. Namely, leaves of the latter species is usally less in number of secondaries than those of the former, and finely serrulate in margin. However, the foliar difference between the both species is not so distinct as in the involucres.

This related living species, *C. carpinoides*, is widely distributed in Honshu, Shikoku and Kyushu and has a luxuriant growth at about 1,500 m above sea level in central Honshu.

Occurrence : Ningyo-toge and Onbara formations

Collection : GSJ. Holotype No. 4100

Carpinus subyedoensis KONNO
(Plate IV, Figures 3, 6, 7, 10)

1888. *Carpinus* sp. cfr. *yedoensis*, NATHORST : Plaeont. Abhandl., Vol. 4, p. 38, pl. 13, figs. 12, 12a
1926. *Carpinus* sp. cfr. *yedoensis*, KRYSHTOFOVICH : Ann. Russ. Pal. Soc., Vol. 6, pl. 1, fig. 8
1931. *Carpinus subyedoensis*, KONNO : op. cit. pl. 8, figs. 1～4
1938. *Carpinus heigunensis*, HUZIOKA : Jour. Fac. Sci., Hokkaido Imp. Univ., Ser. 4, Vol. 4, Nos. 1～2, p. 149, text-fig. 1
1941. *Carpinus Tschonoskii*, MIKI : op. cit. p. 268, fig. 10 D, E
1954. *Carpinus Tschonoskii*, TAKAHASHI : op. cit. p. 55, taf. 2, fig. 11 ; taf. 3, fig. 6
1955. *Carpinus protojaponica*, ENDO (in part) : op. cit. pl. 35, fig. 12
1955. *Carpinus Tschonoskii*, OKUTSU : op. cit. p. 87, pl. 7, fig. 6

Description : Leaves variable in size, small to medium, 3.5 to 5.0 cm long and 1.8 to 3.0 cm wide, oblongly elliptical in general shape ; apex acute or slightly acuminate ; base rounded to obtuse ; midrib rather slender, nearly straight to the apex ; secondaries 9 to 12 pairs, leaving the midrib at the angles of 40 to 50 degrees, opposite to subopposite, regularly spaced, parallel, straight to the margin, craspedodrome ; a few tertiary laterals from the secondaries branching off near marginal border, then entering into small teeth ; finer tertiaries thin, percurrent ; nervilles forming fine reticulate meshes ; margin finely serrulate, with sharp and unequal teeth ; petiole thick and short ; texture thin, membranaceous.

Involucres prolongly deltoid, inequilateral in shape, 1.5 to 2.5 cm long and 0.5 to 0.9 cm wide, asymmetrically rounded or sometimes obtusely cuneate at the base, acutely pointed at the apex ; inner margin nearly straight, entire, rarely with a few teeth on the arched margin ; outer margin oblique or arched, distinctly serrate with acute teeth ; principal nerves extending to outerside, leaving from the base, 3 to 4 in number, among which the principal extending to the tip is strongest, other principals slender, frequently forked, thence entering into the marginal teeth ; a few secondaries sometimes leaving from the main strongest nerve to inner margin ; tertiary nerves diverge at right angles from the principals, forming a transverse network ; stalk thick, about 2 mm long ; seeds semicircular, about 2.5 mm in diameter.

Remarks : The present materials, leaves and involucres, are quite indentical to *Carpinus subyedoensis* KONNO figured from late Miocene flora of Shinano, Nagano prefecture by KONNO. This species is closely similar to modern *Carpinus Tschonoskii* MAX. (Synonym : *C. yedoensis* MAX.), which is now distributed in Honshu, Shikoku and Kyushu of Japan, and also extending to Korea. The present species are also somewhat similar to the living *C. laxiflora* BLUME in their leaves, but quite different in the shape of involucres.

Fossil leaves or involucres of *C. Tschonoskii* were frequently described from Neogene floras of Japan, and they are included into this fossil species. Several leaves of the living species were also described from Pleistocene floras in various localities of Japan, and they are scarcely

distinguishable from the present fossil species. The involucres described by HUZIOKA as *C. heigunensis* HUZIOKA from the Pliocene sediments in the Heigun Island, Yamaguchi prefecture, is quite identical to this species. Among the involucre specimens figured by ENDO as *C. protojaponica* ENDO, a specimen (ENDO, 1955 : Pl. 35, fig. 6) is rather closer to the living *C. Tschonoskii* than *C. japonica*, and probably included into the present species.

Occurrence : Onbara and Mitoku formations

Collection : GSJ. Plesiotypes Nos. 4101, 4102 ; Nos. 4103, 4104

Family Fagaceae

Castanea miocrenata sp. nov.
(Plate V, Figures 1~4)

1883. *Castanea vulgaris*, NATHORST : op. cit. p. 84, pl. 15, fig. 10a

Description : Leaves medium in size, oblong-lanceolate or oblanceolate in shape, 10 to 12 cm long (estimated) and 3 to 4 cm wide ; base rounded or slightly cordate, asymmetrical ; apex missing, but apparently acuminate ; midrib stout, nearly straight or slightly curved, gradually thin and slender towards the tip ; secondary nerves about 18 subopposite pairs, diverging from midrib at the angles of 50 to 60 degrees on one side, and 40 to 50 degrees on the other side, curving slightly upwards, distinctly craspedodrome except those of basal two pairs, which are camptodrome ; tertiaries thin, slender, percurrent ; areolation indistinct ; margin dentate with spiny teeth, except the basal part ; spiny teeth slender, spreading or incurved ; petiole stout and thick, 1.3 cm in length ; texture thin, membranaceous.

Remarks : Though the present materials are incomplete, they are closely similar to the modern *Castanea crenata* S. et Z., which is widely distributed from southwestern Hokkaido to Kyushu in Japan. The fragmental leaf described as *Castanes vulgaris* LAMK. from Japan by NATHORST (1883) is quite similar to this new species.

The fossil leaves of *Castanea* are common in Neogene floras of Japan, and *C. Kubinyi* KOVAT shows a general resemblance to this species. *C. rarinervis* KONNO described from the upper Miocene sediments of Nagano prefecture (KONNO, 1931 : Pl. 11, figs. 6~8 ; Pl. 12, fig. 6.) is somewhat similar to this species, but differs in marginal dentation and teeth. This species is also close to *C. miomollissima* HU et CHANEY from Miocene flora of Shantung province, China (HU et CHANEY, 1940 : Pl. 13, fig. 3), but different in number of secondary nerves.

At a glance, the present new species resembles the living *Meliosma myriantha* S. et Z., but the latter is more slender in secondary nervation and cuneate at the base than the former. The fossil leaves of the living *C. crenata* were described from Pleistocene Shiobara Plant beds in Tochigi prefecture by ENDO (1940).

Occurrence : Onbara, Mitoku and Ningyo-toge formations

Collection : GSJ. Holotypes Nos. 4105, 4106 ; Paratype No. 4107 ; No. 4108

Quercus miocrispula HUZIOKA
(Plate VI, Figures 1, 2, 6)

1930. *Quercus dentata*, KONNO (in part) : op. cit. pl. 3, fig. 4 (not fig. 5.)
1937. *Quercus crispula*, MIKI : op. cit. p. 313, fig. 3H
1940. *Quercus crispula*, OKUTSU : op. cit. p. 160, pl. 10, fig. 3
1954. *Quercus miocrispula*, HUZIOKA : Trans. Proc. Palaeont. Soc. Japan, N. S., No. 15, p. 196, pl. 25, fig. 3

Remarks : Fossil leaves being closely indentical to living *Quercus crispula* BLUME were

already reported by many students from the Neogene and Pleistocene sediments in Japan. Recently, HUZIOKA (1954) described *Quercus miocrispula* from the middle Miocene sediments in Korea.

The present excellently-preserved impressions of the large oak leaves in the writers' collection have all the typical characters of *Quercus miocrispula* HUZIOKA. Among our collections, some specimen (Pl. VI, fig. 2) are more or less obtuse in marginal dentation, and they are closely similar to the living *Q. mongolica* FISCHER, which is now widely distributed in Japan, Korea, Manchuria, Saghalien, Siberia, etc.. But, their other characters are fairly identical to those of the present species, and they are included into this species. Among the fossil leaves, the present species is closely similar to some type of *Quercus winstanleyi* CHANEY from the Pliocene sediments in California and Oregon, North America (CHANEY, 1944; AXELORD, 1944).

The fossil species is probably a direct progenitor of living *Quercus crispula* BLUME (Synonym: *Q. mongolica* FISCHER. var. *grosseserrata* (BLUME) R. et W.), which grows now in Hokkaido, Honshu, Shikoku, Kyushu, Saghalien and southern Kurile Islands. In central Honshu of Japan, the living species grows luxuriantly at 1,000 to 1,600 m above the sea level.

Occurrence: Ningyo-toge, Onbara and Mitoku formations

Collection: GSJ. Plesiotype No. 4109; Nos. 4110, 4111

Quercus protodentata sp. nov.
(Plate VII, Figures 1, 2)

1930. *Quercus dentata*, KRYSHTOFOVICH: Ann. Soc. Palaeont. Russie, Vol. 8, p. 27, pl. 4, fig. 39

1931. *Quercus dentata*, KONNO (in part): op. cit. pl. 3, fig. 5 (not fig. 4), pl. 11, figs. 2, 3

1954. cfr. *Quercus dentata*, HUZIOKA: op. cit. p. 197

Description: Leaves medium to large in size, 13 to 20 cm long and 7 to 13 cm wide, broadly oval or obovate in shape; base roundly cuneate and slightly cordate; apex narrowly to bluntly rounded; midrib stout, straight; secondaries 10 to 12 pairs, opposite to subopposite, evenly spaced, nearly straight, diverging from the midrib at the angles of 50 to 60 degrees in the middle portion, entered to marginal lobes, craspedodrome; tertiaries thin, percurrent; nervilles indistinct, forming an irregular mesh; margin deeply dentate or lobed; lobes simple, essentially symmetrical, rounded to bluntly pointed; sinus mostly rounded, asymmetrical, deepest at the widest part of the blade, becoming shallow towards apex and base; petiole thick, short, about 1 cm long; texture thin, membranaceous or subcoriaceous.

Remarks: The present materials are comparatively abundant in the writers' collection, and closely resemble the modern *Quercus dentata* which is now widely distributed in northeastern Asia. The present species is quite identical to the fossil leaves of *Q. dentata* from the Miocene sediments in Nagano prefecture by KONNO (KONNO, 1931: all except Fig. 4 of Pl. 3) and KRYSHTOFOVICH (KRYSHTOFOVICH, 1930), though they are fragmental. This new species is somewhat similar to the above-described *Q. miocrispula* in general, but differs distinctly from the latter species by having large and obtusely-rounded dentation. This species is also somewhat similar to some leaves of *Q. winstanleyi* CHANEY from Pliocene flora in North America (CHANEY, 1944: Pl. 60, fig. 5), which species is variable in shape and marginal characters. But the close American species is medium to thick in texture of leaves, while the new species is thin and membranaceous in texture.

The living *Quercus dentata* THUNB. grows luxuriantly now in Honshu, Shikoku and Hokkaido as one of the temperate trees. The present new species is probably a direct progeni-

tor of the living species.

Occurrence : Onbara Mitoku and Ningyo-toge formations

Collection : GSJ. Holotype No. 4112 ; Paratype No. 4113 ; No. 4114

Quercus protoserrata sp. nov.
(Plate III, Figure 6 ; Plate VI, Figure 7)

1931. *Quercus aliena*, KONNO : op. cit. pl. 11, fig. 1

Description : Leaves variable, small to medium in size, 6 to 14 cm long and 2.2 to 4.2 cm wide, oblanceolate to oblong-ovate in shape ; base asymmetrically cuneate ; apex bluntly acuminate ; midrib stout, nearly straight, thicker towards the base and thinner distantly ; secondaries straight, subparallel, 9 to 16 opposite pairs, diverging from the midrib at the angles of about 45 degrees in the middle portion, craspedodrome, entering straightly into marginal teeth ; tertiaries thin, indistinct percurrent ; margin entire for a short distance near the base, elsewhere remotely shallow-serrate with bluntly pointed teeth ; teeth small, asymmetrical, frequently pointed upwards, sinus between the teeth very broadly-shallow ; petiole stout, thick, 0.5 to 1.0 cm long ; texture medium, subcoriaceous.

Remarks : The present materials are closely related to the modern *Quercus serrata* THUNB., which is widely distributed in eastern Asia. While, the leaves of this species are distinctly different from the previously-described two fossil oaks by their shapes and marginal characters.

Though fossil leaves of oak have been occurred abundantly in Tertiary flora of Japan, the present specimens are scarcely known till today. The present materials are quite identical to the fossil leaves of *Quercus aliena* BL. from the upper Miocene sediments in Shinano, Japan (KONNO, 1931), though the latters lack the upper portion. MIKI (1937) described the fossil cupules and seeds of *Q. serrata* THUNB. from the Pleistocene sediments near Akashi city, Japan.

Occurrence : Onbara, Mitoku and Ningyo-toge formations

Collection : GSJ. Holotype No. 4115 ; Paratype No. 4116

Quercus sp.
(Plate V, Figure 5)

Description : Leaf medium in size, 5 cm wide and length unknown, oblong-ovate in shape, missing in base and apex, but apparently gradually narrowed toward apex ; midrib stout and thick, nearly straight ; secondary nerves stout, comparatively thick, prominent on the lower side, probably over 20 subalternate pairs, evenly spaced, diverging from the midrib at the angles of 45 to 60 degrees, nearly parallel, craspedodrome : tertiaries thin, percurrent ; nervilles thin but distinct, finely reticulate ; margin dentate with obtusely pointed teeth ; teeth large, asymmetrical, sinus between the teeth broadly rounded ; petiole missing ; texture medium, subcoriaceous.

Remarks : This incomplete specimen is closely similar to the above-described *Quercus protoserrata* in general outline, but it is distinctly different from the latter in the secondary number. Namely, the former has more secondary nerves, comparing to the same-sized leaves of the latter species. The present material is close to the leaves described as *Q. spokanensis* KNOWLTON from the Miocene formation of North America (KNOWLTON, 1926) and *Q.* cfr. *grönlandica* HEER from the upper Miocene formation of central Shinano, Japan (KONNO, 1931). It resembles somewhat some leaves of *Castanea castanaefolia* (UNGER) HEER from European and American Tertiary floras.

The present material is too incomplete to be acertained the specific determination, but it is closely similar to the living *Q. serrata* THUNB. or *Q. acutissima* CARR. which are distributed in Japan, China and Korea.

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4117

Fagus palaeocrenata OKUTSU

(Plate VI, Figures 3~5 ; Plate VIII, Figures 1~7 ; Plate IX, Figures 1~6)

1883. *Fagus ferruginea*, NATHORST : op. cit. p. 43, pl. 4, figs. 11~17 ; pl. 5, figs. 3, 9, 11 ; pl. 6, fig. 1

1920. *Fagus ferruginea*, FLORIN : Kgl. Svensk. Vet.-Akad. Handl., Vol. 61, p. 18, 36, pl. 1, figs. 3, 4, 12

1931. *Fagus feruginea*, KONNO : op. cit. pl. 10, fig. 3

1941. *Fagus ferruginea*, MIKI : op. cit. p. 270, fig. 11 B, Cc

1954. cfr. *Fagus crenata*, HUZIOKA et SUZUKI : op. cit. p. 139, pl. 16, fig. 10

1954. *Fagus* cfr. *ferruginea*, TAKAHASHI : op. cit. p. 139, pl. 16, fig. 10

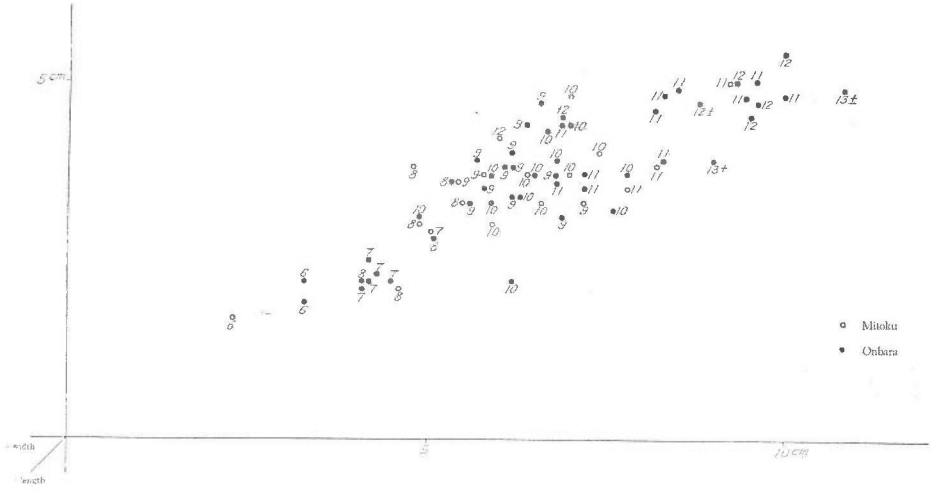
1954. *Fagus crenata*, TAKAHASHI : Do. p. 56, taf. 3, figs. 7~12 ; taf. 4, figs. 1~8

1955. *Fagus palaeocrenata*, OKUTSU : op. cit. p. 92, pl. 6. figs. 4~9

1957. *Fagus palaeocrenata*, MURAI : Rep. Tech. Iwate Univ., No. 10, p. 44, pl. 1, fig. 4 ; pl. 2, fig. 1~6

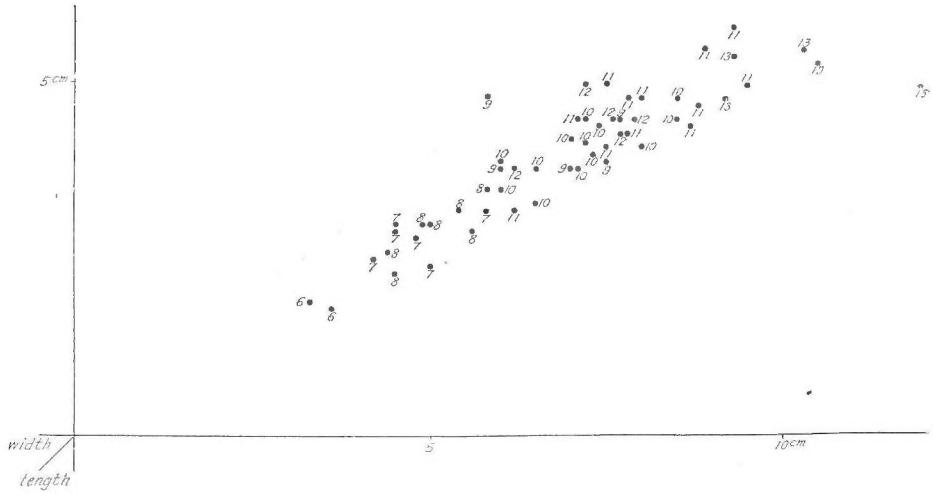
Remarks : The present materials are most abundant in the writers' collection, and occupied about 50% of the total specimens. They are fairly identical to *Fagus palaeocrenata* OKUTSU, which was recently described from late Miocene flora near Sendai by OKUTSU (1955). Most of the fossil leaves which have been once described as *F. ferruginea* AIT., in Japanese Tertiary flora, are included into this species in their general characters.

A plenty of the present specimens are very variable in size and shape, among which the

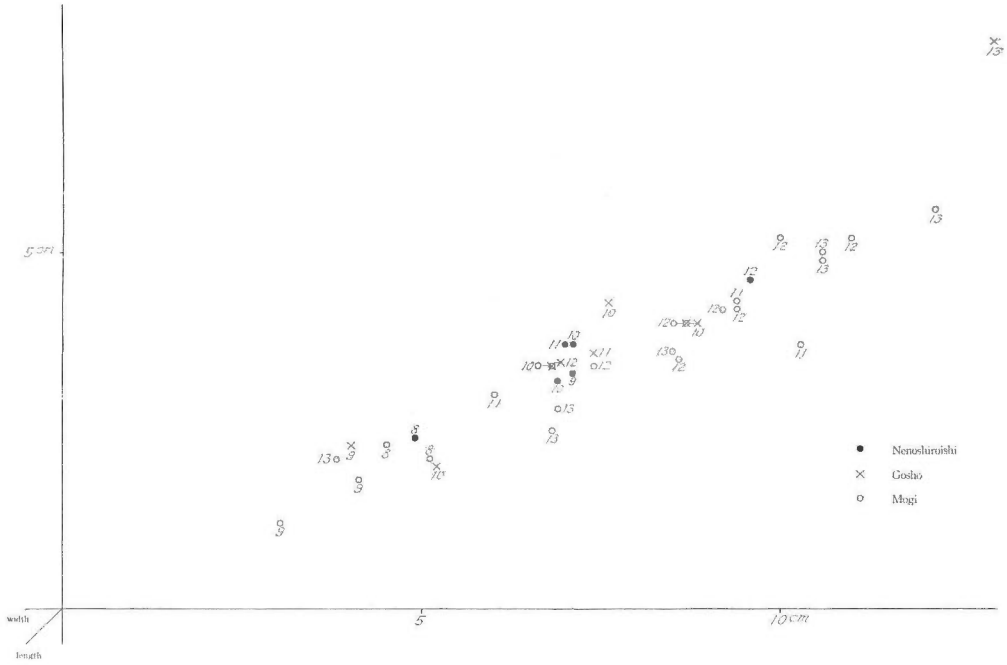


Text-fig. 3 Relationships between the Foliar Dimension and Secondary Numbers of Fossil Beech Leaves (The figures in the graphs show the secondary numbers.)

A) Beech leaves of the Mitoku and Onbara florules



B) Beech leaves of the Ningyo-toge florule



C) Beech leaves of the Nenoshiroishi (OKUTSU, 1955),
Gosho (MURAI, 1957) and Mogi (NATHORST, 1883) florules

relationships between the foliar dimension and secondary numbers of comparatively complete 125 leaves are shown in Fig. 3-A and -B. According to OKUTSU's original description, this species bears 8 to 13 secondaries, and the specimens bearing 9 to 11 secondaries are most predominant as shown Fig. 3-C. The frequency curve on the secondary number of the present materials

shows a similar tendency with that of the living *F. crenata* BLUME.

The average leaf index* of the present materials is smaller than that of OKUTSU's original materials. The fossil leaves figured as *F. ferruginea* from the Mogi Plant beds by NATHORST are probably included into this species, and their leaf index is slightly larger than the present materials. The leaf index of original figures is almost similar to those of Mogi (NATHORST, 1883), Gosho (MURAI, 1957) and Inzyo (MIKI, 1941) materials, though their figured materials are less than the writers' materials.

Recently from the Miocene flora of Korea, HUZIOKA (1951) described following three new species of *Fagus* being similar to this species: *F. Uotanii*, *F. koraica* and *F. protolongipetiolata*. Among them, the present species is most close to *F. koraica* in the general characters. Other two species are also close to this species in their general appearance, but they are distinguished from the latter by the length of petiole. The writers' materials are 5 to 10 mm long in the petiole, and most of them are 7 mm.

Some cupules of *Fagus* occurred from the Onbara florule, and they are probably included into this species. Their cupules are comparatively small in size, 1.0 to 1.2 cm long and 0.9 to 1.0 cm wide. The peduncle of cupula is stout about 1.4 cm long, though somewhat broken.

The present species is one of the most common fossils in the upper Miocene and Pliocene sediments of Japan. The related living species, *F. crenata*, which is one of the most sensitive trees for the vertical distribution, is now occurred from southwestern Hokkaido to Kyushu in Japan. It grows now most luxuriantly at the altitudes of 1,000 to 1,700 m above sea level in the mountains of central Japan, while it grows at the ground level in southern Hokkaido, and often there forms pure forests on the uplands or mountain slopes.

Occurrence: Ningyo-toge, Onbara and Mitoku formations

Collection: GSJ. Plesiotypes Nos. 4118, 4119; Nos. 4120, 4121, 4122, 4123, 4124, 4125, 4126, 4127, 4128, 4129, 4130, 4131, 4132, 4133, 4134

Fagus palaeojaponica sp. nov.

(Plate VII, Figures 3~5)

1883. *Fagus sieboldi*, NATHORST: op. cit. p. 84, pl. 15, fig. 6
1888. *Fagus japonica*, NATHORST: op. cit. p. 227, pl. 9, figs. 3~8
1939. *Fagus japonica*, ENDO: op. cit. p. 344, pl. 23, fig. 8
1958. *Fagus japonica*, MURAI: Rep. Fac. Tech. Iwate Univ., No. 11, p. 20, pl. 2, figs. 1~3

Description: Leaves rather large in size, somewhat asymmetrical and elliptical or oblong-ovate in shape, 9 to 11 cm long (estimated) and 3.3 to 4.5 cm wide; base asymmetrically obtuse or rounded, and rarely cuneate; apex acute or somewhat acuminately pointed; midrib stout prominent, stout near the base, then slender distantly, somewhat zigzag at the upper portion of blade; secondary nerves stout, 13 to 16 pairs, alternate to subopposite, diverging from the midrib at the angles of 40 to 45 degrees, almost straight and subparallel, curving upwards near the margin, camptodrome; tertiaries thin, percurrent; nervilles thin, indistinct, forming polygonal meshes; margin almost entire at the lower half and undulate at the upper half; petiole missing or broken, over 7 mm long; texture slightly firm, membranaceous.

Remarks: Thouth the present materials are fragmental, they are distinctly different from the above-described species, *Fagus palaeocrenata*, in the secondary nervation and marginal characters. Namely, the latter species is usually less in the number of secondaries than the

* leaf index=length/width×100

former and has a undulate margin. *F palaeocrenata* is rarely undulate in margin, but it is not usually over 13 in number of secondaries. Comparing to the abundant occurrence of *F. palaeocrenata*, the present materials are very rare in this flora, and so they may be only a variety or some malformed leaves of the former species. However, their characters between the both are so definitely different that the present materials are now treated as a new species.

The related living species to this new species is *Fagus japonica* MAXIM., which grows only in the mountains of Honshu, Kyushu and Shikoku of Japan. The luxuriant growth of the living species is found rather in a lower altitude than *F. crenate* BLUME.

Occurrence : Ningyo-toge and Onbara formations

Collection : GSJ. Holotypes Nos. 4135, 4136 ; Paratype No. 4137

Family Ulmaceae

Celtis Nathorstii sp. nov.
(Plate X, Figure 1)

1883. *Celtis Nordenskioldii*, NATHORST (in part) : op. cit. p. 47, pl. 15, fig. 2 (not pl. 6, figs. 14~17)

Description : Leaves small in size, basal part missing, 6.5 cm long (estimated) and 3.5 cm wide in the middle, oval or oblong-oval, asymmetrical, slightly falcate in shape, apparently cuneate at base when restored, acuminate at apex ; margin coarsely and regularly serrate on the upper two-third portion, entire on basal portion ; primary nerves three, probably united at top of petiole ; midrib stout below, becoming slender distantly, slightly curved, basal pair of primaries leaving midrib at the angles of about 20 degrees, curving slightly and reaching upwards to the upper one-third of the blade, sending off about 5 secondaries on outer sides ; distinct 3 pairs of secondaries from the midrib nearly parallel to the lateral primaries, alternate ; numerous pairs of inconspicuous inter-secondaries between the secondaries ; tertiaries distinct though thin, percurrent perpendicular to secondaries, forming large polygonal meshes, apparently looping along the margin ; petiole missing ; texture firm, membranaceous.

Remarks : Though the present materials are somewhat fragmental, lacking the basal portion, their nervation details and marginal characters are definitely indicative of *Celtis*. The present species resembles more or less the anew-redesignated species, *Celtis Nordenskioldii* NATHORST, but differs distinctly in the venation and marginal characters, especially distinguishable in the secondary nervation. The present materials are quite similar to a fossil leaf figured as *Celtis Nordenskioldii* by NATHORST from the Mogi plant bed near Nagasaki, Japan (NATHORST, 1883 : Pl. 15, fig. 2). This species is close to *Celtis miobungeana* HU et CHANEY, though it is larger in size and more asymmetrical than the latter species.

Among the modern *Celtis*, the present fossil species is more similar to *C. bungeana* BL. var. *jessoensis* KUDO than any other species. This modern species grows now in Hokkaido, Honshu, Shikoku, and Quelpart Island, and luxuriantly at about 800 to 1,300 m above sea level in central Honshu.

Occurrence : Ningyo-toge formation

Collection : GSJ. Holotype No. 4138

Celtis Nordenskioldii NATHORST
(Plate X, Figure 7)

1883. *Celtis Nordenskioldii*, NATHORST (in part) : op. cit. Bd. 20, No. 2, p. 47, pl. 6, figs. 14~17 (not pl. 15, fig. 2)

1920. *Celtis* sp. (cfr. *C. occidentalis* L.), FLORIN : op. cit. Vol. 61, p. 19, pl. 2, fig. 4
1955. *Celtis occidentalis*, OKUTSU : op. cit. p. 94, pl. 1, fig. 5

Description : Leaves medium in size, 5.5 to 8.0 cm long and 3.0 to 3.5 cm wide in maximum ; inequilateral, ovate, more or less falcate in shape ; base rounded or slightly cordate, oblique ; apex acuminate ; margin coarsely serrate, with acutely pointed teeth ; primary nerves three, united at the top of petiole, median rib stout, nearly straight, sometimes slightly falcate, frequently naked for some distance, then sending off 4 to 6 strong, opposite and slightly curving-up secondaries on each side, the diverging angles from midrib about 30 degrees on middle portion ; lateral primaries nearly straight, diverging from the midrib at the angles of about 20 degrees, extending to the about one-third of the leaves, sending off about five secondaries on their each outer side ; all secondaries and lateral primaries camptodrome, curving upwards near the margin and forming loops ; tertiary nerves thin, not prominent, percurrent, with somewhat reticulate branches and marginal tertiaries enter to the teeth ; petiole thick, stout, over 1.0 cm long ; texture thin, membranaceous.

Remarks : The present material is doubtlessly identical to *Celtis* by the marginal serration and nervation, though lacking the apex. Among the fossil hackberry in Japan the present material is quite similar to *Celtis Nordenskioldii* NATH. (in part) described from the Mogi plant beds near Nagasaki by NATHORST (1883, Pl. 6, figs. 14~17), and also to the fossil leaves of *Celtis occidentalis* L. described by OKUTSU (1955) from the upper Miocene sediments near Sendai.

NATHORST stated that this fossil species is close to the living *Celtis caucasica* WILLD. and *C. tournefortii* LAM.. But, as already described by OKUTSU, the present species closely resembles *Celtis occidentalis* LINNE among the living hackberry trees, which is now living in North America. Though the fossil specimens figured as *Celtis Nordenskioldii* figured by NATHORST are considered to be partially included other species of *Celtis*, the writer redesignate anew this species as the type figure which he described in Pl. 6, fig. 16.

Occurrence : Ningyo-toge and Mitoku formations

Collection : GSJ. Plesiotype No. 4139

Ulmus protolaciniata sp. nov.
(Plate X, Figures 3, 8)

1920. *Ulmus* sp., FLORIN : op. cit. p. 31, pl. 5, fig. 15

Description : Leaves medium in size, obovate to oblong-obvate, and sometimes acutely trilobate in shape, 6.4 to 8.0 cm long and 4.2 to 4.5 cm wide, widest in the one-third portion from the tip, then gradually narrowed to the base ; apex broadly rounded, abruptly short-acuminate ; base obtuse or cuneate, slightly cordate, asymmetrical ; sometimes a pair of acute or acuminate lobes extending on the middle of the blade ; midrib stout, nearly straight, gradually slender towards the apex, slightly curved in the tip ; secondary nerves 11 to 14 pairs, subopposite to alternate, leaving the midrib at the angles of 50 to 65 degrees near the base, 30 to 40 degrees distantly, curving up slightly, craspedodrome, running into the largest teeth ; tertiaries thin, forming a coarse irregular mesh, distantly irregularly percurrent, at the margin branching from the secondaries or from other tertiaries to enter the smaller teeth or to terminate in the notches between them ; nervilles thin, finely areolate ; margin duplicately serrulate, with acute teeth ; petiole thick, short ; texture firm, membranaceous.

Remarks : The present materials are closely similar to the modern *Ulmus laciniata* MAYR. in their shapes and other characters, which is now distributed in northern Honshu and Hokkaido of Japan, and also extended to north China, Manchuria and Siberia. The present

new species has both types of trilobate or single leaves as in those of the living species. The fossil elm comparable to this new species has been scarcely found in Japan. A leaf described as *Ulmus* sp. by FLORIN (1920) from Pliocene flora of Amakusa, Japan, is probably indentical to this new species by their marginal characters, though it is incomplete and somewhat larger.

The present materials resemble closely to *U. paralaciniata* HU et CHANEY described from Miocene flora of Shantung province, China (HU et CHANEY, 1940 : Pl. 16, figs. 4, 5) in their general characters. However, the leaves of the latter species are broadly rounded at the base and have no lobes. In general, the present new species is closer to the modern species than the Chinese fossil species.

Occurrence : Onbara and Mitoku formations

Collection : GSJ. Holotype No. 4140 ; Paratype No. 4141

Ulmus protojaponica sp. nov.
(Plate X, Figures 2, 5)

Description : Leaves small to medium in size, ovate to oblong-ovate in shape, 5 to 12 cm long and 2.5 to 5.5 cm wide ; base obtuse or cuneate, slightly inequilateral ; apex acute or caudate-acute ; midrib stout, thick, straight ; secondary nerves 15 to 20 pairs, opposite to sub-opposite, gently curved up, diverging from the midrib at the angles of 25 to 40 degrees at one side and 40 to 60 degrees at other side, craspedodrome, frequently branching near the marginal boarder ; tertiaries thin, irregularly percurrent ; nervilles indistinct ; margin duplicately serrate, with slightly incurved and acute teeth ; petiole stout, 1 to 3 cm long ; texture firm, membranaceous.

Remarks : The present materials are closely similar to the modern *Ulmus Davidiana* PLANCH. var. *japonica* NAKAI in the general characters. The leaves of this recent species have a wide range of variation, and similarly the present specimens are also somewhat variable in general outline.

The fossil leaves of elm are common not only in the Cenozoic flora of Japan, but in the Cenozoic flora of the world. The present materials are closely similar to *U. miopumila* HU et CHANEY from Miocene flora in Shantung province, China (HU et CHANEY, 1940 : Pl. 14, figs. 2, 3), but differs distinctly by the number of secondaries. They are also related to some leaves described as *U. carpinoides* GOEPP., *U. plurinervia* UNGER from the Tertiary floras of various localities in the Europe.

The most resembling modern species, *U. japonica* is now distributed widely over the Japanese Islands, and extended to Korea, Manchuria, China and Amur-Ussuri province. It is one of the most common trees in northern Japan, and in Hokkaido growing in fertile alluvial plains and moist valleys.

Occurrence : Mitoku formation

Collection : GSJ. Holotype No. 4142 ; Paratype No. 4143

Zelkova Ungeri (ETTINGS.) KOVATS
(Plate X, Figure 4 ; Plate XI, Figures 1～3, 5)

1851. *Planera Ungeri*, ETTINGSHAUSEN : K.-k Geol. Reichasanstalt Abh., Vol. 1, pt. 3, p. 14, figs. 5～18
1856. *Zelkova Ungeri*, KOVATS : Art. Geol. Ges. Ungarn, Vol. 1, p. 27
1883. *Zelkova Keaki*. NATHORST : op. cit. p. 45, pl. 7, figs. 2～6 ; pl. 3, fig. 1
1888. *Planera Ungeri*, NATHORST : op. cit. p. 201, 203, pl. 1, fig. 5 (7～11)

1931. *Zelkova Ungeri*, KONNO : op. cit. pl. 9, figs. 4, 5
1937. *Zelkova Ungeri*, MIKI : op. cit. p. 312, pl. 9, N～O ; fig. 3, D～E
1941. *Zelkova Ungeri*, HUZIOKA : Trans. Proc. Palaeont. Soc. Japan, N.S., No. 3, p. 71, pl. 5, fig. 9
1952. *Zelkova Ungeri*, TAKAHASHI : op. cit. p. 57, taf. 5, figs. 8 a～g

Remarks : The leaves of the present species are common in the writers' collection, and especially abundant in the Mitoku florule. This species is one of the most widely distributed plants in the Tertiary floras of the world. It is closely similar to the modern *Zelkova serrata* MAXIM., which is widely distributed in Japan, Korea, China and Manchuria, and also close to *Z. crenata* SPACH. existing in western Asia. The present species is related rather closely to the latter living species than the former.

As in the leaves of the living species, the present species has a wide range in their shape and size of leaves. OISHI and HUZIOKA (1954) described *Zelkova praelonga* (UNGER) BERGER from the Miocene deposit in Hokkaido, which species has a elongate leaf with more acutely tipped apex than this species. But there are many intermediate forms between the both species in the writers' collection, and so the both species may be probably the same species.

Occurrence : Ningyo-toge, Onbara and Mitoku formations
Collection : GSJ. Nos. 4144, 4145, 4146, 4147, 4148

Family Moraceae

Ficus sp.
(Plate XI, Figure 6)

Description : Leaves incomplete, missing in upper portion, large in size, probably oblong-ovate in shape, 7 cm wide (estimated), length unknown ; base gradually narrowed, roundly truncate ; apex unknown ; midrib stout and thick, slightly curved ; two basal pairs of slender secondary nerves diverging from the midrib at the angles of 40 to 45 degrees ; prominent secondaries leaving the midrib at the angles of 20 to 25 degrees, nearly straight ; tertiaries distinct, branching off from the secondaries, along the margin forming several series of loops, tertiaries in the inter-secondary spaces irregularly percurrent ; nervilles thin but distinct, reticulate ; margin entire ; petiole missing ; texture firm, subcoriaceous.

Remarks : Unfortunately there is only one incomplete leaf represented in the writers' collections, and it is therefore doubtful to be certain of its reference to this genus. Among the fossil or living species of figs in Japan, there are no leaves resembling this present material. But this characteristic secondary nervation seems to be close to that of some leaves of *Ficus*. At a glance, the present material is somewhat close to the living *Ficus erect* THUNB. which grows now in southern Japan, but their detail nervation is distinctly different. While, some leaves of the living *Populus Maximowiczii* HENRY. have occasionally such secondary nervation, but they are distinctly different from this material in the marginal characters. The present material is also somewhat similar to *Drimys americana* CHANEY et SANBORN described from the Eocene Goshen flora of North America.

Occurrence : Mitoku formation
Collection : GSJ. Holotype No. 4149

Family Magnoliaceae

Liriodendron honsyuensis ENDO
(Plate XI, Figure 7)

1934. *Liriodendron honsyuensis*, ENDO : Proc. Imp. Acad. Tokyo, Vol. 10, No. 9, p. 591, figs. 1, 2
1940. *Liriodendron honsyuensis*, OKUTSU : Jub. Publ. Comm. Prof. H. YABE's 60th Birth. Vol. 2, p. 629, pl. 33, figs. 1, 2
1943. *Liriodendron honsyuensis*, OKUTSU : Acta Phytotax. Geobot., Vol. 13, p. 153~162, pl. 3, figs. 1~6
1955. *Liriodendron honsyuensis*, OKUTSU : op. cit. pl. 6, figs. 1~3
1958. *Liriodendron* cfr. *honshuensis*, MURAI : op. cit. p. 19, pl. 1, fig. 1

Remarks : The present material is only one fragmental leaf impression, which occurred in the Mitoku florule. It is, however, distinctly identified as genus *Liriodendron* by the lobated leaf and characters of venation. The fossil leaves of the tulip tree are frequently known from the Miocene floras of Japan, and named as *Liriodendron honsyuensis* ENDO (ENDO, 1934), which is similar to *L. tulipifera* L. existing in southeastern North America. Though the restored figure of the present specimen is somewhat larger in size than already-described specimens, it is probably identical to this species.

Occurrence : Mitoku formation

Collection : GSJ. No. 4150

Magnolia elliptica sp. nov.
(Plate XII, Figures 1, 5)

Description : Leaves large in size, elliptical in shape, 11 to 13.5 cm long and 5.0 to 6.7 cm wide ; base missing, probably obtusely cuneate ; apex obtuse ; midrib stout, nearly straight ; about 12 pairs of subopposite secondaries regularly spaced, diverging from the midrib at the angles of 40 to 50 degrees, curving upwards, thence branching near the margin, and anastomosing, forming marginal loops, occasionally a few slender laterals leave from the midrib among the main laterals ; tertiaries thin, irregularly percurrent with sinuous crossties ; nervilles indistinct, finely areolate ; margin entire ; petiole missing ; texture thin, membranaceous.

Remarks : The present large leaves are identified to the genus *Magnolia* by their shape and venation. The fossil leaves of *Magnolia* are not rare in the Neogene and Pleistocene floras of Japan, but there are no comparable fossil leaves to the present materials.

The present leaves are somewhat similar to the living *Magnolia Kobus* DC. in the characters of venation, but differs distinctly by the size and shape of leaves. The fossil leaves *Excoecaria japonica* MUELL. described from the Pliocene Mogi plant beds near Nagasaki (NATHORST, 1883 : Pl. 10, fig. 13 ; Pl. 13, fig.5) are somewhat similar to the present materials, but the formers are wider in the diverging angles of secondaries than the latter.

Occurrence : Mitoku formation

Collection : GSJ. Holotype No. 4151 ; Paratype No. 4152

Family Lauraceae

Sassafras subtriloba (KONNO) new comb.
(Plate XIII, Figures 1~5)

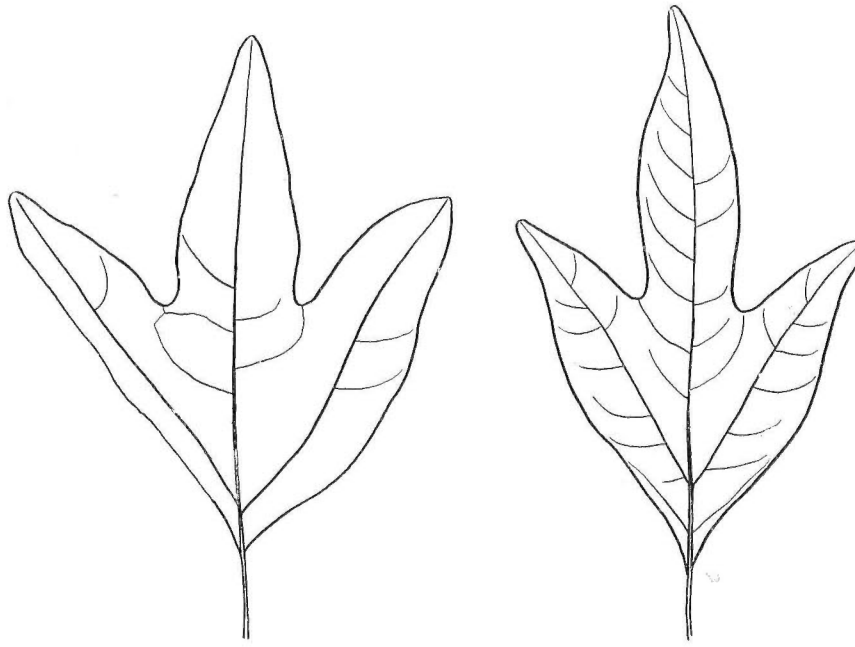
1931. *Lindera subtriloba*, KONNO : op. cit. pl. 18, figs. 1~8

1952. *Sassafras Oishii*, OKUTSU : Saito Ho-on kai Mus. Res. Bull., No. 23, p. 9, pl. 1, fig. 2

1955. *Sassafras Oishii*, OKUTSU : op. cit. p. 96, pl. 3, figs. 2a, 2b

Description : Leaves medium to large, variable in size and shape, broadly oval or suborbicular in general outline, about 10 to 11.6 cm long (restored) and 7 to 9 cm wide (restored), palmately three-lobed, divided by somewhat narrow and acute sinus ; base cuneate or broadly cuneate, and deccurrent below along the petiole ; medial lobe ovate to lanceolate in shape, bluntly pointed or slightly acuminated at apex ; lateral lobes usually smaller than the medial, ovate to ovate-lanceolate in shape, obtuse to bluntly pointed at apex ; midrib stout below, distantly thin, slightly curved ; lateral primaries stout almost prominent as the midrib, opposite to subopposite, leaving the midrib at the angles of 20 to 35 degrees, slightly curved, extending to the tip of lateral lobes ; secondaries in the lobes thin, numerous, but prominent secondaries about 8 to 10 pairs, diverging from the primaries at the angles of 60 to 70 degrees, curving upwards, camptodrome ; a pair of prominent secondaries in the decurrent part, diverging from the midrib at the angles of 30 to 50 degrees, then extending almost parallel to the basal margin ; tertiaries thin, irregularly percurrent ; nervilles obscure, finely reticulate ; margin entire ; petiole stout and thick, over 1.5 cm in length ; texture thin, membranaceous.

Remarks : The present materials are fragmental, and there are no completely-preserved specimen in this flora. However, they are apparently identical to the genus *Sassafras* by the trilobated shape and decurrent base. The fossil leaves described as *Lindera subtriloba* KONNO from late Miocene flora of Nagano prefecure, are fairly identical to the present materials. At a glance, these specimens resemble the modern *Parabenzoin triloba* NAKAI (Synonym : *Lindera triloba* BLUME) which grows in southern Japan, but the latter is scarcely decurrent in the basal part of leaves.



Text-fig. 4 A Restoration of *Sassafras subtriloba* (KONNO) TANAI et ONOE (×2/3)

S. Oishii OKUTSU described from late Miocene flora near Sendai, are larger in size and somewhat broader in lobes than this species, but the former quite agrees with the latter in the general outline and vanation character. As the leaves of the living *Sassafras* are very variable in size, even in shape, it is better that the both species are treated as the same species. This species is closely similar to *S. hesperia* BERRY (BERRY, 1929; BROWN, 1937; etc.), which was occurred from Miocene floras of North America. This species is somewhat similar to *S. ferrettianum* MASS. (MASSALONGO et SCARABELLI, 1858: Pl. 12, figs. 1~3) and *S. variifolium* NIL. (STRAUS, 1930: Pl. 41, figs. 8, 9; Pl. 22, fig. 2) from Pliocene floras of Europe, but it differs from the latters by venation of decurrent part and longer medial lobes. Recently, *S. Yamanei* IMAMURA was described from Miocene flora of Shimane prefecture (IMAMURA, 1957: Pl. 5, figs. 1~5, Text-fiig. 3). However, it is two times larger in size than this species, and prolongly lanceolate at lateral lobes.

The recent distribution of *Sassafras* is confined to southwest China (*S. thumu* HEMSL.) and the southeastern part of North America, (*S. Sassafras* (L.) KARST), but the fossil leaves of this genus are known from Oligocene to Pliocene floras of Japan.

Occurrence: Onbara and Mitoku formations

Collection: GSJ. Holotypes Nos. 4153, 4154; Paratypes Nos. 4155, 4156; No. 4157

Family Saxifragaceae

Schizophragma mitokuensis sp. nov.

(Plate XI, Figure 4)

Description: Leaves medium in size, ovate in shape, 7.2 cm long and 4 cm wide (estimated); base incomplete, probably rounded, slightly asymmetrical; apex prolongly acuminate, somewhat tapered; midrib stout, nearly straight; secondary nerves 6 subopposite pairs, diverging from the midrib at the angles of 30 to 45 degrees, slightly curved up, thence running into marginal teeth, craspedodrome; a few tertiaries from each secondaries branching off on the marginal border, and entering into small teeth, other tertiaries thin, indistinct, irregularly percurrent; nervilles indistinct; margin duplicately denticulate, with acute teeth; petiole missing; texture firm, membranaceous.

Remarks: This species is based on a inclomplete leaf impression which occurred in the Mitoku florule. It is somewhat similar to the living *Schizophragma hydrangeoides* S. et Z., but the latter is camptodrome in the secondary nerves. It is also similar to some leaves of *Viburnum* in general characters.

The resembling modern species is distributed widely in Hokkaido, Honshu, Shikoku and Kyushu of Japan, and also extends to Korea.

Occurrence: Mitoku formation

Collection: GSJ. Holotype No. 4158

Family Hamamelidaceae

Hamamelis sp.

(Plate XII, Figure 3)

Description: Leaves incomplete, missing in the apex and base, medium in size, rhomboid-elliptical in shape, about 3.5 cm wide, length unknown; apex missing; base unknown but apparently gradually-narrowed, asymmetrical; midrib stout, straight; secondary nerves about 6 subalternate pairs, leaving the midrib at the angles of 20 to 30 degrees, nearly straight or slightly curved up to terminate in the marginal teeth; distinct tertiary nerves may branch from

the lower secondaries, ending in smaller marginal teeth; tertiaries in the inter-secondary spaces irregularly percurrent; nervilles indistinct, forming a polygonal areolation; margin coarsely dentate or undulate; texture thin, membranaceous.

Remarks: The present material is certainly identical to the genus *Hamamelis* by nervation and marginal characters, though it is a very incomplete specimen. This incomplete leaf is closely similar to the living *H. japonica* S. et Z. in general characters, which species is distributed widely from Hokkaido to Kyushu in Japan.

This species resembles closely *Forthergilla viburnifolia* HU et CHANEY from Miocene Shuntung flora of China in general outline.

Occurrence: Onbara formation

Collection: GSJ. Holotype No. 4159

Liquidambar mioformosana TANAI (MS)
(Plate XII, Figures 2, 4)

1883. *Liquidambar formosana*, NATHORST: op. cit. p. 55, pl. 8, figs. 6~9
1888. *Liquidambar formosana*, NATHORST: op. cit. p. 24, pl. 6, figs. 14~15
1920. *Liquidambar formosana*, FLORIN: op. cit. p. 20, pl. 3, fig. 4; p. 32, fig. 4
1920. *Liquidambar formosana*, KRYSHTOFOVICH: Jour. Geol. Soc. Tokyo, Vol. 27, p. 9, pl. 2. figs. 3~4
1931. *Liquidambar formosana*, KONNO: op. cit. pl. 4, fig. 1; pl. 12, fig. 7
1932. *Liquidambar formosana*, ENDO & MORITA: Sci. Rep. Tohoku Imp. Univ., Ser. 2, Vol. 15, No. 2, p. 47, pl. 6, figs. 1~10; pl. 7, figs. 1~8
1941. *Liquidambar formosana*, MIKI: op. cit. p. 275, pl. 6, A-B; figs. 14 A~C
1948. *Liquidambar formosana*, MIKI: op. cit. p. 114, pl. 3, F. a~c
1954. *Liquidambar* cfr. *formosana*, TAKAHASHI: op. cit. p. 58, taf. 6, fig. 4
1954. *Liquidambar formosana*, ENDO: Kumamoto Jour. Sci., Ser. B. No. 4, p. 5, pl. 4, figs. 10, 11
1955. *Liquidambar formosana*, OKUTSU: op. cit. p. 98, pl. 2, figs. 1~3
1955. *Liquidambar formosana*, TANAI: op. cit. pl. 12, figs. 8~11

Description: Leaves variable in size, 3 palmately lobed with incised sinuses, orbicular to semiorbicular in general outline, 5 to 12 cm and 6 to 16 cm wide; lobes prolonged, ovate to ovate-lanceolate, and acute or slightly acuminate at apex, lateral lobes nearly at right angles to the medial lobe; margin finely serrate, with acute glandular teeth; base cordate or concave; middle primary nerve stout and straight, lateral primaries leaving middle one at angles of 45 to 60 degrees, nearly straight and then slightly curving upwards near the tips, all primaries run to the tip from the base; secondary nerves from the middle primary 4 to 8 pairs, subopposite to alternate, curving upwards, camptodrome; secondaries from the lateral primaries 4 to 6 pairs on outer side and 3 to 5 on inner side, curving upwards, camptodrome; the basal pair of secondaries diverging outwards from the lateral primaries very stout, extending almost parallel to marginal border of lareral lobes; tertiaries thin, irregularly percurrent; nervilles thin indistinct, coarsely reticulate; petiole stout and thick, 2 to 4 cm long; texture thin, membranaceous.

Remarks: The above characters are described on the basis of many materials which were collected from the Neogene sediments of Japan by the senior writer. The present materials are quite similar to this species in general characters, though they are somewhat small in size and missing in the upper part of medial lobe. This species is closely similar to the modern *Liquidambar formosana* HANCE in their features, which grows now in Formosa and southern China. Many fossil leaves and fruits described as *L. formosana* in Japan, are fairly identical

to this fossil species.

The present species is closely similar to *L. miosinica* HU et CHANEY from Miocene Shantung flora of China (HU et CHANEY, 1940 : Pl. 23, figs. 1, 2), but the latter species is more slender and elongate in lobe shapes than the former. Some leaves of the former species is, however, frequently unable to be distingished from those of the latter. Beside this, the trilobed fossil leaves of *Liquidamber* are known from North America, namely, *L. californicum* LESQ. from Miocene flora of California, and *L. pachyphyllum* KNOWLTON from Miocene Latah flora of Washington. These two American species are also similar to the present species.

This species, *L. mioformosana*, is one of the most common fossils in Japanese Tertiary flora, and ranged from middle Miocene to late Pliocene time. Accordingly, it does not become a stratigraphical index fossil, but it is available for the climate-indicator.

Occurrence : Mitoku formation

Collection : GSJ. Nos. 4160, 4161

Family Rosaceae

Sorbus nipponica sp. nov.
(Plate XIV, Figure 8)

Description : Leaflets oblong-elliptical in shape, small in size, 3.3 cm in length and 1.3 cm wide ; base obtuse or roundly obtuse, asymmetrical ; apex abruptly pointed, acute ; midrib rather slender, nearly straight except near the base ; secondary nerves thin, about 9 pairs, alternate, diverging from midrib at the angles of 30 to 45 degrees, curving upwards, then entering into marginal teeth, craspedodrome ; tertiaries thin, indistinct ; margin serrulate with acute teeth ; petiole very short, or almost absent ; texture thin, membranaceous.

Remarks : The present materials are identical to the genus *Sorbus* by general characters. Among the living species of *Sorbus*, this fossil species is closely similar to *Sorbus comixta* HEDL. var. *rufo-ferruginea* C. K. SCHNEIDER by the simply-sarrate margin of leaves. The fossil leaves of *Sorbus* are not rare in the Neogene sediments of Japan, and the fossil leaves of *S. rufo-ferruginea* were described from the Pleistocene Shiobara Plant beds by ENDO (1940).

This related living species grows now in Honshu, Shikoku and Kyushu, and luxuriantly at about 900 to 1,800 m above sea level in central Honshu.

Occurrence : Mitoku formation

Collection : GSJ. Holotype No. 4162

Prunus protossiori sp. nov.
(Plate XIII, Figures 6, 7)

1955. *Prunus Ssiori*, OKUTSU : op. cit. p. 100, pl. 4, fig. 2

Description : Leaves in moderate size, obovate or elliptical in shape, 7.8 cm long and 4.3 cm wide ; base slightly cordate, apex abruptly acuminate ; midrib stout, almost straight, slightly tapered to apex ; secondary nerves slender, 12 to 14 pairs, diverging at the angles of 40 to 50 degrees, subopposite or alternate, slightly curved upwards, camptodrome and looping with next secondary above, frequently with abaxial branches near the margin ; tertiaries thin, mainly percurrent ; nervilles numerous, forming pentagonal meshes ; margin serrulate, with unequal and sharply aristate teeth ; petiole stout, over 2 cm long ; texture membranaceous, thin.

Seeds small, 12.6 mm long and 9.3 mm wide, cordate in shape, bluntly pointed at apex, tuberculated at surface ; some part of husk remains.

Remarks : This fossil material is fairly well-preserved, though petiole is partially mis-

sing. This cherry leaf which was described as *Prunus Ssiori* SCHN. by OKUTSU (1955) from the Shirasawa formation near Sendai, is quite similar to our specimen in their general characters. The former is more or less larger in size than the latter, and 10.5 cm long and 4.0 cm in width. Our material is 7.8 cm long and 4.3 cm wide.

The present materials are closely similar to *Prunus Ssiori* SCHMIDT which is grown now in southern Kurile, Saghalien, Hokkaido, northern and central Honshu. Accordingly, it is considered as one of the direct progenitor of the living species.

Locality : Ningyo-toge formation

Collection : GSJ. Holotype No. 4163 ; Paratype No. 4164

Family Leguminoceae

Wistaria fallax (NATHORST) new comb.
(Plate X, Figure 6 ; Plate XIV, Figures 2~4)

1883. *Sophora* (?) *fallax*, NATHORST : op. cit. p. 58, pl. 10, figs. 11, 12 ; pl. 12, figs. 1, 2
1931. *Krauhia fallaxi*, KONNO : op. cit. pl. 16, fig. 8 ; pl. 18, figs. 9, 10 ; pl. 19, figs. 2, 4~8, 10 ; pl. 20, figs. 1, 2
1937. *Wistaria floribunda*, MIKI : op. cit. p. 318, figs. 6 F~H
1938. *Wistaria floribunda*, MIKI : op. cit. p. 220, fig. 5 G ; p. 224, fig. 6 J ; p. 237, fig. 14 K
1954. cfr. *Wistaria floribunda*, HUZIOKA et SUZUKI : op. cit. p. 140
1954. *Wistaria* cfr. *brachybotys*, TAKAHASHI : op. cit. p. 58, taf. 6, figs. 7a, b
1958. *Wistaria* sp. TANAI et ONOE : op. cit. p. 281, pl. 7, fig. 5

Description : Leaflets small in size, ovate to elongate-ovate in shape, 4.3 to 7 cm long and 2.4 to 2.6 cm wide ; apex somewhat acuminate, with bluntly pointed tip ; base asymmetrical, broadly rounded and frequently somewhat cordate in the lateral leaflets, and broadly cuneate in the terminals ; midrib stout below, distantly thin, nearly straight then commonly curving at the apex ; secondaries slender, 7 to 10 subopposite pairs, rather variable as to spacing and angles of divergence, the latter averaging 60 degrees, curving upwards near the margin, camptodrome ; tertiaries indistinct, forming loops with the secondaries along the margin ; nervilles thin, finely reticulate ; margin entire ; petiole short, 3 to 6 mm in length ; texture thin, membranaceous.

Remarks : This species is comparatively common in the Onbara and Mitoku florules. The present materials are identical certainly to some leaflets of Family Leguminoceae in their shape and venation and refered to the genus *Sophora*, *Cladrastis*, *Maackia* or *Wistaria*. It is difficult to determine Leguminoceae only by leaves, but the features of venation in these materials are rather close to those of *Wistaria*. *Sophora* (?) *fallax* NATH. from Mogi flora in Nagasaki prefecture and *Krauhia fallaxi* (NATH.) KONNO from the Omi flora in Nagano prefecture, are fairly identical to these materials. The present specimens in this flora are closely similar to the modern *Wistaria floribunda* DC. in general outline, which is distributed now in Honshu, Shikoku and Kyushu of Japan, and extends to China. The fossil leaflets or pods of this living species were described from the upper Miocene and Pliocene sediments in various areas of Japan, and they are quite identical to this species.

This species is closely similar to *W. ligniata* MIKI described from late Pliocene floras in Gifu prefecture (MIKI, 1941 : Fig. 15 C~D), and it is frequently unable to be distinguished respectively. Recently, the writers described a fossil pods being close to the modern *W. floribunda* from Miocene flora of the Joban coal field. Therefore, it is probably included into the present species.

Occurrence : Onbara, Mitoku and Ningyo-toge formations
Collction : GSJ., Holotype No. 4165 ; Paratypes Nos. 4166, 4167 ; Nos. 4168, 4169

Family Buxaceae

Buxus protojaponica sp. nov.
(Plate XIV, Figure 5)

1937. *Buxus japonica*, MIKI : op. cit. p. 320, figs. 7 A, B
1941. *Buxus japonica*, MIKI : op. cit. p. 281, fig. 16 D
1954. *Buxus japonica*, TAKAHASHI : op. cit. p. 60, taf. 7, figs. 13a~g

Description : Leaves very small in size, 1.2 to 2.2 cm long and 0.5 to 1.1 cm wide, oblong to obovate in shape ; base gradually narrowed below, cuneate, decurrent the petiole ; apex rounded or emarginate ; margin entire ; primary nerve stout, nearly straight ; secondaries slender, indistinct owing to thick blade, densely crowded, leaving the midrib at the angles of about 60 degrees and thence generally twice or thrice dichotomously branched ; tertiaries thin, indistinct ; petiole very short, 1 to 2 mm long ; texture thick, coriaceous, with well-developed cuticle.

Remarks : The present materials are distinctly identified to *Buxus* by the nervation and well developed cuticle, though they are somewhat in incomplete preservation. The present specimens are quite similar to the fossil leaves and fruits of *Buxus japonica* MUELL. described from the Pliocene sediments in Kinki district, Japan (MIKI, 1934, 1941), and also identical to fossil leaves of the same species described from the Shimabara peninsula, Kyushu (TAKAHASHI, 1954). The present species is closely similar to the modern *B. japonica* MUELL., which is now distributed in southern Honshu, Shikoku and Kyushu of Japan.

Recently, ENDO (1955) figured only a fossil fruits of *Buxus* from the Miocene sediments in Korea, and gave the new name of *Buxus miosempervirens* ENDO. The present new species is closely similar to the fossil leaves of *B. semperviens* L. from the upper Pliocene sediments in the Main Vally near Frankfurt, Germany (ENGERHALDT & KINKELIN, 1930 : Pl. 33, fig. 1).

Occurrence : Onbara formation
Collection : GSJ. Holotype No. 4170

Family Aquifoliaceae

Ilex sp.
(Plate XIV, Figure 7)

Description : Leaves incomplete and missing in upper portion, oblong-lanceolate in shape, length unknown and width 2.8 cm ; base cuneate, somewhat asymmetrical ; apex unknown ; midrib stout, thick, straight ; secondary nerves thin, leaving the midrib at the angles of 50 to 60 degrees, curving upwards, extending up along the margin, forming series of loops in the marginal border ; tertiaries very thin, irregularly percurrent, or with reticulate areas ; nervilles thin, finely areolate ; margin finely serrate with bristle-like small teeth ; petiole stout, 7 mm long ; texture thick, coriaceous.

Remarks : Though the present material is missing in upper portion, it is identical to the genus *Ilex* by above-described characters. It is closely similar to the modern *Ilex latifolia* THUNB. by the secondary venation and characteristic margin, which species grows now in southern Japan. The present specimen is somewhat close to *Ilex Heeri* NATHORST from the Pliocene Mogi Plant beds (NATHORST, 1883 : Pl. 10, figs. 7~10 ; Pl. 11, fig. 3), but the latter is entire at the margin. There are no comparable species to this specimen in the fossil

Ilex of Japan.

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4171

Family Celastraceae

Euonymus palaeosieboldianus sp. nov.

(Plate XIV, Figure 6)

Description : Leaves medium in size, oblong-ovate in shape, about 8 cm long (estimated) and 3 cm wide ; base obtuse or broadly cuneate ; apex missing, but apparently acute ; midrib stout, nearly straight ; secondaries thin, about 14 subopposite pairs, diverging from the midrib at the angles of about 50 degrees, nearly straight or gently curved upwards, then in the marginal border abruptly curved up along the margin, and forming regular series of loops ; tertiaries thin, irregularly percurrent ; nervilles obscure ; margin finely serrulate, with small acute teeth ; petiole stout and thick, 1.1 cm long ; texture membranaceous.

Remarks : The present material is so ill-preserved that the identification to this gunus is somewhat doubtful. It refers to some leaves of *Rhamus*, *Celastrus*, *Euonymus* or other proteaceous genus, and especially shown a close relationships to the modern *Euonymus sieboldianus* BLUME in their shape, nervation and marginal characters. However, this living species is more slender in secondary nerves and more obtuse in marginal teeth than fossil species. This related living species is distributed widely from Hokkaido to Kyushu in Japan. None of the fossil leaves from Japan show any resemblance to this new species.

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4172

Family Aceraceae

Acer Nordenskiöldi NATHORST

(Plate XV, Figure 1 ; Plate XVII, Figure 12)

1883. *Acer Nordenskiöldi*, NATHORST : op. cit. p. 60, pl. 11, figs. 10～17
1920. *Acer palmatum*, FLORIN : op. cit. p. 23, pl. 4, figs. 1～4
1931. *Acer palmatum*, KONNO : op. cit. pl. 4, fig. 9 ; pl. 13, fig. 8
1931. *Acer Nordenskiöldi*, KONNO : Do. pl. 13, fig. 3 ; pl. 21, figs. 4, 5
1937. *Acer Nordenskiöldi*, MIKI : op. cit. p. 322, pl. 9 A, figs. 9 P～Q
1940. *Acer Nordenskiöldi*, HU et CHANEY : op. cit. p. 60, pl. 34, figs. 1, 6
1941. *Acer palmatum*, MIKI : op. cit. p. 283, figs. 17 B～Cd
1943. *Acer ornatum*, HUZIOKA : Jour. Fac. Sci. Hokkaido Imp. Univ., Ser. 4, Vol. 7, No. 1, p. 133, pl. 23, fig. 9
1952. *Acer ornatum*, TANAI : Trans. Proc. Palaeont. Soc. Japan, N.S., No. 8, p. 234, pl. 22, figs. 10, 11
1954. *Acer palmatum*, TAKAHASHI : op. cit. p. 60, taf. 7, figs. 5, 6, 7a, 7b
1955. *Acer ornatum*, TANAI : op. cit. pl. 16, fig. 5, 6 ; pl. 17, fig. 10
1955. *Acer Nordenskiöldi*, BERGER : Palaeontographica, Bd. 97, Abt. B, s. 101, abb. 137～139

Remarks : The present leaves are identical to this species, which was at first described from the Pliocene Mogi Plant beds near Nagasaki by NATHORST (1883). The fossil leaves of *Acer ornatum* CARR. or *A. palmatum* THUNB. are commonly reported their occurrence from

the Neogene sediments of Japan, and they are closely similar to the present materials in general characters. Though the former two species are frequently smaller in size and more finely serrate margin of leaves than the present species, these three species are probably synonymous. As the living *A. palmatum* has many varieties, the fossil leaves of such type may be better at present to be treated as the present species. In our collection there are a fossil samara closely similar to that of the living *A. palmatum*. The present species was designated by several leaf impressions, but it is represented by both leaves and samaras.

The present materials resemble closely the modern *Acer palmatum* THUNB., especially related to *A. palmatum* var. *Matumurae* (KOIDZ.) MAKINO. This living related species is one of the common maples in Japan, and now widely distributed in Hokkaido, Honshu, Shikoku, and Kyushu.

Occurrence : Ningyo-toge and Mitoku formations

Collection : GSJ. Plesiotype No. 4173 ; No. 4174

Acer palaeodiabolicum ENDO

(Plate XV, Figures 2, 4 ; Plate XVI, Figure 1 ; Plate XVII, Figures 1~4)

1930. *Acer diabolicum*, KONNO : op. cit. pl. 13, fig. 4
1940. *Acer diabolicum*, OKUTSU : op. cit. p. 161, pl. 7, fig. 7
1950. *Acer palaeodiabolicum*, ENDO : Short Papers I. G. P. S., No. 1, p. 12, pl. 3, fig. 3
1952. *Acer palaeodiabolicum*, TANAI : Trans. Proc. Palaeont. Soc. Japan, N. S., No. 8, pl. 22, fig. 12
1954. *Acer* cfr. *diabolicum*, TAKAHASHI : op. cit. p. 61, taf. 7, fig. 2
1955. *Acer palaeodiabolicum*, TANAI : op. cit. pl. 17, figs. 6~8
1955. *Acer palaeodiabolicum*, ENDO : op. cit. pl. 37, fig. 3
1958. *Acer Miyabei*, MURAI : op. cit. p. 18, pl. 1, fig. 4
1959. *Acer palaeodiabolicum*, TANAI et ONOE : op. cit. pl. 6, fig. 6

Description : Leaves medium in size, 5.0 to 11 cm long and 6 to 12 cm wide ; orbiculate or semi-orbiculate in shape, palmately five-lobate ; deeply cordate at base ; apex of each lobes acuminate ; margin with a few unequal large dentations, acuminate or acute-toothed ; medial primary nerve stout, straight ; lateral primaries straight, diverging from the medial primary at the angles of 40 to 50 degrees of about 80 to 90 degrees, all primaries prominent on lower surface of leaf, and running to the tip of each lobes ; secondary nerves from the medial and lateral primaries 5 to 7 pairs, subalternate, diverging at the angles of about 25 to 30 degrees, craspedodrome, running to the tips of the marginal teeth ; secondaries of the basal primary pair thin, slender, with about 5 pairs, camptodrome ; petiole stout and long, 3.5 to 8 cm in length ; texture membranaceous.

Samaras medium in size, 2.5 to 3.5 cm long ; wing 0.8 to 1.3 cm wide at the middle, and gradually narrowed to the base and the apex, outer margin nearly straight, inner rounded ; veins fine, 15 to 18 in number at the base, curving inwards and irregularly dichotomously branching ; seeds semicircular to oval in shape, slightly bulged outside, 0.4 to 0.6 cm wide and 0.5 to 0.7 cm long ; angles between outer margin and contact line of seed 20 to 30 degrees ; contact line of seeds 0.5 to 0.9 cm long.

Remarks : This fossil species is described by ENDO (1950) on the basis of a fruit which was occurred from the Miocene Kankyodo formation in Korea. Since then, the occurrence of fossil fruits belonging to this species was reported by the senior writer (TANAI, 1955) from the Miocene sediments in various area of Japan. The fossil leaves being closely identical

to living *Acer diabolicum* BLUME was described by OKUTSU (1940) from the upper Miocene sediments near Sendai, Japan.

At this time, the writers found a plenty of fossil maple leaves and fruits being closely similar to the living *Acer diabolicum* in this flora. Accordingly, the writers propose that *Acer palaeodiabolicum* ENDO is anew designated by fossil leaves and samaras.

The fossil leaves are more or less similar to living *Acer Miyabei* MAXIM. in general shape, but differs distinctly from the latter by marginal dentation. The latter is more obtusely rounded in dentation and apex of each lobe than the former. The leaves of both species, however, is frequently not distinguishable in general outline. For instance, the fossil leaves described as *Acer Miyabei* MAXIM. by OKUTSU (1940) from the upper Miocene formation near Sendai are scarcely distinguishable from the present materials, but their samaras are different and very characteristic respectively. This fossil species is also close to *Acer Saccharum* MARSH. and *A. nigrum* MICHX., which are growing now in the eastern half of North America.

The present species is closely similar to *Acer diabolicum* BL. in leaves and samaras, which is now growing in Honshu, Shikoku and Kyushu, and it is probably a direct progenitor of the living species.

Occurrence : Onbara and Mitoku formations

Collection : GSJ. Plesiotype No. 4175 ; Nos. 4176~4181

Acer palaeorufinerve sp. nov.
(Plate XVI, Figures 2, 3)

1930. *Acer* cfr. *rufinerve*, KONNO : op. cit. pl. 5, fig. 1
1937. *Acer rufinerve*, MIKI : op. cit. p. 322, fig. 80
1940. *Acer rufinerve*, OKUTSU : op. cit. p. 164, pl. 6, figs. 1, 2
1940. *Acer Nomurai*, OKUTSU : op. cit. p. 162, pl. 6, fig. 5
1951. *Acer rufinerve*, ENDO : Short Papers I. G. P. S., No. 3, p. 53, pl. 8, figs. 4, 5
1957. *Acer Nomurai*, MURAI : op. cit. p. 43, pl. 1, fig. 3

Description : Leaves variable in size, medium in general, 5 to 12 cm long and 4 to 7 cm wide, ovate or rounded-ovate in shape ; palmately 3 to 5 lobate, sinus between each lobes shallow, broadly rounded ; base cordate ; lobes triangular-ovate, pointed at apex, with doubly serrate margins ; marginal teeth small, obtusely pointed ; main middle lobe largest, triangular-ovate, with acuminate apex, lateral lobes small, triangular or obtusely triangular in shape, acutely or acuminately pointed at apex, basal pair of lobes in five-lobate leaf very small, frequently indistinct ; medial primary stout, straight ; lateral primaries diverging from the medial primary at the angles of 30 to 45 degrees, basal pairs at the angles of 80 to 95 degrees ; all primaries run to the tips of each lobe ; secondaries from the medial rib diverge at the angles of 30 to 45 degrees, 6 to 8 pairs, subopposite, stout, curving slightly upwards, secondaries from the laterals slightly arched, 7 to 9 pairs in outer side, secondaries in the inner side slender, 5 to 7 pairs in the upper portion ; all secondaries craspedodrome, entering into marginal teeth, frequently branching near the margin ; tertiaries thin, indistinct, percurrent, forming a large polygonal mesh ; petiole stout, 3 to 5 cm long ; texture membranaceous.

Samaras 2 cm long and 0.5 to 0.8 cm wide in maximum ; wing gradually narrowed towards the apex and base, apex rounded ; outer margin nearly straight, inner margin convex, veins about 7 in number at base, curving inwards and dichotomously branching ; seeds spherical in shape, about 2.5 to 3.0 mm in diameter ; contact line of fruits about 3 mm long, angles between outer margin of wing and contact line of fruits 50 to 60 degrees.

Remarks : Though the present materials are incomplete leaf impression and samara,

they are closely similar to the living *Acer rufinerve* S. et Z. in general character. The fossil maple being closely similar to this living species were reported from the Neogene and Pleistocene sediments in Japan. The present materials are quite identical to the fossil leaves and samara of the existing *Acer rufinerve* described from the upper Miocene sediments near Sendai by ENDO (1951). OKUTSU (1940) described *Acer Nomurai* OKUTSU resembling to this living species from the upper Miocene sediments near Sendai, and the former was distinguished from the fossil leaves of the latter. But the writers consider that there is no essential difference between the both species. According his original description, *Acer rufinerve* S. et Z. is trilobate and with duplicate-serrate margin, while *Acer Nomurai* is five-lobate and doubly serrate on margin. But there are both three and five lobated leaves in the living *Acer rufinerve*. Namely, their basal lobes are small and variable in size, and they are frequently not almost observed. Consequently, the both species described by OKUTSU (1940) may be included in the same species, and belong to the present new species.

The living *Acer rufinerve* is now growing in Honshu, Shikoku and Kyushu of Japan, and luxuriantly at altitudes of 600 to 1,500 m above sea level in the mountains of central Honshu.

Occurrence : Mitoku formation

Collection : GSJ. Holotypes Nos. 4182, 4183

Acer protosieboldianum sp. nov.
(Plate XV, Figure 5)

Description : Leaves small, orbiculate in general outline, about 6 cm in diameter, palmately nine-lobate, median lobe largest, basal lobes smallest ; base cordate ; lobes conical, acuminate at apex, seperated by narrowly incised sinuses ; margin duplicately serrate ; primary nerves nine in number, radiating from the base and running to the tips of each lobe, midrib and lateral primaries of next three pairs stout and straight, basal pairs slender and short ; secondary nerves of midrib and the next two primaries numerous, arranged in about six alternate pairs, curving upwards, thin, slender craspedodrome ; secondaries of basal two primaries few and indistinct ; tertiary nerves distinct though thin and slender, forming irregular-polygonal meshes ; petiole missing ; texture thin, membranaceous.

Remarks : The present materials are closely similar to the leaves of living *Acer sieboldianum* S. et Z., which is widely distributed at present from Hokkaido to Kyushu in Japan, and extends to Korea and Manchuria. They are also somewhat similar to the leaves of *Acer japonica* THUNB., but the former is generally smaller in size than the latter. The fossil leaf described as *A. sieboldianum* ? from Pleistocene flora of Shiobara, Tochigi prefecture (ENDO, 1934 : Pl. 31, fig. 6), is closely similar to the present species.

The present new species is a progenitor of the living *Acer seiboldianum.*

Occurrence : Ningyo-toge formation

Collection : GSJ. Holotype No. 4184

Acer submayrii sp. nov.
(Plate XVII, Figure 5)

1951. *Acer Mayrii*, ENDO : op. cit. p. 57, pl. 8, fig. 2

Description : Samara medium in size, about 2.7 cm long : wing 0.7 mm wide in the middle part, 1.9 cm long, gradually narrowed towards the apex and base, apex obtuse ; outer margin slightly broad-concave, inner margin broadly convex ; veins curving inwards and di-

chotomously branching.

Seeds ovate in shape, about 0.8 cm long and 0.5 cm wide ; contact line of fruit about 4 mm long, angles between outer margin of wing and contact line of fruits about 40 degrees.

Remarks : The present material is closely similar to the samara of the modern *Acer Mono* MAXIM, var. *Mayrii* (SCHWERIN) KOIDZ., which grows now in the mountains of Hokkaido and Honshu, Japan. It is also identical to the fossil samara described as *Acer Mayrii* SCHWER. from the upper Miocene sediments near Sendai by ENDO (1951), though it is somewhat smaller than the latter. This fossil species is not common in Neogene flora of Japan.

Occurrence : Mitoku formation

Collection : GSJ. Holotype No. 4185

Acer subpictum SAPORTA
(Plate XVI, Figures 4~6)

1873. *Aber subpictum*, SAPORTA : Bull. Soc. Géol. France, Sér. 3, Tom. 1
1883. *Acer pictum*, NATHORST : op. cit. p. 60, pl. 12, figs. 2~8
1888. *Acer pictum*, NATHORST : op. cit. p. 38, pl. 13, figs. 1, 2
1920. *Acer pictum*, FLORIN : op. cit. p. 24, pl. 4, fig. 5
1931. *Acer pictum*, KONNO : op. cit. pl. 4, fig. 7 ; pl. 13, fig. 7
1940. *Acer subpictum*, HU et CHANEY : op. cit. p. 61, pl. 34, figs. 3~5, 7 ; pl. 35, fig. 1
1940. *Acer pictum*, OKUTSU : op. cit. p. 153, pl. 7, fig. 3 ; pl. 8, figs. 1~4
1943. *Acer subpictum*, OISHI et HUZIOKA : Jour. Fac. Sci., Hokkaido Imp. Univ., Ser. 4, Vol. 7, No. 1, p. 93, pl. 13, figs. 1~4 ; pl. 14, figs. 3, 4
1943. *Acer subpictum*, HUZIOKA : op. cit. p. 129, pl. 24, figs. 4~6 ; pl. 25, fig. 3
1952. *Acer subpictum*, TANAI : Jap. Jour. Geol. Geogr., Vol. 22, p. 131, pl. 4, fig. 7
1954. *Acer pictum*, TAKAHASHI : op. cit. p. 60, taf. 7, figs. 3, 4a, 4b
1955. *Acer pictum*, OKUTSU : op. cit. pl. 7, figs. 1, 2, 8

Remarks : The present materials are quite identical to this species, which is closely similar to the modern *Acer Mono* MAX. distributed widely over Japan, and extends to Korea, north China, Saghalien, Amur and Manchuria.

The leaves of the living *A. Mono* are considerably variable in shape, and also this species is divided into many varieties by their foliar or other characters. Accordingly, it seems desirable to give the specific name of *Acer subpictum* to the fossil leaves and samaras which are closely similar to the living *Acer Mono* MAXIM.. In our collection, there are a samara being close to that of the living *Acer subpictume* and it is included into the present species.

This fossil species is most common in Neogene flora of Japan, and occurred from many localities of Japan.

Occurrence : Mitoku, Onbara and Ningyo-toge formations

Collection : GSJ. Nos. 4186, 4187, 4188

Acer cfr. *pseudocarpinifolium* ENDO
(Plate XV, Figure 3)

cfr. 1950. *Acer pseudocarpinifolium*, ENDO : op. cit. p. 14, pl. 3, fig.6

Remarks : The present material is closely similar to *Acer pseudocarpinifolium* described from the upper Miocene sediments near Sendai by ENDO (1950) in its general shape and spindle-shaped seeds, though it is incomplete in the upper portion. But the present samara is somewhat smaller in size and narrower in width of wing than the original specimen.

This species is somewhat similar to the modern *Acer carpinifolium* S. et Z., which is widely distributed in Honshu, Shikoku and Kyushu, Japan. The angle between outer margin of wing and the contact line of the seed is about 30 degrees in this fossil material, and somewhat less than in the modern related species.

Occurrence : Mitoku formation

Collection : GSJ. No. 4189

Family Rhamnaceae

Paliurus nipponicus MIKI
(Plate XIV, Figure 1)

1888. *Zizuphus tiliaefolia*, HATHORST : op. cit. p. 208, pl. 4, fig. 5
1933. *Paliurus nipponicus*, MIKI : Bot. Mag. (Tokyo), Vol. 47, p. 624, pl. Q~U, figs. 2 F~J
1937. *Paliurus nipponicus*, MIKI : op. cit. p. 324, pl. 9 H, I, figs. 8 A~E
1938. *Paliurus nipponicus*, MIKI : op. cit. p. 216, fig. 2 A ; p. 220
1941. *Paliurus* cfr. *nipponicus*, MIKI : op. cit. p. 285, figs. 17 G
1954. *Paliurus nipponicus*, TAKAHASHI : op. cit. p. 61, taf. 7, figs. 11 a~d

Remarks : Present material is only one fragmental leaf, missing in basal portion, 3.5 cm long and 1.9 cm wide (both estimated). It is identical to the present species by their shape, venation and finely serrate margin. The fossil leaves, fruits and twigs are occurred abundantly from late Pliocene floras in Japan. As described already by MIKI (1937), this species is close to the modern *Paliurus Spina-Christii* MILL. which grows in Mediterranean and Persia.

The present material closely resembles *P. miosenicus* HU et CHANEY which was described from Miocene flora of Shantung province, China (HU et CHANEY, 1940 : Pl. 41, figs. 2, 3, 5, 7, 8), but differs by the marginal serration.

Occurrence : Onbara formation

Collection : GSJ. No. 4190

Family Tiliaceae

Tilia miohenryana HU et CHANEY
(Plate XIV, Figure 9)

1940. *Tilia miohenryana*, HU et CHANEY : op. cit. p. 69, pl. 33, fig. 3 a ; pl. 44, figs. 1, 2 ; pl. 45, fig. 3

Remarks : Though the present materials are fragmental, they are well-preserved in the nervation and marginal characters. These leaves are quite identical to *Tilia miohenryana* HU et CHANEY from Shantung Miocene flora by their setose-serrate margin and considerably oblique base. Two species of *Tilia*, *T. protojaponica* ENDO and *T. distans* NATHORST, are known from late Miocene flora in Japan, but the both are different from this species in their marginal serration.

The present species is closely similar to the modern *T. henryana* SYZS. distributed now from central to southern China, and also to the existing *T. Miyabei* JACK. which grows now in northern or central Honshu and Hokkaido.

Occurrence : Mitoku formation

Collection : GSJ. Plesiotype No. 4191

Family Theaceae

Stewartia submonadelpha sp. nov.
(Plate XVIII, Figure 6)

1883. *Stuartia monadelpha*, NATHORST : op. cit. p. 66, pl. 14, figs. 11, 12
1920. *Stuartia monadeloha*, FLORIN : op. cit. p. 26, pl. 5, fig. 4
1931. *Stuartia monadelpha*, KONNO : op. cit. pl. 14, fig. 6
1937. *Stuartia monadelpha*, MIKI : op. cit. p. 324, fig. 8 K
1941. *Stewatia monadelpha*, MIKI : op. cit. p. 288, figs. 18 E, G
1954. *Stewartia* cfr. *monadelpha*, TAKAHASHI : op. cit. p. 62, taf. 7, fig. 12

Description : Leaves medium in size, 5.3 to 7.0 cm long and 2.4 to 3.0 cm wide, oval to ovate-lanceolate in shape ; apex acute base gradually narrowed, cuneate ; midrib stout, straight extending to the tip ; secondaries thin, slender, about 7 pairs, opposite to subopposite, leaving the midrib at the angles of about 30 degrees, thence curving upwards and connecting of festoon near the margin ; tertiaries thin, indistinct, forming a polygonal mesh ; nervilles indistinct, finely reticulate ; margin finely serrate, with small acute teeth ; petiole missing ; texture thin to medium, subcoriaceous.

Remarks : Though the present material is ill in the preservation, it is probably identical to *Stewartia* by the foregoing characters. Among the living leaves of *Stewartia*, the present material is closely similar to the modern *S. monadelpha* S. et Z., which is now growing in Honshu, Shikoku and Kyushu of Japan.

The present new species is also identical to the fossil leaves of *S. monadelpha* S. et Z. described already from the Pliocene sediments in various areas of Japan. It is similar to the fossil leaves of *S. pseudocamellia* MAXIM. described from the Pliocene and Pleistocene sediments of Japan (NATHORST, 1888 : ENDO, 1940 : MIKI, 1939, 1941), but differs from them in having thin texture and finely well-defined teeth.

Occurrence : Mitoku formation
Collection : GSJ. Holotype No. 4192

Family Cornaceae

Cornus subkousa sp. nov.
(Plate XVII, Figures 6, 7)

1920. *Cornus buchii*, FLORIN : op. cit. p. 26, pl. 3, fig. 2

Description : Leaves small in size, ovate in shape, 5 to 7 cm long (estimated) and 2.5 to 3.8 cm wide ; base missing, probably rounded ; apex obtuse or mucronate, tapered ; midrib stout, then slender distantly, tapered near the apex ; secondary nerves slender, 4 to 5 pairs, opposite to subopposite, diverging from the midrib at the angles of 30 to 35 degrees, curving broadly and almost parallel to the margin, acrodrome ; tertiaries thin, indistinct, percurrent, at right angles to the secondaries, forming small loops on the abaxial side of the secondaries near the margin ; margin entire ; petiole missing ; texture firm, subcoriaceous.

Remarks : The present materials are so fragmental and missing in basal portion, but they are identical to the genus *Cornus* by their shape and nervation characters. This species may be distinguished from *C. megaphylla* by its broader forms and smaller average size, and especially by the smaller number of secondaries. They are closely similar to the modern *Cornus Kousa* BUERG. (Synonym : *Cynoxylon japonica* NAKAI) in general characters, but the latter is acute or somewhat acuminate at apex. The fossil leaves of this living species described from

the Shiobara Pleistocene Plant beds in Tochigi prefecture (ENDO, 1940 : pl. 9, figs. 17, 19), are closely similar to the present materials.

The present new species is also close to *C. miowalteri* HU et CHANEY from Miocene flora of Shantung, China (HU et CHANEY, 1940 : Pl. 47, figs. 1, 2, 4) and *C. ovalis*, LESQ. (LESQUEREUX, 1878 ; KNWOLTON, 1883 ; AXELROD, 1944 ; etc.) from Miocene flora of Oregon and California, North America in their size and small number of secondaries.

The living close species, *C. Kousa*, is now distributed in Honshu and Shikoku, and also extends to Korea and China.

Occurrence : Ningyo-toge and Mitoku formations
Collection : GSJ. Holotypes Nos. 4194, 4195 ; No. 4196

Cornus megaphylla HU et CHANEY
(Plate XVII, Figure 9)

1940. *Cornus megaphylla*, HU et CHANEY : op. cit. p. 71, pl. 48, figs. 3~5 ; pl. 49, fig. 2

Remarks : The present material is fairly identical to this species described from Shantung Miocene flora of China by general characters, though they are somewhat fragmental. This species is closely similar to the modern *Cornus macrophylla* WALLICH, which is now distributed from southwest and west China across central, southeast and north China to Korea and Japan. The fossil fruits of *Cornus controversa* HEMSL. is described from the upper Pliocene sediments in the various localities of Japan (MIKI, 1940, 1941, 1956 ; ENDO, 1955), but the leaves of its species is cuneate at the base.

Occurrence : Mitoku formation
Collection : GSJ. Plesiotype No. 4193

Family Clethraceae

Clethra sp.
(Plate XVII, Figure 10)

Description : Leaves incomplete, missing in the upper two-third portion of blade slightly inequilateral, probably broadly oblanceolate in shape, gradually narrowed to petiole ; base cuneate or rarely rounded ; apex unknown ; midrib thick, straight ; secondaries distinct though thin, subalternate, leaving the midrib at the angles of 40 to 70 degrees, curved upwards near the margin, thence forming bow by dichotomous branches, camptodrome ; tertiary nerves thin, indistinct, mainly percurrent ; nervilles obscure ; margin finely serrate with acute teeth except the basal portion ; petiole stout, thick ; texture membranaceous.

Remarks : The present materials are so fragmental, but they are close to the genus *Clethra* in the characters of margin and venation. They are also quite identical to the fossil leaves of *C. barbinervis* described from the upper Miocene sediments near Sendai by OKUTSU (1940). ENDO (1940) described the well-preserved leaves of this resembling living species from the Pleistocene Shiobara Plant beds in Tochigi prefecture, Japan.

This living species is distributed in Hokkaido, Honshu, Shikoku, Kyushu of Japan, and also in Korea.

Occurrence : Ningyo-toge formation
Collection : GSJ. Holotype No. 4197

Family Ericaceae

Rhododendron protodilatatum sp. nov.
(Plate XVIII, Figures 2, 4)

Description : Leaves small in size, rhomboidal or broadly ovate in shape, 2.9 to 3.1 cm long and 2.5 to 2.7 cm wide ; base broadly cuneate ; apex shortly acute or mucronate ; midrib thick below, gradually thin toward the apex, gently curved ; secondary nerves slender, 4 or 5 pairs, subopposite, especially basal two pairs of secondaries prominent, acrodromic and leaving the midrib at the angles of 40 to 60 degrees, upper pairs diverging at the angles of 35 to 40 degrees, all secondaries curving upwards along the margin, camptodrome ; tertiaries few on basal secondaries ; nervilles indistinct, forming fine areolation ; margin entire, but finely serrate on upper portion ; petiole thick, 4 mm long ; texture firm, membranaceous.

Remarks : The present materials are closely similar to the living *Rhododendron dilatatum* MIQ. by the foliar shape and basal two pairs of secondaries. The fossil leaves of this living species were described from the Pleistocene Shiobara Plant beds by ENDO (1940).

This living species is distributed in Honshu of Japan, and grows luxuriantly at the altitudes of about 700 to 1,300 m above sea level in central Honshu. The present fossil species is probably a direct progenitor of the living species.

Occurrence : Mitoku formation

Collection : GSJ. Holotype No. 4198 ; Paratype No. 4199

Tripetaleia pseudopaniculata sp. nov.
(Plate XVIII, Figure 3)

Description : Leaves small in size, oval in shape, 4 cm long (estimated) and 2 cm wide ; apex missing, but probably bluntly-pointed ; base gradually narrowed and pointed as equally as in the apex ; midrib stout, straight ; secondary nerves 4 subopposite pairs, diverging from the midrib at the angles of 20 to 30 degrees, curving upwards along the margin, acrodrome ; the secondaries leaving at the one-third portion of blade from the base, most prominent, rather stout, but the others very slender and thin ; thin basal pair of secondaries running in the marginal border and parallel to the margin ; between the midrib and the prominent secondaries, a few intermittent thin secondaries leaving the midrib at the wider angles ; thin tertiary nerves branching off towards outside from the prominent secondary pair, other tertiaries thin and indistinct ; nervilles indistinct, forming a irregular areolation ; margin entire ; petiole stout, thick, 0.4 cm long ; texture thick, coriaceous.

Remarks : The present species is based on only one leaf impression, which is somewhat incomplete in preservation. The material is identical to the genus *Tripetaleia* by the characteristic secondary nervation, which nervation somewhat resembles that of the genus *Cinnamomum*.

The present material is closely similar to the modern *T. paniculata* S. et Z., which is widely distributed in Hokkaido, Honshu, Shikoku and Kyushu. It is somewhat close to *T. Almquisti* NATHORST from the Pliocene Mogi Plant beds (NATHORST, 1883 : Pl. 9, figs. 12, 13 ; Pl. 13, fig. 12 ; Pl. 14, fig. 14), but the latter is more in number of prominent secondary nerves. This fossil species is very rare in this flora, and so the material seems to be derived from the higher mountain slope to the depositional "field".

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4200

Family Symplocaceae

Symplocos sp.
(Plate XVII, Figure 8)

Description : Leaves medium in size, oblong-ovate in shape, broadly rounded at the base, about 6 cm long (estimated) and 3.2 cm wide ; apex missing ; midrib stout, then slender distantly, slightly curved ; secondary nerves slender, about 4 alternate pairs, diverging from the midrib at the angles of 25 to 30 degrees, curving upwards along the margin, camptodrome ; the tertiaries in the marginal border forming loops with the secondary branches, tertiaries in the inter-secondary spaces very thin, obscure ; nervilles indistinct, finely reticulate ; margin finely serrulate ; petiole stout, 1 cm long ; texture firm, subcoriaceous.

Remarks : The present material is somewhat fragmental and ill-preserved, but they resemble closely some leaves of *Hydrangea* or *Symplocos* in general outline. Their characteristic venation shows a close resemblance to *Symplocos crataegoides* MIQ., which is widely distributed from Hokkaido to Kyushu of Japan and also in Korea. But the recent leaves of *S. crataegoides* are usually cuneate at the base, and somewhat more in secondary number. The fossil leaves of this living species were described from the Pleistocene Shiobara Plant beds (ENDO, 1940 : Pl. 11, fig. 8), but they are almost identical to the recent leaves in general characters. Beside them, there are no fossil leaves comparable to the present material.

Occurrence : Ningyo-toge formation

Collection : GSJ. Holotype No. 4201

Family Styraceae

Styrax protoobassia sp. nov.
(Plate XVIII, Figures 1, 8)

1883. *Styrax obassia*, NATHORST : op. cit. p. 50, pl. 10, figs. 2~6 ; pl. 11, fig. 7
1920. *Styrax obassia*, FLORIN : op. cit.
1930. *Styrax obassia*, KONNO : op. cit. pl. 15, figs. 1, 2
1940. *Styrax obassia*, OKUTSU : op. cit. pl. 13, fig. 3 ; pl. 13, fig. 4

Description : Leaves large in size, 10 to 15 cm long and 8 to 13 cm wide, orbicular or broadly ovate in general shape, obtusely cuspidate at apex, rounded or slightly cordate at base ; margin entire or remotely denticulate ; midrib stout, straight below, and becoming thin, slightly sinuate near the apex ; 7 to 12 alternate or subalternate secondaries diverging at the angles of 40 to 60 degrees from the primary, about regularly spaced, slightly curving upwards near the margin and camptodrome or subcamptodrome, forked, the lower secondaries given off prominent abaxial tertiaries ; tertiary nerves thin, forming irregular elongate-quadrangular meshes ; petiole missing ; texture medium or firm, membranaceous.

Remarks : The leaves of this new species are generally large in size, but frequently small leaves were occurred in Japanese Tertiary sediments. They are variable in marginal characters, and entire, remotely denticulate, slightly waved, or rarely incised on margin. However, the present materials matches closely the leaf variation displayed by living *Styrax obassia* S. et Z., though they are more or less fragmental. The specimens from the upper Tertiary sediments in various areas of Japan, which were described by NATHORST, FLORIN, KONNO and OKUTSU as *Styrax obassia* S. et Z., are quitely identical to the present new species. Among the leaves of the living *Styrax* in Japan, the present materials are closely similar to *Styrax obassia* S. et Z., which grows luxuriantly at the altitudes of 500 to 700 m above sea level in

central Japan. The living species grows in Hokkaido, Honshu, Shikoku and Korea, and is especially one of the common trees in southern Hokkaido.

The fossil seeds of *Styrax obassia* S. et Z. are frequently found by MIKI (1937, 1938, 1941) from various Pliocene and Pleistocene floras of Japan.

Occurrence : Ningyo-toge formation

Collection : GSJ. Holotype No. 4202 ; Paratype No. 4203

Family Oleaceae

Fraxinus honshuensis sp. nov.

(Plate XVIII, Figure 7)

1941. *Fraxinus* cfr. *japonica*, MIKI : op. cit. p. 295, fig. 21 C

Description : Samara linear in outline, with short pedicel, over 2.1 cm in length and 4 mm in width ; wing lanceolate, somewhat broken but apparently round at the tip, attached at the end of seed, but slightly clasping the seeds ; nerves thin, numerous, dichotomously branching to the tip, subparallel to long axis of samara ; seed narrowly lanceolate, 0.8 cm long and 3 mm wide.

Remarks : This new species is based on only one well-preserved samara in the Ningyo-toge florule. There are some fragmental leaves being referable to the genus *Fraxinus* in the collection, but it is too ill-preserved to make certain whether they are included into this new species or not.

The present samara is certainly identical to the genus *Fraxinus* in the characteristic shape, and closely similar to the modern *F. japonica* BL. by the size and shape. The samaras described as *F.* cfr. *japonica* BL. from the Pliocene flora of Gihu prefecture by MIKI are identical to this species, though they are somewhat larger than the latter in size. The fossil samara of *F. longicuspis* S. et Z. described from the Pleistocene Shiobara Plant beds (ENDO, 1940 : Pl. 11, fig. 12) is close to this species, but the former is somewhat narrower than the latter. Generally, the samara of the modern *F. longicuspis* are emarginate at the apex, and those of modern *F. japonica* rounded. This species is closely similar to *F. alcorni* AXELROD from the Mio-Pliocene floras in Nevada of North America (AXELROD, 1956 : Pl. 9, figs. 4, 5, 7~9), but in the latter, the wing does not clasp the seeds at all.

Occurrence : Ningyo-toge formation

Collection : GSJ. Holotype No. 4204

Family Caprifoliaceae

Lonicera protojaponica sp. nov.

(Plate XVIII, Figure 5)

1883. *Phyllites* sp., NATHORST : op. cit. p. 75, pl. 12, figs. 9, 10 ; pl. 14, fig. 20

Description : Leaves small in size, oval in shape, 3.5 cm long and 2.1 cm wide ; base broadly rounded, slightly asymmetrical ; apex missing, but apparently pointed ; midrib stout and thick below, distantly slender and thin, somewhat arched ; secondary nerves slender, 5 prominent pairs, subopposite, leaving the midrib at the angles of 30 to 40 degrees, forking near the margin, curved up along the margin, camptodrome, a few intermittent secondaries diverging from the midrib between the prominent secondaries ; tertiaries very fine and thin ; nervilles obscure, probably forming irregular meshes ; margin entire ; petiole thick and short, about 2 mm in length ; texture firm, subcoriaceous.

Remarks : The present material somewhat resembles some leaves of the genus *Vaccinium*, *Tripetaleia*, or *Meisteria* in general outline, but it is identical to the genus *Lonicera* by the characteristic nervation. It is closely similar to the modern *Lonicera japonica* THUNB. in the general characters, which is widely distributed over Japan, and extend to Korea, Manchuria and China. There are few fossil leaves comparable to the present material, and a fragmental leaves figured as *Phyllites* sp. from the Mogi Plant beds by NATHORST (1883) is probably identical to this species.

The present species resembles more or less some leaves of *Tripetaleja Almquisti* NATHORST from the Mogi Plant beds of Japan (NATHORST, 1883 : Pl. 9, figs. 12, 13 ; Pl. 14, fig. 14), and *Salix spokanensis* (BERRY) BROWN from the Miocene Latah formation of Idaho, North America (BROWN, 1937 : Pl. 46, figs. 3～6, 8). But the latter two species differ from this new species in the detail of secondary nervation.

Occurrence : Onbara formation

Collection : GSJ. Holotype No. 4205

(submitted in January, 1959)

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要　旨

鳥取・岡山県境の人形峠地域産の中新—鮮新世植物群について

棚井敏雅・尾上亨

鳥取・岡山県境の人形峠付近に分布する人形峠層は，燐灰ウラン鉱を含み，わが国における稼行可能のウラン鉱床の1つとして，多くの注目を浴びている。筆者らはこの人形峠周辺地域から産出する多くの植物化石について研究し，含化石層の地質時代を検討するとともに，古植物群の組成および生態的環境についても併せて考察した。

“伯耆植物群”と呼ぶこの植物群は27科47属67種からなつているが（第1表），それらの大部分は温帯性の植物であり，数種の熱帯または亜熱帯性の要素を含んでいる。この植物群は三徳・恩原および人形峠の3亜植物群からなり，前2者には，*Taiwania*, *Carya*, *Liriodendron*, *Sassafras*, *Liquidambar* などのわが国に現存しない属が含まれているが，人形峠亜植物群には，それらは全然認められない。3亜植物群の各構成種の産出頻度，過去における生育地および葉の形状などについて，3亜植物群を相互に比較・検討した。これらの結果から，次の2，3のことが明らかになつた。

（1） 3亜植物群はいずれも *Fagus palaeocrenata* が著しく多く，ことに人形峠亜植物群においては，その全個体数の71%を占める。すなわち，伯耆植物群は現在のブナ林の植生に近似している。

（2） 構成種の解析結果から考えると，三徳亜植物群は山腹から平地にかけた地域の森林相を示し，恩原亜植物群はそれよりやゝ高い地域の森林相を示している。人形峠亜植物群は前2者よりも，さらにやゝ高い地域の森林相を示し，山腹から高地にかけての地域に，生育したものであろう。

（3） わが国の他の新第三紀植物群と比較すると，三徳亜植物群は中新世後期，恩原亜植物群は中新—鮮新世および人形峠亜植物群は鮮新世前期のものとそれぞれ考えられる。

（4） これら3亜植物群の組成は時代とともに漸変しているが，それらの変化は明らかに当時の環境変化に対応している。植物群の構成変化から考えると，当地域においては，中新世後期から鮮新世へと気温は漸次低下しているが，この傾向はわが国におけるこの時代の気温変化と一致する。

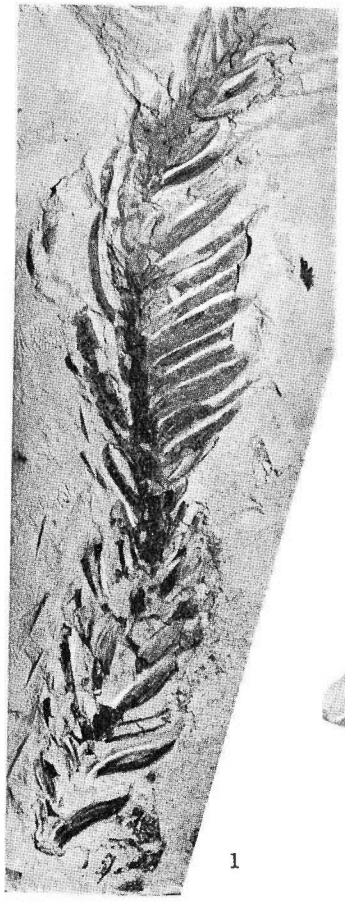
PLATES
AND
EXPLANATIONS

(with 18 Plates)

PLATE I

1 *Cunninghamia protokonishii* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4067
2 *Abies* sp., Geol. Surv. Japan Holotype No. 4059
3 *Juniperus honshuensis* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4072
4 *Taiwania japonica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4068
5 *Pseudolarix japonica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4063
6, 7 *Larix onbaraensis* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4060, Paratype No. 4061
8 *Pinus palaeopentaphylla* TANAI et ONOE, Geol. Surv. Japan No. 4066
9 *Picea Kaneharai* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4062
10 *Pinus palaeopentaphylla* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4065
11 a, b *Thuja nipponica* TANAI et ONOE, Geol. Surv. Japan ×1.5 Holotype No. 4069, Paratype No. 4070
12 *Pinus palaeopentaphylla* TANAI, et ONOE, Geol. Surv. Japan Holotype No. 4064
13 *Populus aizuana* HUZIOKA et SUZUKI, Geol. Surv. Japan Plesiotype No. 4074

(All natural size unless otherwise stated)



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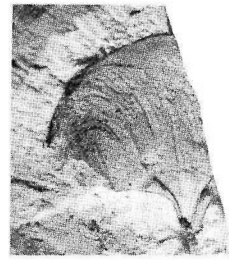

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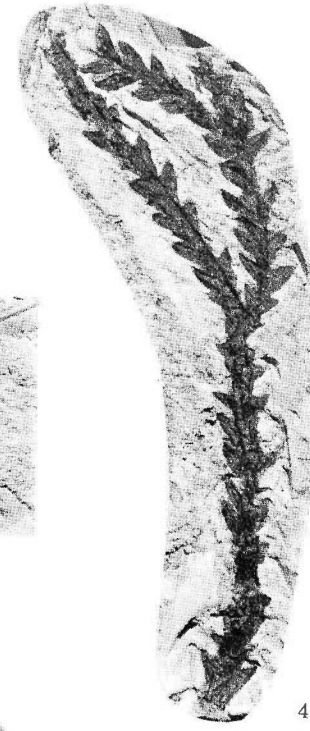

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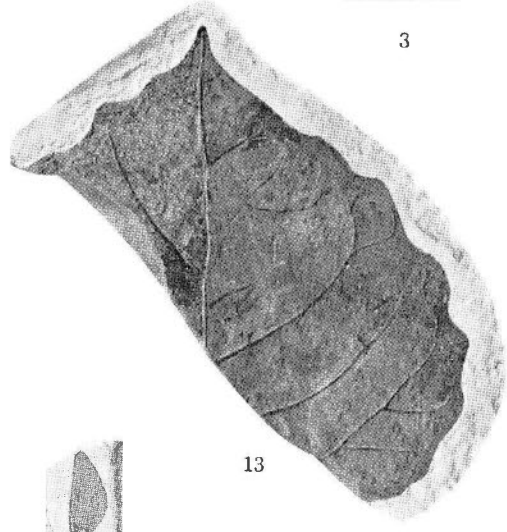

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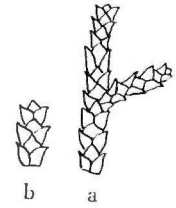

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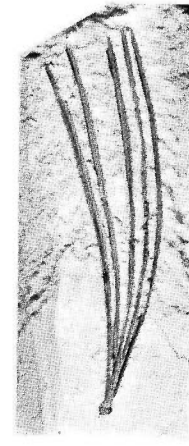

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PLATE II

1 *Alnus protohirsuta* ENDO, Geol. Surv. Japan ×2/3, Plesiotype No. 4083

2 *Pterocarya nipponica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4078

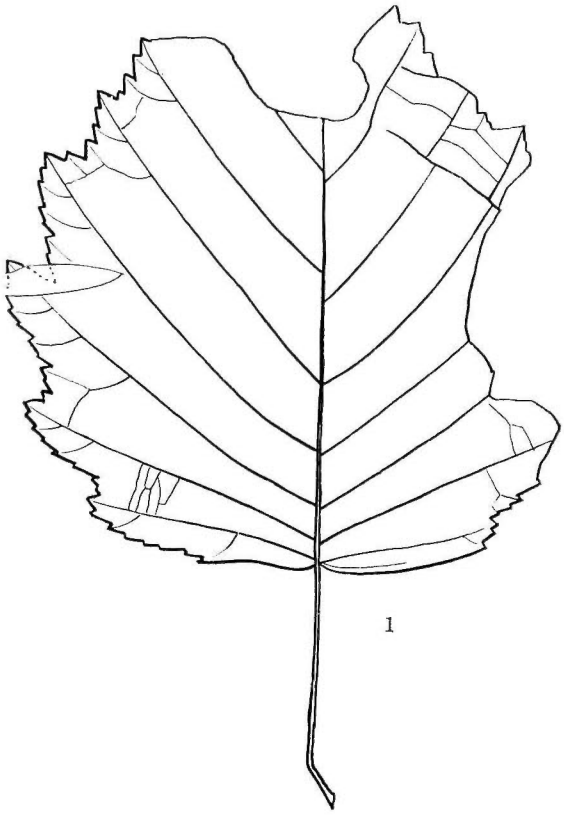
3 *Juglans* sp., Geol. Surv. Japan Holotype No. 4076

4, 5 *Pterocarya nipponica* TANAI et ONOE, Paratypes Nos. 4079, 4080

6 *Carya miocathayensis* HU et CHANEY, Geol. Surv. Japan No. 4082

7 *Alnus miojaponica* TANAI, Geol. Surv. Japan Paratype No. 4086

(All natural size unless otherwise stated)



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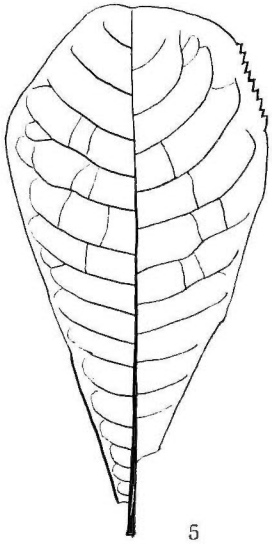

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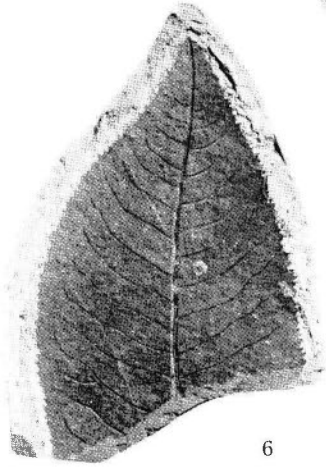

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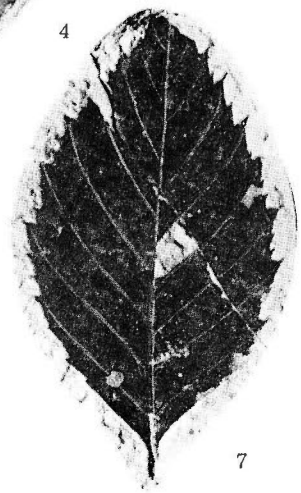

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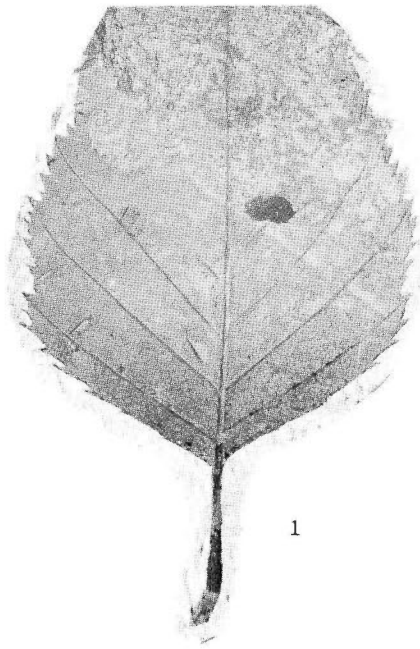
PLATE III

1 *Betula protoglobispica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4089
2 *Betula protoglobispica* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4090
3 *Carpinus miocenica* TANAI, Geol. Surv. Japan Plesiotype No. 4097
4 *Betula protoermanni* ENDO, Geol. Surv. Japan Plesiotype No. 4087
5 *Alnus protohirsuta* ENDO, Geol. Surv. Japan No. 4085
6 *Quercus protoserrata* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4116
7 *Betula* sp., Geol. Surv. Japan Holotype No. 4094

(All natural size)



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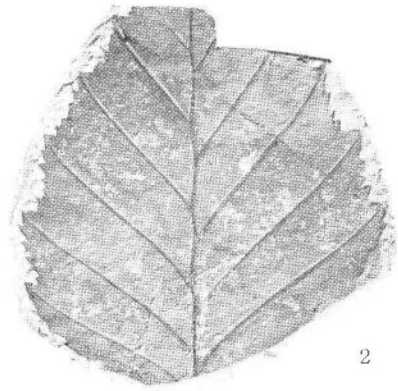

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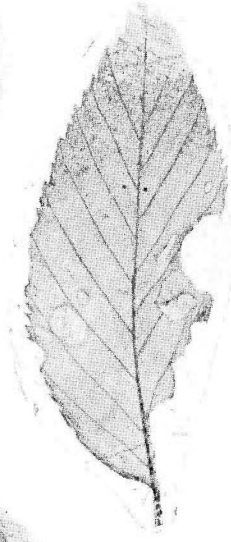

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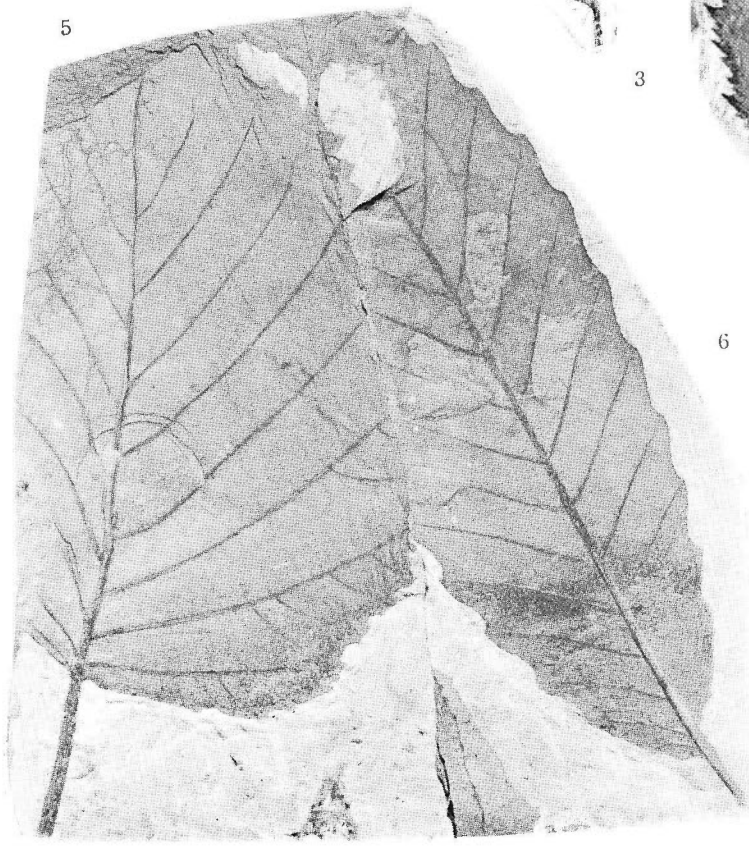

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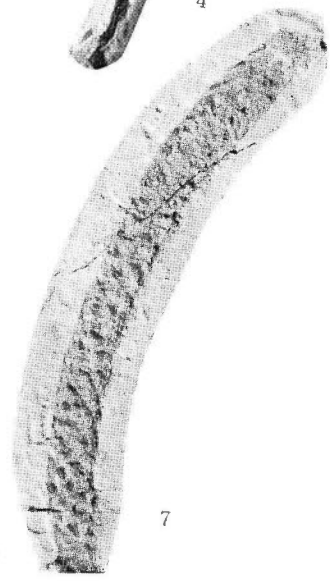

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PLATE IV

1, 2 *Betula onbaraensis* TANAI et ONOE, Geol. Surv. Japan Holotypes Nos. 4091, 4092

3, 7 *Carpinus subyedoensis* KONNO, Geol. Surv. Japan Nos. 4103, 4104

4 *Carpinus miocenica* TANAI, Geol. Surv. Japan No. 4098

5 *Carpinus nipponica* ENDO, Geol. Surv. Japan ×1.5 Plesiotype No. 4095

6 *Carpinus subyedoensis* KONNO, Geol. Surv. Japan Plesiotype No. 4102

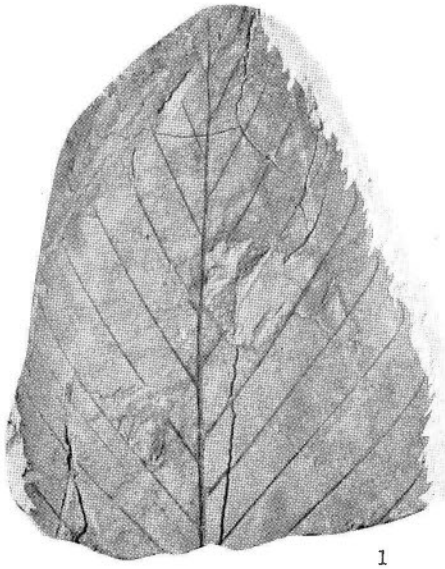
8 *Carpinus nipponica* ENDO, Geol. Surv. Japan No. 4095

9 *Carpinus subcarpinoides* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4100

10 *Carpinus subyedoensis* KONNO, Geol. Surv. Japan Plesiotype No. 4101

11 *Carpinus subcordata* NATHORST, Geol. Surv. Japan No. 4099

(All natural size unless otherwise stated)



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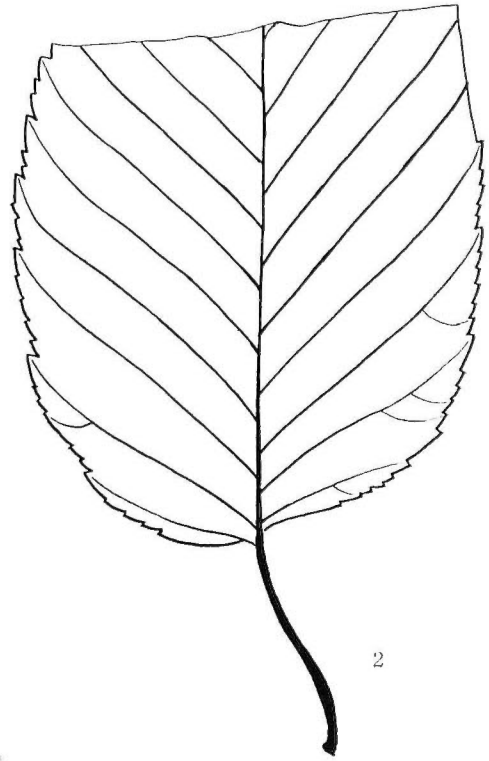

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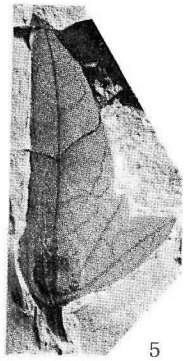

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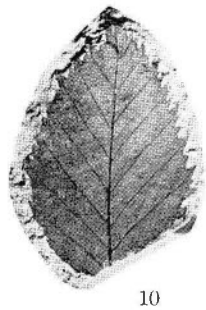

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PLATE V

1, 4 *Castanea miocrenata* TANAI et ONOE, Geol. Surv. Japan Holotypes Nos. 4105, 4106

2, 3 *Castanea miocrenata* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4107; No. 4108

5 *Quercus* sp., Geol. Surv. Japan Holotype No. 4117

(All natural size)

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PLATE VI

1 *Quercus miocrispula* HUZIOKA, Geol. Surv. Japan Plesiotype No. 4109

2, 6 *Quercus miocrispula* HUZIOKA, Geol. Surv. Japan Nos. 4110, 4111

3 *Fagus palaeocrenata* OKUTSU (cupula), Geol. Surv. Japan No. 4126

4, 5 *Fagus palaeocrenata* OKUTSU (bud scale), Geol. Surv. Japan ×1.5 Nos. 4127, 4128

7 *Quercus protoserrata* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4115

(All natural size unless otherwise stated)

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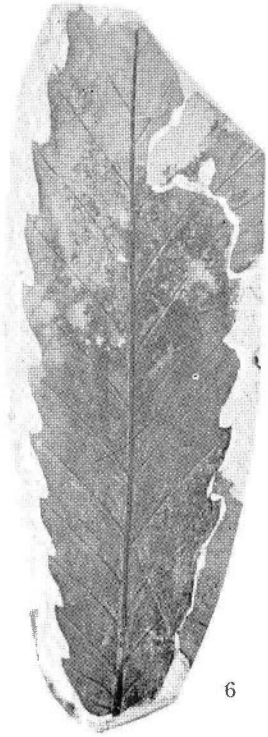

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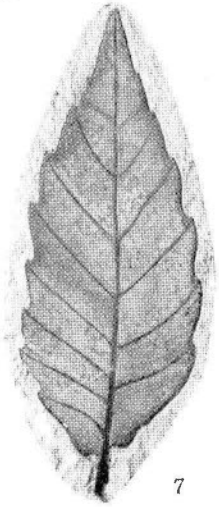

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PLATE VII

1 *Quercus protodentata* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4112

2 *Quercus protodentata* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4113

3 *Fagus palaeojaponica* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4137

4, 5 *Fagus palaeojaponica* TANAI et ONOE, Geol. Surv. Japan Holotypes Nos. 4135, 4136

(All natural size)

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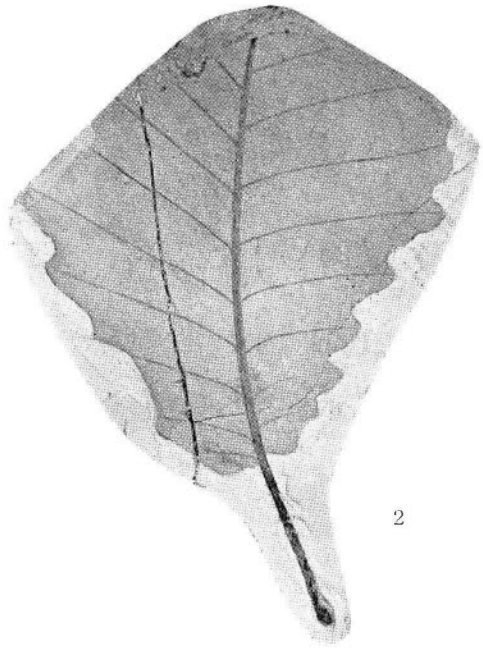

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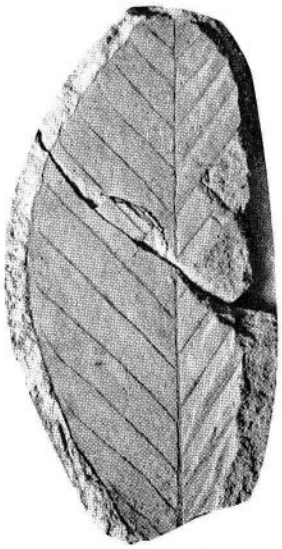

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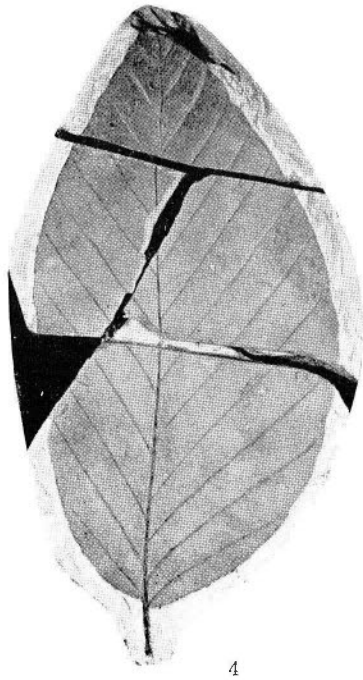

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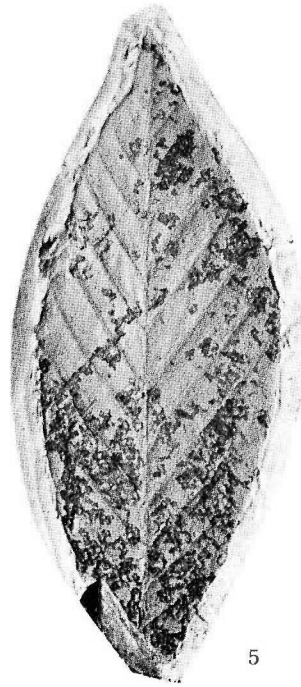

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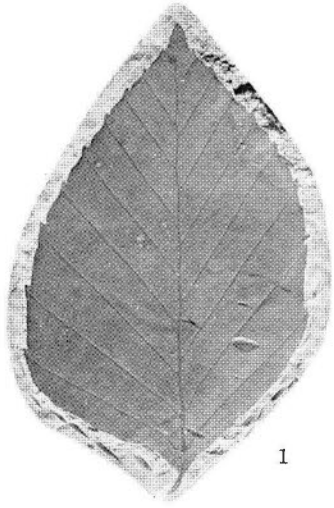
PLATE VIII

1, 2 *Fagus palaeocrenata* OKUTSU, Geol. Surv. Japan Plesiotypes Nos. 4118, 4119

3~7 *Fagus palaeocrenata* OKUTSU, Geol. Surv. Japan Nos. 4120, 4121, 4122, 4123

(All natural size)



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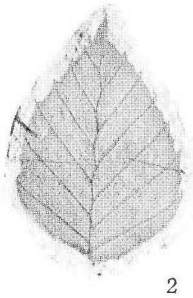

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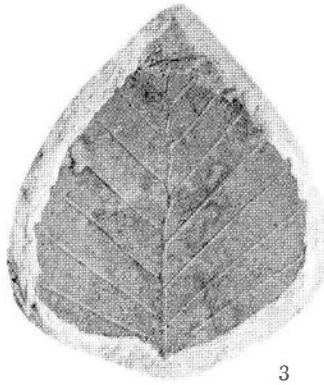

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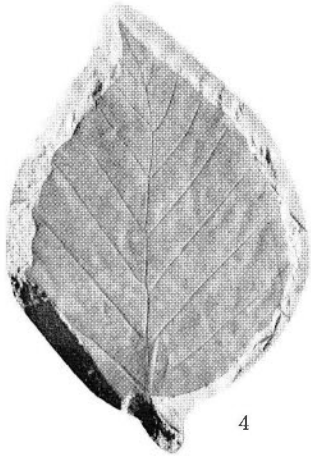

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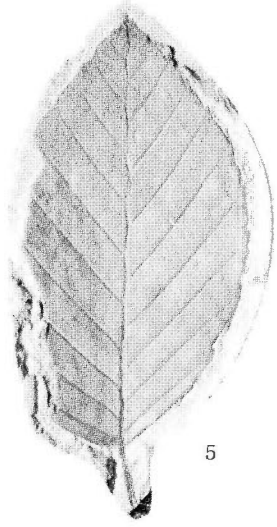

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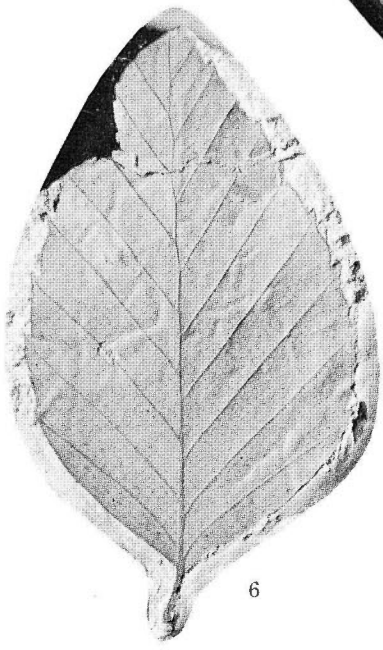

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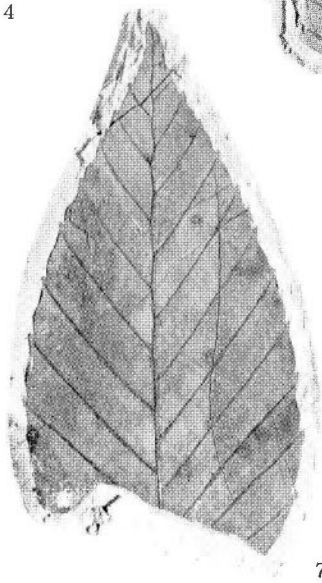

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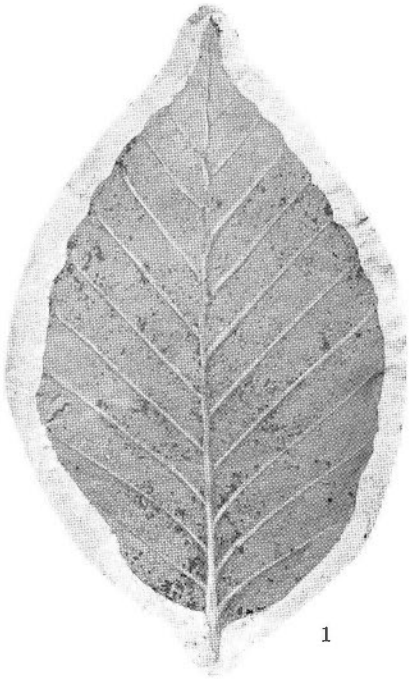
PLATE IX

1~6 *Fagus palaeocrenata* OKUTSU, Geol. Surv. Japan Nos. 4129, 4130, 4131, 4132, 4133, 4134

(All natural size)



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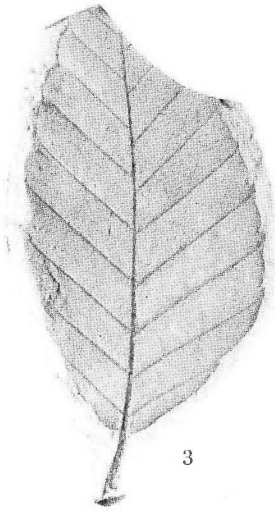

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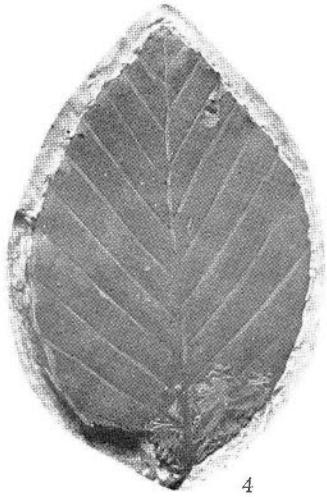

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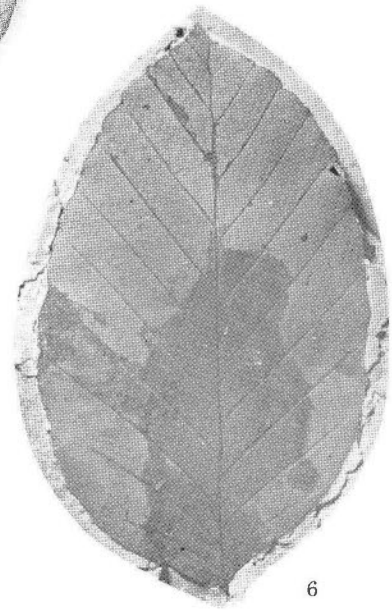

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PLATE X

1 *Celtis Nathorstii* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4138
2 *Ulmus protojaponica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4142
3 *Ulmus protolaciniata* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4141
4 *Zelkova Ungeri* (ETTINGS.) KOVATS, Geol. Surv. Japan No. 4144
5 *Ulmus protojaponica* TANAI et ONOE, Paratype No. 4143
6 *Wistaria fallax* (NATHORST) TANAI et ONOE, Geol. Surv. Japan No. 4168
7 *Celtis Nordenskioldii* NATHORST, Geol. Surv. Japan Plesiotype No. 4139
8 *Ulmus protolaciniata* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4140

(All natural size)

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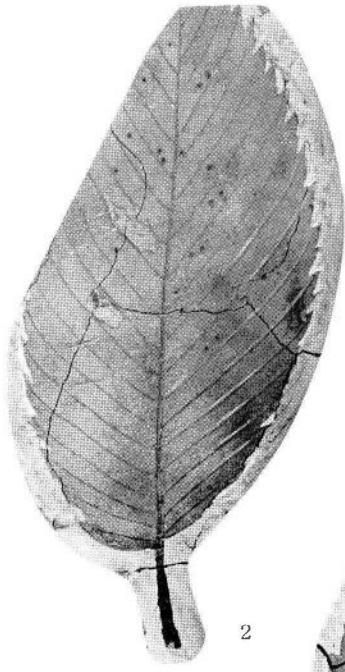

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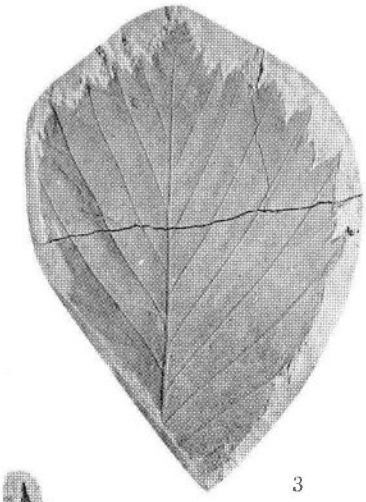

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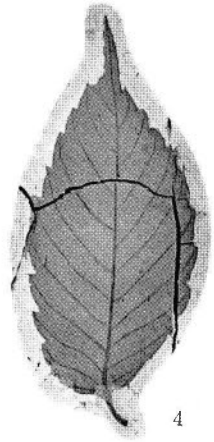

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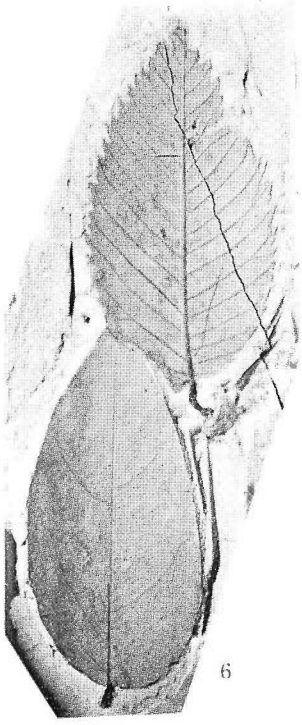

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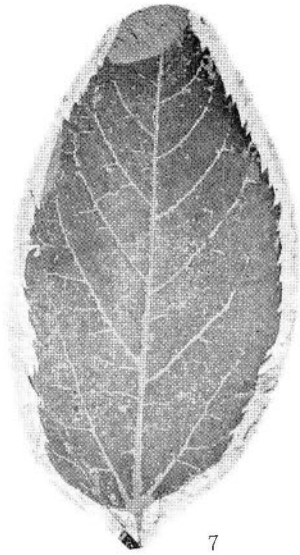

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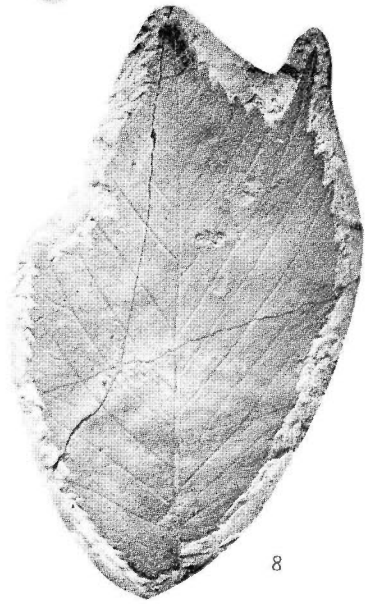


8

PLATE XI

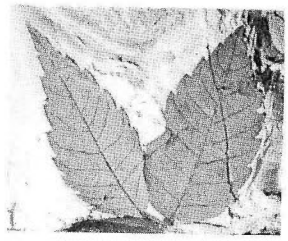
1~3, 5 *Zelkova Ungeri* (ETTINGS.) KOVATS, Geol. Surv. Japan Nos. 4145, 4146, 4147, 4148

4 *Schizophragma mitokuensis* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4158

6 *Ficus* sp., Geol. Surv. Japan Holotype No. 4149

7 *Liriodendron honsyuensis* ENDO, Geol. Surv. Japan No. 4150

(All natural size)



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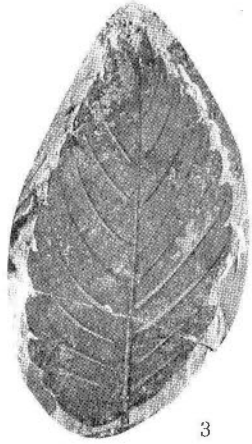

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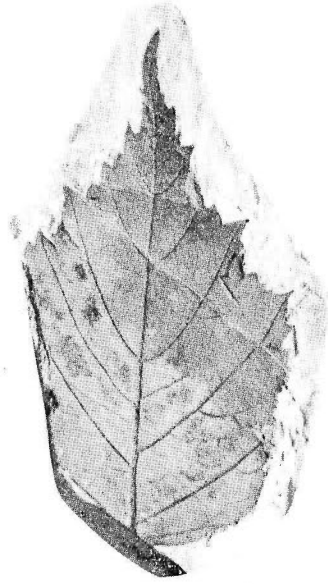

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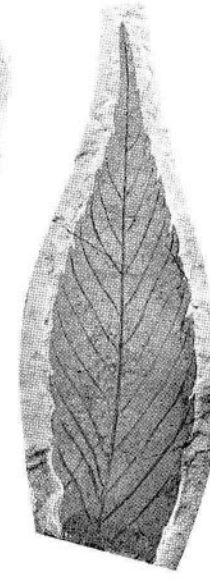

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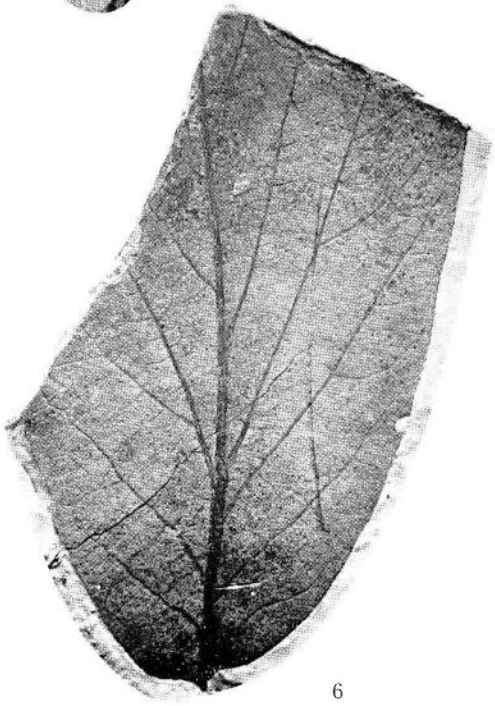

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PLATE XII

1 *Magnolia elliptica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4151

2, 4 *Liquidambar mioformosana* TANAI (MS), Geol. Surv. Japan Nos. 4160, 4161

3 *Hamamelis* sp., Geol. Surv. Japan Holotype No. 4159

5 *Magnolia elliptica* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4152

(All natural size)

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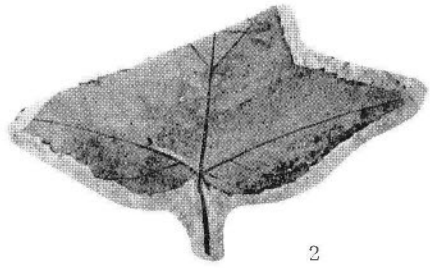

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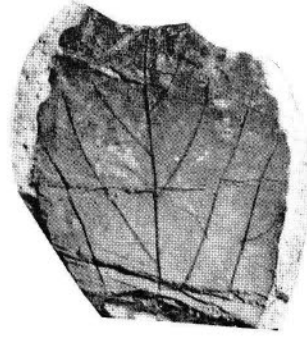

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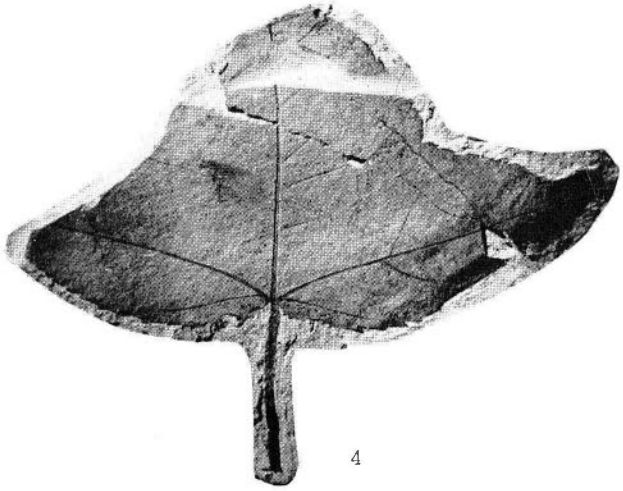

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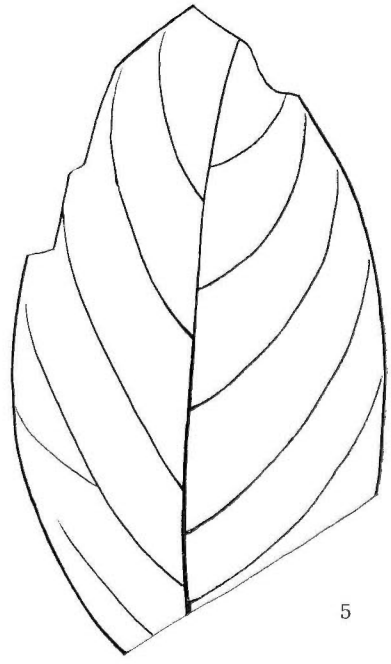


5

PLATE XIII

1, 2 *Sassafras subtriloba* (KONNO) TANAI et ONOE, Geol. Surv. Japan Paratypes Nos. 4155, 4156

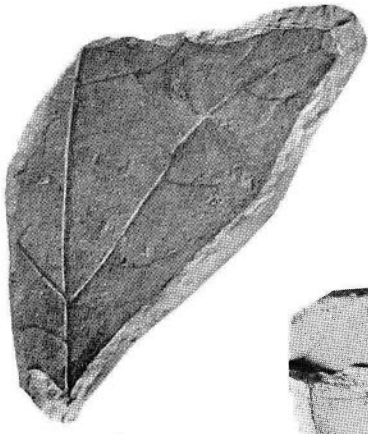
3, 4 *Sassafras subtriloba* (KONNO) TANAI et ONOE, Geol. Surv. Japan Holotypes Nos. 4153, 4154

5 *Sassafras subtriloba* (KONNO) TANAI et ONOE, Geol. Surv. Japan No. 4157

6 *Prunus protossiori* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4163

7 *Prunus protossiori* TANAI et ONOE, Geol. Surv. Japan ×1.5 Paratype No. 4164

(All natural size unless otherwise stated)



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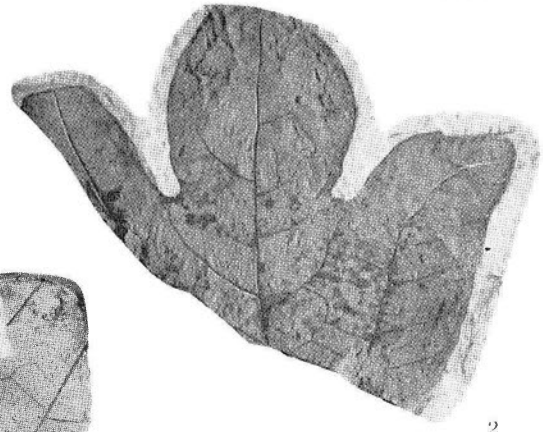

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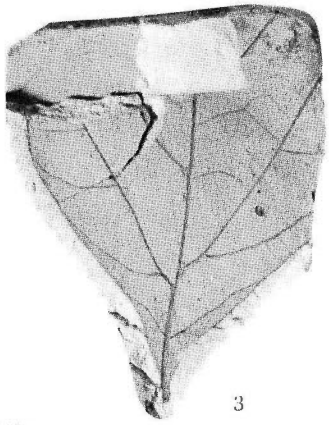

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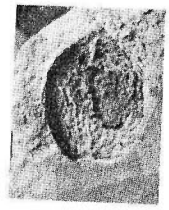

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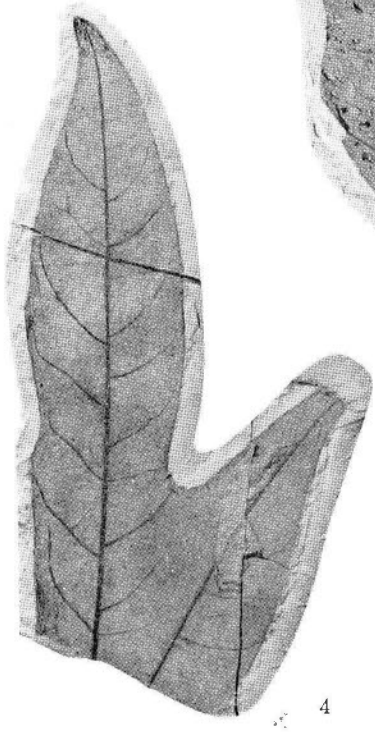

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PLATE XIV

1 *Paliurus nipponicus* MIKI, Geol. Surv. Japan Plesiotype No. 4190

2 *Wistaria fallax* (NATHORST) TANAI et ONOE, Geol. Surv. Japan Holotype No. 4165

3, 4 *Wistaria fallax* (NATHORST) TANAI et ONOE, Geol. Surv. Japan Paratypes Nos. 4166, 4167

5 *Buxus protojaponica* TANAI et ONOE, Geol. Surv. Japan ×2, Holotype No. 4170

6 *Euonymus palaeosieboldianus* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4172

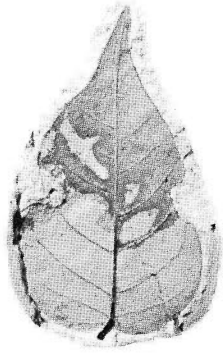
7 *Ilex* sp., Geol. Surv. Japan Holotype No. 4171

8 *Sorbus nipponica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4162

9 *Tilia miohenryana* HU et CHANEY, Geol. Surv. Japan No. 4191

(All natural size unless otherwise stated)

1



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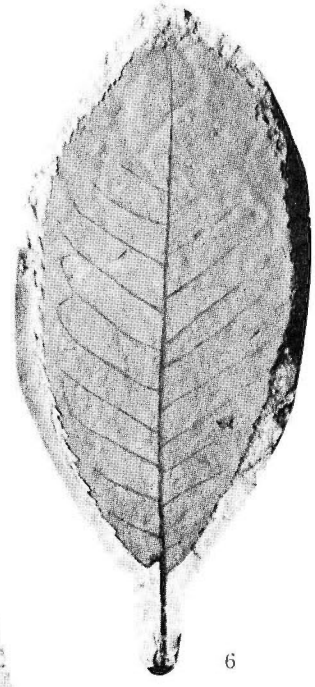

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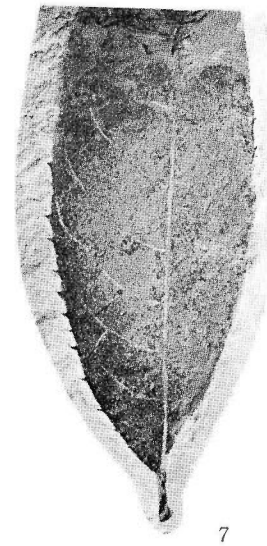

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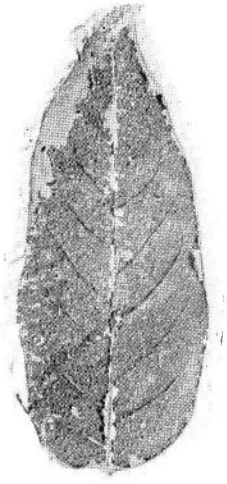

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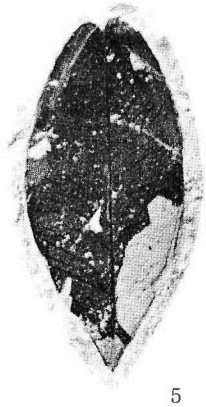

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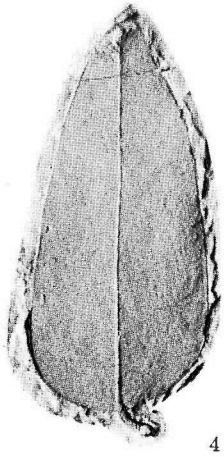

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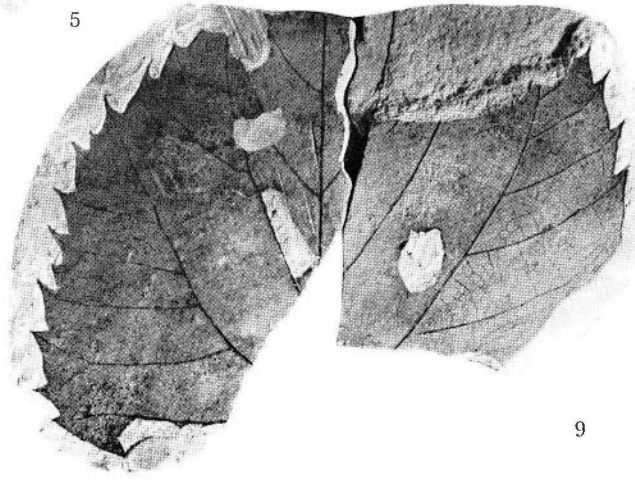
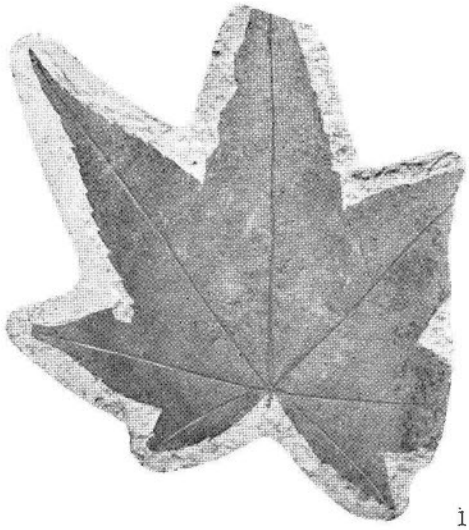


9

PLATE XV

1 *Acer Nordenskiöldi* NATHORST, Geol. Surv. Japan Plesiotype No. 4173
2 *Acer palaeodiabolicum* ENDO, Geol. Surv. Japan Plesiotype No. 4175
3 *Acer* cfr. *pseudocarpinifolium* ENDO, Geol. Surv. Japan No. 4189
4 *Acer palaeodiabolicum* ENDO, Geol. Surv. Japan No. 4176
5 *Acer protosieboldianum* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4184

(All natural size)



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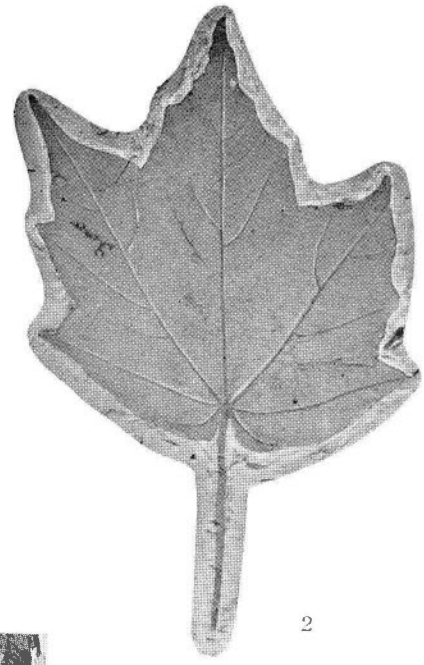

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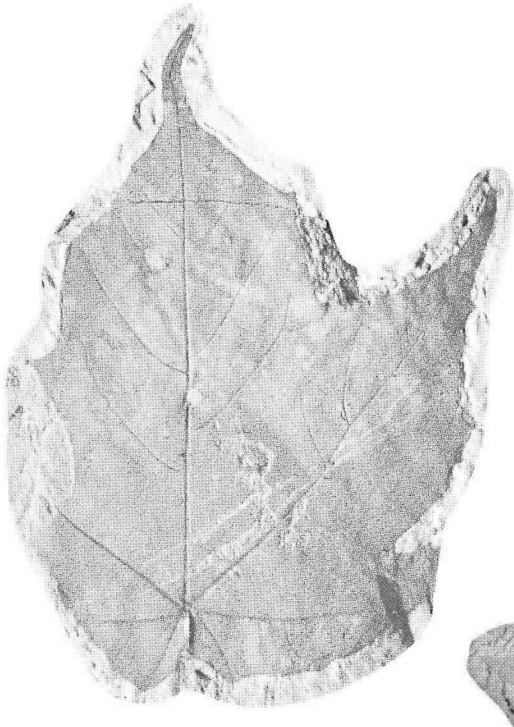

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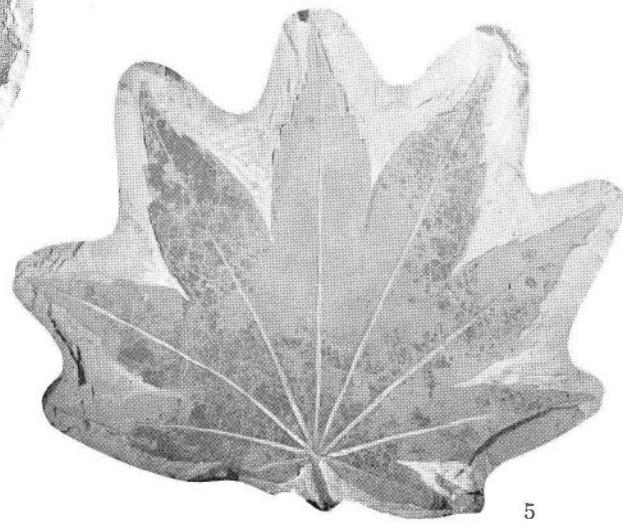

5

PLATE XVI

1 *Acer palaeodiabolicum* ENDO, Geol. Surv. Japan No. 4177

2, 3 *Acer palaeorufinerve* TANAI et ONOE, Geol. Surv. Japan Holotypes Nos. 4182, 4183

4 *Acer subpictum* SAPORTA, Geol. Surv. Japan No. 4188

5, 6 *Acer subpictum* SAPORTA, Geol. Surv. Japan Nos. 4186, 4187

(All natural size)

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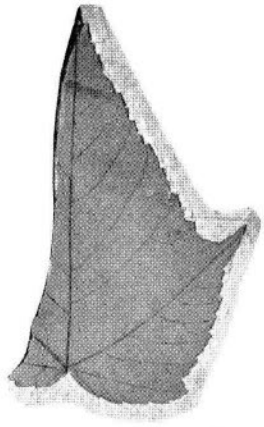

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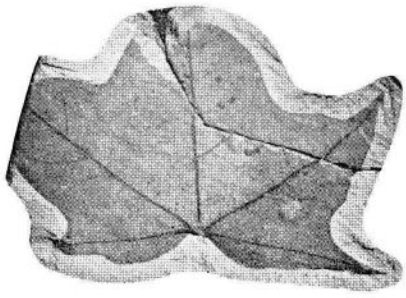
4



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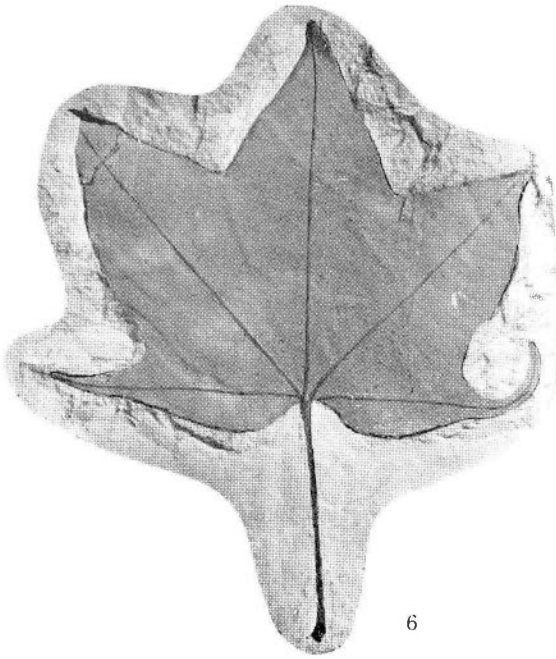

6

PLATE XVII

1~4 *Acer palaeodiabolicum* ENDO, Geol. Surv. Japan Nos. 4178, 4179, 4180, 4181

5 *Acer submayrii* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4185

6, 7 *Cornus subkousa* TANAI et ONOE, Geol. Surv. Japan Holotypes Nos. 4194, 4195

8 *Symplocos* sp., Geol. Surv. Japan Holotype No. 4201

9 *Cornus megaphylla* HU et CHANEY, Geol. Surv. Japan Plesiotype No. 4193

10 *Clethra* sp., Geol. Surv. Japan Holotype No. 4197

11 Sketch of Fig. 8

12 *Acer Nordenskiöldi* NATHORST, Geol. Surv. Japan No. 4174

(All natural size)

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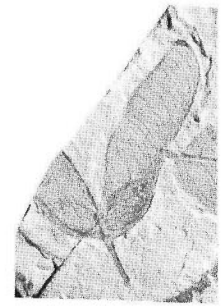

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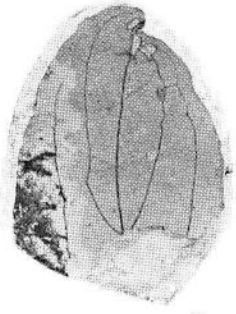

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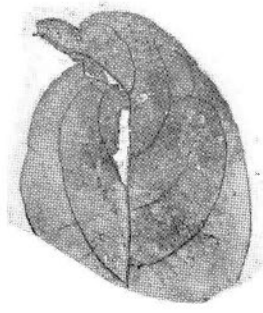

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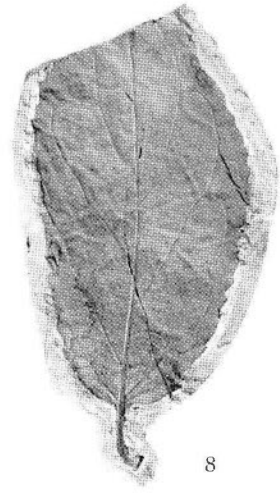

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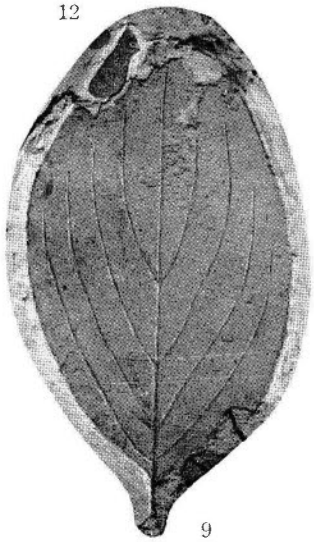

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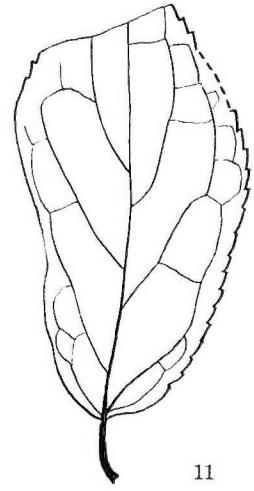


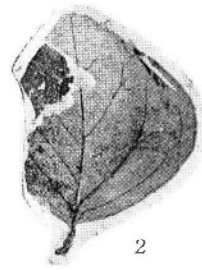
11

PLATE XVIII

1 *Styrax protoobassia* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4202
2 *Rhododendron protodilatatum* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4198
3 *Tripetaleia pseudopaniculata* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4200
4 *Rhododendron protodilatatum* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4199
5 *Lonicera protojaponica* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4205
6 *Stewartia submonadelpha* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4192
7 *Fraxinus honshuensis* TANAI et ONOE, Geol. Surv. Japan Holotype No. 4204
8 *Styrax protoobassia* TANAI et ONOE, Geol. Surv. Japan Paratype No. 4203
9 Sketch of Fig. 3

(All natural size)

1



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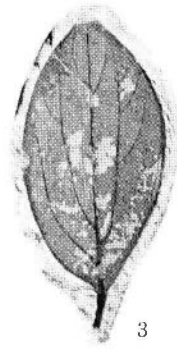

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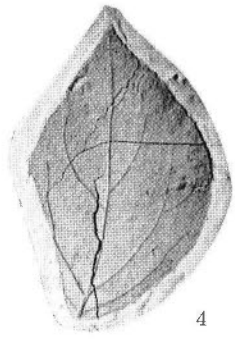

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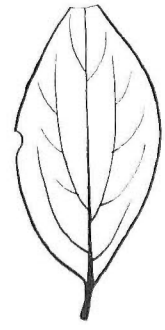

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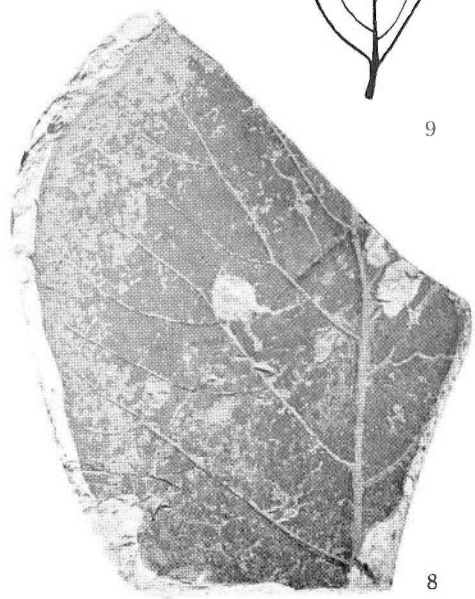

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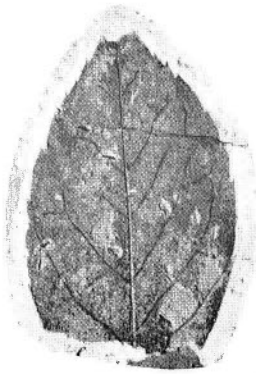

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7

Tanai, T.
Onoe, T.

A Mio-Pliocene Flora from the Ningyo-toge Area on the Border between Tottori and Okayama Prefectures, Japan

Toshimasa Tanai & Toru Onoe

地質調査所報告, No. 187, p. 1～54, 1961

4 illus., 18 pl., 11 tab.

The writers have studied the fossil flora which was found around the uranium-bearing deposits in the Ningyo-toge area. The fossil localities are situated on the border between Tottori and Okayama prefectures. The purposes of this study are to grasp the characteristics of the floristic composition and to determine the geologic age of the fossil bearing area. In the result of this study, this flora was presumed from late Miocene to early Pliocene in geological age. This fossil flora was named the "Hoki flora" by the writers.

561 : 551.782(521.81+521.83)

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B. Applied geology
- a. Ore deposits
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  Chemical prospecting & Boring

C. Miscellaneous

D. Annual Report of Progress

本所刊行の報文類の種目には従来地質要報・地質調査所報告等があつたが，今後はすべて刊行する報文は地質調査所報告に改めることとし，その番号は従来の地質調査所報告を追つて附けることにする。そして報告は1報文につき報告1冊を原則とし，その分類の便宜のために次の如くアルファベットによる略号を附けることにする。

A　地質およびその基礎科学に関するもの
- a. 地　質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・温泉
- e. 地球物理
- f. 地球化学

B　応用地質に関するもの
- a. 鉱　床
- b. 石　炭
- c. 石油・天然ガス
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鉱・化学探鉱および試錐

C　そ の 他

D　事業報告

地質調査所報告

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